United States Patent	12383296
Kind Code	B2
Date of Patent	August 12, 2025
Inventor(s)	Robertson; Galen C.

Ultrasonic surgical instrument blades

Abstract

An ultrasonic surgical instrument including an ultrasonically actuated blade or end effector having a treatment portion. The blade can define a central axis and at least one axis which is transverse to the central axis, wherein the transverse axis can lie within a plane which is perpendicular, or normal, to the longitudinal axis and can define a cross-section of the treatment portion. Such a cross-section can include a central portion and a step extending from the central portion, wherein the central portion can comprise a width, and wherein the step can comprise a cutting edge. In at least one embodiment, the cutting edge can be defined by first and second surfaces which define an angle therebetween. In various embodiments, the position of the cutting edge and/or the angle between the cutting edge surfaces can be selected in order to balance the blade with respect to the transverse axis.

Inventors:	**Robertson; Galen C. (Apex, NC)**
Applicant:	**Cilag GmbH International** (Zug, CH)
Family ID:	**1000008749184**
Assignee:	**Cilag GmbH International (Zug, CH)**
Appl. No.:	**17/683477**
Filed:	**March 01, 2022**

Prior Publication Data

Document Identifier	Publication Date
US 20220257276 A1	Aug. 18, 2022

Related U.S. Application Data

continuation parent-doc US 16577307 20190920 US 11266433 child-doc US 17683477
continuation parent-doc US 15155367 20160516 US 10441308 20191015 child-doc US 16577307
division parent-doc US 14743687 20150618 US 9339289 20160517 child-doc US 15155367

division parent-doc US 14069837 20131101 US 9066747 20150630 child-doc US 14743687
division parent-doc US 13270459 20111011 US 8591536 20131126 child-doc US 14069837
division parent-doc US 11998543 20071130 US 8057498 20111115 child-doc US 13270459

Publication Classification

Int. Cl.: **A61B17/3205** (20060101); **A61B17/00** (20060101); **A61B17/32** (20060101)

U.S. Cl.:

CPC **A61B17/3205** (20130101); **A61B17/320068** (20130101); **A61B17/320092** (20130101); A61B2017/00973 (20130101); A61B2017/320069 (20170801); A61B2017/320071 (20170801); A61B2017/320072 (20130101); A61B2017/320074 (20170801); A61B2017/320082 (20170801); A61B2017/320084 (20130101); A61B2017/320088 (20130101); A61B2017/320089 (20170801); A61B2017/320094 (20170801); Y10S83/956 (20130101)

Field of Classification Search

CPC: A61B (17/320068); A61B (17/320092); A61B (17/3205); A61B (2017/00973); A61B (2017/320069); A61B (2017/320071); A61B (2017/320072); A61B (2017/320082); A61B (2017/320088); A61B (2017/320089); Y10S (83/956)

USPC: 606/169

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
969528	12/1909	Disbrow	N/A	N/A
1570025	12/1925	Young	N/A	N/A
1813902	12/1930	Bovie	N/A	N/A
2188497	12/1939	Calva	N/A	N/A
2366274	12/1944	Luth et al.	N/A	N/A
2425245	12/1946	Johnson	N/A	N/A
2442966	12/1947	Wallace	N/A	N/A
2458152	12/1948	Eakins	N/A	N/A
2510693	12/1949	Green	N/A	N/A
2597564	12/1951	Bugg	N/A	N/A
2704333	12/1954	Calosi et al.	N/A	N/A
2736960	12/1955	Armstrong	N/A	N/A
2743726	12/1955	Grieshaber	N/A	N/A
2748967	12/1955	Roach	N/A	N/A
2845072	12/1957	Shafer	N/A	N/A
2849788	12/1957	Creek	N/A	N/A
2867039	12/1958	Zach	N/A	N/A
2874470	12/1958	Richards	N/A	N/A
2990616	12/1960	Balamuth et al.	N/A	N/A
RE25033	12/1960	Balamuth et al.	N/A	N/A

3015961	12/1961	Roney	N/A	N/A
3033407	12/1961	Alfons	N/A	N/A
3053124	12/1961	Balamuth et al.	N/A	N/A
3082805	12/1962	Royce	N/A	N/A
3166971	12/1964	Stoecker	N/A	N/A
3322403	12/1966	Murphy	N/A	N/A
3432691	12/1968	Shoh	N/A	N/A
3433226	12/1968	Boyd	N/A	N/A
3489930	12/1969	Shoh	N/A	N/A
3503396	12/1969	Pierie et al.	N/A	N/A
3503397	12/1969	Fogarty et al.	N/A	N/A
3503398	12/1969	Fogarty et al.	N/A	N/A
3513848	12/1969	Winston et al.	N/A	N/A
3514856	12/1969	Camp et al.	N/A	N/A
3525912	12/1969	Wallin	N/A	N/A
3526219	12/1969	Balamuth	N/A	N/A
3554198	12/1970	Tatoian et al.	N/A	N/A
3580841	12/1970	Cadotte et al.	N/A	N/A
3606682	12/1970	Camp et al.	N/A	N/A
3614484	12/1970	Shoh	N/A	N/A
3616375	12/1970	Inoue	N/A	N/A
3629726	12/1970	Popescu	N/A	N/A
3636943	12/1971	Balamuth	N/A	N/A
3668486	12/1971	Silver	N/A	N/A
3702948	12/1971	Balamuth	N/A	N/A
3703651	12/1971	Blowers	N/A	N/A
3776238	12/1972	Peyman et al.	N/A	N/A
3777760	12/1972	Essner	N/A	N/A
3792701	12/1973	Kloz et al.	N/A	N/A
3805787	12/1973	Banko	N/A	N/A
3809977	12/1973	Balamuth et al.	N/A	N/A
3830098	12/1973	Antonevich	N/A	N/A
3832776	12/1973	Sawyer	N/A	N/A
3854737	12/1973	Gilliam, Sr.	N/A	N/A
3862630	12/1974	Balamuth	N/A	N/A
3875945	12/1974	Friedman	N/A	N/A
3885438	12/1974	Harris, Sr. et al.	N/A	N/A
3900823	12/1974	Sokal et al.	N/A	N/A
3918442	12/1974	Nikolaev et al.	N/A	N/A
3924335	12/1974	Balamuth et al.	N/A	N/A
3946738	12/1975	Newton et al.	N/A	N/A
3955859	12/1975	Stella et al.	N/A	N/A
3956826	12/1975	Perdreaux, Jr.	N/A	N/A
3989952	12/1975	Hohmann	N/A	N/A
4005714	12/1976	Hiltebrandt	N/A	N/A
4012647	12/1976	Balamuth et al.	N/A	N/A
4034762	12/1976	Cosens et al.	N/A	N/A
4057660	12/1976	Yoshida et al.	N/A	N/A
4058126	12/1976	Leveen	N/A	N/A
4074719	12/1977	Semm	N/A	N/A

4085893	12/1977	Durley, III	N/A	N/A
4156187	12/1978	Murry et al.	N/A	N/A
4167944	12/1978	Banko	N/A	N/A
4169984	12/1978	Parisi	N/A	N/A
4173725	12/1978	Asai et al.	N/A	N/A
4188927	12/1979	Harris	N/A	N/A
4193009	12/1979	Durley, III	N/A	N/A
4200106	12/1979	Douvas et al.	N/A	N/A
4203430	12/1979	Takahashi	N/A	N/A
4203444	12/1979	Bonnell et al.	N/A	N/A
4220154	12/1979	Semm	N/A	N/A
4237441	12/1979	van Konynenburg et al.	N/A	N/A
4281785	12/1980	Brooks	N/A	N/A
4300083	12/1980	Heiges	N/A	N/A
4302728	12/1980	Nakamura	N/A	N/A
4304987	12/1980	van Konynenburg	N/A	N/A
4306570	12/1980	Matthews	N/A	N/A
4314559	12/1981	Allen	N/A	N/A
4352459	12/1981	Berger et al.	N/A	N/A
4445063	12/1983	Smith	N/A	N/A
4452473	12/1983	Ruschke	N/A	N/A
4463759	12/1983	Garito et al.	N/A	N/A
4491132	12/1984	Aikins	N/A	N/A
4492231	12/1984	Auth	N/A	N/A
4494759	12/1984	Kieffer	N/A	N/A
4504264	12/1984	Kelman	N/A	N/A
4512344	12/1984	Barber	N/A	N/A
4526571	12/1984	Wuchinich	N/A	N/A
4535773	12/1984	Yoon	N/A	N/A
4541638	12/1984	Ogawa et al.	N/A	N/A
4545374	12/1984	Jacobson	N/A	N/A
4545926	12/1984	Fouts, Jr. et al.	N/A	N/A
4550870	12/1984	Krumme et al.	N/A	N/A
4553544	12/1984	Nomoto et al.	N/A	N/A
4562838	12/1985	Walker	N/A	N/A
4574615	12/1985	Bower et al.	N/A	N/A
4582236	12/1985	Hirose	N/A	N/A
4617927	12/1985	Manes	N/A	N/A
4633119	12/1985	Thompson	N/A	N/A
4633874	12/1986	Chow et al.	N/A	N/A
4634420	12/1986	Spinosa et al.	N/A	N/A
4640279	12/1986	Beard	N/A	N/A
4641053	12/1986	Takeda	N/A	N/A
4646738	12/1986	Trott	N/A	N/A
4646756	12/1986	Watmough et al.	N/A	N/A
4649919	12/1986	Thimsen et al.	N/A	N/A
4662068	12/1986	Polonsky	N/A	N/A
4663677	12/1986	Griffith et al.	N/A	N/A
4674502	12/1986	Imonti	N/A	N/A

4696667	12/1986	Masch	N/A	N/A
4708127	12/1986	Abdelghani	N/A	N/A
4712722	12/1986	Hood et al.	N/A	N/A
4735603	12/1987	Goodson et al.	N/A	N/A
4750488	12/1987	Wuchinich et al.	N/A	N/A
4761871	12/1987	O'Connor et al.	N/A	N/A
4783997	12/1987	Lynnworth	N/A	N/A
4808154	12/1988	Freeman	N/A	N/A
4819635	12/1988	Shapiro	N/A	N/A
4821719	12/1988	Fogarty	N/A	N/A
4827911	12/1988	Broadwin et al.	N/A	N/A
4830462	12/1988	Karny et al.	N/A	N/A
4832683	12/1988	Idemoto et al.	N/A	N/A
4836186	12/1988	Scholz	N/A	N/A
4838853	12/1988	Parisi	N/A	N/A
4844064	12/1988	Thimsen et al.	N/A	N/A
4849133	12/1988	Yoshida et al.	N/A	N/A
4850354	12/1988	Mcgurk-Burleson et al.	N/A	N/A
4852578	12/1988	Companion et al.	N/A	N/A
4860745	12/1988	Farin et al.	N/A	N/A
4861332	12/1988	Parisi	N/A	N/A
4862890	12/1988	Stasz et al.	N/A	N/A
4865159	12/1988	Jamison	N/A	N/A
4867157	12/1988	Mcgurk-Burleson et al.	N/A	N/A
4869715	12/1988	Sherburne	N/A	N/A
4878493	12/1988	Pasternak et al.	N/A	N/A
4880015	12/1988	Nierman	N/A	N/A
4881550	12/1988	Kothe	N/A	N/A
4896009	12/1989	Pawlowski	N/A	N/A
4903696	12/1989	Stasz et al.	N/A	N/A
4910389	12/1989	Sherman et al.	N/A	N/A
4915643	12/1989	Samejima et al.	N/A	N/A
4920978	12/1989	Colvin	N/A	N/A
4922902	12/1989	Wuchinich et al.	N/A	N/A
4936842	12/1989	D'Amelio et al.	N/A	N/A
4954960	12/1989	Lo et al.	N/A	N/A
4965532	12/1989	Sakurai	N/A	N/A
4978067	12/1989	Berger et al.	N/A	N/A
4979952	12/1989	Kubota et al.	N/A	N/A
4981756	12/1990	Rhandhawa	N/A	N/A
4983160	12/1990	Steppe et al.	N/A	N/A
5013956	12/1990	Kurozumi et al.	N/A	N/A
5015227	12/1990	Broadwin et al.	N/A	N/A
5020514	12/1990	Heckele	N/A	N/A
5026370	12/1990	Lottick	N/A	N/A
5026387	12/1990	Thomas	N/A	N/A
5035695	12/1990	Weber, Jr. et al.	N/A	N/A
5042461	12/1990	Inoue et al.	N/A	N/A

5042707	12/1990	Taheri	N/A	N/A
5047043	12/1990	Kubota et al.	N/A	N/A
5057119	12/1990	Clark et al.	N/A	N/A
5058570	12/1990	Idemoto et al.	N/A	N/A
5059210	12/1990	Clark et al.	N/A	N/A
5061269	12/1990	Muller	N/A	N/A
5084052	12/1991	Jacobs	N/A	N/A
5088687	12/1991	Stender	N/A	N/A
5096532	12/1991	Neuwirth et al.	N/A	N/A
5099840	12/1991	Goble et al.	N/A	N/A
5104025	12/1991	Main et al.	N/A	N/A
5105117	12/1991	Yamaguchi	N/A	N/A
5106538	12/1991	Barma et al.	N/A	N/A
5108383	12/1991	White	N/A	N/A
5109819	12/1991	Custer et al.	N/A	N/A
5112300	12/1991	Ureche	N/A	N/A
5123903	12/1991	Quaid et al.	N/A	N/A
5126618	12/1991	Takahashi et al.	N/A	N/A
D327872	12/1991	McMills et al.	N/A	N/A
D330253	12/1991	Burek	N/A	N/A
5152762	12/1991	McElhenney	N/A	N/A
5156613	12/1991	Sawyer	N/A	N/A
5156633	12/1991	Smith	N/A	N/A
5159226	12/1991	Montgomery	N/A	N/A
5160334	12/1991	Billings et al.	N/A	N/A
5162044	12/1991	Gahn et al.	N/A	N/A
5163421	12/1991	Bernstein et al.	N/A	N/A
5163537	12/1991	Radev	N/A	N/A
5167619	12/1991	Wuchinich	N/A	N/A
5167725	12/1991	Clark et al.	N/A	N/A
5172344	12/1991	Ehrlich	N/A	N/A
5174276	12/1991	Crockard	N/A	N/A
D332660	12/1992	Rawson et al.	N/A	N/A
5176677	12/1992	Wuchinich	N/A	N/A
5176695	12/1992	Dulebohn	N/A	N/A
5184605	12/1992	Grzeszykowski	N/A	N/A
5188102	12/1992	Idemoto et al.	N/A	N/A
D334173	12/1992	Liu et al.	N/A	N/A
5190518	12/1992	Takasu	N/A	N/A
5190541	12/1992	Abele et al.	N/A	N/A
5196007	12/1992	Ellman et al.	N/A	N/A
5205459	12/1992	Brinkerhoff et al.	N/A	N/A
5205817	12/1992	Idemoto et al.	N/A	N/A
5209719	12/1992	Baruch et al.	N/A	N/A
5209776	12/1992	Bass et al.	N/A	N/A
5213103	12/1992	Martin et al.	N/A	N/A
5213569	12/1992	Davis	N/A	N/A
5214339	12/1992	Naito	N/A	N/A
5217460	12/1992	Knoepfler	N/A	N/A
5218529	12/1992	Meyer et al.	N/A	N/A

5221282	12/1992	Wuchinich	N/A	N/A
5222937	12/1992	Kagawa	N/A	N/A
5226909	12/1992	Evans et al.	N/A	N/A
5226910	12/1992	Kajiyama et al.	N/A	N/A
5234428	12/1992	Kaufman	N/A	N/A
5234436	12/1992	Eaton et al.	N/A	N/A
5241236	12/1992	Sasaki et al.	N/A	N/A
5241968	12/1992	Slater	N/A	N/A
5242385	12/1992	Strukel	N/A	N/A
5242460	12/1992	Klein et al.	N/A	N/A
5254129	12/1992	Alexander	N/A	N/A
5257988	12/1992	L'Esperance, Jr.	N/A	N/A
5258004	12/1992	Bales et al.	N/A	N/A
5258006	12/1992	Rydell et al.	N/A	N/A
5261922	12/1992	Hood	N/A	N/A
5263957	12/1992	Davison	N/A	N/A
5264925	12/1992	Shipp et al.	N/A	N/A
5269297	12/1992	Weng et al.	N/A	N/A
5275166	12/1993	Vaitekunas et al.	N/A	N/A
5275607	12/1993	Lo et al.	N/A	N/A
5275609	12/1993	Pingleton et al.	N/A	N/A
5282800	12/1993	Foshee et al.	N/A	N/A
5282817	12/1993	Hoogeboom et al.	N/A	N/A
5285795	12/1993	Ryan et al.	N/A	N/A
5285945	12/1993	Brinkerhoff et al.	N/A	N/A
5289436	12/1993	Terhune	N/A	N/A
5290286	12/1993	Parins	N/A	N/A
5293863	12/1993	Zhu et al.	N/A	N/A
5300068	12/1993	Rosar et al.	N/A	N/A
5304115	12/1993	Pflueger et al.	N/A	N/A
5306280	12/1993	Bregen et al.	N/A	N/A
D347474	12/1993	Olson	N/A	N/A
5307976	12/1993	Olson et al.	N/A	N/A
5309927	12/1993	Welch	N/A	N/A
5312023	12/1993	Green et al.	N/A	N/A
5312327	12/1993	Bales et al.	N/A	N/A
5312425	12/1993	Evans et al.	N/A	N/A
5318525	12/1993	West et al.	N/A	N/A
5318563	12/1993	Malis et al.	N/A	N/A
5318564	12/1993	Eggers	N/A	N/A
5318570	12/1993	Hood et al.	N/A	N/A
5318589	12/1993	Lichtman	N/A	N/A
5322055	12/1993	Davison et al.	N/A	N/A
5323055	12/1993	Yamazaki	N/A	N/A
5324297	12/1993	Hood et al.	N/A	N/A
5324299	12/1993	Davison et al.	N/A	N/A
5326013	12/1993	Green et al.	N/A	N/A
5326342	12/1993	Pflueger et al.	N/A	N/A
5330471	12/1993	Eggers	N/A	N/A
5330502	12/1993	Hassler et al.	N/A	N/A

5338292	12/1993	Clement et al.	N/A	N/A
5339723	12/1993	Huitema	N/A	N/A
5342292	12/1993	Nita et al.	N/A	N/A
5342359	12/1993	Rydell	N/A	N/A
5344420	12/1993	Hilal et al.	N/A	N/A
5345937	12/1993	Middleman et al.	N/A	N/A
5346502	12/1993	Estabrook et al.	N/A	N/A
5353474	12/1993	Good et al.	N/A	N/A
5354265	12/1993	Mackool	N/A	N/A
5356064	12/1993	Green et al.	N/A	N/A
5357164	12/1993	Imabayashi et al.	N/A	N/A
5357423	12/1993	Weaver et al.	N/A	N/A
5358506	12/1993	Green et al.	N/A	N/A
5359994	12/1993	Krauter et al.	N/A	N/A
5361583	12/1993	Huitema	N/A	N/A
5366466	12/1993	Christian et al.	N/A	N/A
5368557	12/1993	Nita et al.	N/A	N/A
5370645	12/1993	Klicek et al.	N/A	N/A
5371429	12/1993	Manna	N/A	N/A
5372585	12/1993	Tiefenbrun et al.	N/A	N/A
5374813	12/1993	Shipp	N/A	N/A
D354564	12/1994	Medema	N/A	N/A
5381067	12/1994	Greenstein et al.	N/A	N/A
5383874	12/1994	Jackson et al.	N/A	N/A
5383883	12/1994	Wilk et al.	N/A	N/A
5387207	12/1994	Dyer et al.	N/A	N/A
5387215	12/1994	Fisher	N/A	N/A
5389098	12/1994	Tsuruta et al.	N/A	N/A
5391144	12/1994	Sakurai et al.	N/A	N/A
5394187	12/1994	Shipp	N/A	N/A
5395033	12/1994	Byrne et al.	N/A	N/A
5395312	12/1994	Desai	N/A	N/A
5395363	12/1994	Billings et al.	N/A	N/A
5395364	12/1994	Anderhub et al.	N/A	N/A
5396266	12/1994	Brimhall	N/A	N/A
5396900	12/1994	Slater et al.	N/A	N/A
5397293	12/1994	Alliger et al.	N/A	N/A
5400267	12/1994	Denen et al.	N/A	N/A
5403312	12/1994	Yates et al.	N/A	N/A
5403334	12/1994	Evans et al.	N/A	N/A
5406503	12/1994	Williams, Jr. et al.	N/A	N/A
5408268	12/1994	Shipp	N/A	N/A
5409453	12/1994	Lundquist et al.	N/A	N/A
D358887	12/1994	Feinberg	N/A	N/A
5411481	12/1994	Allen et al.	N/A	N/A
5413107	12/1994	Oakley et al.	N/A	N/A
5417709	12/1994	Slater	N/A	N/A
5419761	12/1994	Narayanan et al.	N/A	N/A
5421829	12/1994	Olichney et al.	N/A	N/A
5423844	12/1994	Miller	N/A	N/A

5428504	12/1994	Bhatla	N/A	N/A
5429131	12/1994	Scheinman et al.	N/A	N/A
5438997	12/1994	Sieben et al.	N/A	N/A
5441499	12/1994	Fritzsch	N/A	N/A
5443463	12/1994	Stern et al.	N/A	N/A
5445638	12/1994	Rydell et al.	N/A	N/A
5445639	12/1994	Kuslich et al.	N/A	N/A
5447509	12/1994	Mills et al.	N/A	N/A
5449370	12/1994	Vaitekunas	N/A	N/A
5451220	12/1994	Ciervo	N/A	N/A
5451227	12/1994	Michaelson	N/A	N/A
5456684	12/1994	Schmidt et al.	N/A	N/A
5458598	12/1994	Feinberg et al.	N/A	N/A
5462604	12/1994	Shibano et al.	N/A	N/A
5465895	12/1994	Knodel et al.	N/A	N/A
5471988	12/1994	Fujio et al.	N/A	N/A
5472443	12/1994	Cordis et al.	N/A	N/A
5476479	12/1994	Green et al.	N/A	N/A
5478003	12/1994	Green et al.	N/A	N/A
5480409	12/1995	Riza	N/A	N/A
5483501	12/1995	Park et al.	N/A	N/A
5484436	12/1995	Eggers et al.	N/A	N/A
5486162	12/1995	Brumbach	N/A	N/A
5486189	12/1995	Mudry et al.	N/A	N/A
5490860	12/1995	Middle et al.	N/A	N/A
5496317	12/1995	Goble et al.	N/A	N/A
5496411	12/1995	Candy	N/A	N/A
5499992	12/1995	Meade et al.	N/A	N/A
5500216	12/1995	Julian et al.	N/A	N/A
5501654	12/1995	Failla et al.	N/A	N/A
5503616	12/1995	Jones	N/A	N/A
5504650	12/1995	Katsui et al.	N/A	N/A
5505693	12/1995	Mackool	N/A	N/A
5507738	12/1995	Ciervo	N/A	N/A
5509922	12/1995	Aranyi et al.	N/A	N/A
5511556	12/1995	DeSantis	N/A	N/A
5520704	12/1995	Castro et al.	N/A	N/A
5522832	12/1995	Kugo et al.	N/A	N/A
5522839	12/1995	Pilling	N/A	N/A
5527273	12/1995	Manna et al.	N/A	N/A
5527331	12/1995	Kresch et al.	N/A	N/A
5531744	12/1995	Nardella et al.	N/A	N/A
5540681	12/1995	Strul et al.	N/A	N/A
5540693	12/1995	Fisher	N/A	N/A
5542916	12/1995	Hirsch et al.	N/A	N/A
5553675	12/1995	Pitzen et al.	N/A	N/A
5558671	12/1995	Yates	N/A	N/A
5562609	12/1995	Brumbach	N/A	N/A
5562610	12/1995	Brumbach	N/A	N/A
5562659	12/1995	Morris	N/A	N/A

5562703	12/1995	Desai	N/A	N/A
5563179	12/1995	Stone et al.	N/A	N/A
5569164	12/1995	Lurz	N/A	N/A
5571121	12/1995	Heifetz	N/A	N/A
5573424	12/1995	Poppe	N/A	N/A
5573534	12/1995	Stone	N/A	N/A
5575799	12/1995	Bolanos et al.	N/A	N/A
5577654	12/1995	Bishop	N/A	N/A
5582618	12/1995	Chin et al.	N/A	N/A
5584830	12/1995	Ladd et al.	N/A	N/A
5591187	12/1996	Dekel	N/A	N/A
5593414	12/1996	Shipp et al.	N/A	N/A
5599350	12/1996	Schulze et al.	N/A	N/A
5601601	12/1996	Tal et al.	N/A	N/A
5603773	12/1996	Campbell	N/A	N/A
5607436	12/1996	Pratt et al.	N/A	N/A
5607450	12/1996	Zvenyatsky et al.	N/A	N/A
5609573	12/1996	Sandock	N/A	N/A
5611813	12/1996	Lichtman	N/A	N/A
5618304	12/1996	Hart et al.	N/A	N/A
5618307	12/1996	Donlon et al.	N/A	N/A
5618492	12/1996	Auten et al.	N/A	N/A
5620447	12/1996	Smith et al.	N/A	N/A
5624452	12/1996	Yates	N/A	N/A
5626578	12/1996	Tihon	N/A	N/A
5626587	12/1996	Bishop et al.	N/A	N/A
5626595	12/1996	Sklar et al.	N/A	N/A
5628760	12/1996	Knoepfler	N/A	N/A
5630420	12/1996	Vaitekunas	N/A	N/A
5632432	12/1996	Schulze et al.	N/A	N/A
5632717	12/1996	Yoon	N/A	N/A
5640741	12/1996	Yano	N/A	N/A
D381077	12/1996	Hunt	N/A	N/A
5643301	12/1996	Mollenauer	N/A	N/A
5647851	12/1996	Pokras	N/A	N/A
5647871	12/1996	Levine et al.	N/A	N/A
5649937	12/1996	Bito et al.	N/A	N/A
5649955	12/1996	Hashimoto et al.	N/A	N/A
5651780	12/1996	Jackson et al.	N/A	N/A
5653713	12/1996	Michelson	N/A	N/A
5658281	12/1996	Heard	N/A	N/A
5662662	12/1996	Bishop et al.	N/A	N/A
5662667	12/1996	Knodel	N/A	N/A
5665085	12/1996	Nardella	N/A	N/A
5665100	12/1996	Yoon	N/A	N/A
5669922	12/1996	Hood	N/A	N/A
5674219	12/1996	Monson et al.	N/A	N/A
5674220	12/1996	Fox et al.	N/A	N/A
5674235	12/1996	Parisi	N/A	N/A
5678568	12/1996	Uchikubo et al.	N/A	N/A

5688270	12/1996	Yates et al.	N/A	N/A
5690269	12/1996	Bolanos et al.	N/A	N/A
5693051	12/1996	Schulze et al.	N/A	N/A
5694936	12/1996	Fujimoto et al.	N/A	N/A
5695510	12/1996	Hood	N/A	N/A
5700261	12/1996	Brinkerhoff	N/A	N/A
5704534	12/1997	Huitema et al.	N/A	N/A
5704791	12/1997	Gillio	N/A	N/A
5709680	12/1997	Yates et al.	N/A	N/A
5711472	12/1997	Bryan	N/A	N/A
5713896	12/1997	Nardella	N/A	N/A
5715817	12/1997	Stevens-Wright et al.	N/A	N/A
5716366	12/1997	Yates	N/A	N/A
5717306	12/1997	Shipp	N/A	N/A
5720742	12/1997	Zacharias	N/A	N/A
5720744	12/1997	Eggleston et al.	N/A	N/A
5722980	12/1997	Schulz et al.	N/A	N/A
5725536	12/1997	Oberlin et al.	N/A	N/A
5728130	12/1997	Ishikawa et al.	N/A	N/A
5730752	12/1997	Alden et al.	N/A	N/A
5733074	12/1997	Stock et al.	N/A	N/A
5735848	12/1997	Yates et al.	N/A	N/A
5735875	12/1997	Bonutti et al.	N/A	N/A
5741226	12/1997	Strukel et al.	N/A	N/A
5743906	12/1997	Parins et al.	N/A	N/A
5752973	12/1997	Kieturakis	N/A	N/A
5755717	12/1997	Yates et al.	N/A	N/A
5762255	12/1997	Chrisman et al.	N/A	N/A
5766164	12/1997	Mueller et al.	N/A	N/A
5772659	12/1997	Becker et al.	N/A	N/A
5776130	12/1997	Buysse et al.	N/A	N/A
5776155	12/1997	Beaupre et al.	N/A	N/A
5779130	12/1997	Alesi et al.	N/A	N/A
5779701	12/1997	McBrayer et al.	N/A	N/A
5782834	12/1997	Lucey et al.	N/A	N/A
5792135	12/1997	Madhani et al.	N/A	N/A
5792138	12/1997	Shipp	N/A	N/A
5792165	12/1997	Klieman et al.	N/A	N/A
5796188	12/1997	Bays	N/A	N/A
5797537	12/1997	Oberlin et al.	N/A	N/A
5797941	12/1997	Schulze et al.	N/A	N/A
5797959	12/1997	Castro et al.	N/A	N/A
5800432	12/1997	Swanson	N/A	N/A
5800448	12/1997	Banko	N/A	N/A
5800449	12/1997	Wales	N/A	N/A
5805140	12/1997	Rosenberg et al.	N/A	N/A
5807310	12/1997	Hood	N/A	N/A
5807393	12/1997	Williamson, IV et al.	N/A	N/A

5808396	12/1997	Boukhny	N/A	N/A
5810811	12/1997	Yates et al.	N/A	N/A
5810828	12/1997	Lightman et al.	N/A	N/A
5810859	12/1997	DiMatteo et al.	N/A	N/A
5810869	12/1997	Kaplan et al.	N/A	N/A
5817033	12/1997	DeSantis et al.	N/A	N/A
5817084	12/1997	Jensen	N/A	N/A
5817093	12/1997	Williamson, IV et al.	N/A	N/A
5817119	12/1997	Klieman et al.	N/A	N/A
5820009	12/1997	Melling et al.	N/A	N/A
5823197	12/1997	Edwards	N/A	N/A
5827323	12/1997	Klieman et al.	N/A	N/A
5828160	12/1997	Sugishita	N/A	N/A
5833696	12/1997	Whitfield et al.	N/A	N/A
5836897	12/1997	Sakurai et al.	N/A	N/A
5836909	12/1997	Cosmescu	N/A	N/A
5836943	12/1997	Miller, III	N/A	N/A
5836957	12/1997	Schulz et al.	N/A	N/A
5836990	12/1997	Li	N/A	N/A
5843109	12/1997	Mehta et al.	N/A	N/A
5851212	12/1997	Zirps et al.	N/A	N/A
5853290	12/1997	Winston	N/A	N/A
5853412	12/1997	Mayenberger	N/A	N/A
5858018	12/1998	Shipp et al.	N/A	N/A
5865361	12/1998	Milliman et al.	N/A	N/A
5873873	12/1998	Smith et al.	N/A	N/A
5873882	12/1998	Straub et al.	N/A	N/A
5876401	12/1998	Schulze et al.	N/A	N/A
5878193	12/1998	Wang et al.	N/A	N/A
5879363	12/1998	Urich	N/A	N/A
5879364	12/1998	Bromfield et al.	N/A	N/A
5880668	12/1998	Hall	N/A	N/A
5883615	12/1998	Fago et al.	N/A	N/A
5891142	12/1998	Eggers et al.	N/A	N/A
5893835	12/1998	Witt et al.	N/A	N/A
5893880	12/1998	Egan et al.	N/A	N/A
5895412	12/1998	Tucker	N/A	N/A
5897523	12/1998	Wright et al.	N/A	N/A
5897569	12/1998	Kellogg et al.	N/A	N/A
5903607	12/1998	Tailliet	N/A	N/A
5904681	12/1998	West, Jr.	N/A	N/A
5906625	12/1998	Bito et al.	N/A	N/A
5906627	12/1998	Spaulding	N/A	N/A
5906628	12/1998	Miyawaki et al.	N/A	N/A
5910129	12/1998	Koblish et al.	N/A	N/A
5910150	12/1998	Saadat	N/A	N/A
5911699	12/1998	Anis et al.	N/A	N/A
5916229	12/1998	Evans	N/A	N/A
5921956	12/1998	Grinberg et al.	N/A	N/A

5929846	12/1998	Rosenberg et al.	N/A	N/A
5935143	12/1998	Hood	N/A	N/A
5935144	12/1998	Estabrook	N/A	N/A
5938633	12/1998	Beaupre	N/A	N/A
5941887	12/1998	Steen et al.	N/A	N/A
5944718	12/1998	Austin et al.	N/A	N/A
5944737	12/1998	Tsonton et al.	N/A	N/A
5947984	12/1998	Whipple	N/A	N/A
5954736	12/1998	Bishop et al.	N/A	N/A
5954746	12/1998	Holthaus et al.	N/A	N/A
5957882	12/1998	Nita et al.	N/A	N/A
5957943	12/1998	Vaitekunas	N/A	N/A
5968007	12/1998	Simon et al.	N/A	N/A
5968060	12/1998	Kellogg	N/A	N/A
5971949	12/1998	Levin et al.	N/A	N/A
5974342	12/1998	Petrofsky	N/A	N/A
D416089	12/1998	Barton et al.	N/A	N/A
5980510	12/1998	Tsonton et al.	N/A	N/A
5980546	12/1998	Hood	N/A	N/A
5984938	12/1998	Yoon	N/A	N/A
5989274	12/1998	Davison et al.	N/A	N/A
5989275	12/1998	Estabrook et al.	N/A	N/A
5993465	12/1998	Shipp et al.	N/A	N/A
5993972	12/1998	Reich et al.	N/A	N/A
5994855	12/1998	Lundell et al.	N/A	N/A
6001120	12/1998	Levin	N/A	N/A
6003517	12/1998	Sheffield et al.	N/A	N/A
6004335	12/1998	Vaitekunas et al.	N/A	N/A
6007552	12/1998	Fogarty et al.	N/A	N/A
6010054	12/1999	Johnson et al.	N/A	N/A
6013052	12/1999	Durman et al.	N/A	N/A
6024741	12/1999	Williamson, IV et al.	N/A	N/A
6024744	12/1999	Kese et al.	N/A	N/A
6024750	12/1999	Mastri et al.	N/A	N/A
6027515	12/1999	Cimino	N/A	N/A
6031526	12/1999	Shipp	N/A	N/A
6033375	12/1999	Brumbach	N/A	N/A
6033399	12/1999	Gines	N/A	N/A
6036667	12/1999	Manna et al.	N/A	N/A
6036707	12/1999	Spaulding	N/A	N/A
6039734	12/1999	Goble	N/A	N/A
6048224	12/1999	Kay	N/A	N/A
6050943	12/1999	Slayton et al.	N/A	N/A
6050996	12/1999	Schmaltz et al.	N/A	N/A
6051010	12/1999	DiMatteo et al.	N/A	N/A
6053906	12/1999	Honda et al.	N/A	N/A
6056735	12/1999	Okada et al.	N/A	N/A
6063050	12/1999	Manna et al.	N/A	N/A
6063098	12/1999	Houser et al.	N/A	N/A

6066132	12/1999	Chen et al.	N/A	N/A
6066151	12/1999	Miyawaki et al.	N/A	N/A
6068627	12/1999	Orszulak et al.	N/A	N/A
6068629	12/1999	Haissaguerre et al.	N/A	N/A
6068647	12/1999	Witt et al.	N/A	N/A
6074389	12/1999	Levine et al.	N/A	N/A
6077285	12/1999	Boukhny	N/A	N/A
6083191	12/1999	Rose	N/A	N/A
6086544	12/1999	Hibner et al.	N/A	N/A
6086584	12/1999	Miller	N/A	N/A
6090120	12/1999	Wright et al.	N/A	N/A
6091995	12/1999	Ingle et al.	N/A	N/A
6096033	12/1999	Tu et al.	N/A	N/A
6099483	12/1999	Palmer et al.	N/A	N/A
6099542	12/1999	Cohn et al.	N/A	N/A
6099550	12/1999	Yoon	N/A	N/A
6109500	12/1999	Alli et al.	N/A	N/A
6110127	12/1999	Suzuki	N/A	N/A
6113594	12/1999	Savage	N/A	N/A
6113598	12/1999	Baker	N/A	N/A
6117152	12/1999	Huitema	N/A	N/A
6120519	12/1999	Weber et al.	N/A	N/A
H1904	12/1999	Yates et al.	N/A	N/A
6126629	12/1999	Perkins	N/A	N/A
6129735	12/1999	Okada et al.	N/A	N/A
6129740	12/1999	Michelson	N/A	N/A
6132368	12/1999	Cooper	N/A	N/A
6132427	12/1999	Jones et al.	N/A	N/A
6132448	12/1999	Perez et al.	N/A	N/A
6139320	12/1999	Hahn	N/A	N/A
6139561	12/1999	Shibata et al.	N/A	N/A
6142615	12/1999	Qiu et al.	N/A	N/A
6142994	12/1999	Swanson et al.	N/A	N/A
6144402	12/1999	Norsworthy et al.	N/A	N/A
6147560	12/1999	Erhage et al.	N/A	N/A
6152902	12/1999	Christian et al.	N/A	N/A
6152923	12/1999	Ryan	N/A	N/A
6154198	12/1999	Rosenberg	N/A	N/A
6156029	12/1999	Mueller	N/A	N/A
6159160	12/1999	Hsei et al.	N/A	N/A
6159175	12/1999	Strukel et al.	N/A	N/A
6162194	12/1999	Shipp	N/A	N/A
6162208	12/1999	Hipps	N/A	N/A
6165150	12/1999	Banko	N/A	N/A
6165186	12/1999	Fogarty et al.	N/A	N/A
6165191	12/1999	Shibata et al.	N/A	N/A
6174309	12/2000	Wrublewski et al.	N/A	N/A
6174310	12/2000	Kirwan, Jr.	N/A	N/A
6176857	12/2000	Ashley	N/A	N/A
6179853	12/2000	Sachse et al.	N/A	N/A

6183426	12/2000	Akisada et al.	N/A	N/A
6187003	12/2000	Buysse et al.	N/A	N/A
6190386	12/2000	Rydell	N/A	N/A
6193709	12/2000	Miyawaki et al.	N/A	N/A
6204592	12/2000	Hur	N/A	N/A
6205855	12/2000	Pfeiffer	N/A	N/A
6206844	12/2000	Reichel et al.	N/A	N/A
6206876	12/2000	Levine et al.	N/A	N/A
6206877	12/2000	Kese et al.	N/A	N/A
6210337	12/2000	Dunham et al.	N/A	N/A
6210402	12/2000	Olsen et al.	N/A	N/A
6210403	12/2000	Klicek	N/A	N/A
6214023	12/2000	Whipple et al.	N/A	N/A
6217591	12/2000	Egan et al.	N/A	N/A
6228080	12/2000	Gines	N/A	N/A
6228104	12/2000	Fogarty et al.	N/A	N/A
6231565	12/2000	Tovey et al.	N/A	N/A
6233476	12/2000	Strommer et al.	N/A	N/A
6238366	12/2000	Savage et al.	N/A	N/A
6241724	12/2000	Fleischman et al.	N/A	N/A
6245065	12/2000	Panescu et al.	N/A	N/A
6251110	12/2000	Wampler	N/A	N/A
6252110	12/2000	Uemura et al.	N/A	N/A
D444365	12/2000	Bass et al.	N/A	N/A
D445092	12/2000	Lee	N/A	N/A
D445764	12/2000	Lee	N/A	N/A
6254623	12/2000	Haibel, Jr. et al.	N/A	N/A
6257241	12/2000	Wampler	N/A	N/A
6258034	12/2000	Hanafy	N/A	N/A
6259230	12/2000	Chou	N/A	N/A
6267761	12/2000	Ryan	N/A	N/A
6270471	12/2000	Hechel et al.	N/A	N/A
6270831	12/2000	Kumar et al.	N/A	N/A
6273852	12/2000	Lehe et al.	N/A	N/A
6273902	12/2000	Fogarty et al.	N/A	N/A
6274963	12/2000	Estabrook et al.	N/A	N/A
6277115	12/2000	Saadat	N/A	N/A
6277117	12/2000	Tetzlaff et al.	N/A	N/A
6278218	12/2000	Madan et al.	N/A	N/A
6280407	12/2000	Manna et al.	N/A	N/A
6283981	12/2000	Beaupre	N/A	N/A
6287344	12/2000	Wampler et al.	N/A	N/A
6290575	12/2000	Shipp	N/A	N/A
6292700	12/2000	Morrison et al.	N/A	N/A
6293954	12/2000	Fogarty et al.	N/A	N/A
6299591	12/2000	Banko	N/A	N/A
6299621	12/2000	Fogarty et al.	N/A	N/A
6306131	12/2000	Hareyama et al.	N/A	N/A
6306157	12/2000	Shchervinsky	N/A	N/A
6309400	12/2000	Beaupre	N/A	N/A

6311783	12/2000	Harpell	N/A	N/A
6312434	12/2000	Sutrina et al.	N/A	N/A
6312445	12/2000	Fogarty et al.	N/A	N/A
6319221	12/2000	Savage et al.	N/A	N/A
6325795	12/2000	Lindemann et al.	N/A	N/A
6325799	12/2000	Goble	N/A	N/A
6325811	12/2000	Messerly	N/A	N/A
6328751	12/2000	Beaupre	N/A	N/A
6332891	12/2000	Himes	N/A	N/A
6333488	12/2000	Lawrence et al.	N/A	N/A
6338657	12/2001	Harper et al.	N/A	N/A
6340352	12/2001	Okada et al.	N/A	N/A
6340878	12/2001	Oglesbee	N/A	N/A
6350269	12/2001	Shipp et al.	N/A	N/A
6352532	12/2001	Kramer et al.	N/A	N/A
6358264	12/2001	Banko	N/A	N/A
6364888	12/2001	Niemeyer et al.	N/A	N/A
6379320	12/2001	Lafon et al.	N/A	N/A
D457958	12/2001	Dycus et al.	N/A	N/A
6383194	12/2001	Pothula	N/A	N/A
6384690	12/2001	Wilhelmsson et al.	N/A	N/A
6387094	12/2001	Eitenmuller	N/A	N/A
6387109	12/2001	Davison et al.	N/A	N/A
6387112	12/2001	Fogarty et al.	N/A	N/A
6388657	12/2001	Natoli	N/A	N/A
6391026	12/2001	Hung et al.	N/A	N/A
6391042	12/2001	Cimino	N/A	N/A
6398779	12/2001	Buysse et al.	N/A	N/A
6402743	12/2001	Orszulak et al.	N/A	N/A
6402748	12/2001	Schoenman et al.	N/A	N/A
6405733	12/2001	Fogarty et al.	N/A	N/A
6409722	12/2001	Hoey et al.	N/A	N/A
6409743	12/2001	Fenton, Jr.	N/A	N/A
H2037	12/2001	Yates et al.	N/A	N/A
6416469	12/2001	Phung et al.	N/A	N/A
6416486	12/2001	Wampler	N/A	N/A
6416525	12/2001	Shibata	N/A	N/A
6419675	12/2001	Gallo, Sr.	N/A	N/A
6423073	12/2001	Bowman	N/A	N/A
6423082	12/2001	Houser et al.	N/A	N/A
6425906	12/2001	Young et al.	N/A	N/A
6425907	12/2001	Shibata et al.	N/A	N/A
6428538	12/2001	Blewett et al.	N/A	N/A
6428539	12/2001	Baxter et al.	N/A	N/A
6430446	12/2001	Knowlton	N/A	N/A
6432118	12/2001	Messerly	N/A	N/A
6436114	12/2001	Novak et al.	N/A	N/A
6436115	12/2001	Beaupre	N/A	N/A
6440062	12/2001	Ouchi	N/A	N/A
6443968	12/2001	Holthaus et al.	N/A	N/A

6443969	12/2001	Novak et al.	N/A	N/A
6449006	12/2001	Shipp	N/A	N/A
6454781	12/2001	Witt et al.	N/A	N/A
6454782	12/2001	Schwemberger	N/A	N/A
6458128	12/2001	Schulze	N/A	N/A
6458130	12/2001	Frazier et al.	N/A	N/A
6458142	12/2001	Faller et al.	N/A	N/A
6461363	12/2001	Gadberry et al.	N/A	N/A
6464689	12/2001	Qin et al.	N/A	N/A
6464702	12/2001	Schulze et al.	N/A	N/A
6468286	12/2001	Mastri et al.	N/A	N/A
6475211	12/2001	Chess et al.	N/A	N/A
6475215	12/2001	Tanrisever	N/A	N/A
6480796	12/2001	Wiener	N/A	N/A
6485490	12/2001	Wampler et al.	N/A	N/A
6491690	12/2001	Goble et al.	N/A	N/A
6491701	12/2001	Tierney et al.	N/A	N/A
6491708	12/2001	Madan et al.	N/A	N/A
6497715	12/2001	Satou	N/A	N/A
6498421	12/2001	Oh et al.	N/A	N/A
6500112	12/2001	Khouri	N/A	N/A
6500176	12/2001	Truckai et al.	N/A	N/A
6500188	12/2001	Harper et al.	N/A	N/A
6500312	12/2001	Wedekamp	N/A	N/A
6503248	12/2002	Levine	N/A	N/A
6506208	12/2002	Hunt et al.	N/A	N/A
6511478	12/2002	Burnside et al.	N/A	N/A
6511480	12/2002	Tetzlaff et al.	N/A	N/A
6511493	12/2002	Moutafis et al.	N/A	N/A
6514252	12/2002	Nezhat et al.	N/A	N/A
6514267	12/2002	Jewett	N/A	N/A
6517565	12/2002	Whitman et al.	N/A	N/A
6524251	12/2002	Rabiner et al.	N/A	N/A
6524316	12/2002	Nicholson et al.	N/A	N/A
6526976	12/2002	Baran	N/A	N/A
6527736	12/2002	Attinger et al.	N/A	N/A
6531846	12/2002	Smith	N/A	N/A
6533784	12/2002	Truckai et al.	N/A	N/A
6537272	12/2002	Christopherson et al.	N/A	N/A
6537291	12/2002	Friedman et al.	N/A	N/A
6543452	12/2002	Lavigne	N/A	N/A
6543456	12/2002	Freeman	N/A	N/A
6544260	12/2002	Markel et al.	N/A	N/A
6551309	12/2002	LePivert	N/A	N/A
6554829	12/2002	Schulze et al.	N/A	N/A
6558376	12/2002	Bishop	N/A	N/A
6561983	12/2002	Cronin et al.	N/A	N/A
6562035	12/2002	Levin	N/A	N/A
6562037	12/2002	Paton et al.	N/A	N/A

6562059	12/2002	Edwards et al.	N/A	N/A
6565558	12/2002	Lindenmeier et al.	N/A	N/A
6569109	12/2002	Sakurai et al.	N/A	N/A
6569178	12/2002	Miyawaki et al.	N/A	N/A
6572563	12/2002	Ouchi	N/A	N/A
6572632	12/2002	Zisterer et al.	N/A	N/A
6572639	12/2002	Ingle et al.	N/A	N/A
6575929	12/2002	Sussman et al.	N/A	N/A
6575969	12/2002	Rittman, III et al.	N/A	N/A
6582427	12/2002	Goble et al.	N/A	N/A
6582451	12/2002	Marucci et al.	N/A	N/A
6584360	12/2002	Francischelli et al.	N/A	N/A
D477408	12/2002	Bromley	N/A	N/A
6585735	12/2002	Frazier et al.	N/A	N/A
6588277	12/2002	Giordano et al.	N/A	N/A
6589200	12/2002	Schwemberger et al.	N/A	N/A
6589239	12/2002	Khandkar et al.	N/A	N/A
6599288	12/2002	Maguire et al.	N/A	N/A
6602229	12/2002	Coss	N/A	N/A
6602252	12/2002	Mollenauer	N/A	N/A
6607540	12/2002	Shipp	N/A	N/A
6610059	12/2002	West, Jr.	N/A	N/A
6610060	12/2002	Mulier et al.	N/A	N/A
6616450	12/2002	Mossle et al.	N/A	N/A
6619529	12/2002	Green et al.	N/A	N/A
6620161	12/2002	Schulze et al.	N/A	N/A
6622731	12/2002	Daniel et al.	N/A	N/A
6623444	12/2002	Babaev	N/A	N/A
6623482	12/2002	Pendekanti et al.	N/A	N/A
6623500	12/2002	Cook et al.	N/A	N/A
6623501	12/2002	Heller et al.	N/A	N/A
6626848	12/2002	Neuenfeldt	N/A	N/A
6626926	12/2002	Friedman et al.	N/A	N/A
6629974	12/2002	Penny et al.	N/A	N/A
6633234	12/2002	Wiener et al.	N/A	N/A
6635057	12/2002	Harano et al.	N/A	N/A
6644532	12/2002	Green et al.	N/A	N/A
6648839	12/2002	Manna et al.	N/A	N/A
6648883	12/2002	Francischelli et al.	N/A	N/A
6651669	12/2002	Burnside	N/A	N/A
6652513	12/2002	Panescu et al.	N/A	N/A
6652539	12/2002	Shipp et al.	N/A	N/A
6652545	12/2002	Shipp et al.	N/A	N/A
6656124	12/2002	Flesch et al.	N/A	N/A
6656132	12/2002	Ouchi	N/A	N/A
6656177	12/2002	Truckai et al.	N/A	N/A
6656198	12/2002	Tsonton et al.	N/A	N/A
6660017	12/2002	Beaupre	N/A	N/A
6662127	12/2002	Wiener et al.	N/A	N/A

6663941	12/2002	Brown et al.	N/A	N/A
6666860	12/2002	Takahashi	N/A	N/A
6666875	12/2002	Sakurai et al.	N/A	N/A
6669690	12/2002	Okada et al.	N/A	N/A
6669696	12/2002	Bacher et al.	N/A	N/A
6669710	12/2002	Moutafis et al.	N/A	N/A
6673248	12/2003	Chowdhury	N/A	N/A
6676660	12/2003	Wampler et al.	N/A	N/A
6678621	12/2003	Wiener et al.	N/A	N/A
6679875	12/2003	Honda et al.	N/A	N/A
6679882	12/2003	Kornerup	N/A	N/A
6679899	12/2003	Wiener et al.	N/A	N/A
6682501	12/2003	Nelson et al.	N/A	N/A
6682544	12/2003	Mastri et al.	N/A	N/A
6685701	12/2003	Orszulak et al.	N/A	N/A
6685703	12/2003	Pearson et al.	N/A	N/A
6689086	12/2003	Nita et al.	N/A	N/A
6689145	12/2003	Lee et al.	N/A	N/A
6689146	12/2003	Himes	N/A	N/A
6690960	12/2003	Chen et al.	N/A	N/A
6692514	12/2003	Fogarty et al.	N/A	N/A
6695782	12/2003	Ranucci et al.	N/A	N/A
6695840	12/2003	Schulze	N/A	N/A
6699214	12/2003	Gellman	N/A	N/A
6702761	12/2003	Damadian et al.	N/A	N/A
6702821	12/2003	Bonutti	N/A	N/A
6712805	12/2003	Weimann	N/A	N/A
6716215	12/2003	David et al.	N/A	N/A
6719692	12/2003	Kleffner et al.	N/A	N/A
6719765	12/2003	Bonutti	N/A	N/A
6719766	12/2003	Buelna et al.	N/A	N/A
6719776	12/2003	Baxter et al.	N/A	N/A
6722552	12/2003	Fenton, Jr.	N/A	N/A
6723091	12/2003	Goble et al.	N/A	N/A
D490059	12/2003	Conway et al.	N/A	N/A
6731047	12/2003	Kauf et al.	N/A	N/A
6733498	12/2003	Paton et al.	N/A	N/A
6733506	12/2003	McDevitt et al.	N/A	N/A
6736813	12/2003	Yamauchi et al.	N/A	N/A
6739872	12/2003	Turri	N/A	N/A
6740079	12/2003	Eggers et al.	N/A	N/A
D491666	12/2003	Kimmell et al.	N/A	N/A
6743245	12/2003	Lobdell	N/A	N/A
6746284	12/2003	Spink, Jr.	N/A	N/A
6746443	12/2003	Morley et al.	N/A	N/A
6752154	12/2003	Fogarty et al.	N/A	N/A
6752815	12/2003	Beaupre	N/A	N/A
6755825	12/2003	Shoenman et al.	N/A	N/A
6761698	12/2003	Shibata et al.	N/A	N/A
6762535	12/2003	Take et al.	N/A	N/A

6766202	12/2003	Underwood et al.	N/A	N/A
6770072	12/2003	Truckai et al.	N/A	N/A
6773409	12/2003	Truckai et al.	N/A	N/A
6773434	12/2003	Ciarrocca	N/A	N/A
6773435	12/2003	Schulze et al.	N/A	N/A
6773443	12/2003	Truwit et al.	N/A	N/A
6773444	12/2003	Messerly	N/A	N/A
6775575	12/2003	Bommannan et al.	N/A	N/A
6778023	12/2003	Christensen	N/A	N/A
6783524	12/2003	Anderson et al.	N/A	N/A
6786382	12/2003	Hoffman	N/A	N/A
6786383	12/2003	Stegelmann	N/A	N/A
6789939	12/2003	Schrodinger et al.	N/A	N/A
6790173	12/2003	Saadat et al.	N/A	N/A
6790216	12/2003	Ishikawa	N/A	N/A
6794027	12/2003	Araki et al.	N/A	N/A
6796981	12/2003	Wham et al.	N/A	N/A
D496997	12/2003	Dycus et al.	N/A	N/A
6800085	12/2003	Selmon et al.	N/A	N/A
6802843	12/2003	Truckai et al.	N/A	N/A
6808525	12/2003	Latterell et al.	N/A	N/A
6809508	12/2003	Donofrio	N/A	N/A
6810281	12/2003	Brock et al.	N/A	N/A
6811842	12/2003	Ehrnsperger et al.	N/A	N/A
6814731	12/2003	Swanson	N/A	N/A
6821273	12/2003	Mollenauer	N/A	N/A
6827712	12/2003	Tovey et al.	N/A	N/A
6828712	12/2003	Battaglin et al.	N/A	N/A
6832988	12/2003	Sproul	N/A	N/A
6835082	12/2003	Gonnering	N/A	N/A
6835199	12/2003	McGuckin, Jr. et al.	N/A	N/A
6840938	12/2004	Morley et al.	N/A	N/A
6849073	12/2004	Hoey et al.	N/A	N/A
6860878	12/2004	Brock	N/A	N/A
6860880	12/2004	Treat et al.	N/A	N/A
6863676	12/2004	Lee et al.	N/A	N/A
6869439	12/2004	White et al.	N/A	N/A
6875220	12/2004	Du et al.	N/A	N/A
6877647	12/2004	Green et al.	N/A	N/A
6882439	12/2004	Ishijima	N/A	N/A
6887209	12/2004	Kadziauskas et al.	N/A	N/A
6887221	12/2004	Baillargeon et al.	N/A	N/A
6887252	12/2004	Okada et al.	N/A	N/A
6893435	12/2004	Goble	N/A	N/A
6899685	12/2004	Kermode et al.	N/A	N/A
6905497	12/2004	Truckai et al.	N/A	N/A
6908463	12/2004	Treat et al.	N/A	N/A
6908466	12/2004	Bonutti et al.	N/A	N/A
6908472	12/2004	Wiener et al.	N/A	N/A

6913579	12/2004	Truckai et al.	N/A	N/A
6915623	12/2004	Dey et al.	N/A	N/A
6923804	12/2004	Eggers et al.	N/A	N/A
6926712	12/2004	Phan	N/A	N/A
6926716	12/2004	Baker et al.	N/A	N/A
6926717	12/2004	Garito et al.	N/A	N/A
6929602	12/2004	Hirakui et al.	N/A	N/A
6929622	12/2004	Chian	N/A	N/A
6929632	12/2004	Nita et al.	N/A	N/A
6929644	12/2004	Truckai et al.	N/A	N/A
6932876	12/2004	Statnikov	N/A	N/A
6933656	12/2004	Matsushita et al.	N/A	N/A
D509589	12/2004	Wells	N/A	N/A
6942660	12/2004	Pantera et al.	N/A	N/A
6942676	12/2004	Buelna	N/A	N/A
6942677	12/2004	Nita et al.	N/A	N/A
6945981	12/2004	Donofrio et al.	N/A	N/A
6946779	12/2004	Birgel	N/A	N/A
6948503	12/2004	Refior et al.	N/A	N/A
6953461	12/2004	McClurken et al.	N/A	N/A
6958070	12/2004	Witt et al.	N/A	N/A
D511145	12/2004	Donofrio et al.	N/A	N/A
6974450	12/2004	Weber et al.	N/A	N/A
6976844	12/2004	Hickok et al.	N/A	N/A
6976969	12/2004	Messerly	N/A	N/A
6977495	12/2004	Donofrio	N/A	N/A
6979332	12/2004	Adams	N/A	N/A
6981628	12/2005	Wales	N/A	N/A
6984220	12/2005	Wuchinich	N/A	N/A
6988295	12/2005	Tillim	N/A	N/A
6989017	12/2005	Howell et al.	N/A	N/A
6994708	12/2005	Manzo	N/A	N/A
6994709	12/2005	Iida	N/A	N/A
7000818	12/2005	Shelton, IV et al.	N/A	N/A
7001335	12/2005	Adachi et al.	N/A	N/A
7001382	12/2005	Gallo, Sr.	N/A	N/A
7002283	12/2005	Li et al.	N/A	N/A
7004951	12/2005	Gibbens, III	N/A	N/A
7011657	12/2005	Truckai et al.	N/A	N/A
7014638	12/2005	Michelson	N/A	N/A
7018354	12/2005	Tazi	N/A	N/A
7018389	12/2005	Camerlengo	N/A	N/A
7033357	12/2005	Baxter et al.	N/A	N/A
7037306	12/2005	Podany et al.	N/A	N/A
7041083	12/2005	Chu et al.	N/A	N/A
7041088	12/2005	Nawrocki et al.	N/A	N/A
7041102	12/2005	Truckai et al.	N/A	N/A
7044949	12/2005	Orszulak et al.	N/A	N/A
7052494	12/2005	Goble et al.	N/A	N/A
7052496	12/2005	Yamauchi	N/A	N/A

7055731	12/2005	Shelton, IV et al.	N/A	N/A
7062314	12/2005	Zhu et al.	N/A	N/A
7063699	12/2005	Hess et al.	N/A	N/A
7066893	12/2005	Hibner et al.	N/A	N/A
7066895	12/2005	Podany	N/A	N/A
7066936	12/2005	Ryan	N/A	N/A
7070597	12/2005	Truckai et al.	N/A	N/A
7074218	12/2005	Washington et al.	N/A	N/A
7074219	12/2005	Levine et al.	N/A	N/A
7077036	12/2005	Adams	N/A	N/A
7077039	12/2005	Gass et al.	N/A	N/A
7077845	12/2005	Hacker et al.	N/A	N/A
7077853	12/2005	Kramer et al.	N/A	N/A
7083075	12/2005	Swayze et al.	N/A	N/A
7083618	12/2005	Couture et al.	N/A	N/A
7083619	12/2005	Truckai et al.	N/A	N/A
7087054	12/2005	Truckai et al.	N/A	N/A
7090672	12/2005	Underwood et al.	N/A	N/A
7094235	12/2005	Francischelli	N/A	N/A
7101371	12/2005	Dycus et al.	N/A	N/A
7101372	12/2005	Dycus et al.	N/A	N/A
7101373	12/2005	Dycus et al.	N/A	N/A
7101378	12/2005	Salameh et al.	N/A	N/A
7104834	12/2005	Robinson et al.	N/A	N/A
7108695	12/2005	Witt et al.	N/A	N/A
7111769	12/2005	Wales et al.	N/A	N/A
7112201	12/2005	Truckai et al.	N/A	N/A
D531311	12/2005	Guerra et al.	N/A	N/A
7117034	12/2005	Kronberg	N/A	N/A
7118564	12/2005	Ritchie et al.	N/A	N/A
7118570	12/2005	Tetzlaff et al.	N/A	N/A
7119516	12/2005	Denning	N/A	N/A
7124932	12/2005	Isaacson et al.	N/A	N/A
7125409	12/2005	Truckai et al.	N/A	N/A
7128720	12/2005	Podany	N/A	N/A
7131860	12/2005	Sartor et al.	N/A	N/A
7131970	12/2005	Moses et al.	N/A	N/A
7131983	12/2005	Murakami	N/A	N/A
7135018	12/2005	Ryan et al.	N/A	N/A
7135029	12/2005	Makin et al.	N/A	N/A
7135030	12/2005	Schwemberger et al.	N/A	N/A
7137980	12/2005	Buysse et al.	N/A	N/A
7143925	12/2005	Shelton, IV et al.	N/A	N/A
7144403	12/2005	Booth	N/A	N/A
7147138	12/2005	Shelton, IV	N/A	N/A
7153315	12/2005	Miller	N/A	N/A
D536093	12/2006	Nakajima et al.	N/A	N/A
7156189	12/2006	Bar-Cohen et al.	N/A	N/A
7156201	12/2006	Peshkovskiy et al.	N/A	N/A

7156846	12/2006	Dycus et al.	N/A	N/A
7156853	12/2006	Muratsu	N/A	N/A
7157058	12/2006	Marhasin et al.	N/A	N/A
7159750	12/2006	Racenet et al.	N/A	N/A
7160259	12/2006	Tardy et al.	N/A	N/A
7160296	12/2006	Pearson et al.	N/A	N/A
7160298	12/2006	Lawes et al.	N/A	N/A
7160299	12/2006	Baily	N/A	N/A
7163548	12/2006	Stulen et al.	N/A	N/A
7169144	12/2006	Hoey et al.	N/A	N/A
7169146	12/2006	Truckai et al.	N/A	N/A
7169156	12/2006	Hart	N/A	N/A
7179254	12/2006	Pendekanti et al.	N/A	N/A
7179271	12/2006	Friedman et al.	N/A	N/A
7182762	12/2006	Bortkiewicz	N/A	N/A
7186253	12/2006	Truckai et al.	N/A	N/A
7189233	12/2006	Truckai et al.	N/A	N/A
7195631	12/2006	Dumbauld	N/A	N/A
D541418	12/2006	Schechter et al.	N/A	N/A
7198635	12/2006	Danek et al.	N/A	N/A
7204820	12/2006	Akahoshi	N/A	N/A
7207471	12/2006	Heinrich et al.	N/A	N/A
7207997	12/2006	Shipp et al.	N/A	N/A
7208005	12/2006	Frecker et al.	N/A	N/A
7210881	12/2006	Greenberg	N/A	N/A
7211079	12/2006	Treat	N/A	N/A
7217128	12/2006	Atkin et al.	N/A	N/A
7217269	12/2006	El-Galley et al.	N/A	N/A
7220951	12/2006	Truckai et al.	N/A	N/A
7223229	12/2006	Inman et al.	N/A	N/A
7225964	12/2006	Mastri et al.	N/A	N/A
7226448	12/2006	Bertolero et al.	N/A	N/A
7229455	12/2006	Sakurai et al.	N/A	N/A
7232440	12/2006	Dumbauld et al.	N/A	N/A
7235071	12/2006	Gonnering	N/A	N/A
7235073	12/2006	Levine et al.	N/A	N/A
7241294	12/2006	Reschke	N/A	N/A
7244262	12/2006	Wiener et al.	N/A	N/A
7251531	12/2006	Mosher et al.	N/A	N/A
7252667	12/2006	Moses et al.	N/A	N/A
7258688	12/2006	Shah et al.	N/A	N/A
7264618	12/2006	Murakami et al.	N/A	N/A
7267677	12/2006	Johnson et al.	N/A	N/A
7267685	12/2006	Butaric et al.	N/A	N/A
7269873	12/2006	Brewer et al.	N/A	N/A
7273483	12/2006	Wiener et al.	N/A	N/A
D552241	12/2006	Bromley et al.	N/A	N/A
7282048	12/2006	Goble et al.	N/A	N/A
7282836	12/2006	Kwon et al.	N/A	N/A
7285895	12/2006	Beaupre	N/A	N/A

7287682	12/2006	Ezzat et al.	N/A	N/A
7300431	12/2006	Dubrovsky	N/A	N/A
7300435	12/2006	Wham et al.	N/A	N/A
7300446	12/2006	Beaupre	N/A	N/A
7300450	12/2006	Vleugels et al.	N/A	N/A
7303531	12/2006	Lee et al.	N/A	N/A
7303557	12/2006	Wham et al.	N/A	N/A
7306597	12/2006	Manzo	N/A	N/A
7307313	12/2006	Ohyanagi et al.	N/A	N/A
7309849	12/2006	Truckai et al.	N/A	N/A
7311706	12/2006	Schoenman et al.	N/A	N/A
7311709	12/2006	Truckai et al.	N/A	N/A
7317955	12/2007	McGreevy	N/A	N/A
7318831	12/2007	Alvarez et al.	N/A	N/A
7318832	12/2007	Young et al.	N/A	N/A
7326236	12/2007	Andreas et al.	N/A	N/A
7329257	12/2007	Kanehira et al.	N/A	N/A
7331410	12/2007	Yong et al.	N/A	N/A
7335165	12/2007	Truwit et al.	N/A	N/A
7335997	12/2007	Wiener	N/A	N/A
7337010	12/2007	Howard et al.	N/A	N/A
7338463	12/2007	Vigil	N/A	N/A
7353068	12/2007	Tanaka et al.	N/A	N/A
7354440	12/2007	Truckal et al.	N/A	N/A
7357287	12/2007	Shelton, IV et al.	N/A	N/A
7361172	12/2007	Cimino	N/A	N/A
7364577	12/2007	Wham et al.	N/A	N/A
7367976	12/2007	Lawes et al.	N/A	N/A
7371227	12/2007	Zeiner	N/A	N/A
RE40388	12/2007	Gines	N/A	N/A
7380695	12/2007	Doll et al.	N/A	N/A
7380696	12/2007	Shelton, IV et al.	N/A	N/A
7381209	12/2007	Truckai et al.	N/A	N/A
7384420	12/2007	Dycus et al.	N/A	N/A
7390317	12/2007	Taylor et al.	N/A	N/A
7396356	12/2007	Mollenauer	N/A	N/A
7403224	12/2007	Fuller et al.	N/A	N/A
7404508	12/2007	Smith et al.	N/A	N/A
7407077	12/2007	Ortiz et al.	N/A	N/A
7408288	12/2007	Hara	N/A	N/A
7413123	12/2007	Ortenzi	N/A	N/A
7416101	12/2007	Shelton, IV et al.	N/A	N/A
7416437	12/2007	Sartor et al.	N/A	N/A
D576725	12/2007	Shumer et al.	N/A	N/A
7419490	12/2007	Falkenstein et al.	N/A	N/A
7422139	12/2007	Shelton, IV et al.	N/A	N/A
7422463	12/2007	Kuo	N/A	N/A
D578643	12/2007	Shumer et al.	N/A	N/A
D578644	12/2007	Shumer et al.	N/A	N/A
D578645	12/2007	Shumer et al.	N/A	N/A

7431694	12/2007	Stefanchik et al.	N/A	N/A
7431704	12/2007	Babaev	N/A	N/A
7435582	12/2007	Zimmermann et al.	N/A	N/A
7441684	12/2007	Shelton, IV et al.	N/A	N/A
7442168	12/2007	Novak et al.	N/A	N/A
7442193	12/2007	Shields et al.	N/A	N/A
7445621	12/2007	Dumbauld et al.	N/A	N/A
7449004	12/2007	Yamada et al.	N/A	N/A
7451904	12/2007	Shelton, IV	N/A	N/A
7455208	12/2007	Wales et al.	N/A	N/A
7455641	12/2007	Yamada et al.	N/A	N/A
7462181	12/2007	Kraft et al.	N/A	N/A
7464846	12/2007	Shelton, IV et al.	N/A	N/A
7472815	12/2008	Shelton, IV et al.	N/A	N/A
7473253	12/2008	Dycus et al.	N/A	N/A
7473263	12/2008	Johnston et al.	N/A	N/A
7479148	12/2008	Beaupre	N/A	N/A
7479160	12/2008	Branch et al.	N/A	N/A
7481775	12/2008	Weikel, Jr. et al.	N/A	N/A
7488285	12/2008	Honda et al.	N/A	N/A
7488319	12/2008	Yates	N/A	N/A
7491201	12/2008	Shields et al.	N/A	N/A
7491202	12/2008	Odom et al.	N/A	N/A
7494468	12/2008	Rabiner et al.	N/A	N/A
7494501	12/2008	Ahlberg et al.	N/A	N/A
7498080	12/2008	Tung et al.	N/A	N/A
7502234	12/2008	Goliszek et al.	N/A	N/A
7503893	12/2008	Kucklick	N/A	N/A
7503895	12/2008	Rabiner et al.	N/A	N/A
7506790	12/2008	Shelton, IV	N/A	N/A
7506791	12/2008	Omaits et al.	N/A	N/A
7510107	12/2008	Timm et al.	N/A	N/A
7510556	12/2008	Nguyen et al.	N/A	N/A
7513025	12/2008	Fischer	N/A	N/A
7517349	12/2008	Truckai et al.	N/A	N/A
7520865	12/2008	Radley Young et al.	N/A	N/A
7524320	12/2008	Tierney et al.	N/A	N/A
7530986	12/2008	Beaupre et al.	N/A	N/A
7533830	12/2008	Rose	N/A	N/A
7534243	12/2008	Chin et al.	N/A	N/A
D594983	12/2008	Price et al.	N/A	N/A
7540871	12/2008	Gonnering	N/A	N/A
7540872	12/2008	Schechter et al.	N/A	N/A
7543730	12/2008	Marczyk	N/A	N/A
7544200	12/2008	Houser	N/A	N/A
7549564	12/2008	Boudreaux	N/A	N/A
7550216	12/2008	Ofer et al.	N/A	N/A
7553309	12/2008	Buysse et al.	N/A	N/A
7559450	12/2008	Wales et al.	N/A	N/A

7559452	12/2008	Wales et al.	N/A	N/A
7563259	12/2008	Takahashi	N/A	N/A
7563269	12/2008	Hashiguchi	N/A	N/A
7566318	12/2008	Haefner	N/A	N/A
7567012	12/2008	Namikawa	N/A	N/A
7568603	12/2008	Shelton, IV et al.	N/A	N/A
7569057	12/2008	Liu et al.	N/A	N/A
7572266	12/2008	Young et al.	N/A	N/A
7572268	12/2008	Babaev	N/A	N/A
7578166	12/2008	Ethridge et al.	N/A	N/A
7578820	12/2008	Moore et al.	N/A	N/A
7582084	12/2008	Swanson et al.	N/A	N/A
7582086	12/2008	Privitera et al.	N/A	N/A
7582095	12/2008	Shipp et al.	N/A	N/A
7585181	12/2008	Olsen	N/A	N/A
7586289	12/2008	Andruk et al.	N/A	N/A
7587536	12/2008	McLeod	N/A	N/A
7588176	12/2008	Timm et al.	N/A	N/A
7588177	12/2008	Racenet	N/A	N/A
7594925	12/2008	Danek et al.	N/A	N/A
7597693	12/2008	Garrison	N/A	N/A
7601119	12/2008	Shahinian	N/A	N/A
7604150	12/2008	Boudreaux	N/A	N/A
7607557	12/2008	Shelton, IV et al.	N/A	N/A
7608054	12/2008	Soring et al.	N/A	N/A
7617961	12/2008	Viola	N/A	N/A
7621930	12/2008	Houser	N/A	N/A
7625370	12/2008	Hart et al.	N/A	N/A
7627936	12/2008	Bromfield	N/A	N/A
7628791	12/2008	Garrison et al.	N/A	N/A
7628792	12/2008	Guerra	N/A	N/A
7632267	12/2008	Dahla	N/A	N/A
7632269	12/2008	Truckai et al.	N/A	N/A
7637410	12/2008	Marczyk	N/A	N/A
7641653	12/2009	Dalla Betta et al.	N/A	N/A
7641671	12/2009	Crainich	N/A	N/A
7644848	12/2009	Swayze et al.	N/A	N/A
7645245	12/2009	Sekino et al.	N/A	N/A
7645277	12/2009	McClurken et al.	N/A	N/A
7645278	12/2009	Ichihashi et al.	N/A	N/A
7648499	12/2009	Orszulak et al.	N/A	N/A
7654431	12/2009	Hueil et al.	N/A	N/A
7658311	12/2009	Boudreaux	N/A	N/A
7659833	12/2009	Warner et al.	N/A	N/A
7662151	12/2009	Crompton, Jr. et al.	N/A	N/A
7665647	12/2009	Shelton, IV et al.	N/A	N/A
7666206	12/2009	Taniguchi et al.	N/A	N/A
7670334	12/2009	Hueil et al.	N/A	N/A
7670338	12/2009	Albrecht et al.	N/A	N/A
7674263	12/2009	Ryan	N/A	N/A

7678069	12/2009	Baker et al.	N/A	N/A
7678125	12/2009	Shipp	N/A	N/A
7682366	12/2009	Sakurai et al.	N/A	N/A
7686763	12/2009	Vaezy et al.	N/A	N/A
7686770	12/2009	Cohen	N/A	N/A
7686826	12/2009	Lee et al.	N/A	N/A
7688028	12/2009	Phillips et al.	N/A	N/A
7691095	12/2009	Bednarek et al.	N/A	N/A
7691098	12/2009	Wallace et al.	N/A	N/A
7696670	12/2009	Sakamoto	N/A	N/A
7699846	12/2009	Ryan	N/A	N/A
7703459	12/2009	Saadat et al.	N/A	N/A
7703653	12/2009	Shah et al.	N/A	N/A
7708735	12/2009	Chapman et al.	N/A	N/A
7708751	12/2009	Hughes et al.	N/A	N/A
7708758	12/2009	Lee et al.	N/A	N/A
7713202	12/2009	Boukhny et al.	N/A	N/A
7713267	12/2009	Pozzato	N/A	N/A
7714481	12/2009	Sakai	N/A	N/A
7717312	12/2009	Beetel	N/A	N/A
7717914	12/2009	Kimura	N/A	N/A
7717915	12/2009	Miyazawa	N/A	N/A
7721935	12/2009	Racenet et al.	N/A	N/A
7722527	12/2009	Bouchier et al.	N/A	N/A
7722607	12/2009	Dumbauld et al.	N/A	N/A
D618797	12/2009	Price et al.	N/A	N/A
7726537	12/2009	Olson et al.	N/A	N/A
7727177	12/2009	Bayat	N/A	N/A
7734476	12/2009	Wildman et al.	N/A	N/A
7738969	12/2009	Bleich	N/A	N/A
7740594	12/2009	Hibner	N/A	N/A
7749240	12/2009	Takahashi et al.	N/A	N/A
7749273	12/2009	Cauthen, III et al.	N/A	N/A
7751115	12/2009	Song	N/A	N/A
7753904	12/2009	Shelton, IV et al.	N/A	N/A
7753908	12/2009	Swanson	N/A	N/A
7762445	12/2009	Heinrich et al.	N/A	N/A
7762979	12/2009	Wuchinich	N/A	N/A
D621503	12/2009	Otten et al.	N/A	N/A
7766210	12/2009	Shelton, IV et al.	N/A	N/A
7766693	12/2009	Sartor et al.	N/A	N/A
7766910	12/2009	Hixson et al.	N/A	N/A
7770774	12/2009	Mastri et al.	N/A	N/A
7770775	12/2009	Shelton, IV et al.	N/A	N/A
7771425	12/2009	Dycus et al.	N/A	N/A
7771444	12/2009	Patel et al.	N/A	N/A
7775972	12/2009	Brock et al.	N/A	N/A
7776036	12/2009	Schechter et al.	N/A	N/A
7776037	12/2009	Odom	N/A	N/A
7778733	12/2009	Nowlin et al.	N/A	N/A

7780054	12/2009	Wales	N/A	N/A
7780593	12/2009	Ueno et al.	N/A	N/A
7780651	12/2009	Madhani et al.	N/A	N/A
7780659	12/2009	Okada et al.	N/A	N/A
7780663	12/2009	Yates et al.	N/A	N/A
7784662	12/2009	Wales et al.	N/A	N/A
7784663	12/2009	Shelton, IV	N/A	N/A
7785324	12/2009	Eberl	N/A	N/A
7789883	12/2009	Takashino et al.	N/A	N/A
7793814	12/2009	Racenet et al.	N/A	N/A
7796969	12/2009	Kelly et al.	N/A	N/A
7798386	12/2009	Schall et al.	N/A	N/A
7799020	12/2009	Shores et al.	N/A	N/A
7799045	12/2009	Masuda	N/A	N/A
7803152	12/2009	Honda et al.	N/A	N/A
7803156	12/2009	Eder et al.	N/A	N/A
7803168	12/2009	Gifford et al.	N/A	N/A
7806891	12/2009	Nowlin et al.	N/A	N/A
7810693	12/2009	Broehl et al.	N/A	N/A
7811283	12/2009	Moses et al.	N/A	N/A
7815641	12/2009	Dodde et al.	N/A	N/A
7815658	12/2009	Murakami	N/A	N/A
7819298	12/2009	Hall et al.	N/A	N/A
7819299	12/2009	Shelton, IV et al.	N/A	N/A
7819819	12/2009	Quick et al.	N/A	N/A
7819872	12/2009	Johnson et al.	N/A	N/A
7821143	12/2009	Wiener	N/A	N/A
D627066	12/2009	Romero	N/A	N/A
7824401	12/2009	Manzo et al.	N/A	N/A
7828808	12/2009	Hinman et al.	N/A	N/A
7832408	12/2009	Shelton, IV et al.	N/A	N/A
7832611	12/2009	Boyden et al.	N/A	N/A
7832612	12/2009	Baxter, III et al.	N/A	N/A
7834484	12/2009	Sartor	N/A	N/A
7834521	12/2009	Habu et al.	N/A	N/A
7837699	12/2009	Yamada et al.	N/A	N/A
7845537	12/2009	Shelton, IV et al.	N/A	N/A
7846155	12/2009	Houser et al.	N/A	N/A
7846159	12/2009	Morrison et al.	N/A	N/A
7846160	12/2009	Payne et al.	N/A	N/A
7846161	12/2009	Dumbauld et al.	N/A	N/A
7854735	12/2009	Houser et al.	N/A	N/A
D631155	12/2010	Peine et al.	N/A	N/A
7861906	12/2010	Doll et al.	N/A	N/A
7862560	12/2010	Marion	N/A	N/A
7867228	12/2010	Nobis et al.	N/A	N/A
7871392	12/2010	Sartor	N/A	N/A
7871423	12/2010	Livneh	N/A	N/A
7876030	12/2010	Taki et al.	N/A	N/A
D631965	12/2010	Price et al.	N/A	N/A

7878991	12/2010	Babaev	N/A	N/A
7879033	12/2010	Sartor et al.	N/A	N/A
7879035	12/2010	Garrison et al.	N/A	N/A
7879070	12/2010	Ortiz et al.	N/A	N/A
7883465	12/2010	Donofrio et al.	N/A	N/A
7883475	12/2010	Dupont et al.	N/A	N/A
7892606	12/2010	Thies et al.	N/A	N/A
7896875	12/2010	Heim et al.	N/A	N/A
7897792	12/2010	Iikura et al.	N/A	N/A
7901400	12/2010	Wham et al.	N/A	N/A
7901423	12/2010	Stulen et al.	N/A	N/A
7905881	12/2010	Masuda et al.	N/A	N/A
7909220	12/2010	Viola	N/A	N/A
7909824	12/2010	Masuda et al.	N/A	N/A
7918848	12/2010	Lau et al.	N/A	N/A
7919184	12/2010	Mohapatra et al.	N/A	N/A
7922061	12/2010	Shelton, IV et al.	N/A	N/A
7922651	12/2010	Yamada et al.	N/A	N/A
7922716	12/2010	Malecki et al.	N/A	N/A
7931611	12/2010	Novak et al.	N/A	N/A
7931649	12/2010	Couture et al.	N/A	N/A
D637288	12/2010	Houghton	N/A	N/A
D638540	12/2010	Ijiri et al.	N/A	N/A
7935114	12/2010	Takashino et al.	N/A	N/A
7936203	12/2010	Zimlich	N/A	N/A
7951095	12/2010	Makin et al.	N/A	N/A
7951165	12/2010	Golden et al.	N/A	N/A
7955331	12/2010	Truckai et al.	N/A	N/A
7959050	12/2010	Smith et al.	N/A	N/A
7959626	12/2010	Hong et al.	N/A	N/A
7963963	12/2010	Francischelli et al.	N/A	N/A
7967602	12/2010	Lindquist	N/A	N/A
7972329	12/2010	Refior et al.	N/A	N/A
7976544	12/2010	McClurken et al.	N/A	N/A
7980443	12/2010	Scheib et al.	N/A	N/A
7981050	12/2010	Ritchart et al.	N/A	N/A
7981113	12/2010	Truckai et al.	N/A	N/A
7997278	12/2010	Utley et al.	N/A	N/A
7998157	12/2010	Culp et al.	N/A	N/A
8002732	12/2010	Visconti	N/A	N/A
8006358	12/2010	Cooke et al.	N/A	N/A
8016843	12/2010	Escaf	N/A	N/A
8020743	12/2010	Shelton, IV	N/A	N/A
8025630	12/2010	Murakami et al.	N/A	N/A
8028885	12/2010	Smith et al.	N/A	N/A
8033173	12/2010	Ehlert et al.	N/A	N/A
8038693	12/2010	Allen	N/A	N/A
8048011	12/2010	Okabe	N/A	N/A
8048070	12/2010	O'Brien et al.	N/A	N/A
8052672	12/2010	Laufer et al.	N/A	N/A

8056720	12/2010	Hawkes	N/A	N/A
8057467	12/2010	Faller et al.	N/A	N/A
8057468	12/2010	Konesky	N/A	N/A
8057498	12/2010	Robertson	N/A	N/A
8058771	12/2010	Giordano et al.	N/A	N/A
8061014	12/2010	Smith et al.	N/A	N/A
8066167	12/2010	Measamer et al.	N/A	N/A
8070036	12/2010	Knodel	N/A	N/A
8070711	12/2010	Bassinger et al.	N/A	N/A
8070762	12/2010	Escudero et al.	N/A	N/A
8075555	12/2010	Truckai et al.	N/A	N/A
8075558	12/2010	Truckai et al.	N/A	N/A
8089197	12/2011	Rinner et al.	N/A	N/A
8092475	12/2011	Cotter et al.	N/A	N/A
8097012	12/2011	Kagarise	N/A	N/A
8100894	12/2011	Mucko et al.	N/A	N/A
8105230	12/2011	Honda et al.	N/A	N/A
8105323	12/2011	Buysse et al.	N/A	N/A
8105324	12/2011	Palanker et al.	N/A	N/A
8114104	12/2011	Young et al.	N/A	N/A
8128624	12/2011	Couture et al.	N/A	N/A
8133218	12/2011	Daw et al.	N/A	N/A
8136712	12/2011	Zingman	N/A	N/A
8137263	12/2011	Marescaux et al.	N/A	N/A
8141762	12/2011	Bedi et al.	N/A	N/A
8142421	12/2011	Cooper et al.	N/A	N/A
8142461	12/2011	Houser et al.	N/A	N/A
8147488	12/2011	Masuda	N/A	N/A
8147508	12/2011	Madan et al.	N/A	N/A
8152801	12/2011	Goldberg et al.	N/A	N/A
8152825	12/2011	Madan et al.	N/A	N/A
8157145	12/2011	Shelton, IV et al.	N/A	N/A
8161977	12/2011	Shelton, IV et al.	N/A	N/A
8162966	12/2011	Connor et al.	N/A	N/A
8172846	12/2011	Brunnett et al.	N/A	N/A
8172870	12/2011	Shipp	N/A	N/A
8177800	12/2011	Spitz et al.	N/A	N/A
8182501	12/2011	Houser et al.	N/A	N/A
8182502	12/2011	Stulen et al.	N/A	N/A
8186560	12/2011	Hess et al.	N/A	N/A
8186877	12/2011	Klimovitch et al.	N/A	N/A
8187267	12/2011	Pappone et al.	N/A	N/A
D661801	12/2011	Price et al.	N/A	N/A
D661802	12/2011	Price et al.	N/A	N/A
D661803	12/2011	Price et al.	N/A	N/A
D661804	12/2011	Price et al.	N/A	N/A
8197472	12/2011	Lau et al.	N/A	N/A
8197479	12/2011	Olson et al.	N/A	N/A
8197502	12/2011	Smith et al.	N/A	N/A
8207651	12/2011	Gilbert	N/A	N/A

8210411	12/2011	Yates et al.	N/A	N/A
8221306	12/2011	Okada et al.	N/A	N/A
8221415	12/2011	Francischelli	N/A	N/A
8226665	12/2011	Cohen	N/A	N/A
8226675	12/2011	Houser et al.	N/A	N/A
8231607	12/2011	Takuma	N/A	N/A
8235917	12/2011	Joseph et al.	N/A	N/A
8236018	12/2011	Yoshimine et al.	N/A	N/A
8236019	12/2011	Houser	N/A	N/A
8236020	12/2011	Smith et al.	N/A	N/A
8241235	12/2011	Kahler et al.	N/A	N/A
8241271	12/2011	Millman et al.	N/A	N/A
8241282	12/2011	Unger et al.	N/A	N/A
8241283	12/2011	Guerra et al.	N/A	N/A
8241284	12/2011	Dycus et al.	N/A	N/A
8241312	12/2011	Messerly	N/A	N/A
8246575	12/2011	Viola	N/A	N/A
8246615	12/2011	Behnke	N/A	N/A
8246618	12/2011	Bucciaglia et al.	N/A	N/A
8246642	12/2011	Houser et al.	N/A	N/A
8251994	12/2011	McKenna et al.	N/A	N/A
8252012	12/2011	Stulen	N/A	N/A
8253303	12/2011	Giordano et al.	N/A	N/A
8257377	12/2011	Wiener et al.	N/A	N/A
8257387	12/2011	Cunningham	N/A	N/A
8262563	12/2011	Bakos et al.	N/A	N/A
8267300	12/2011	Boudreaux	N/A	N/A
8273087	12/2011	Kimura et al.	N/A	N/A
D669992	12/2011	Schafer et al.	N/A	N/A
D669993	12/2011	Merchant et al.	N/A	N/A
8277446	12/2011	Heard	N/A	N/A
8277447	12/2011	Garrison et al.	N/A	N/A
8277471	12/2011	Wiener et al.	N/A	N/A
8282581	12/2011	Zhao et al.	N/A	N/A
8282669	12/2011	Gerber et al.	N/A	N/A
8286846	12/2011	Smith et al.	N/A	N/A
8287485	12/2011	Kimura et al.	N/A	N/A
8287528	12/2011	Wham et al.	N/A	N/A
8287532	12/2011	Carroll et al.	N/A	N/A
8292886	12/2011	Kerr et al.	N/A	N/A
8292888	12/2011	Whitman	N/A	N/A
8298223	12/2011	Wham et al.	N/A	N/A
8298225	12/2011	Gilbert	N/A	N/A
8298232	12/2011	Unger	N/A	N/A
8298233	12/2011	Mueller	N/A	N/A
8303576	12/2011	Brock	N/A	N/A
8303580	12/2011	Wham et al.	N/A	N/A
8303583	12/2011	Hosier et al.	N/A	N/A
8303613	12/2011	Crandall et al.	N/A	N/A
8306629	12/2011	Mioduski et al.	N/A	N/A

8308040	12/2011	Huang et al.	N/A	N/A
8319400	12/2011	Houser et al.	N/A	N/A
8323302	12/2011	Robertson et al.	N/A	N/A
8323310	12/2011	Kingsley	N/A	N/A
8328061	12/2011	Kasvikis	N/A	N/A
8328761	12/2011	Widenhouse et al.	N/A	N/A
8328802	12/2011	Deville et al.	N/A	N/A
8328833	12/2011	Cuny	N/A	N/A
8328834	12/2011	Isaacs et al.	N/A	N/A
8333778	12/2011	Smith et al.	N/A	N/A
8333779	12/2011	Smith et al.	N/A	N/A
8334468	12/2011	Palmer et al.	N/A	N/A
8334635	12/2011	Voegele et al.	N/A	N/A
8337407	12/2011	Quistgaard et al.	N/A	N/A
8338726	12/2011	Palmer et al.	N/A	N/A
8343146	12/2012	Godara et al.	N/A	N/A
8344596	12/2012	Nield et al.	N/A	N/A
8348880	12/2012	Messerly et al.	N/A	N/A
8348967	12/2012	Stulen	N/A	N/A
8353297	12/2012	Dacquay et al.	N/A	N/A
8353847	12/2012	Kuhns et al.	N/A	N/A
8357103	12/2012	Mark et al.	N/A	N/A
8357158	12/2012	McKenna et al.	N/A	N/A
8366727	12/2012	Witt et al.	N/A	N/A
8372064	12/2012	Douglass et al.	N/A	N/A
8372099	12/2012	Deville et al.	N/A	N/A
8372101	12/2012	Smith et al.	N/A	N/A
8372102	12/2012	Stulen et al.	N/A	N/A
8374670	12/2012	Selkee	N/A	N/A
8377044	12/2012	Coe et al.	N/A	N/A
8377059	12/2012	Deville et al.	N/A	N/A
8377085	12/2012	Smith et al.	N/A	N/A
8382748	12/2012	Geisel	N/A	N/A
8382775	12/2012	Bender et al.	N/A	N/A
8382782	12/2012	Robertson et al.	N/A	N/A
8382792	12/2012	Chojin	N/A	N/A
8388646	12/2012	Chojin	N/A	N/A
8388647	12/2012	Nau, Jr. et al.	N/A	N/A
8394096	12/2012	Moses et al.	N/A	N/A
8394115	12/2012	Houser et al.	N/A	N/A
8397971	12/2012	Yates et al.	N/A	N/A
8403926	12/2012	Nobis et al.	N/A	N/A
8403945	12/2012	Whitfield et al.	N/A	N/A
8403948	12/2012	Deville et al.	N/A	N/A
8403949	12/2012	Palmer et al.	N/A	N/A
8403950	12/2012	Palmer et al.	N/A	N/A
8409234	12/2012	Stahler et al.	N/A	N/A
8414577	12/2012	Boudreaux et al.	N/A	N/A
8418073	12/2012	Mohr et al.	N/A	N/A
8418349	12/2012	Smith et al.	N/A	N/A

8419757	12/2012	Smith et al.	N/A	N/A
8419758	12/2012	Smith et al.	N/A	N/A
8419759	12/2012	Dietz	N/A	N/A
8423182	12/2012	Robinson et al.	N/A	N/A
8425161	12/2012	Nagaya et al.	N/A	N/A
8425410	12/2012	Murray et al.	N/A	N/A
8425545	12/2012	Smith et al.	N/A	N/A
8430811	12/2012	Hess et al.	N/A	N/A
8430876	12/2012	Kappus et al.	N/A	N/A
8430897	12/2012	Novak et al.	N/A	N/A
8430898	12/2012	Wiener et al.	N/A	N/A
8435257	12/2012	Smith et al.	N/A	N/A
8435258	12/2012	Young et al.	N/A	N/A
8439912	12/2012	Cunningham et al.	N/A	N/A
8439939	12/2012	Deville et al.	N/A	N/A
8444637	12/2012	Podmore et al.	N/A	N/A
8444662	12/2012	Palmer et al.	N/A	N/A
8444663	12/2012	Houser et al.	N/A	N/A
8444664	12/2012	Balanev et al.	N/A	N/A
8453906	12/2012	Huang et al.	N/A	N/A
8454599	12/2012	Inagaki et al.	N/A	N/A
8454639	12/2012	Du et al.	N/A	N/A
8460288	12/2012	Tamai et al.	N/A	N/A
8460292	12/2012	Truckai et al.	N/A	N/A
8460326	12/2012	Houser et al.	N/A	N/A
8461744	12/2012	Wiener et al.	N/A	N/A
8469981	12/2012	Robertson et al.	N/A	N/A
8479969	12/2012	Shelton, IV	N/A	N/A
8480703	12/2012	Nicholas et al.	N/A	N/A
8484833	12/2012	Cunningham et al.	N/A	N/A
8485413	12/2012	Scheib et al.	N/A	N/A
8485970	12/2012	Widenhouse et al.	N/A	N/A
8486057	12/2012	Behnke, II	N/A	N/A
8486096	12/2012	Robertson et al.	N/A	N/A
8491578	12/2012	Manwaring et al.	N/A	N/A
8491625	12/2012	Horner	N/A	N/A
8496682	12/2012	Guerra et al.	N/A	N/A
D687549	12/2012	Johnson et al.	N/A	N/A
8506555	12/2012	Ruiz Morales	N/A	N/A
8509318	12/2012	Tailliet	N/A	N/A
8512336	12/2012	Couture	N/A	N/A
8512359	12/2012	Whitman et al.	N/A	N/A
8512364	12/2012	Kowalski et al.	N/A	N/A
8512365	12/2012	Wiener et al.	N/A	N/A
8518067	12/2012	Masuda et al.	N/A	N/A
8523889	12/2012	Stulen et al.	N/A	N/A
8528563	12/2012	Gruber	N/A	N/A
8529437	12/2012	Taylor et al.	N/A	N/A
8529565	12/2012	Masuda et al.	N/A	N/A
8531064	12/2012	Robertson et al.	N/A	N/A

8535311	12/2012	Schall	N/A	N/A
8535340	12/2012	Allen	N/A	N/A
8535341	12/2012	Allen	N/A	N/A
8540128	12/2012	Shelton, IV et al.	N/A	N/A
8546996	12/2012	Messerly et al.	N/A	N/A
8546999	12/2012	Houser et al.	N/A	N/A
8551077	12/2012	Main et al.	N/A	N/A
8551086	12/2012	Kimura et al.	N/A	N/A
8562592	12/2012	Conlon et al.	N/A	N/A
8562598	12/2012	Falkenstein et al.	N/A	N/A
8562604	12/2012	Nishimura	N/A	N/A
8568390	12/2012	Mueller	N/A	N/A
8568400	12/2012	Gilbert	N/A	N/A
8568412	12/2012	Brandt et al.	N/A	N/A
8569997	12/2012	Lee	N/A	N/A
8573461	12/2012	Shelton, IV et al.	N/A	N/A
8573465	12/2012	Shelton, IV	N/A	N/A
8574231	12/2012	Boudreaux et al.	N/A	N/A
8574253	12/2012	Gruber et al.	N/A	N/A
8579176	12/2012	Smith et al.	N/A	N/A
8579897	12/2012	Vakharia et al.	N/A	N/A
8579928	12/2012	Robertson et al.	N/A	N/A
8579937	12/2012	Gresham	N/A	N/A
8591459	12/2012	Clymer et al.	N/A	N/A
8591506	12/2012	Wham et al.	N/A	N/A
8591536	12/2012	Robertson	N/A	N/A
D695407	12/2012	Price et al.	N/A	N/A
D696631	12/2012	Price et al.	N/A	N/A
8597193	12/2012	Grunwald et al.	N/A	N/A
8602031	12/2012	Reis et al.	N/A	N/A
8602288	12/2012	Shelton, IV et al.	N/A	N/A
8608745	12/2012	Guzman et al.	N/A	N/A
8610334	12/2012	Bromfield	N/A	N/A
8613383	12/2012	Beckman et al.	N/A	N/A
8616431	12/2012	Timm et al.	N/A	N/A
8622274	12/2013	Yates et al.	N/A	N/A
8623011	12/2013	Spivey	N/A	N/A
8623016	12/2013	Fischer	N/A	N/A
8623027	12/2013	Price et al.	N/A	N/A
8623044	12/2013	Timm et al.	N/A	N/A
8628529	12/2013	Aldridge et al.	N/A	N/A
8628534	12/2013	Jones et al.	N/A	N/A
8632461	12/2013	Glossop	N/A	N/A
8636736	12/2013	Yates et al.	N/A	N/A
8638428	12/2013	Brown	N/A	N/A
8640788	12/2013	Dachs, II et al.	N/A	N/A
8641663	12/2013	Kirschenman et al.	N/A	N/A
8647350	12/2013	Mohan et al.	N/A	N/A
8650728	12/2013	Wan et al.	N/A	N/A
8651230	12/2013	Peshkovsky et al.	N/A	N/A

8652120	12/2013	Giordano et al.	N/A	N/A
8652132	12/2013	Tsuchiya et al.	N/A	N/A
8652155	12/2013	Houser et al.	N/A	N/A
8659208	12/2013	Rose et al.	N/A	N/A
8663220	12/2013	Wiener et al.	N/A	N/A
8663222	12/2013	Anderson et al.	N/A	N/A
8663262	12/2013	Smith et al.	N/A	N/A
8668691	12/2013	Heard	N/A	N/A
8668710	12/2013	Slipszenko et al.	N/A	N/A
8684253	12/2013	Giordano et al.	N/A	N/A
8685016	12/2013	Wham et al.	N/A	N/A
8685020	12/2013	Weizman et al.	N/A	N/A
8690582	12/2013	Rohrbach et al.	N/A	N/A
8691268	12/2013	Weimann	N/A	N/A
8695866	12/2013	Leimbach et al.	N/A	N/A
8696366	12/2013	Chen et al.	N/A	N/A
8696665	12/2013	Hunt et al.	N/A	N/A
8702609	12/2013	Hadjicostis	N/A	N/A
8702704	12/2013	Shelton, IV et al.	N/A	N/A
8704425	12/2013	Giordano et al.	N/A	N/A
8708213	12/2013	Shelton, IV et al.	N/A	N/A
8709031	12/2013	Stulen	N/A	N/A
8709035	12/2013	Johnson et al.	N/A	N/A
8715270	12/2013	Weitzner et al.	N/A	N/A
8715277	12/2013	Weizman	N/A	N/A
8715306	12/2013	Faller et al.	N/A	N/A
8721640	12/2013	Taylor et al.	N/A	N/A
8721657	12/2013	Kondoh et al.	N/A	N/A
8734443	12/2013	Hixson et al.	N/A	N/A
8734476	12/2013	Rhee et al.	N/A	N/A
8747238	12/2013	Shelton, IV et al.	N/A	N/A
8747351	12/2013	Schultz	N/A	N/A
8747404	12/2013	Boudreaux et al.	N/A	N/A
8749116	12/2013	Messerly et al.	N/A	N/A
8752264	12/2013	Ackley et al.	N/A	N/A
8752749	12/2013	Moore et al.	N/A	N/A
8753338	12/2013	Widenhouse et al.	N/A	N/A
8754570	12/2013	Voegele et al.	N/A	N/A
8758342	12/2013	Bales et al.	N/A	N/A
8758352	12/2013	Cooper et al.	N/A	N/A
8764735	12/2013	Coe et al.	N/A	N/A
8764747	12/2013	Cummings et al.	N/A	N/A
8767970	12/2013	Eppolito	N/A	N/A
8770459	12/2013	Racenet et al.	N/A	N/A
8771269	12/2013	Sherman et al.	N/A	N/A
8771270	12/2013	Burbank	N/A	N/A
8773001	12/2013	Wiener et al.	N/A	N/A
8777944	12/2013	Frankhouser et al.	N/A	N/A
8779648	12/2013	Giordano et al.	N/A	N/A
8783541	12/2013	Shelton, IV et al.	N/A	N/A

8784415	12/2013	Malackowski et al.	N/A	N/A
8784418	12/2013	Romero	N/A	N/A
8790342	12/2013	Stulen et al.	N/A	N/A
8795276	12/2013	Dietz et al.	N/A	N/A
8795327	12/2013	Dietz et al.	N/A	N/A
8800838	12/2013	Shelton, IV	N/A	N/A
8801710	12/2013	Ullrich et al.	N/A	N/A
8801752	12/2013	Fortier et al.	N/A	N/A
8808319	12/2013	Houser et al.	N/A	N/A
8814856	12/2013	Elmouelhi et al.	N/A	N/A
8814870	12/2013	Paraschiv et al.	N/A	N/A
8820605	12/2013	Shelton, IV	N/A	N/A
8821388	12/2013	Naito et al.	N/A	N/A
8827992	12/2013	Koss et al.	N/A	N/A
8827995	12/2013	Schaller et al.	N/A	N/A
8834466	12/2013	Cummings et al.	N/A	N/A
8834518	12/2013	Faller et al.	N/A	N/A
8844789	12/2013	Shelton, IV et al.	N/A	N/A
8845537	12/2013	Tanaka et al.	N/A	N/A
8845630	12/2013	Mehta et al.	N/A	N/A
8848808	12/2013	Dress	N/A	N/A
8851354	12/2013	Swensgard et al.	N/A	N/A
8852184	12/2013	Kucklick	N/A	N/A
8858547	12/2013	Brogna	N/A	N/A
8862955	12/2013	Cesari	N/A	N/A
8864709	12/2013	Akagane et al.	N/A	N/A
8864749	12/2013	Okada	N/A	N/A
8864757	12/2013	Klimovitch et al.	N/A	N/A
8864761	12/2013	Johnson et al.	N/A	N/A
8870865	12/2013	Frankhouser et al.	N/A	N/A
8870867	12/2013	Walberg et al.	N/A	N/A
8882766	12/2013	Couture et al.	N/A	N/A
8882791	12/2013	Stulen	N/A	N/A
8882792	12/2013	Dietz et al.	N/A	N/A
8888776	12/2013	Dietz et al.	N/A	N/A
8888783	12/2013	Young	N/A	N/A
8888809	12/2013	Davison et al.	N/A	N/A
8899462	12/2013	Kostrzewski et al.	N/A	N/A
8900259	12/2013	Houser et al.	N/A	N/A
8906016	12/2013	Boudreaux et al.	N/A	N/A
8906017	12/2013	Rioux et al.	N/A	N/A
8911438	12/2013	Swoyer et al.	N/A	N/A
8911460	12/2013	Neurohr et al.	N/A	N/A
8920412	12/2013	Fritz et al.	N/A	N/A
8920414	12/2013	Stone et al.	N/A	N/A
8920421	12/2013	Rupp	N/A	N/A
8926607	12/2014	Norvell et al.	N/A	N/A
8926608	12/2014	Bacher et al.	N/A	N/A
8931682	12/2014	Timm et al.	N/A	N/A
8936614	12/2014	Allen, IV	N/A	N/A

8939974	12/2014	Boudreaux et al.	N/A	N/A
8951248	12/2014	Messerly et al.	N/A	N/A
8951272	12/2014	Robertson et al.	N/A	N/A
8956349	12/2014	Aldridge et al.	N/A	N/A
8961515	12/2014	Twomey et al.	N/A	N/A
8961547	12/2014	Dietz et al.	N/A	N/A
8968283	12/2014	Kharin	N/A	N/A
8968294	12/2014	Maass et al.	N/A	N/A
8968355	12/2014	Malkowski et al.	N/A	N/A
8974447	12/2014	Kimball et al.	N/A	N/A
8974477	12/2014	Yamada	N/A	N/A
8974479	12/2014	Ross et al.	N/A	N/A
8979843	12/2014	Timm et al.	N/A	N/A
8979844	12/2014	White et al.	N/A	N/A
8979890	12/2014	Boudreaux	N/A	N/A
8986287	12/2014	Park et al.	N/A	N/A
8986302	12/2014	Aldridge et al.	N/A	N/A
8989855	12/2014	Murphy et al.	N/A	N/A
8989903	12/2014	Weir et al.	N/A	N/A
8991678	12/2014	Wellman et al.	N/A	N/A
8992422	12/2014	Spivey et al.	N/A	N/A
8992526	12/2014	Brodbeck et al.	N/A	N/A
9005199	12/2014	Beckman et al.	N/A	N/A
9011437	12/2014	Woodruff et al.	N/A	N/A
9011471	12/2014	Timm et al.	N/A	N/A
9017326	12/2014	DiNardo et al.	N/A	N/A
9017355	12/2014	Smith et al.	N/A	N/A
9017372	12/2014	Artale et al.	N/A	N/A
9023071	12/2014	Miller et al.	N/A	N/A
9023072	12/2014	Young et al.	N/A	N/A
9028397	12/2014	Naito	N/A	N/A
9028476	12/2014	Bonn	N/A	N/A
9028494	12/2014	Shelton, IV et al.	N/A	N/A
9028519	12/2014	Yates et al.	N/A	N/A
9031667	12/2014	Williams	N/A	N/A
9033973	12/2014	Krapohl et al.	N/A	N/A
9035741	12/2014	Hamel et al.	N/A	N/A
9039690	12/2014	Kersten et al.	N/A	N/A
9039695	12/2014	Giordano et al.	N/A	N/A
9039705	12/2014	Takashino	N/A	N/A
9043018	12/2014	Mohr	N/A	N/A
9044227	12/2014	Shelton, IV et al.	N/A	N/A
9044243	12/2014	Johnson et al.	N/A	N/A
9044245	12/2014	Condie et al.	N/A	N/A
9044256	12/2014	Cadeddu et al.	N/A	N/A
9044261	12/2014	Houser	N/A	N/A
9050093	12/2014	Aldridge et al.	N/A	N/A
9050098	12/2014	Deville et al.	N/A	N/A
9050124	12/2014	Houser	N/A	N/A
9055961	12/2014	Manzo et al.	N/A	N/A

9059547	12/2014	McLawhorn	N/A	N/A
9060770	12/2014	Shelton, IV et al.	N/A	N/A
9060775	12/2014	Wiener et al.	N/A	N/A
9060776	12/2014	Yates et al.	N/A	N/A
9063049	12/2014	Beach et al.	N/A	N/A
9066723	12/2014	Beller et al.	N/A	N/A
9066747	12/2014	Robertson	N/A	N/A
9072535	12/2014	Shelton, IV et al.	N/A	N/A
9072536	12/2014	Shelton, IV et al.	N/A	N/A
9072539	12/2014	Messerly et al.	N/A	N/A
9084624	12/2014	Larkin et al.	N/A	N/A
9084878	12/2014	Kawaguchi et al.	N/A	N/A
9089327	12/2014	Worrell et al.	N/A	N/A
9089360	12/2014	Messerly et al.	N/A	N/A
9095362	12/2014	Dachs, II et al.	N/A	N/A
9095367	12/2014	Olson et al.	N/A	N/A
9101385	12/2014	Shelton, IV et al.	N/A	N/A
9107684	12/2014	Ma	N/A	N/A
9107689	12/2014	Robertson et al.	N/A	N/A
9107690	12/2014	Bales, Jr. et al.	N/A	N/A
9113900	12/2014	Buysse et al.	N/A	N/A
9113940	12/2014	Twomey	N/A	N/A
9114245	12/2014	Dietz et al.	N/A	N/A
9119657	12/2014	Shelton, IV et al.	N/A	N/A
9119957	12/2014	Gantz et al.	N/A	N/A
9125662	12/2014	Shelton, IV	N/A	N/A
9125667	12/2014	Stone et al.	N/A	N/A
9125722	12/2014	Schwartz	N/A	N/A
9147965	12/2014	Lee	N/A	N/A
9149324	12/2014	Huang et al.	N/A	N/A
9149325	12/2014	Worrell et al.	N/A	N/A
9161803	12/2014	Yates et al.	N/A	N/A
9168054	12/2014	Turner et al.	N/A	N/A
9168055	12/2014	Houser et al.	N/A	N/A
9168085	12/2014	Juzkiw et al.	N/A	N/A
9168089	12/2014	Buysse et al.	N/A	N/A
9168090	12/2014	Strobl et al.	N/A	N/A
9173656	12/2014	Schurr et al.	N/A	N/A
9179912	12/2014	Yates et al.	N/A	N/A
9186199	12/2014	Strauss et al.	N/A	N/A
9186204	12/2014	Nishimura et al.	N/A	N/A
9192380	12/2014	(Tarinelli) Racenet et al.	N/A	N/A
9192431	12/2014	Woodruff et al.	N/A	N/A
9198714	12/2014	Worrell et al.	N/A	N/A
9198715	12/2014	Livneh	N/A	N/A
9204879	12/2014	Shelton, IV	N/A	N/A
9204891	12/2014	Weitzman	N/A	N/A
9204918	12/2014	Germain et al.	N/A	N/A
9204923	12/2014	Manzo et al.	N/A	N/A

9216050	12/2014	Condie et al.	N/A	N/A
9216062	12/2014	Duque et al.	N/A	N/A
9220483	12/2014	Frankhouser et al.	N/A	N/A
9220527	12/2014	Houser et al.	N/A	N/A
9220559	12/2014	Worrell et al.	N/A	N/A
9226750	12/2015	Weir et al.	N/A	N/A
9226751	12/2015	Shelton, IV et al.	N/A	N/A
9226766	12/2015	Aldridge et al.	N/A	N/A
9226767	12/2015	Stulen et al.	N/A	N/A
9232979	12/2015	Parihar et al.	N/A	N/A
9237891	12/2015	Shelton, IV	N/A	N/A
9237921	12/2015	Messerly et al.	N/A	N/A
9237923	12/2015	Worrell et al.	N/A	N/A
9241060	12/2015	Fujisaki	N/A	N/A
9241692	12/2015	Gunday et al.	N/A	N/A
9241728	12/2015	Price et al.	N/A	N/A
9241730	12/2015	Babaev	N/A	N/A
9241731	12/2015	Boudreaux et al.	N/A	N/A
9241768	12/2015	Sandhu et al.	N/A	N/A
9247953	12/2015	Palmer et al.	N/A	N/A
9254165	12/2015	Aronow et al.	N/A	N/A
9254171	12/2015	Trees et al.	N/A	N/A
9259234	12/2015	Robertson et al.	N/A	N/A
9259265	12/2015	Harris et al.	N/A	N/A
9265567	12/2015	Orban et al.	N/A	N/A
9265926	12/2015	Strobl et al.	N/A	N/A
9265973	12/2015	Akagane	N/A	N/A
9277962	12/2015	Koss et al.	N/A	N/A
9282974	12/2015	Shelton, IV	N/A	N/A
9283027	12/2015	Monson et al.	N/A	N/A
9283045	12/2015	Rhee et al.	N/A	N/A
9289256	12/2015	Shelton, IV et al.	N/A	N/A
9295514	12/2015	Shelton, IV et al.	N/A	N/A
9301759	12/2015	Spivey et al.	N/A	N/A
9301772	12/2015	Kimball et al.	N/A	N/A
9307388	12/2015	Liang et al.	N/A	N/A
9307986	12/2015	Hall et al.	N/A	N/A
9308009	12/2015	Madan et al.	N/A	N/A
9308014	12/2015	Fischer	N/A	N/A
9314292	12/2015	Trees et al.	N/A	N/A
9314301	12/2015	Ben-Haim et al.	N/A	N/A
9326754	12/2015	Polster	N/A	N/A
9326787	12/2015	Sanai et al.	N/A	N/A
9326788	12/2015	Batross et al.	N/A	N/A
9333025	12/2015	Monson et al.	N/A	N/A
9339289	12/2015	Robertson	N/A	N/A
9339323	12/2015	Eder et al.	N/A	N/A
9339326	12/2015	McCullagh et al.	N/A	N/A
9345534	12/2015	Artale et al.	N/A	N/A
9345900	12/2015	Wu et al.	N/A	N/A

9351642	12/2015	Nadkarni et al.	N/A	N/A
9351754	12/2015	Vakharia et al.	N/A	N/A
9352173	12/2015	Yamada et al.	N/A	N/A
9358065	12/2015	Ladtkow et al.	N/A	N/A
9358407	12/2015	Akagane	N/A	N/A
9364230	12/2015	Shelton, IV et al.	N/A	N/A
9370400	12/2015	Parihar	N/A	N/A
9370611	12/2015	Ross et al.	N/A	N/A
9375230	12/2015	Ross et al.	N/A	N/A
9375232	12/2015	Hunt et al.	N/A	N/A
9375267	12/2015	Kerr et al.	N/A	N/A
9381058	12/2015	Houser et al.	N/A	N/A
9386983	12/2015	Swensgard et al.	N/A	N/A
9393037	12/2015	Olson et al.	N/A	N/A
D763442	12/2015	Price et al.	N/A	N/A
9402680	12/2015	Ginnebaugh et al.	N/A	N/A
9402682	12/2015	Worrell et al.	N/A	N/A
9408606	12/2015	Shelton, IV	N/A	N/A
9408622	12/2015	Stulen et al.	N/A	N/A
9408660	12/2015	Strobl et al.	N/A	N/A
9414853	12/2015	Stulen et al.	N/A	N/A
9414880	12/2015	Monson et al.	N/A	N/A
9421060	12/2015	Monson et al.	N/A	N/A
9427249	12/2015	Robertson et al.	N/A	N/A
9439668	12/2015	Timm et al.	N/A	N/A
9439669	12/2015	Wiener et al.	N/A	N/A
9439671	12/2015	Akagane	N/A	N/A
9445784	12/2015	O'Keeffe	N/A	N/A
9445832	12/2015	Wiener et al.	N/A	N/A
9445833	12/2015	Akagane	N/A	N/A
9451967	12/2015	Jordan et al.	N/A	N/A
9456863	12/2015	Moua	N/A	N/A
9456864	12/2015	Witt et al.	N/A	N/A
9468498	12/2015	Sigmon, Jr.	N/A	N/A
9474542	12/2015	Slipszenko et al.	N/A	N/A
9486235	12/2015	Harrington et al.	N/A	N/A
9486236	12/2015	Price et al.	N/A	N/A
9492187	12/2015	Ravikumar et al.	N/A	N/A
9492224	12/2015	Boudreaux et al.	N/A	N/A
9498245	12/2015	Voegele et al.	N/A	N/A
9504483	12/2015	Houser et al.	N/A	N/A
9504524	12/2015	Behnke, II	N/A	N/A
9504855	12/2015	Messerly et al.	N/A	N/A
9510850	12/2015	Robertson et al.	N/A	N/A
9510906	12/2015	Boudreaux et al.	N/A	N/A
9522029	12/2015	Yates et al.	N/A	N/A
9526564	12/2015	Rusin	N/A	N/A
9526565	12/2015	Strobl	N/A	N/A
9545253	12/2016	Worrell et al.	N/A	N/A
9545497	12/2016	Wenderow et al.	N/A	N/A

9554846	12/2016	Boudreaux	N/A	N/A
9554854	12/2016	Yates et al.	N/A	N/A
9561038	12/2016	Shelton, IV et al.	N/A	N/A
9574644	12/2016	Parihar	N/A	N/A
9592072	12/2016	Akagane	N/A	N/A
9597143	12/2016	Madan et al.	N/A	N/A
9610091	12/2016	Johnson et al.	N/A	N/A
9610114	12/2016	Baxter, III et al.	N/A	N/A
9615877	12/2016	Tyrrell et al.	N/A	N/A
9622729	12/2016	Dewaele et al.	N/A	N/A
9623237	12/2016	Turner et al.	N/A	N/A
9636135	12/2016	Stulen	N/A	N/A
9638770	12/2016	Dietz et al.	N/A	N/A
9642644	12/2016	Houser et al.	N/A	N/A
9642669	12/2016	Takashino et al.	N/A	N/A
9643052	12/2016	Tchao et al.	N/A	N/A
9649111	12/2016	Shelton, IV et al.	N/A	N/A
9649126	12/2016	Robertson et al.	N/A	N/A
9662131	12/2016	Omori et al.	N/A	N/A
9668806	12/2016	Unger et al.	N/A	N/A
9671860	12/2016	Ogawa et al.	N/A	N/A
9675374	12/2016	Stulen et al.	N/A	N/A
9675375	12/2016	Houser et al.	N/A	N/A
9687290	12/2016	Keller	N/A	N/A
9700339	12/2016	Nield	N/A	N/A
9700343	12/2016	Messerly et al.	N/A	N/A
9707004	12/2016	Houser et al.	N/A	N/A
9707027	12/2016	Ruddenklau et al.	N/A	N/A
9707030	12/2016	Davison et al.	N/A	N/A
9713507	12/2016	Stulen et al.	N/A	N/A
9724118	12/2016	Schulte et al.	N/A	N/A
9724152	12/2016	Horlle et al.	N/A	N/A
9737326	12/2016	Worrell et al.	N/A	N/A
9737355	12/2016	Yates et al.	N/A	N/A
9737358	12/2016	Beckman et al.	N/A	N/A
9737735	12/2016	Dietz et al.	N/A	N/A
9743947	12/2016	Price et al.	N/A	N/A
9757142	12/2016	Shimizu	N/A	N/A
9757186	12/2016	Boudreaux et al.	N/A	N/A
9764164	12/2016	Wiener et al.	N/A	N/A
9782214	12/2016	Houser et al.	N/A	N/A
9788851	12/2016	Dannaher et al.	N/A	N/A
9795405	12/2016	Price et al.	N/A	N/A
9795436	12/2016	Yates et al.	N/A	N/A
9795808	12/2016	Messerly et al.	N/A	N/A
9801648	12/2016	Houser et al.	N/A	N/A
9801675	12/2016	Sanai et al.	N/A	N/A
9808308	12/2016	Faller et al.	N/A	N/A
9814514	12/2016	Shelton, IV et al.	N/A	N/A
9820768	12/2016	Gee et al.	N/A	N/A

9820771	12/2016	Norton et al.	N/A	N/A
9820806	12/2016	Lee et al.	N/A	N/A
9826976	12/2016	Parihar et al.	N/A	N/A
9839443	12/2016	Brockman et al.	N/A	N/A
9839796	12/2016	Sawada	N/A	N/A
9848901	12/2016	Robertson et al.	N/A	N/A
9848902	12/2016	Price et al.	N/A	N/A
9848937	12/2016	Trees et al.	N/A	N/A
9861428	12/2017	Trees et al.	N/A	N/A
9872725	12/2017	Worrell et al.	N/A	N/A
9877720	12/2017	Worrell et al.	N/A	N/A
9877776	12/2017	Boudreaux	N/A	N/A
9883884	12/2017	Neurohr et al.	N/A	N/A
9888958	12/2017	Evans et al.	N/A	N/A
9901339	12/2017	Farascioni	N/A	N/A
9901359	12/2017	Faller et al.	N/A	N/A
9907563	12/2017	Germain et al.	N/A	N/A
9913655	12/2017	Scheib et al.	N/A	N/A
9913656	12/2017	Stulen	N/A	N/A
9913680	12/2017	Voegele et al.	N/A	N/A
9918736	12/2017	Van Tol et al.	N/A	N/A
9925003	12/2017	Parihar et al.	N/A	N/A
9943325	12/2017	Faller et al.	N/A	N/A
9949785	12/2017	Price et al.	N/A	N/A
9949788	12/2017	Boudreaux	N/A	N/A
9962182	12/2017	Dietz et al.	N/A	N/A
9987033	12/2017	Neurohr et al.	N/A	N/A
10010339	12/2017	Witt et al.	N/A	N/A
10010341	12/2017	Houser et al.	N/A	N/A
10016207	12/2017	Suzuki et al.	N/A	N/A
10022142	12/2017	Aranyi et al.	N/A	N/A
10022567	12/2017	Messerly et al.	N/A	N/A
10022568	12/2017	Messerly et al.	N/A	N/A
10028765	12/2017	Hibner et al.	N/A	N/A
10028786	12/2017	Mucilli et al.	N/A	N/A
10034684	12/2017	Weisenburgh, II et al.	N/A	N/A
10034685	12/2017	Boudreaux et al.	N/A	N/A
10034704	12/2017	Asher et al.	N/A	N/A
10039588	12/2017	Harper et al.	N/A	N/A
10045794	12/2017	Witt et al.	N/A	N/A
10045819	12/2017	Jensen et al.	N/A	N/A
10070916	12/2017	Artale	N/A	N/A
10085762	12/2017	Timm et al.	N/A	N/A
10092310	12/2017	Boudreaux et al.	N/A	N/A
10092344	12/2017	Mohr et al.	N/A	N/A
10092348	12/2017	Boudreaux	N/A	N/A
10092350	12/2017	Rothweiler et al.	N/A	N/A
10111699	12/2017	Boudreaux	N/A	N/A
10117667	12/2017	Robertson et al.	N/A	N/A

10117702	12/2017	Danziger et al.	N/A	N/A
10130410	12/2017	Strobl et al.	N/A	N/A
10154852	12/2017	Conlon et al.	N/A	N/A
10159524	12/2017	Yates et al.	N/A	N/A
10166060	12/2018	Johnson et al.	N/A	N/A
10172669	12/2018	Felder et al.	N/A	N/A
10179022	12/2018	Yates et al.	N/A	N/A
10182837	12/2018	Isola et al.	N/A	N/A
10188385	12/2018	Kerr et al.	N/A	N/A
10194972	12/2018	Yates et al.	N/A	N/A
10194973	12/2018	Wiener et al.	N/A	N/A
10194976	12/2018	Boudreaux	N/A	N/A
10194977	12/2018	Yang	N/A	N/A
10201365	12/2018	Boudreaux et al.	N/A	N/A
10201382	12/2018	Wiener et al.	N/A	N/A
10226273	12/2018	Messerly et al.	N/A	N/A
10231747	12/2018	Stulen et al.	N/A	N/A
10245064	12/2018	Rhee et al.	N/A	N/A
10245065	12/2018	Witt et al.	N/A	N/A
10245095	12/2018	Boudreaux	N/A	N/A
10251664	12/2018	Shelton, IV et al.	N/A	N/A
10263171	12/2018	Wiener et al.	N/A	N/A
10265094	12/2018	Witt et al.	N/A	N/A
10265117	12/2018	Wiener et al.	N/A	N/A
10265118	12/2018	Gerhardt	N/A	N/A
D847990	12/2018	Kimball	N/A	N/A
10278721	12/2018	Dietz et al.	N/A	N/A
10285723	12/2018	Conlon et al.	N/A	N/A
10285724	12/2018	Faller et al.	N/A	N/A
10299810	12/2018	Robertson et al.	N/A	N/A
10299821	12/2018	Shelton, IV et al.	N/A	N/A
10314638	12/2018	Gee et al.	N/A	N/A
10321950	12/2018	Yates et al.	N/A	N/A
10335182	12/2018	Stulen et al.	N/A	N/A
10335614	12/2018	Messerly et al.	N/A	N/A
10342602	12/2018	Strobl et al.	N/A	N/A
10357303	12/2018	Conlon et al.	N/A	N/A
10363058	12/2018	Roberson et al.	N/A	N/A
10368892	12/2018	Stulen et al.	N/A	N/A
10368894	12/2018	Madan et al.	N/A	N/A
10368957	12/2018	Denzinger et al.	N/A	N/A
10398466	12/2018	Stulen et al.	N/A	N/A
10398497	12/2018	Batross et al.	N/A	N/A
10413352	12/2018	Thomas et al.	N/A	N/A
10420579	12/2018	Wiener et al.	N/A	N/A
10420580	12/2018	Messerly et al.	N/A	N/A
10420607	12/2018	Woloszko et al.	N/A	N/A
10426507	12/2018	Wiener et al.	N/A	N/A
10426978	12/2018	Akagane	N/A	N/A
10433865	12/2018	Witt et al.	N/A	N/A

10433866	12/2018	Witt et al.	N/A	N/A
10433900	12/2018	Harris et al.	N/A	N/A
10441308	12/2018	Robertson	N/A	N/A
10441310	12/2018	Olson et al.	N/A	N/A
10441345	12/2018	Aldridge et al.	N/A	N/A
10463421	12/2018	Boudreaux et al.	N/A	N/A
10463887	12/2018	Witt et al.	N/A	N/A
10470788	12/2018	Sinelnikov	N/A	N/A
10512795	12/2018	Voegele et al.	N/A	N/A
10517627	12/2018	Timm et al.	N/A	N/A
10524854	12/2019	Woodruff et al.	N/A	N/A
10531910	12/2019	Houser et al.	N/A	N/A
10537351	12/2019	Shelton, IV et al.	N/A	N/A
10537352	12/2019	Faller et al.	N/A	N/A
10537667	12/2019	Anim	N/A	N/A
10543008	12/2019	Vakharia et al.	N/A	N/A
10555750	12/2019	Conlon et al.	N/A	N/A
10555769	12/2019	Worrell et al.	N/A	N/A
10561436	12/2019	Asher et al.	N/A	N/A
10575892	12/2019	Danziger et al.	N/A	N/A
10595929	12/2019	Boudreaux et al.	N/A	N/A
10595930	12/2019	Scheib et al.	N/A	N/A
10603064	12/2019	Zhang	N/A	N/A
10610286	12/2019	Wiener et al.	N/A	N/A
10624665	12/2019	Noui et al.	N/A	N/A
10624691	12/2019	Wiener et al.	N/A	N/A
10639092	12/2019	Corbett et al.	N/A	N/A
10646267	12/2019	Ding	N/A	N/A
10677764	12/2019	Ross et al.	N/A	N/A
10687884	12/2019	Wiener et al.	N/A	N/A
10709469	12/2019	Shelton, IV et al.	N/A	N/A
10709906	12/2019	Nield	N/A	N/A
10716615	12/2019	Shelton, IV et al.	N/A	N/A
10722261	12/2019	Houser et al.	N/A	N/A
10729458	12/2019	Stoddard et al.	N/A	N/A
10736649	12/2019	Messerly et al.	N/A	N/A
10736685	12/2019	Wiener et al.	N/A	N/A
10751108	12/2019	Yates et al.	N/A	N/A
10758294	12/2019	Jones	N/A	N/A
10779845	12/2019	Timm et al.	N/A	N/A
10779847	12/2019	Messerly et al.	N/A	N/A
10779848	12/2019	Houser	N/A	N/A
10779849	12/2019	Shelton, IV et al.	N/A	N/A
10779879	12/2019	Yates et al.	N/A	N/A
10820920	12/2019	Scoggins et al.	N/A	N/A
10820938	12/2019	Fischer et al.	N/A	N/A
10828056	12/2019	Messerly et al.	N/A	N/A
10828057	12/2019	Neurohr et al.	N/A	N/A
10828058	12/2019	Shelton, IV et al.	N/A	N/A
10828059	12/2019	Price et al.	N/A	N/A

10835307	12/2019	Shelton, IV et al.	N/A	N/A
10835768	12/2019	Robertson et al.	N/A	N/A
10842522	12/2019	Messerly et al.	N/A	N/A
10842523	12/2019	Shelton, IV et al.	N/A	N/A
10842580	12/2019	Gee et al.	N/A	N/A
10856896	12/2019	Eichmann et al.	N/A	N/A
10874418	12/2019	Houser et al.	N/A	N/A
10881449	12/2020	Boudreaux et al.	N/A	N/A
10881451	12/2020	Worrell et al.	N/A	N/A
10888347	12/2020	Witt et al.	N/A	N/A
10893883	12/2020	Dannaher	N/A	N/A
10912603	12/2020	Boudreaux et al.	N/A	N/A
10952759	12/2020	Messerly et al.	N/A	N/A
10959769	12/2020	Mumaw et al.	N/A	N/A
10966744	12/2020	Rhee et al.	N/A	N/A
10987123	12/2020	Weir et al.	N/A	N/A
11000707	12/2020	Voegele et al.	N/A	N/A
11006971	12/2020	Faller et al.	N/A	N/A
11020140	12/2020	Gee et al.	N/A	N/A
11033292	12/2020	Green et al.	N/A	N/A
11033322	12/2020	Wiener et al.	N/A	N/A
D924400	12/2020	Kimball	N/A	N/A
11051840	12/2020	Shelton, IV et al.	N/A	N/A
11058447	12/2020	Houser	N/A	N/A
11058448	12/2020	Shelton, IV et al.	N/A	N/A
11058475	12/2020	Wiener et al.	N/A	N/A
11129670	12/2020	Shelton, IV et al.	N/A	N/A
11134978	12/2020	Shelton, IV et al.	N/A	N/A
11141213	12/2020	Yates et al.	N/A	N/A
11179582	12/2020	Voegele et al.	N/A	N/A
11229450	12/2021	Shelton, IV et al.	N/A	N/A
11229471	12/2021	Shelton, IV et al.	N/A	N/A
11229472	12/2021	Shelton, IV et al.	N/A	N/A
11253288	12/2021	Robertson	N/A	N/A
11266433	12/2021	Robertson	N/A	N/A
11272952	12/2021	Messerly et al.	N/A	N/A
11324527	12/2021	Aldridge et al.	N/A	N/A
11350959	12/2021	Messerly et al.	N/A	N/A
11369402	12/2021	Robertson et al.	N/A	N/A
11439426	12/2021	Witt et al.	N/A	N/A
11553954	12/2022	Conlon et al.	N/A	N/A
11602371	12/2022	Gee et al.	N/A	N/A
11607268	12/2022	Houser et al.	N/A	N/A
11666784	12/2022	Wiener et al.	N/A	N/A
11690641	12/2022	Stulen et al.	N/A	N/A
11690643	12/2022	Witt et al.	N/A	N/A
11730507	12/2022	Houser et al.	N/A	N/A
11766276	12/2022	Witt et al.	N/A	N/A
2001/0011176	12/2000	Boukhny	N/A	N/A
2001/0025173	12/2000	Ritchie et al.	N/A	N/A

2001/0025183	12/2000	Shahidi	N/A	N/A
2001/0025184	12/2000	Messerly	N/A	N/A
2001/0031950	12/2000	Ryan	N/A	N/A
2001/0032002	12/2000	McClurken et al.	N/A	N/A
2001/0039419	12/2000	Francischelli et al.	N/A	N/A
2002/0002377	12/2001	Cimino	N/A	N/A
2002/0002378	12/2001	Messerly	N/A	N/A
2002/0016603	12/2001	Wells	N/A	N/A
2002/0019649	12/2001	Sikora et al.	N/A	N/A
2002/0022836	12/2001	Goble et al.	N/A	N/A
2002/0029055	12/2001	Bonutti	N/A	N/A
2002/0049551	12/2001	Friedman et al.	N/A	N/A
2002/0052595	12/2001	Witt et al.	N/A	N/A
2002/0052617	12/2001	Anis et al.	N/A	N/A
2002/0077550	12/2001	Rabiner et al.	N/A	N/A
2002/0099373	12/2001	Schulze et al.	N/A	N/A
2002/0107446	12/2001	Rabiner et al.	N/A	N/A
2002/0107517	12/2001	Witt et al.	N/A	N/A
2002/0120266	12/2001	Truckai et al.	N/A	N/A
2002/0156466	12/2001	Sakurai et al.	N/A	N/A
2002/0156493	12/2001	Houser et al.	N/A	N/A
2002/0165577	12/2001	Witt et al.	N/A	N/A
2003/0014053	12/2002	Nguyen et al.	N/A	N/A
2003/0014087	12/2002	Fang et al.	N/A	N/A
2003/0036705	12/2002	Hare et al.	N/A	N/A
2003/0040758	12/2002	Wang et al.	N/A	N/A
2003/0050572	12/2002	Brautigam et al.	N/A	N/A
2003/0055443	12/2002	Spotnitz	N/A	N/A
2003/0093113	12/2002	Fogarty et al.	N/A	N/A
2003/0109875	12/2002	Tetzlaff et al.	N/A	N/A
2003/0114851	12/2002	Truckai et al.	N/A	N/A
2003/0114874	12/2002	Craig et al.	N/A	N/A
2003/0120306	12/2002	Burbank et al.	N/A	N/A
2003/0130675	12/2002	Kasahara et al.	N/A	N/A
2003/0130693	12/2002	Levin et al.	N/A	N/A
2003/0139741	12/2002	Goble et al.	N/A	N/A
2003/0144652	12/2002	Baker et al.	N/A	N/A
2003/0144680	12/2002	Kellogg et al.	N/A	N/A
2003/0158548	12/2002	Phan et al.	N/A	N/A
2003/0160698	12/2002	Andreasson et al.	N/A	N/A
2003/0163130	12/2002	Manna	606/50	A61B 18/1402
2003/0171747	12/2002	Kanehira et al.	N/A	N/A
2003/0195496	12/2002	Maguire et al.	N/A	N/A
2003/0199794	12/2002	Sakurai et al.	N/A	N/A
2003/0204199	12/2002	Novak et al.	N/A	N/A
2003/0212332	12/2002	Fenton et al.	N/A	N/A
2003/0212363	12/2002	Shipp	N/A	N/A
2003/0212391	12/2002	Fenton et al.	N/A	N/A
2003/0212392	12/2002	Fenton et al.	N/A	N/A
2003/0212422	12/2002	Fenton et al.	N/A	N/A

2003/0225332	12/2002	Okada et al.	N/A	N/A
2003/0229344	12/2002	Dycus et al.	N/A	N/A
2004/0030254	12/2003	Babaev	N/A	N/A
2004/0030330	12/2003	Brassell et al.	N/A	N/A
2004/0039242	12/2003	Tolkoff et al.	N/A	N/A
2004/0047485	12/2003	Sherrit et al.	N/A	N/A
2004/0054364	12/2003	Aranyi et al.	N/A	N/A
2004/0064151	12/2003	Mollenauer	N/A	N/A
2004/0087943	12/2003	Dycus et al.	N/A	N/A
2004/0092921	12/2003	Kadziauskas et al.	N/A	N/A
2004/0092992	12/2003	Adams et al.	N/A	N/A
2004/0097911	12/2003	Murakami et al.	N/A	N/A
2004/0097912	12/2003	Gonnering	N/A	N/A
2004/0097919	12/2003	Wellman et al.	N/A	N/A
2004/0097996	12/2003	Rabiner et al.	N/A	N/A
2004/0116952	12/2003	Sakurai et al.	N/A	N/A
2004/0121159	12/2003	Cloud et al.	N/A	N/A
2004/0122423	12/2003	Dycus et al.	N/A	N/A
2004/0132383	12/2003	Langford et al.	N/A	N/A
2004/0138621	12/2003	Jahns et al.	N/A	N/A
2004/0147934	12/2003	Kiester	N/A	N/A
2004/0147945	12/2003	Fritzsch	N/A	N/A
2004/0147946	12/2003	Mastri et al.	N/A	N/A
2004/0167508	12/2003	Wham et al.	N/A	N/A
2004/0176686	12/2003	Hare et al.	N/A	N/A
2004/0176751	12/2003	Weitzner et al.	N/A	N/A
2004/0193150	12/2003	Sharkey et al.	N/A	N/A
2004/0199193	12/2003	Hayashi et al.	N/A	N/A
2004/0199194	12/2003	Witt et al.	N/A	N/A
2004/0215132	12/2003	Yoon	N/A	N/A
2004/0243147	12/2003	Lipow	N/A	N/A
2004/0249374	12/2003	Tetzlaff et al.	N/A	N/A
2004/0260273	12/2003	Wan	N/A	N/A
2004/0260300	12/2003	Gorensek et al.	N/A	N/A
2004/0267298	12/2003	Cimino	N/A	N/A
2005/0015125	12/2004	Mioduski et al.	N/A	N/A
2005/0020967	12/2004	Ono	N/A	N/A
2005/0021018	12/2004	Anderson et al.	N/A	N/A
2005/0021065	12/2004	Yamada et al.	N/A	N/A
2005/0021078	12/2004	Vleugels et al.	N/A	N/A
2005/0033278	12/2004	McClurken et al.	N/A	N/A
2005/0033337	12/2004	Muir et al.	N/A	N/A
2005/0049546	12/2004	Messerly	606/169	A61B 17/320092
2005/0070800	12/2004	Takahashi	N/A	N/A
2005/0085728	12/2004	Fukuda	N/A	N/A
2005/0090817	12/2004	Phan	N/A	N/A
2005/0096683	12/2004	Ellins et al.	N/A	N/A
2005/0099824	12/2004	Dowling et al.	N/A	N/A
2005/0131390	12/2004	Heinrich et al.	N/A	N/A

2005/0143759	12/2004	Kelly	N/A	N/A
2005/0143769	12/2004	White et al.	N/A	N/A
2005/0149108	12/2004	Cox	N/A	N/A
2005/0165429	12/2004	Douglas et al.	N/A	N/A
2005/0171522	12/2004	Christopherson	N/A	N/A
2005/0177184	12/2004	Easley	N/A	N/A
2005/0182339	12/2004	Lee et al.	N/A	N/A
2005/0188743	12/2004	Land	N/A	N/A
2005/0192610	12/2004	Houser et al.	N/A	N/A
2005/0192611	12/2004	Houser	N/A	N/A
2005/0222598	12/2004	Ho et al.	N/A	N/A
2005/0228425	12/2004	Boukhny et al.	N/A	N/A
2005/0234484	12/2004	Houser et al.	N/A	N/A
2005/0249667	12/2004	Tuszynski et al.	N/A	N/A
2005/0256405	12/2004	Makin et al.	N/A	N/A
2005/0261588	12/2004	Makin et al.	N/A	N/A
2005/0267464	12/2004	Truckai et al.	N/A	N/A
2005/0273090	12/2004	Nieman et al.	N/A	N/A
2005/0288659	12/2004	Kimura et al.	N/A	N/A
2006/0025802	12/2005	Sowers	N/A	N/A
2006/0030797	12/2005	Zhou et al.	N/A	N/A
2006/0030848	12/2005	Craig et al.	N/A	N/A
2006/0058825	12/2005	Ogura et al.	N/A	N/A
2006/0063130	12/2005	Hayman et al.	N/A	N/A
2006/0064086	12/2005	Odom	N/A	N/A
2006/0066181	12/2005	Bromfield et al.	N/A	N/A
2006/0074442	12/2005	Noriega et al.	N/A	N/A
2006/0079874	12/2005	Faller et al.	N/A	N/A
2006/0079877	12/2005	Houser et al.	N/A	N/A
2006/0079879	12/2005	Faller et al.	N/A	N/A
2006/0095046	12/2005	Trieu et al.	N/A	N/A
2006/0100652	12/2005	Beaupre	N/A	N/A
2006/0159731	12/2005	Shoshan	N/A	N/A
2006/0190034	12/2005	Nishizawa et al.	N/A	N/A
2006/0206100	12/2005	Eskridge et al.	N/A	N/A
2006/0206115	12/2005	Schomer et al.	N/A	N/A
2006/0211943	12/2005	Beaupre	N/A	N/A
2006/0217729	12/2005	Eskridge et al.	N/A	N/A
2006/0224160	12/2005	Trieu et al.	N/A	N/A
2006/0241580	12/2005	Mittelstein et al.	N/A	N/A
2006/0247558	12/2005	Yamada	N/A	N/A
2006/0253050	12/2005	Yoshimine et al.	N/A	N/A
2006/0257819	12/2005	Johnson	N/A	N/A
2006/0264809	12/2005	Hansmann et al.	N/A	N/A
2006/0270916	12/2005	Skwarek et al.	N/A	N/A
2006/0271030	12/2005	Francis et al.	N/A	N/A
2006/0293656	12/2005	Shadduck et al.	N/A	N/A
2007/0016235	12/2006	Tanaka et al.	N/A	N/A
2007/0016236	12/2006	Beaupre	N/A	N/A
2007/0032704	12/2006	Gandini et al.	N/A	N/A

2007/0055228	12/2006	Berg et al.	N/A	N/A
2007/0056596	12/2006	Fanney et al.	N/A	N/A
2007/0060935	12/2006	Schwardt et al.	N/A	N/A
2007/0063618	12/2006	Bromfield	N/A	N/A
2007/0073185	12/2006	Nakao	N/A	N/A
2007/0073341	12/2006	Smith et al.	N/A	N/A
2007/0074584	12/2006	Talarico et al.	N/A	N/A
2007/0106317	12/2006	Shelton et al.	N/A	N/A
2007/0118115	12/2006	Artale et al.	N/A	N/A
2007/0130771	12/2006	Ehlert et al.	N/A	N/A
2007/0149881	12/2006	Rabin	N/A	N/A
2007/0156163	12/2006	Davison et al.	N/A	N/A
2007/0166663	12/2006	Telles et al.	N/A	N/A
2007/0173803	12/2006	Wham et al.	N/A	N/A
2007/0173813	12/2006	Odom	N/A	N/A
2007/0173872	12/2006	Neuenfeldt	N/A	N/A
2007/0185474	12/2006	Nahen	N/A	N/A
2007/0191712	12/2006	Messerly et al.	N/A	N/A
2007/0191713	12/2006	Eichmann et al.	N/A	N/A
2007/0198005	12/2006	Ichihashi et al.	N/A	N/A
2007/0203483	12/2006	Kim et al.	N/A	N/A
2007/0208340	12/2006	Ganz et al.	N/A	N/A
2007/0219481	12/2006	Babaev	N/A	N/A
2007/0232926	12/2006	Stulen et al.	N/A	N/A
2007/0232928	12/2006	Wiener et al.	N/A	N/A
2007/0236213	12/2006	Paden et al.	N/A	N/A
2007/0239101	12/2006	Kellogg	N/A	N/A
2007/0249941	12/2006	Salehi et al.	N/A	N/A
2007/0260242	12/2006	Dycus et al.	N/A	N/A
2007/0265560	12/2006	Soltani et al.	N/A	N/A
2007/0265613	12/2006	Edelstein et al.	N/A	N/A
2007/0265616	12/2006	Couture et al.	N/A	N/A
2007/0275348	12/2006	Lemon	N/A	N/A
2007/0276419	12/2006	Rosenthal	N/A	N/A
2007/0282333	12/2006	Fortson et al.	N/A	N/A
2007/0287933	12/2006	Phan et al.	N/A	N/A
2007/0288055	12/2006	Lee	N/A	N/A
2008/0013809	12/2007	Zhu et al.	N/A	N/A
2008/0015575	12/2007	Odom et al.	N/A	N/A
2008/0033465	12/2007	Schmitz et al.	N/A	N/A
2008/0039746	12/2007	Hissong et al.	N/A	N/A
2008/0051812	12/2007	Schmitz et al.	N/A	N/A
2008/0058775	12/2007	Darian et al.	N/A	N/A
2008/0058845	12/2007	Shimizu et al.	N/A	N/A
2008/0071269	12/2007	Hilario et al.	N/A	N/A
2008/0077145	12/2007	Boyden et al.	N/A	N/A
2008/0082039	12/2007	Babaev	N/A	N/A
2008/0082098	12/2007	Tanaka et al.	N/A	N/A
2008/0097281	12/2007	Zusman et al.	N/A	N/A
2008/0097501	12/2007	Blier	N/A	N/A

2008/0114355	12/2007	Whayne et al.	N/A	N/A
2008/0114364	12/2007	Goldin et al.	N/A	N/A
2008/0125768	12/2007	Tahara et al.	N/A	N/A
2008/0147058	12/2007	Horrell et al.	N/A	N/A
2008/0147062	12/2007	Truckai et al.	N/A	N/A
2008/0147092	12/2007	Rogge et al.	N/A	N/A
2008/0171938	12/2007	Masuda et al.	N/A	N/A
2008/0177268	12/2007	Daum et al.	N/A	N/A
2008/0188755	12/2007	Hart	N/A	N/A
2008/0200940	12/2007	Eichmann et al.	N/A	N/A
2008/0208108	12/2007	Kimura	N/A	N/A
2008/0208231	12/2007	Ota et al.	N/A	N/A
2008/0214967	12/2007	Aranyi et al.	N/A	N/A
2008/0234709	12/2007	Houser	N/A	N/A
2008/0234710	12/2007	Neurohr	606/169	A61B 17/320068
2008/0243162	12/2007	Shibata et al.	N/A	N/A
2008/0281200	12/2007	Voic et al.	N/A	N/A
2008/0281315	12/2007	Gines	N/A	N/A
2008/0287948	12/2007	Newton et al.	N/A	N/A
2008/0294051	12/2007	Koshigoe et al.	N/A	N/A
2008/0296346	12/2007	Shelton, IV et al.	N/A	N/A
2008/0300588	12/2007	Groth et al.	N/A	N/A
2009/0012516	12/2008	Curtis et al.	N/A	N/A
2009/0023985	12/2008	Ewers	N/A	N/A
2009/0043228	12/2008	Northrop et al.	N/A	N/A
2009/0048537	12/2008	Lydon et al.	N/A	N/A
2009/0048589	12/2008	Takashino et al.	N/A	N/A
2009/0054886	12/2008	Yachi et al.	N/A	N/A
2009/0054889	12/2008	Newton et al.	N/A	N/A
2009/0054894	12/2008	Yachi	N/A	N/A
2009/0069830	12/2008	Mulvihill et al.	N/A	N/A
2009/0076506	12/2008	Baker	N/A	N/A
2009/0082716	12/2008	Akahoshi	N/A	N/A
2009/0082766	12/2008	Unger et al.	N/A	N/A
2009/0088785	12/2008	Masuda	N/A	N/A
2009/0118751	12/2008	Wiener et al.	N/A	N/A
2009/0143678	12/2008	Keast et al.	N/A	N/A
2009/0143799	12/2008	Smith et al.	N/A	N/A
2009/0143800	12/2008	Deville et al.	N/A	N/A
2009/0163807	12/2008	Sliwa	N/A	N/A
2009/0182322	12/2008	D'Amelio et al.	N/A	N/A
2009/0182331	12/2008	D'Amelio et al.	N/A	N/A
2009/0182332	12/2008	Long et al.	N/A	N/A
2009/0216157	12/2008	Yamada	N/A	N/A
2009/0223033	12/2008	Houser	N/A	N/A
2009/0248021	12/2008	McKenna	N/A	N/A
2009/0254077	12/2008	Craig	N/A	N/A
2009/0254080	12/2008	Honda	N/A	N/A
2009/0259149	12/2008	Tahara et al.	N/A	N/A

2009/0264909	12/2008	Beaupre	N/A	N/A
2009/0270771	12/2008	Takahashi	N/A	N/A
2009/0270812	12/2008	Litscher et al.	N/A	N/A
2009/0270853	12/2008	Yachi et al.	N/A	N/A
2009/0270891	12/2008	Beaupre	N/A	N/A
2009/0270899	12/2008	Carusillo et al.	N/A	N/A
2009/0287205	12/2008	Ingle	N/A	N/A
2009/0299141	12/2008	Downey et al.	N/A	N/A
2009/0327715	12/2008	Smith et al.	N/A	N/A
2010/0004508	12/2009	Naito et al.	N/A	N/A
2010/0022825	12/2009	Yoshie	N/A	N/A
2010/0030233	12/2009	Whitman et al.	N/A	N/A
2010/0034605	12/2009	Huckins et al.	N/A	N/A
2010/0036370	12/2009	Mirel et al.	N/A	N/A
2010/0042126	12/2009	Houser et al.	N/A	N/A
2010/0049180	12/2009	Wells et al.	N/A	N/A
2010/0057118	12/2009	Dietz et al.	N/A	N/A
2010/0063525	12/2009	Beaupre et al.	N/A	N/A
2010/0063528	12/2009	Beaupre	N/A	N/A
2010/0081863	12/2009	Hess et al.	N/A	N/A
2010/0081864	12/2009	Hess et al.	N/A	N/A
2010/0081883	12/2009	Murray et al.	N/A	N/A
2010/0094323	12/2009	Isaacs et al.	N/A	N/A
2010/0106173	12/2009	Yoshimine	N/A	N/A
2010/0109480	12/2009	Forslund et al.	N/A	N/A
2010/0158307	12/2009	Kubota et al.	N/A	N/A
2010/0168741	12/2009	Sanai et al.	N/A	N/A
2010/0181966	12/2009	Sakakibara	N/A	N/A
2010/0187283	12/2009	Crainich et al.	N/A	N/A
2010/0204721	12/2009	Young et al.	N/A	N/A
2010/0222714	12/2009	Muir et al.	N/A	N/A
2010/0222752	12/2009	Collins, Jr. et al.	N/A	N/A
2010/0228191	12/2009	Alvarez et al.	N/A	N/A
2010/0234906	12/2009	Koh	N/A	N/A
2010/0274160	12/2009	Yachi et al.	N/A	N/A
2010/0274278	12/2009	Fleenor et al.	N/A	N/A
2010/0280368	12/2009	Can et al.	N/A	N/A
2010/0298743	12/2009	Nield et al.	N/A	N/A
2010/0312186	12/2009	Suchdev et al.	N/A	N/A
2010/0331742	12/2009	Masuda	N/A	N/A
2010/0331873	12/2009	Dannaher et al.	N/A	N/A
2011/0004233	12/2010	Muir et al.	N/A	N/A
2011/0028964	12/2010	Edwards	N/A	N/A
2011/0106141	12/2010	Nakamura	N/A	N/A
2011/0125151	12/2010	Strauss et al.	N/A	N/A
2011/0278343	12/2010	Knodel et al.	N/A	N/A
2011/0284014	12/2010	Cadeddu et al.	N/A	N/A
2011/0290856	12/2010	Shelton, IV et al.	N/A	N/A
2011/0291526	12/2010	Abramovich et al.	N/A	N/A
2011/0295295	12/2010	Shelton, IV et al.	N/A	N/A

2011/0306967	12/2010	Payne et al.	N/A	N/A
2011/0313415	12/2010	Fernandez et al.	N/A	N/A
2012/0004655	12/2011	Kim et al.	N/A	N/A
2012/0016413	12/2011	Timm et al.	N/A	N/A
2012/0022519	12/2011	Huang et al.	N/A	N/A
2012/0022526	12/2011	Aldridge et al.	N/A	N/A
2012/0022583	12/2011	Sugalski et al.	N/A	N/A
2012/0041358	12/2011	Mann et al.	N/A	N/A
2012/0059289	12/2011	Nield et al.	N/A	N/A
2012/0071863	12/2011	Lee et al.	N/A	N/A
2012/0078244	12/2011	Worrell et al.	N/A	N/A
2012/0078249	12/2011	Eichmann et al.	N/A	N/A
2012/0101495	12/2011	Young et al.	N/A	N/A
2012/0109186	12/2011	Parrott et al.	N/A	N/A
2012/0116222	12/2011	Sawada et al.	N/A	N/A
2012/0116265	12/2011	Houser et al.	N/A	N/A
2012/0116363	12/2011	Houser et al.	N/A	N/A
2012/0136279	12/2011	Tanaka et al.	N/A	N/A
2012/0143211	12/2011	Kishi	N/A	N/A
2012/0172904	12/2011	Muir et al.	N/A	N/A
2012/0265241	12/2011	Hart et al.	N/A	N/A
2012/0296371	12/2011	Kappus et al.	N/A	N/A
2012/0330338	12/2011	Messerly	N/A	N/A
2013/0023925	12/2012	Mueller	N/A	N/A
2013/0072948	12/2012	States, III et al.	N/A	N/A
2013/0090576	12/2012	Stulen et al.	N/A	N/A
2013/0116717	12/2012	Balek et al.	N/A	N/A
2013/0123776	12/2012	Monson et al.	N/A	N/A
2013/0158659	12/2012	Bergs et al.	N/A	N/A
2013/0158660	12/2012	Bergs et al.	N/A	N/A
2013/0165929	12/2012	Muir et al.	N/A	N/A
2013/0197511	12/2012	Balanev et al.	N/A	N/A
2013/0231691	12/2012	Houser	N/A	N/A
2013/0253256	12/2012	Griffith et al.	N/A	N/A
2013/0277410	12/2012	Fernandez et al.	N/A	N/A
2013/0296843	12/2012	Boudreaux et al.	N/A	N/A
2013/0331873	12/2012	Ross et al.	N/A	N/A
2014/0001231	12/2013	Shelton, IV et al.	N/A	N/A
2014/0001234	12/2013	Shelton, IV et al.	N/A	N/A
2014/0005640	12/2013	Shelton, IV et al.	N/A	N/A
2014/0005678	12/2013	Shelton, IV et al.	N/A	N/A
2014/0005702	12/2013	Timm et al.	N/A	N/A
2014/0005705	12/2013	Weir et al.	N/A	N/A
2014/0005718	12/2013	Shelton, IV et al.	N/A	N/A
2014/0014544	12/2013	Bugnard et al.	N/A	N/A
2014/0081299	12/2013	Dietz et al.	N/A	N/A
2014/0121569	12/2013	Schafer et al.	N/A	N/A
2014/0135663	12/2013	Funakubo et al.	N/A	N/A
2014/0135804	12/2013	Weisenburgh, II et al.	N/A	N/A

2014/0194874	12/2013	Dietz et al.	N/A	N/A
2014/0194875	12/2013	Reschke et al.	N/A	N/A
2014/0207135	12/2013	Winter	N/A	N/A
2014/0207163	12/2013	Eichmann et al.	N/A	N/A
2014/0276963	12/2013	Ranucci et al.	N/A	N/A
2014/0323926	12/2013	Akagane	N/A	N/A
2014/0371735	12/2013	Long	N/A	N/A
2015/0011889	12/2014	Lee	N/A	N/A
2015/0080876	12/2014	Worrell et al.	N/A	N/A
2015/0083774	12/2014	Measamer et al.	N/A	N/A
2015/0112335	12/2014	Boudreaux et al.	N/A	N/A
2015/0157356	12/2014	Gee	N/A	N/A
2015/0164533	12/2014	Felder et al.	N/A	N/A
2015/0164534	12/2014	Felder et al.	N/A	N/A
2015/0164535	12/2014	Felder et al.	N/A	N/A
2015/0164536	12/2014	Czarnecki et al.	N/A	N/A
2015/0164537	12/2014	Cagle et al.	N/A	N/A
2015/0165240	12/2014	Stoddard et al.	N/A	N/A
2015/0272659	12/2014	Boudreaux et al.	N/A	N/A
2015/0289854	12/2014	Cho et al.	N/A	N/A
2016/0045248	12/2015	Unger et al.	N/A	N/A
2016/0051316	12/2015	Boudreaux	N/A	N/A
2016/0114355	12/2015	Sakai et al.	N/A	N/A
2016/0128769	12/2015	Rontal et al.	N/A	N/A
2016/0175029	12/2015	Witt et al.	N/A	N/A
2016/0206342	12/2015	Robertson et al.	N/A	N/A
2016/0240768	12/2015	Fujii et al.	N/A	N/A
2016/0262786	12/2015	Madan et al.	N/A	N/A
2016/0270842	12/2015	Strobl et al.	N/A	N/A
2016/0296251	12/2015	Olson et al.	N/A	N/A
2016/0296252	12/2015	Olson et al.	N/A	N/A
2016/0296270	12/2015	Strobl et al.	N/A	N/A
2017/0027624	12/2016	Wilson et al.	N/A	N/A
2017/0036044	12/2016	Ito	N/A	N/A
2017/0086909	12/2016	Yates et al.	N/A	N/A
2017/0119426	12/2016	Akagane	N/A	N/A
2017/0135751	12/2016	Rothweiler et al.	N/A	N/A
2017/0164972	12/2016	Johnson et al.	N/A	N/A
2017/0189095	12/2016	Danziger et al.	N/A	N/A
2017/0202595	12/2016	Shelton, IV	N/A	N/A
2017/0205234	12/2016	Honda	N/A	N/A
2018/0125523	12/2017	Johnson	N/A	N/A
2019/0350615	12/2018	Messerly et al.	N/A	N/A
2020/0015798	12/2019	Wiener et al.	N/A	N/A
2020/0085466	12/2019	Faller et al.	N/A	N/A
2020/0323551	12/2019	Faller et al.	N/A	N/A
2021/0038248	12/2020	Houser	N/A	N/A
2021/0128191	12/2020	Messerly et al.	N/A	N/A
2021/0236157	12/2020	Rhee et al.	N/A	N/A
2021/0315605	12/2020	Gee et al.	N/A	N/A

2021/0378700	12/2020	Houser	N/A	N/A
2022/0346824	12/2021	Messerly et al.	N/A	N/A
2023/0191161	12/2022	Wiener et al.	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
837241	12/1969	CA	N/A
2535467	12/1992	CA	N/A
2214413	12/1995	CA	N/A
2460047	12/2000	CN	N/A
1634601	12/2004	CN	N/A
1775323	12/2005	CN	N/A
1922563	12/2006	CN	N/A
2868227	12/2006	CN	N/A
101766869	12/2009	CN	N/A
202027624	12/2010	CN	N/A
102335778	12/2011	CN	N/A
103668171	12/2013	CN	N/A
103921215	12/2013	CN	N/A
106077718	12/2015	CN	N/A
2065681	12/1974	DE	N/A
3904558	12/1989	DE	N/A
9210327	12/1991	DE	N/A
4300307	12/1993	DE	N/A
4434938	12/1995	DE	N/A
29623113	12/1996	DE	N/A
20004812	12/1999	DE	N/A
20021619	12/2000	DE	N/A
10042606	12/2000	DE	N/A
10201569	12/2002	DE	N/A
0171967	12/1985	EP	N/A
0336742	12/1988	EP	N/A
0136855	12/1988	EP	N/A
0705571	12/1995	EP	N/A
1543854	12/2004	EP	N/A
1698289	12/2005	EP	N/A
1862133	12/2006	EP	N/A
1972264	12/2007	EP	N/A
2060238	12/2008	EP	N/A
1747761	12/2008	EP	N/A
2131760	12/2008	EP	N/A
1214913	12/2009	EP	N/A
1946708	12/2010	EP	N/A
1767164	12/2012	EP	N/A
2578172	12/2012	EP	N/A
2510891	12/2015	EP	N/A
2454351	12/1979	FR	N/A
2964554	12/2011	FR	N/A
2032221	12/1979	GB	N/A

2317566	12/1997	GB	N/A
2318298	12/1997	GB	N/A
2425480	12/2005	GB	N/A
S50100891	12/1974	JP	N/A
S5968513	12/1983	JP	N/A
S59141938	12/1983	JP	N/A
S62213746	12/1986	JP	N/A
S62221343	12/1986	JP	N/A
S62227343	12/1986	JP	N/A
S62292153	12/1986	JP	N/A
S62292154	12/1986	JP	N/A
S63109386	12/1987	JP	N/A
S63315049	12/1987	JP	N/A
H01151452	12/1988	JP	N/A
H01198540	12/1988	JP	N/A
H0271510	12/1989	JP	N/A
H02286149	12/1989	JP	N/A
H02292193	12/1989	JP	N/A
H0337061	12/1990	JP	N/A
H0425707	12/1991	JP	N/A
H0464351	12/1991	JP	N/A
H0430508	12/1991	JP	N/A
H04152942	12/1991	JP	N/A
H04161078	12/1991	JP	N/A
H0595955	12/1992	JP	N/A
H05115490	12/1992	JP	N/A
H0647048	12/1993	JP	N/A
H0670938	12/1993	JP	N/A
H06104503	12/1993	JP	N/A
H07185457	12/1994	JP	N/A
H07299415	12/1994	JP	N/A
H0824266	12/1995	JP	N/A
H08229050	12/1995	JP	N/A
H08275950	12/1995	JP	N/A
H08275951	12/1995	JP	N/A
H08299351	12/1995	JP	N/A
H08336545	12/1995	JP	N/A
H09135553	12/1996	JP	N/A
H09140722	12/1996	JP	N/A
H105236	12/1997	JP	N/A
H105237	12/1997	JP	N/A
H10295700	12/1997	JP	N/A
H11128238	12/1998	JP	N/A
2000139943	12/1999	JP	N/A
2000210296	12/1999	JP	N/A
2000210299	12/1999	JP	N/A
2000271145	12/1999	JP	N/A
2000287987	12/1999	JP	N/A
2000312682	12/1999	JP	N/A
2001029353	12/2000	JP	N/A

2001057985	12/2000	JP	N/A
2001170066	12/2000	JP	N/A
2001198137	12/2000	JP	N/A
2002035002	12/2001	JP	N/A
2002186901	12/2001	JP	N/A
2002233533	12/2001	JP	N/A
2002263579	12/2001	JP	N/A
2002330977	12/2001	JP	N/A
2003000612	12/2002	JP	N/A
2003010201	12/2002	JP	N/A
2003116870	12/2002	JP	N/A
2003126104	12/2002	JP	N/A
2003126110	12/2002	JP	N/A
2003153919	12/2002	JP	N/A
2003230567	12/2002	JP	N/A
2003339730	12/2002	JP	N/A
2004129871	12/2003	JP	N/A
2004147701	12/2003	JP	N/A
2004209043	12/2003	JP	N/A
2005027026	12/2004	JP	N/A
2005074088	12/2004	JP	N/A
2005094552	12/2004	JP	N/A
2005253674	12/2004	JP	N/A
2006217716	12/2005	JP	N/A
2006288431	12/2005	JP	N/A
3841627	12/2005	JP	N/A
2007177931	12/2006	JP	N/A
D1339835	12/2007	JP	N/A
2009071439	12/2008	JP	N/A
2009082904	12/2008	JP	N/A
2009297352	12/2008	JP	N/A
2010009686	12/2009	JP	N/A
2010121865	12/2009	JP	N/A
2011160586	12/2010	JP	N/A
2012235658	12/2011	JP	N/A
2014121340	12/2013	JP	N/A
2015529140	12/2014	JP	N/A
2016022136	12/2015	JP	N/A
100789356	12/2006	KR	N/A
2154437	12/1999	RU	N/A
22035	12/2001	RU	N/A
2201169	12/2002	RU	N/A
2405603	12/2009	RU	N/A
850068	12/1980	SU	N/A
WO-8103272	12/1980	WO	N/A
WO-9308757	12/1992	WO	N/A
WO-9314708	12/1992	WO	N/A
WO-9421183	12/1993	WO	N/A
WO-9424949	12/1993	WO	N/A
WO-9639086	12/1995	WO	N/A

WO-9800069	12/1997	WO	N/A
WO-9805437	12/1997	WO	N/A
WO-9816157	12/1997	WO	N/A
WO-9920213	12/1998	WO	N/A
WO-9923960	12/1998	WO	N/A
WO-0024322	12/1999	WO	N/A
WO-0024330	12/1999	WO	N/A
WO-0064358	12/1999	WO	N/A
WO-0128444	12/2000	WO	N/A
WO-0132087	12/2000	WO	N/A
WO-0167970	12/2000	WO	N/A
WO-0170112	12/2000	WO	N/A
WO-0195810	12/2000	WO	N/A
WO-02076685	12/2001	WO	N/A
WO-02080799	12/2001	WO	N/A
WO-2004037095	12/2003	WO	N/A
WO-2004078051	12/2003	WO	N/A
WO-2004098426	12/2003	WO	N/A
WO-2005084250	12/2004	WO	N/A
WO-2007008710	12/2006	WO	N/A
WO-2008118709	12/2007	WO	N/A
WO-2008130793	12/2007	WO	N/A
WO-2008154338	12/2007	WO	N/A
WO-2010104755	12/2009	WO	N/A
WO-2011008672	12/2010	WO	N/A
WO-2011052939	12/2010	WO	N/A
WO-2011060031	12/2010	WO	N/A
WO-2012044606	12/2011	WO	N/A
WO-2012066983	12/2011	WO	N/A
WO-2013048963	12/2012	WO	N/A

OTHER PUBLICATIONS

Arnoczky et al., “Thermal Modification of Conective Tissues: Basic Science Considerations and Clinical Implications,” J. Am Acad Orthop Surg, vol. 8, No. 5, pp. 305-313 (Sep./Oct. 2000). cited by applicant

AST Products, Inc., “Principles of Video Contact Angle Analysis,” 20 pages, (2006). cited by applicant

Campbell et al., “Thermal Imaging in Surgery,” p. 19-3, in Medical Infrared Imaging, N. A. Diakides and J. D. Bronzino, Eds. (2008). cited by applicant

Chen et al., “Heat-Induced Changes in the Mechanics of a Collagenous Tissue: Isothermal Free Shrinkage,” Transactions of the ASME, vol. 119, pp. 372-378 (Nov. 1997). cited by applicant

Chen et al., “Heat-Induced Changes in the Mechanics of a Collagenous Tissue: Isothermal, Isotonic Shrinkage,” Transactions of the ASME, vol. 120, pp. 382-388 (Jun. 1998). cited by applicant

Chen et al., “Heat-induced changes in the mechanics of a collagenous tissue: pseudoelastic behavior at 37° C,” Journal of Biomechanics, 31, pp. 211-216 (1998). cited by applicant

Chen et al., “Phenomenological Evolution Equations for Heat-Induced Shrinkage of a Collagenous Tissue,” IEEE Transactions on Biomedical Engineering, vol. 45, No. 10, pp. 1234-1240 (Oct. 1998). cited by applicant

Covidien 501(k) Summary Sonicision, dated Feb. 24, 2011 (7 pages). cited by applicant

Covidien Brochure, [Value Analysis Brief], LigaSure Advance™ Pistol Grip, dated Rev. Apr. 2010

(7 pages). cited by applicant
Covidien Brochure, LigaSure Atlas™ Hand Switching Instruments, dated Dec. 2008 (2 pages). cited by applicant
Covidien Brochure, LigaSure Impact™ Instrument LF4318, dated Feb. 2013 (3 pages). cited by applicant
Covidien Brochure, The LigaSure Precise™ Instrument, dated Mar. 2011 (2 pages). cited by applicant
Covidien Brochure, The LigaSure™ 5 mm Blunt Tip Sealer/Divider Family, dated Apr. 2013 (2 pages). cited by applicant
Douglas, S.C. "Introduction to Adaptive Filter". Digital Signal Processing Handbook. Ed. Vijay K. Madisetti and Douglas B. Williams. Boca Raton: CRC Press LLC, 1999. cited by applicant
Emam, Tarek A et al., "How Safe is High-Power Ultrasonic Dissection?," Annals of Surgery, (2003), pp. 186-191, vol. 237, No. 2, Lippincott Williams & Wilkins, Inc., Philadelphia, PA. cited by applicant
Erbe Electrosurgery VIO® 200 S, (2012), p. 7, 12 pages, accessed Mar. 31, 2014 at http://www.erbe-med.com/erbe/media/Marketing materialien/85140170 ERBE EN VIO 200 S D027541. cited by applicant
F. A. Duck, "Optical Properties of Tissue Including Ultraviolet and Infrared Radiation," pp. 43-71 in Physical Properties of Tissue (1990). cited by applicant
Feil, Wolfgang, M.D., et al., "Ultrasonic Energy for Cutting, Coagulating, and Dissecting," (2005), pp. IV, 17, 21, and 23; ISBN 3-13-127521-9 (New York, NY, Thieme, New York). cited by applicant
Fowler, K.R., "A Programmable, Arbitrary Waveform Electrosurgical Device," IEEE Engineering in Medicine and Biology Society 10th Annual International Conference, pp. 1324, 1325 (1988). cited by applicant
Gerhard, Glen C., "Surgical Electrotechnology: Quo Vadis?," IEEE Transactions on Biomedical Engineering, vol. BME-31, No. 12, pp. 787-792, Dec. 1984. cited by applicant
Gibson, "Magnetic Refrigerator Successfully Tested," U.S. Department of Energy Research News, accessed online on Aug. 6, 2010 at http://www.eurekalert.org/features/doe/2001-11/dl-mrs062802.php (Nov. 1, 2001). cited by applicant
Glaser and Subak-Sharpe, Integrated Circuit Engineering, Addison-Wesley Publishing, Reading, MA (1979). (book--not attached). cited by applicant
Gooch et al., "Recommended Infection-Control Practices for Dentistry, 1993," Published: May 28, 1993; [retrieved on Aug. 23, 2008]. Retrieved from the internet: URL: http//wonder.cdc.gov/wonder/prevguid/p0000191/p0000191.asp (15 pages). cited by applicant
Graff, K.F., "Elastic Wave Propagation in a Curved Sonic Transmission Line," IEEE Transactions on Sonics and Ultrasonics, SU-17(1), 1-6 (1970). cited by applicant
Harris et al., "Altered Mechanical Behavior of Epicardium Due to Isothermal Heating Under Biaxial Isotonic Loads," Journal of Biomechanical Engineering, vol. 125, pp. 381-388 (Jun. 2003). cited by applicant
Harris et al., "Kinetics of Thermal Damage to a Collagenous Membrane Under Biaxial Isotonic Loading," IEEE Transactions on Biomedical Engineering, vol. 51, No. 2, pp. 371-379 (Feb. 2004). cited by applicant
Hayashi et al., "The Effect of Thermal Heating on the Length and Histologic Properties of the Glenohumeral Joint Capsule," American Journal of Sports Medicine, vol. 25, Issue 1, 11 pages (Jan. 1997), URL: http://www.mdconsult.com/das/article/body/156183648-2/jorg=journal&source=MI&sp=1 . . . , accessed Aug. 25, 2009. cited by applicant
Henriques. F.C., "Studies in thermal injury V. The predictability and the significance of thermally induced rate processes leading to irreversible epidermal injury." Archives of Pathology, 434, pp. 489-502 (1947). cited by applicant

http://www.4-traders.com/JOHNSON-JOHNSON-4832/news/Johnson-Johnson-Ethicon-E . . . . cited by applicant
http://www.apicalinstr.com/generators.htm. cited by applicant
http://www.dotmed.com/listing/electrosurical-unit/ethicon/ultracision-g110-/1466724. cited by applicant
http://www.medicalexpo.com/medical-manufacturer/electrosurgical-generator-6951.html. cited by applicant
http://www.megadyne.com/es_generator.php. cited by applicant
http://www.valleylab.com/product/es/generators/index.html. cited by applicant
http:/www.ethicon.com/gb-en/healthcare-professionals/products/energy-devices/capital//ge . . . . cited by applicant
https://www.kjmagnetics.com/fieldcalculator.asp, retrieved Jul. 11, 2016, backdated to Nov. 11, 2011 via https://web.archive.org/web/20111116164447/http://www.kjmagnetics.com/fieldcalculator.asp. cited by applicant
Humphrey, J.D., “Continuum Thermomechanics and the Clinical Treatment of Disease and Injury,” Appl. Mech. Rev., vol. 56, No. 2 pp. 231-260 (Mar. 2003). cited by applicant
Huston et al., “Magnetic and Magnetostrictive Properties of Cube Textured Nickel for Magnetostrictive Transducer Applications,” IEEE Transactions on Magnetics, vol. 9(4), pp. 636-640 (Dec. 1973). cited by applicant
Incropera et al., Fundamentals of Heat and Mass Transfer, Wiley, New York (1990). (Book--not attached). cited by applicant
Jang, J. et al. “Neuro-fuzzy and Soft Computing.” Prentice Hall, 1997, pp. 13-89, 199-293, 335-393, 453-496, 535-549. cited by applicant
Kurt Gieck & Reiner Gieck, *Engineering Formulas* § Z.7 (7th ed. 1997). cited by applicant
LaCourse, J.R.; Vogt, M.C.; Miller, W.T., III; Selikowitz, S.M., “Spectral Analysis Interpretation of Electrosurgical Generator Nerve and Muscle Stimulation,” IEEE Transactions on Biomedical Engineering, vol. 35, No. 7, pp. 505-509, Jul. 1988. cited by applicant
Lee et al., “A multi-sample denaturation temperature tester for collagenous biomaterials,” Med. Eng. Phy., vol. 17, No. 2, pp. 115-121 (Mar. 1995). cited by applicant
Leonard I. Malis, M.D., “The Value of Irrigation During Bipolar Coagulation,” 1989. cited by applicant
Lim et al., “A Review of Mechanism Used in Laparoscopic Surgical Instruments,” Mechanism and Machine Theory, vol. 38, pp. 1133-1147, (2003). cited by applicant
Makarov, S. N., Ochmann, M., Desinger, K., “The longitudinal vibration response of a curved fiber used for laser ultrasound surgical therapy,” Journal of the Acoustical Society of America 102, 1191-1199 (1997). cited by applicant
McCarus, Steven D. M.D., “Physiologic Mechanism of the Ultrasonically Activated Scalpel,” The Journal of the American Association of Gynecologic Laparoscopists; (Aug. 1996), vol. 3, No. 4., pp. 601-606 and 608. cited by applicant
Mitsui Chemicals Names DuPont™ Vespel® Business as Exclusive U.S., European Distributor of AUTUM® Thermoplastic Polyimide Resin, Feb. 24, 2003; http://www2.dupont.com/Vespel/en_US/news_events/article20030224.html. cited by applicant
Moran et al., “Thermally Induced Shrinkage of Joint Capsule,” Clinical Orthopaedics and Related Research, No. 281, pp. 248-255 (Dec. 2000). cited by applicant
Morley, L. S. D., “Elastic Waves in a Naturally Curved Rod,” Quarterly Journal of Mechanics and Applied Mathematics, 14: 155-172 (1961). cited by applicant
National Semiconductors Temperature Sensor Handbook—http://www.national.com/appinfo/tempsensors/files/temphb.pdf; accessed online: Apr. 1, 2011. cited by applicant

Orr et al., “Overview of Bioheat Transfer,” pp. 367-384 in Optical-Thermal Response of Laser-Irradiated Tissue, A. J. Welch and M. J. C. van Gemert, eds., Plenum, New York (1995). cited by applicant
Sadiq Muhammad et al: “High-performance planar ultrasonic tool based on d31-mode piezocrystal”, IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, IEEE, US, vol. 62, No. 3, Mar. 30, 2015 (Mar. 30, 2015), pp. 428-438, XP011574640, ISSN: 0885-3010, DOI: 10.1109/TUFFC.2014.006437. cited by applicant
Sherrit et al., “Novel Horn Designs for Ultrasonic/Sonic Cleaning Welding, Soldering, Cutting and Drilling,” Proc. SPIE Smart Structures Conference, vol. 4701, Paper No. 34, San Diego, CA, pp. 353-360, Mar. 2002. cited by applicant
Sullivan, “Cost-Constrained Selection of Strand Diameter and Number in a Litz-Wire Transformer Winding,” IEEE Transactions on Power Electronics, vol. 16, No. 2, Mar. 2001, pp. 281-288. cited by applicant
Sullivan, “Optimal Choice for Number of Strands in a Litz-Wire Transformer Winding,” IEEE Transactions on Power Electronics, vol. 14, No. 2, Mar. 1999, pp. 283-291. cited by applicant
Technology Overview, printed from www.harmonicscalpel.com, Internet site, website accessed on Jun. 13, 2007, (3 pages). cited by applicant
Wall et al., “Thermal modification of collagen,” J Shoulder Elbow Surg, No. 8, pp. 339-344 (Jul./Aug. 1999). cited by applicant
Walsh, S. J., White, R. G., “Vibrational Power Transmission in Curved Beams,” Journal of Sound and Vibration, 233(3), 455-488 (2000). cited by applicant
Weir, C.E., “Rate of shrinkage of tendon collagen - heat, entropy and free energy of activation of the shrinkage of untreated tendon. Effect of acid salt, pickle, and tannage on the activation of tendon collagen.” Journal of the American Leather Chemists Association, 44, pp. 108-140 (1949). cited by applicant
Wells et al., “Altered Mechanical Behavior of Epicardium Under Isothermal Biaxial Loading,” Transactions of the ASME, Journal of Biomedical Engineering, vol. 126, pp. 492-497 (Aug. 2004). cited by applicant
Wright, et al., “Time-Temperature Equivalence of Heat-Induced Changes in Cells and Proteins,” Feb. 1998. ASME Journal of Biomechanical Engineering, vol. 120, pp. 22-26. cited by applicant

---

Primary Examiner: Tanner; Jocelin C

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) The present application is a continuation application claiming priority under 35 U.S.C. § 120 to U.S. patent application Ser. No. 16/577,307, filed Sep. 20, 2019, entitled ULTRASONIC SURGICAL INSTRUMENT BLADES, which issued on Sep. 20, 2019 as U.S. Pat. No. 11,266,433, which is a continuation application claiming priority under 35 U.S.C. § 120 to U.S. patent application Ser. No. 15/155,367, filed May 16, 2016, entitled ULTRASONIC SURGICAL INSTRUMENT BLADES, which issued on Oct. 15, 2019 as U.S. Pat. No. 10,441,308, which is a divisional application claiming priority under 35 U.S.C. § 121 to U.S. patent application Ser. No. 14/743,687, filed Jun. 18, 2015, entitled ULTRASONIC SURGICAL INSTRUMENT BLADES, which issued on May 17, 2016 as U.S. Pat. No. 9,339,289, which is a divisional application claiming priority under 35 U.S.C. § 121 to U.S. patent application Ser. No. 14/069,837, filed Nov. 1, 2013, entitled ULTRASONIC SURGICAL INSTRUMENT BLADES, which issued on Jun. 30, 2015 as U.S. Pat. No. 9,066,747, which is a divisional application claiming priority under 35 U.S.C. § 121 from U.S. patent application Ser. No. 13/270,459, filed on Oct. 11, 2011, entitled ULTRASONIC SURGICAL INSTRUMENT BLADES, which issued on Nov. 26, 2013 as U.S. Pat. No. 8,591,536, which is a divisional application claiming priority under 35 U.S.C. § 121 from U.S. patent application Ser. No. 11/998,543, filed on Nov. 30, 2007, entitled ULTRASONIC SURGICAL INSTRUMENT BLADES, which issued on Nov. 15, 2011 as U.S. Pat. No. 8,057,498, the entire disclosures of which are incorporated by reference herein.

BACKGROUND

(1) Ultrasonic instruments, including both hollow core and solid core instruments, are used for the safe and effective treatment of many medical conditions. Ultrasonic instruments, and particularly solid core ultrasonic instruments, are advantageous because they may be used to cut and/or coagulate organic tissue using energy in the form of mechanical vibrations transmitted to a surgical end effector at ultrasonic frequencies. Ultrasonic vibrations, when transmitted to organic tissue at suitable energy levels and using a suitable end effector, may be used to cut, dissect, elevate or cauterize tissue or to separate muscle tissue off bone. Ultrasonic instruments utilizing solid core technology are particularly advantageous because of the amount of ultrasonic energy that may be transmitted from the ultrasonic transducer, through a waveguide, to the surgical end effector. Such instruments may be used for open procedures or minimally invasive procedures, such as endoscopic or laparoscopic procedures, wherein the end effector is passed through a trocar to reach the surgical site.

(2) Activating or exciting the end effector (e.g., cutting blade) of such instruments at ultrasonic frequencies induces longitudinal vibratory movement that generates localized heat within adjacent tissue, facilitating both cutting and coagulation. Because of the nature of ultrasonic instruments, a particular ultrasonically actuated end effector may be designed to perform numerous functions, including, for example, cutting and coagulation.

(3) Ultrasonic vibration is induced in the surgical end effector by electrically exciting a transducer, for example. The transducer may be constructed of one or more piezoelectric or magnetostrictive elements in the instrument hand piece. Vibrations generated by the transducer section are transmitted to the surgical end effector via an ultrasonic waveguide extending from the transducer section to the surgical end effector. The waveguides and end effectors are designed to resonate at the same frequency as the transducer. Therefore, when an end effector is attached to a transducer the overall system frequency is the same frequency as the transducer itself.

(4) The amplitude of the longitudinal ultrasonic vibration at the tip, d, of the end effector behaves as a simple sinusoid at the resonant frequency as given by:

(5) $d = A\sin(\omega t)$

where: ω=the radian frequency which equals 2π times the cyclic frequency, f; and A=the zero-to-peak amplitude. The longitudinal excursion is defined as the peak-to-peak (p-t-p) amplitude, which is just twice the amplitude of the sine wave or 2A.

(6) The shape of an ultrasonic surgical blade or end-effector used in an ultrasonic surgical instrument can define at least four important aspects of the instrument. These are: (1) the visibility of the end-effector and its relative position in the surgical field, (2) the ability of the end-effector to access or approach targeted tissue, (3) the manner in which ultrasonic energy is coupled to tissue for cutting and coagulation, and (4) the manner in which tissue can be manipulated with the ultrasonically inactive end-effector. It would be advantageous to provide an improved ultrasonic surgical instrument blade or end-effector optimizing at least these four aspects of the instrument.

(7) However, as features are added to an ultrasonic surgical instrument blade to achieve the above-listed aspects, the shape of the blade is typically altered which creates asymmetries therein and causes the blade to become unbalanced, meaning that the blade can have the tendency to vibrate in directions other than the longitudinal direction along the length of the instrument, such as transverse directions. Substantial transverse motion in the blade and/or waveguide may lead to

excess heat generation and/or premature stress failure therein. Long, thin ultrasonic waveguides, such as those used in instruments for minimally invasive surgery, are particularly susceptible to transverse vibrations introduced by imbalances, or asymmetries, in the end effector.
(8) U.S. Pat. No. 6,283,981, which issued on Sep. 4, 2001 and is entitled METHOD OF BALANCING ASYMMETRIC ULTRASONIC SURGICAL BLADES, U.S. Pat. No. 6,309,400, which issued on Oct. 30, 2001 and is entitled CURVED ULTRASONIC BLADE HAVING A TRAPEZOIDAL CROSS SECTION, and U.S. Pat. No. 6,436,115, which issued on Aug. 20, 2002 and is entitled BALANCED ULTRASONIC BLADE INCLUDING A PLURALITY OF BALANCE ASYMMETRIES, the disclosures of which are hereby incorporated by reference herein, address balancing blades having asymmetries within a treatment portion of the blade by utilizing asymmetries within an adjacent balance portion. While such approaches have proven eminently successful, there are some applications where balancing may be desirable within the treatment, or functional, portion of a blade.
(9) Solid core ultrasonic surgical instruments may be divided into two types, single element end effector devices and multiple-element end effector. Single element end effector devices include instruments such as scalpels, and ball coagulators. Single-element end effector instruments have limited ability to apply blade-to-tissue pressure when the tissue is soft and loosely supported. Substantial pressure may be necessary to effectively couple ultrasonic energy to the tissue. This inability to grasp the tissue results in a further inability to fully coapt tissue surfaces while applying ultrasonic energy, leading to less-than-desired hemostasis and tissue joining. The use of multiple-element end effectors such as clamping coagulators includes a mechanism to press tissue against an ultrasonic blade that can overcome these deficiencies.
(10) Ultrasonic clamp coagulators provide an improved ultrasonic surgical instrument for cutting/coagulating tissue, particularly loose and unsupported tissue, wherein the ultrasonic blade is employed in conjunction with a clamp for applying a compressive or biasing force to the tissue, whereby faster coagulation and cutting of the tissue, with less attenuation of blade motion, are achieved.
(11) Surgical elevators are instruments used to help facilitate the elevation and removal of soft tissue during surgery. Surgical elevators are generally employed to separate muscle from bone. Cobb or curette type surgical elevators and used in spine surgery, especially to assist in posterior access in removing muscle tissue from bone. To remove muscle tissue from bone using conventional surgical elevators, the surgeon must exert a significant amount of force. This may cause premature fatigue. Also, using significant force on a conventional surgical elevator during this technique may increase the likelihood of error and unwanted tissue damage.
(12) It would be desirable to provide an ultrasonic instrument comprising a surgical elevator blade to remove soft tissue such as muscle from bone and to perform additional surgical functions as well. Also, because ultrasonic frequencies induce longitudinal vibratory movements and generate localized heat within adjacent tissue it would be desirable to provide a protective material for the surgical elevator of such ultrasonic instrument. The protective material may reduce the possibility of blade breakage when in contact with bone or metal retractors and may decrease thermal spread from the back edge of the blade.

SUMMARY

(13) In one general aspect, the various embodiments are directed to an ultrasonic surgical instrument that comprises a transducer configured to produce vibrations at a predetermined frequency. The transducer is configured to produce vibrations along a longitudinal axis at a predetermined frequency. An ultrasonic blade extends along the longitudinal axis and is coupled to the transducer. The ultrasonic blade includes a body having a proximal end and a distal end. The distal end is movable relative to the longitudinal axis by the vibrations produced by the transducer. The body includes a treatment region that extends from the proximal end to the distal end. The body includes a substantially flat broad top surface, a bottom surface, and a neck portion protruding

from the proximal end adapted to couple to the transducer.
(14) In at least one form of the invention, an ultrasonic surgical instrument can include an ultrasonically actuated blade or end effector having a treatment portion. In various embodiments, the blade can define a longitudinal axis and at least one axis which is transverse to the longitudinal axis. In at least one such embodiment, the transverse axis can lie within a plane which is perpendicular, or normal, to the longitudinal axis and can define a cross-section of the treatment portion. In various embodiments, such a cross-section can include a central portion and a step, wherein the step can extend from the central portion, wherein the central portion can comprise a width, and wherein the step can comprise a cutting edge. In at least one embodiment, the cutting edge can be defined by first and second surfaces which define an angle therebetween. In various embodiments, the position of the cutting edge and/or the angle between the cutting edge surfaces, for example, can be selected in order to balance the blade with respect to the transverse axis.

Description

FIGURES
(1) The novel features of the various embodiments are set forth with particularity in the appended claims. The various embodiments, however, both as to organization and methods of operation, together with further objects and advantages thereof, may best be understood by reference to the following description, taken in conjunction with the accompanying drawings as follows.
(2) FIG. **1** illustrates one embodiment of an ultrasonic system.
(3) FIG. **2** illustrates one embodiment of a connection union/joint for an ultrasonic instrument.
(4) FIG. **3** illustrates an exploded perspective view of one embodiment of a sterile ultrasonic surgical instrument.
(5) FIGS. **4-7** illustrate one embodiment of an ultrasonic blade, where:
(6) FIG. **4** is a side view of one embodiment of an ultrasonic blade;
(7) FIG. **5** is a top view of the ultrasonic blade shown in FIG. **4**;
(8) FIG. **6** is a cross-sectional view of the ultrasonic blade taken along line **6-6** in FIG. **4**; and
(9) FIG. **7** is a top perspective view of the ultrasonic blade shown in FIG. **4**.
(10) FIGS. **8-11** illustrate one embodiment of an ultrasonic blade, where:
(11) FIG. **8** is a side view of one embodiment of an ultrasonic blade;
(12) FIG. **9** is a top view of the ultrasonic blade shown in FIG. **8**;
(13) FIG. **10** is a cross-sectional view of the ultrasonic blade taken along line **10-10** in FIG. **8**; and
(14) FIG. **11** is a top perspective view of the ultrasonic blade shown in FIG. **8**.
(15) FIGS. **12-15** illustrate one embodiment of an ultrasonic blade, where:
(16) FIG. **12** is a side view of one embodiment of an ultrasonic blade;
(17) FIG. **13** is a top view of the ultrasonic blade shown in FIG. **12**;
(18) FIG. **14** is a cross-sectional view of the ultrasonic blade taken along line **14-14** in FIG. **12**; and
(19) FIG. **15** is a top perspective view of the ultrasonic blade shown in FIG. **12**.
(20) FIGS. **16-19** illustrate one embodiment of an ultrasonic blade, where:
(21) FIG. **16** is a side view of one embodiment of an ultrasonic blade;
(22) FIG. **17** is a top view of the ultrasonic blade shown in FIG. **16**;
(23) FIG. **18** is an end-sectional view of the ultrasonic blade taken along line **18-18** in FIG. **16**; and
(24) FIG. **19** is a top perspective view of the ultrasonic blade shown in FIG. **16**.
(25) FIG. **20** is a top perspective view of one embodiment of an ultrasonic blade.
(26) FIG. **21** illustrates a use of one embodiment of the ultrasonic blade shown in FIG. **20**.
(27) FIGS. **22-24** illustrate one embodiment of an ultrasonic blade comprising a protective sheath, where:
(28) FIG. **22** illustrates a partial cross-sectional view of one embodiment of an ultrasonic blade

comprising a protective sheath taken along the longitudinal axis;
(29) FIG. **23** is a bottom view of the ultrasonic blade taken along line **23-23** in FIG. **22**; and
(30) FIG. **24** is a cross-sectional view of the ultrasonic blade and the protective sheath shown in FIG. **22**.
(31) FIG. **25** illustrates a use of one embodiment of an ultrasonic surgical instrument removing muscle tissue from bone.
(32) FIG. **26** illustrates a use one embodiment of the ultrasonic surgical blade shown in FIGS. **20**, **21** comprising one embodiment of a protective sheath.
(33) FIGS. **27-31** illustrate one embodiment of an ultrasonic surgical instrument comprising an end effector, where:
(34) FIG. **27** is a top perspective view of one embodiment of an ultrasonic surgical instrument;
(35) FIG. **28** is a cross-sectional view of the ultrasonic surgical instrument shown in FIG. **27** taken along the longitudinal axis of the ultrasonic surgical instrument shown in FIG. **27**;
(36) FIG. **29** is a bottom view of the ultrasonic surgical instrument taken along lines **29-29** in FIG. **28**;
(37) FIG. **30** is a cross-sectional view of the ultrasonic surgical instrument taken along lines **30-30** in FIG. **28**; and
(38) FIG. **31** is cross-sectional view of the ultrasonic surgical instrument taken along lines **31-31** in FIG. **28**.
(39) FIGS. **32-35** are cross-sectional views of various embodiments of ultrasonic surgical instruments taken along the longitudinal axis.
(40) FIGS. **36-37** are cross-sectional views of one embodiment of an ultrasonic surgical instrument taken along the longitudinal axis.
(41) FIGS. **38-39** are cross-sectional views of one embodiment of an ultrasonic surgical instrument taken along the longitudinal axis.
(42) FIG. **40** is cross-sectional view of one embodiment of an ultrasonic surgical instrument taken along the longitudinal axis.
(43) FIGS. **41-43** illustrate one embodiment of an ultrasonic system, where:
(44) FIG. **41** is a side view of one embodiment of the ultrasonic system;
(45) FIG. **42** is a cross-sectional side view of the ultrasonic system shown in FIG. **41** and a cross-sectional view of various tube assemblies to couple the hand piece housing with an end effector;
(46) FIG. **43** is a bottom cross-sectional view of the ultrasonic instrument shown in FIG. **41**.
(47) FIGS. **44-51** illustrate one embodiment of an ultrasonic system, where:
(48) FIG. **44** is a side view of one embodiment of a ultrasonic instrument with a deployable protective sheath in a stowed or retracted position;
(49) FIG. **45** is a top view of the ultrasonic instrument with the deployable protective sheath in the stowed or retracted position taken along line **45-45** in FIG. **44**;
(50) FIG. **46** is a side view of the ultrasonic instrument shown in FIG. **44** with the deployable protective sheath in a deployed position;
(51) FIG. **47** is a top view of the ultrasonic instrument in the deployed position taken along line **47-47** in FIG. **46**;
(52) FIG. **48** is a more detailed side view of the ultrasonic instrument shown in FIG. **44** with the deployable protective sheath in a stowed or retracted position;
(53) FIG. **49** is a more detailed top view of the ultrasonic instrument shown in FIG. **45** with the protective sheath in the stowed or retracted position taken along line **49-49** in FIG. **48**;
(54) FIG. **50** is a more detailed side view of the ultrasonic instrument shown in FIG. **46** with the deployable protective sheath in a deployed position; and
(55) FIG. **51** is a more detailed top view of the ultrasonic instrument shown in FIG. **47** in the deployed position taken along line **51-51** in FIG. **50**.
(56) FIGS. **52-55** illustrate one embodiment of an ultrasonic surgical instrument comprising an end

effector, where:
(57) FIG. **52** is a top perspective view of one embodiment of an ultrasonic surgical instrument;
(58) FIG. **53** is a partial cross-sectional view of the ultrasonic surgical instrument shown in FIG. **52** taken along the longitudinal axis of the ultrasonic surgical instrument;
(59) FIG. **54** is a cross-sectional view of the ultrasonic surgical instrument taken along lines **54-54** shown in FIG. **53**; and
(60) FIG. **55** is a top view of the ultrasonic surgical instrument.
(61) FIGS. **56-59** illustrate one embodiment of an ultrasonic blade, where:
(62) FIG. **56** is a side view of one embodiment of an ultrasonic blade;
(63) FIG. **57** is a top view of the ultrasonic blade shown in FIG. **56**;
(64) FIG. **58** is a cross-sectional view of the ultrasonic blade taken along line **58-58** in FIG. **57**; and
(65) FIG. **59** is a top perspective view of the ultrasonic blade shown in FIG. **56**.
(66) FIG. **60** is a schematic of parameters of a cross-section of a blade which can be used to balance the blade.
(67) FIG. **60**A is an additional schematic of the cross-section of FIG. **60**
(68) FIG. **61** is a cross-sectional view of an ultrasonic blade.
(69) FIG. **62** is a cross-sectional view of another ultrasonic blade.
(70) FIG. **63** is a cross-sectional view of an additional ultrasonic blade.
(71) FIG. **64** is a cross-sectional view of a further ultrasonic blade.

DESCRIPTION

(72) Before explaining the various embodiments in detail, it should be noted that the embodiments are not limited in its application or use to the details of construction and arrangement of parts illustrated in the accompanying drawings and description. The illustrative embodiments may be implemented or incorporated in other embodiments, variations and modifications, and may be practiced or carried out in various ways. For example, the surgical instruments and blade configurations disclosed below are illustrative only and not meant to limit the scope or application thereof. Furthermore, unless otherwise indicated, the terms and expressions employed herein have been chosen for the purpose of describing the illustrative embodiments for the convenience of the reader and are not to limit the scope thereof.

(73) The various embodiments relate, in general, to ultrasonic surgical blades for use in surgical instruments and, more particularly, to an ultrasonic surgical blade with improved elevator, cutting and coagulation features and to an ultrasonic blade comprising a protective sheath on a portion thereof. The various embodiments relate, in general, to ultrasonic surgical blades and instruments for improved bone and tissue removal, aspiration, and coagulation features. A blade according to various embodiments is of particular benefit, among others, in orthopedic procedures wherein it is desirable to remove cortical bone and/or tissue while controlling bleeding for removing muscle tissue from bone, due to its cutting and coagulation characteristics. The blade, however, may be useful for general soft tissue cutting and coagulation. The blade may be straight or curved, and useful for either open or laparoscopic applications. A blade according to various embodiments may be useful in spine surgery, especially to assist in posterior access in removing muscle from bone. A blade according to the various embodiments may reduce the user force required to remove muscle from bone and, in one embodiment, may be useful to simultaneously hemostatically seal or cauterize the tissue. Reducing the force to operate the surgical instrument may reduce user fatigue, improve precision and reduce unwanted tissue damage. A variety of different blade configurations are disclosed which may be useful for both open and laparoscopic applications.

(74) Examples of ultrasonic surgical instruments are disclosed in U.S. Pat. Nos. 5,322,055 and 5,954,736 and in combination with ultrasonic blades and surgical instruments disclosed in U.S. Pat. Nos. 6,309,400 B2, 6,278,218 B1, 6,283,981 B1, and 6,325,811 B1, for example, are incorporated herein by reference in their entirety. Also incorporated by reference in its entirety is commonly-owned, co-pending U.S. patent application Ser. No. 11/726,625, entitled ULTRASONIC

SURGICAL INSTRUMENTS, filed on Mar. 22, 2007, now U.S. Pat. No. 8,911,460. Some of these references disclose ultrasonic surgical instrument design and blade designs where a longitudinal node of the blade is excited. Because of asymmetry or asymmetries, these blades exhibit transverse and/or torsional motion where the characteristic "wavelength" of this non-longitudinal motion is less than that of the general longitudinal motion of the blade and its extender portion. Therefore, the wave shape of the non-longitudinal motion will present nodal positions of transverse/torsional motion along the tissue effector while the net motion of the active blade along its tissue effector is non-zero (i.e. will have at least longitudinal motion along the length extending from its distal end, an antinode of longitudinal motion, to the first nodal position of longitudinal motion that is proximal to the tissue effector portion). Certain exemplary embodiments will now be described to provide an overall understanding of the principles of the structure, function, manufacture, and use of the devices and methods disclosed herein. One or more examples of these embodiments are illustrated in the accompanying drawings. Those of ordinary skill in the art will understand that the devices and methods specifically described herein and illustrated in the accompanying drawings are non-limiting exemplary embodiments and that the scope of the various embodiments is defined solely by the claims. The features illustrated or described in connection with one exemplary embodiment may be combined with the features of other embodiments. Such modifications and variations are intended to be included within the scope of the claims.
(75) FIG. **1** illustrates one embodiment of an ultrasonic system **10**. One embodiment of the ultrasonic system **10** comprises an ultrasonic signal generator **12** coupled to an ultrasonic transducer **14**, a hand piece assembly **60** comprising a hand piece housing **16**, and an end effector **50**. The ultrasonic transducer **14**, which is known as a "Langevin stack", generally includes a transduction portion **18**, a first resonator or end-bell **20**, and a second resonator or fore-bell **22**, and ancillary components. The ultrasonic transducer **14** is preferably an integral number of one-half system wavelengths ($n\lambda/2$) in length as will be described in more detail later. An acoustic assembly **24** includes the ultrasonic transducer **14**, a mount **26**, a velocity transformer **28**, and a surface **30**.
(76) It will be appreciated that the terms "proximal" and "distal" are used herein with reference to a clinician gripping the hand piece assembly **60**. Thus, the end effector **50** is distal with respect to the more proximal hand piece assembly **60**. It will be further appreciated that, for convenience and clarity, spatial terms such as "top" and "bottom" also are used herein with respect to the clinician gripping the hand piece assembly **60**. However, surgical instruments are used in many orientations and positions, and these terms are not intended to be limiting and absolute.
(77) The distal end of the end-bell **20** is connected to the proximal end of the transduction portion **18**, and the proximal end of the fore-bell **22** is connected to the distal end of the transduction portion **18**. The fore-bell **22** and the end-bell **20** have a length determined by a number of variables, including the thickness of the transduction portion **18**, the density and modulus of elasticity of the material used to manufacture the end-bell **20** and the fore-bell **22**, and the resonant frequency of the ultrasonic transducer **14**. The fore-bell **22** may be tapered inwardly from its proximal end to its distal end to amplify the ultrasonic vibration amplitude as the velocity transformer **28**, or alternately may have no amplification. A suitable vibrational frequency range may be about 20 Hz to 120 kHz and a well-suited vibrational frequency range may be about 30-70 kHz and one example operational vibrational frequency may be approximately 55.5 kHz.
(78) Piezoelectric elements **32** may be fabricated from any suitable material, such as, for example, lead zirconate-titanate, lead meta-niobate, lead titanate, or other piezoelectric crystal material. Each of positive electrodes **34**, negative electrodes **36**, and the piezoelectric elements **32** has a bore extending through the center. The positive and negative electrodes **34** and **36** are electrically coupled to wires **38** and **40**, respectively. The wires **38** and **40** are encased within a cable **42** and electrically connectable to the ultrasonic signal generator **12** of the ultrasonic system **10**.
(79) The ultrasonic transducer **14** of the acoustic assembly **24** converts the electrical signal from the ultrasonic signal generator **12** into mechanical energy that results in primarily longitudinal

vibratory motion of the ultrasonic transducer **24** and the end effector **50** at ultrasonic frequencies. A suitable generator is available as model number GEN01, from Ethicon Endo-Surgery, Inc., Cincinnati, Ohio. When the acoustic assembly **24** is energized, a vibratory motion standing wave is generated through the acoustic assembly **24**. The amplitude of the vibratory motion at any point along the acoustic assembly **24** may depend upon the location along the acoustic assembly **24** at which the vibratory motion is measured. A minimum or zero crossing in the vibratory motion standing wave is generally referred to as a node (i.e., where motion is usually minimal), and an absolute value maximum or peak in the standing wave is generally referred to as an anti-node (i.e., where motion is usually maximal). The distance between an anti-node and its nearest node is one-quarter wavelength ($\lambda/4$).

(80) The wires **38** and **40** transmit an electrical signal from the ultrasonic signal generator **12** to the positive electrodes **34** and the negative electrodes **36**. The piezoelectric elements **32** are energized by the electrical signal supplied from the ultrasonic signal generator **12** in response to a foot switch **44** to produce an acoustic standing wave in the acoustic assembly **24**. The electrical signal causes disturbances in the piezoelectric elements **32** in the form of repeated small displacements resulting in large compression forces within the material. The repeated small displacements cause the piezoelectric elements **32** to expand and contract in a continuous manner along the axis of the voltage gradient, producing longitudinal waves of ultrasonic energy. The ultrasonic energy is transmitted through the acoustic assembly **24** to the end effector **50** via a an ultrasonic transmission waveguide **104**.

(81) In order for the acoustic assembly **24** to deliver energy to the end effector **50**, all components of the acoustic assembly **24** must be acoustically coupled to the end effector **50**. The distal end of the ultrasonic transducer **14** may be acoustically coupled at the surface **30** to the proximal end of the ultrasonic transmission waveguide **104** by a threaded connection such as a stud **48**.

(82) The components of the acoustic assembly **24** are preferably acoustically tuned such that the length of any assembly is an integral number of one-half wavelengths ($n\lambda/2$), where the wavelength λ is the wavelength of a pre-selected or operating longitudinal vibration drive frequency fa of the acoustic assembly **24**, and where n is any positive integer. It is also contemplated that the acoustic assembly **24** may incorporate any suitable arrangement of acoustic elements.

(83) The ultrasonic end effector **50** may have a length substantially equal to an integral multiple of one-half system wavelengths ($\lambda/2$). A distal end **52** of the ultrasonic end effector **50** may be disposed near an antinode in order to provide the maximum longitudinal excursion of the distal end. When the transducer assembly is energized, the distal end **52** of the ultrasonic end effector **50** may be configured to move in the range of, for example, approximately 10 to 500 microns peak-to-peak, and preferably in the range of about 30 to 150 microns at a predetermined vibrational frequency.

(84) The ultrasonic end effector **50** may be coupled to the ultrasonic transmission waveguide **104**. The ultrasonic end effector **50** and the ultrasonic transmission guide **104** as illustrated are formed as a single unit construction from a material suitable for transmission of ultrasonic energy such as, for example, Ti6Al4V (an alloy of Titanium including Aluminum and Vanadium), Aluminum, Stainless Steel, or other known materials. Alternately, the ultrasonic end effector **50** may be separable (and of differing composition) from the ultrasonic transmission waveguide **104**, and coupled by, for example, a stud, weld, glue, quick connect, or other suitable known methods. The ultrasonic transmission waveguide **104** may have a length substantially equal to an integral number of one-half system wavelengths ($\lambda/2$), for example. The ultrasonic transmission waveguide **104** may be preferably fabricated from a solid core shaft constructed out of material that propagates ultrasonic energy efficiently, such as titanium alloy (i.e., Ti-6Al-4V) or an aluminum alloy, for example.

(85) The ultrasonic transmission waveguide **104** comprises a longitudinally projecting attachment post **54** at a proximal end to couple to the surface **30** of the ultrasonic transmission waveguide **104**

by a threaded connection such as the stud **48**. In the embodiment illustrated in FIG. **1**, the ultrasonic transmission waveguide **104** comprises a plurality of stabilizing silicone rings or compliant supports **56** positioned at a plurality of nodes. The silicone rings **56** dampen undesirable vibration and isolate the ultrasonic energy from a removable sheath **58** assuring the flow of ultrasonic energy in a longitudinal direction to the distal end **52** of the end effector **50** with maximum efficiency.

(86) As shown in FIG. **1**, the removable sheath **58** is coupled to the distal end of the handpiece assembly **60**. The sheath **58** generally includes an adapter or nose cone **62** and an elongated tubular member **64**. The tubular member **64** is attached to the adapter **62** and has an opening extending longitudinally therethrough. The sheath **58** may be threaded or snapped onto the distal end of the housing **16**. The ultrasonic transmission waveguide **104** extends through the opening of the tubular member **64** and the silicone rings **56** isolate the ultrasonic transmission waveguide **104** therein.

(87) The adapter **62** of the sheath **58** is preferably constructed from Ultem®, and the tubular member **64** is fabricated from stainless steel. Alternatively, the ultrasonic transmission waveguide **104** may have polymeric material surrounding it to isolate it from outside contact.

(88) The distal end of the ultrasonic transmission waveguide **104** may be coupled to the proximal end of the end effector **50** by an internal threaded connection, preferably at or near an antinode. It is contemplated that the end effector **50** may be attached to the ultrasonic transmission waveguide **104** by any suitable means, such as a welded joint or the like. Although the end effector **50** may be detachable from the ultrasonic transmission waveguide **104**, it is also contemplated that the end effector **50** and the ultrasonic transmission waveguide **104** may be formed as a single unitary piece.

(89) FIG. **2** illustrates one embodiment of a connection union/joint **70** for an ultrasonic instrument. The connection union/joint **70** may be formed between the attachment post **54** of the ultrasonic transmission waveguide **104** and the surface **30** of the velocity transformer **28** at the distal end of the acoustic assembly **24**. The proximal end of the attachment post **54** comprises a female threaded substantially cylindrical recess **66** to receive a portion of the threaded stud **48** therein. The distal end of the velocity transformer **28** also may comprise a female threaded substantially cylindrical recess **68** to receive a portion of the threaded stud **40**. The recesses **66**, **68** are substantially circumferentially and longitudinally aligned.

(90) FIG. **3** illustrates an exploded perspective view of one embodiment of a sterile ultrasonic surgical instrument **100**. The ultrasonic surgical instrument **100** may be employed with the above-described ultrasonic system **10**. However, as described herein, those of ordinary skill in the art will understand that the various embodiments of the ultrasonic surgical instruments disclosed herein as well as any equivalent structures thereof could conceivably be effectively used in connection with other known ultrasonic surgical instruments without departing from the scope thereof. Thus, the protection afforded to the various ultrasonic surgical blade embodiments disclosed herein should not be limited to use only in connection with the exemplary ultrasonic surgical instrument described above.

(91) The ultrasonic surgical instrument **100** may be sterilized by methods known in the art such as, for example, gamma radiation sterilization, Ethelyne Oxide processes, autoclaving, soaking in sterilization liquid, or other known processes. In the illustrated embodiment, an ultrasonic transmission assembly **102** includes an ultrasonic end effector, the generally designated ultrasonic end effector **50**, and the ultrasonic transmission waveguide **104**. The ultrasonic end effector **50** and the ultrasonic transmission waveguide **104** are illustrated as a single unit construction from a material suitable for transmission of ultrasonic energy such as, for example, Ti6Al4V (an alloy of Titanium including Aluminum and Vanadium), Aluminum, Stainless Steel, or other known materials. Alternately, the ultrasonic end effector **50** may be separable (and of differing composition) from the ultrasonic transmission waveguide **104**, and coupled by, for example, a stud, weld, glue, quick connect, or other known methods. The ultrasonic transmission waveguide **104** may have a length substantially equal to an integral number of one-half system wavelengths ($n\lambda/2$),

for example. The ultrasonic transmission waveguide **104** may be preferably fabricated from a solid core shaft constructed out of material that propagates ultrasonic energy efficiently, such as titanium alloy (i.e., Ti-6Al-4V) or an aluminum alloy, for example.

(92) In the embodiment illustrated in FIG. **3**, the ultrasonic transmission waveguide **104** is positioned in an outer sheath **106** by a mounting O-ring **108** and a sealing ring **110**. One or more additional dampers or support members (not shown) also may be included along the ultrasonic transmission waveguide **104**. The ultrasonic transmission waveguide **104** is affixed to the outer sheath **106** by a mounting pin **112** that passes through mounting holes **114** in the outer sheath **106** and a mounting slot **116** in the ultrasonic transmission waveguide **104**.

(93) FIGS. **4-19** illustrate various embodiments of ultrasonic blades, which may be considered different embodiments of the end effector **50** and are generally well-suited for cutting, coagulating, and reshaping tissue. In various embodiments, the ultrasonic blades may be configured as ultrasonic surgical elevator blades that are well-suited for separating muscle from bone, for example. The ultrasonic blades may be employed in the above-described ultrasonic surgical instruments **10**, **100**. Embodiments of the ultrasonic blades may be suitable in spine surgery, and more particularly, to assist in posterior access in removing muscle tissue from bone and coagulating the tissue. Accordingly, the ultrasonic blades may be employed to simultaneously reshape or remove muscle tissue from bone and to hemostatically seal the tissue as it is removed from the bone. The ultrasonic energy assists the cutting action of the ultrasonic blade and reduces the force required by a surgeon during an operation and thereby reduces surgeon fatigue, improves precision, and reduces unwanted tissue damage. The embodiments, however, are not limited in this context. Those skilled in the art will appreciate that although the various embodiments of the ultrasonic blades are well-suited for cutting, coagulating, and reshaping tissue, e.g., to separate muscle tissue from bone, these ultrasonic blades are multifunctional and may be employed in multiple numerous applications.

(94) FIGS. **4-7** illustrate one embodiment of an ultrasonic blade **120**. The ultrasonic blade **120** is generally well-suited for cutting, coagulating, and reshaping tissue. In one embodiment the ultrasonic blade **120** may be configured as an ultrasonic surgical elevator blade generally well-suited to separate muscle tissue from bone. Nevertheless, the ultrasonic blade **120** may be employed in various other therapeutic procedures. FIG. **4** is a side view of the ultrasonic blade **120**. FIG. **5** is a top view of the ultrasonic blade **120**. FIG. **6** is a cross-sectional view of the ultrasonic blade **120** taken along line **6-6** in FIG. **4**. FIG. **7** is a top perspective view of the ultrasonic blade **120**.

(95) In the embodiment illustrated in FIGS. **4-7**, the ultrasonic blade **120** comprises a blade body **122** having a generally flat top surface **124** that is substantially arcuate about a first axis **121** and a smooth generally round bottom surface **126** that is substantially arcuate about a second axis **123**. As shown in the cross-sectional view of FIG. **6**, the top surface **124** is generally flat and the bottom surface **126** is substantially arcuate with respect to a third axis **125**. The blade body **122** extends along a longitudinal central axis **127**. The blade body **122** may comprise a substantially elongated treatment region, generally designated as **128**, and a neck or transition portion **130** that protrudes from a proximal end **132** of the treatment region **128**. The neck portion **130** may be attached to the ultrasonic transmission waveguide **104** by a stud, weld, glue, quick connect, or other known attachment methods, for example. In alternative embodiments, the ultrasonic blade **120** and the ultrasonic transmission waveguide **104** may be formed as a single unitary body. In either configuration, the ultrasonic transmission waveguide **104** amplifies the mechanical vibrations transmitted to the ultrasonic blade **120** as is well known in the art. The ultrasonic blade **120** is adapted to couple to the ultrasonic surgical instrument **100**, which may be employed with the above-described ultrasonic surgical instruments **10**, **100**.

(96) The ultrasonic blade **120** comprises a treatment region **128** to effect tissue, such as, for example, cut, coagulate, reshape, scrape, and remove tissue. The treatment region **128** comprises

the top surface **124** which is substantially arcuate about the first axis **121** and the smooth bottom surface **126** which is substantially arcuate about the second axis **123**. As shown in the cross-sectional view in FIG. **6**, the treatment region **128** the top surface **124** is generally flat and the bottom surface **126** is substantially arcuate about the third axis **125**. A distal end **134** of the treatment region **128** also comprises a substantially flat tip with a cutting edge **136**. The blade **120** and the distal cutting edge **136** define a broad top surface **124** for effecting tissue. The bottom surface **126** may be a surface for bone contact and atraumatic use along the bone region configured to prevent the cutting edge **136** from cutting into bone tissue. Due to its arcuate shape the bottom surface **126** may be employed to coagulate tissue. The top surface **124** of the blade **120** has a width "W" that is substantially greater than a thickness "T" of the blade **120**. Additional cutting edges **138** may be positioned laterally along both sides of the treatment region **128**. In one embodiment, the cutting edges **138** extend from the proximal end **132** to the distal end **134** of the treatment region **128**. In one example, the flat tip cutting edge **136** or the lateral cutting edges **138** of the ultrasonic blade **120** are suitable to remove muscle tissue from bone while the smooth generally round substantially arcuate bottom surface **126** acts as an atraumatic surface that glides against the bone.

(97) The ultrasonic blade **120** may be fabricated from a material suitable for transmission of ultrasonic energy such as, for example, Ti6Al4V (an alloy of Titanium including Aluminum and Vanadium), Aluminum, Stainless Steel, or other known materials.

(98) FIGS. **8-11** illustrate one embodiment of an ultrasonic blade **150**. The ultrasonic blade **150** is generally well-suited for cutting, coagulating, and reshaping tissue. In one embodiment the ultrasonic blade **150** may be configured as an ultrasonic surgical elevator blade generally well-suited to separate muscle tissue from bone. Nevertheless, the ultrasonic blade **150** may be employed in various other therapeutic procedures. FIG. **8** is a side view of the ultrasonic blade **150**. FIG. **9** is a top view of the ultrasonic blade **150**. FIG. **10** is a cross-sectional view of the ultrasonic blade **150** taken along line **10-10** in FIG. **8**. FIG. **11** is a top perspective view of the ultrasonic blade **150**.

(99) In the embodiment illustrated in FIGS. **8-11**, the ultrasonic blade **150** comprises a blade body **152** having a generally flat planar top surface **154** and a smooth substantially arcuate bottom surface **156**. The top and bottom surfaces **154**, **56** extend along the longitudinal central axis **127**. As shown in the cross-sectional view of FIG. **10**, the top surface **154** is generally flat and planar and the bottom surface **156** is substantially arcuate about axis **129**. The blade body **152** may comprise a substantially elongated treatment region, generally designated as **158**, and a neck or transition portion **160** that protrudes from a proximal end **132** of the treatment region **158**. The neck portion **160** may be attached to the ultrasonic transmission waveguide **104** by a stud, weld, glue, quick connect, or other known attachment methods, for example. In alternative embodiments, the ultrasonic blade **150** and the waveguide **104** may be formed as a single unitary body. In either configuration, the ultrasonic transmission waveguide **104** amplifies the mechanical vibrations transmitted to the ultrasonic blade **150** as is well known in the art. The ultrasonic blade **150** is adapted to couple to the ultrasonic surgical instrument **100**, which may be coupled to above-described ultrasonic system **10**. In one embodiment, the ultrasonic blade **150** and the ultrasonic transmission waveguide **104** may be formed as a single unitary body.

(100) The ultrasonic blade **150** comprises the substantially straight planar treatment region **158** to effect tissue. The treatment region **158** comprises the generally flat planar top surface **154** and the smooth substantially arcuate bottom surface **156**. The bottom surface **156** comprises a smooth atraumatic surface **162** that is substantially arcuate about axis **131** at a distal end **134** of the treatment region **158** for bone contact and atraumatic use along the bone region. The distal end **134** of the treatment region **158** also comprises a substantially flat tip with a distal cutting edge **166**. The atraumatic surface **162** is configured to prevent the distal cutting edge **166** from cutting into bone tissue. The atraumatic surface **162** extends from the bottom surface **156** to the top surface **154**

and is intended to contact and slidingly engage the bone as the cutting edge **166** removes muscle tissue from the bone without cutting into bone tissue. A cutting edge **168** is positioned laterally along one side of the treatment region **158**. The blade **150** and the distal cutting edge **166** define a broad top surface **154** for effecting tissue. The broad top surface **154** of the blade **150** has a width "W" that is substantially greater than a thickness "T". In one embodiment, the cutting edge **168** extends from the proximal end **132** to the distal end **134** of the treatment region **158**. The blade **150** also comprises a dull, smooth, or curved lateral coagulating edge **164** positioned laterally along the side of the treatment region **158** opposite the lateral cutting edge **168**. In one embodiment, the coagulating edge **164** extends from the proximal end **132** to the distal end **134** of the treatment region **158**. The coagulating edge **164** may be used for different tissue effects other than coagulation, for example. In one example, the flat tip distal cutting edge **166** or the lateral cutting edge **168** of the ultrasonic blade **150** is suitable to remove muscle tissue from bone while the atraumatic surface **162** glides against the bone. The clinician may select either one of the cutting edges **166**, **168** or the atraumatic surface **162** for different tissue effects. The ultrasonic blade **150** may be fabricated from a material suitable for transmission of ultrasonic energy as previously described with respect to the ultrasonic blade **120**.

(101) FIGS. **12-15** illustrate one embodiment of an ultrasonic blade **180**. The ultrasonic blade **180** is generally well-suited for cutting, coagulating, and reshaping tissue. In one embodiment the ultrasonic blade **180** may be configured as an ultrasonic surgical elevator blade generally well-suited to separate muscle tissue from bone. Nevertheless, the ultrasonic blade **180** may be employed in various other therapeutic procedures. FIG. **12** is a side view of the ultrasonic blade **180**. FIG. **13** is a top view of the ultrasonic blade **180**. FIG. **14** is a cross-sectional view of the ultrasonic blade **180** taken along line **14-14** in FIG. **12**. FIG. **15** is a top perspective view of the ultrasonic blade **180**.

(102) In the embodiment illustrated in FIGS. **12-15**, the ultrasonic blade **180** comprises a blade body **182** having a generally flat planar top surface **184** and a generally flat planar bottom surface **186**. The top and bottom surfaces **184**, **186** are substantially parallel and extend along the longitudinal central axis **127**. The blade body **182** may comprise a substantially elongated treatment region, generally designated as **188**, and a neck or transition portion **190** that protrudes from a proximal end **132** of the treatment region **188**. The neck portion **190** may be attached to the ultrasonic transmission waveguide **104** by a stud, weld, glue, quick connect, or other known attachment methods, for example. In alternative embodiments, the ultrasonic blade **180** and the ultrasonic transmission waveguide **104** may be formed as a single unitary body. In either configuration, the ultrasonic transmission waveguide **104** amplifies the mechanical vibrations transmitted to the ultrasonic blade **180** as is well known in the art. Accordingly, the ultrasonic blade **180** is adapted to couple to the ultrasonic surgical instrument **100**, which may be employed with the above-described ultrasonic surgical instruments **100**, which may be employed in the above-described ultrasonic system **10**. In one embodiment, the ultrasonic blade **180** and the ultrasonic transmission waveguide **104** may be formed as a single unitary body.

(103) The ultrasonic blade **180** comprises the substantially flat planar treatment region **188** to effect tissue. The treatment region **188** comprises the generally flat planar top surface **184** and the generally flat planar bottom surface **186**. A notch **192** (hook shaped in the illustrated embodiment) is defined at the distal end **134** of the treatment region **188**. The notch **192** extends inwardly into the blade body **182**. The notch **192** comprises a cutting edge **194**. A first straight lateral cutting edge **196** is positioned on the distal end **134** of the treatment region **188**. A second straight lateral cutting edge **198** is positioned laterally along the along the side of the treatment region **188** between the notch **192** and the proximal end **132**. A dull, smooth, or curved coagulating edge **200** is positioned laterally along the side of the treatment region **188** opposite the lateral cutting edge **198**. The dull, smooth, or curved coagulating edge **200** is substantially arcuate about axis **135**. The blade **180** and the lateral cutting edge **198** define a broad top surface **184**. The broad top surface **184** of

the blade **184** has a width "W" that is substantially greater than a thickness "T". In one embodiment, the curved edge **200** extends from the proximal end **132** to the distal end **134** of the treatment region **188**. The coagulating edge **200** may be used different tissue effects other than coagulation, for example. In one example, the cutting edges **194**, **196**, **198** of the ultrasonic blade **180** may be employed to remove muscle tissue from bone while the coagulating edge **200** may be used for coagulation. The notch cutting edge **194** assists in cutting tissue. For example, the notch cutting edge **194** allows for faster tissue cutting in avascular tissue or may aid in entering joint capsules. The ultrasonic blade **180** may be fabricated from a material suitable for transmission of ultrasonic energy as previously described with respect to the ultrasonic blade **120**.

(104) FIGS. **16-19** illustrate one embodiment of an ultrasonic blade **210**. The ultrasonic blade **210** is generally well-suited for cutting, coagulating, and reshaping tissue. In one embodiment the ultrasonic blade **210** may be configured as an ultrasonic surgical elevator blade generally well-suited to separate muscle tissue from bone. Nevertheless, the ultrasonic blade **210** may be employed in various other therapeutic procedures. FIG. **16** is a side view of the ultrasonic blade **210**. FIG. **17** is a top view of the ultrasonic blade **210**. FIG. **18** is an end-sectional view of the ultrasonic blade **210** taken along line **18-18** in FIG. **16**. FIG. **19** is a top perspective view of the ultrasonic blade **210**.

(105) In the embodiment illustrated in FIGS. **16-19**, the ultrasonic blade **210** comprises a blade body **212** having a generally flat planar top surface **214** and a generally flat planar bottom surface **216**. The top and bottom surfaces **212**, **214** are substantially parallel and extend along the longitudinal central axis **127**. The blade body **212** may comprise a substantially elongated treatment region, generally designated as **218**, and a neck or transition portion **220** that protrudes from a proximal end **132** of the treatment region **218**. The neck portion **220** may be attached to the ultrasonic transmission waveguide **104** by a stud, weld, glue, quick connect, or other known attachment methods, for example. In alternative embodiments, the ultrasonic blade **210** and the waveguide **104** may be formed as a single unitary body. In either configuration, the ultrasonic transmission waveguide **104** amplifies the mechanical vibrations transmitted to the ultrasonic blade **210** as is well known in the art. Accordingly, the ultrasonic blade **210** is adapted to couple to the ultrasonic transmission waveguide **104** of the surgical instrument **100**, which may be employed with the above-described ultrasonic system **10**. In one embodiment, the ultrasonic blade **210** and the ultrasonic transmission waveguide **104** may be formed as a single unitary body.

(106) The ultrasonic blade **210** comprises the substantially flat planar treatment region **218** to effect tissue. The treatment region **218** comprises the generally flat planar top surface **214** and the generally flat planar bottom surface **216**. A first atraumatic flat edge **222** may be positioned on the tip at the distal end **134** of the ultrasonic blade **210** for bone contact and atraumatic use along the bone region as well as to characterize the blade **210**. The blade **210** and the distal atraumatic edge **222** define a broad top surface **214** for effecting tissue. The top surface **214** of the blade **210** has a width "W" that is substantially greater than a thickness "T" of the blade **210**. The flat atraumatic edge **222** at the tip of the distal end **134** of the ultrasonic blade **210** may be normal to the longitudinal central axis **127** of the ultrasonic blade **210** and may be employed for benchmarking measurements of the displacement of the distal end **134**, for example. This may be employed to make measurements and to characterize the ultrasonic blade **210**. A smooth atraumatic surface **228** that is substantially arcuate about axis **135** may be provided at the distal end **134** for bone contact and atraumatic use along the bone region. Cutting edges **224**, **226** may be disposed laterally along both sides of the treatment region **218**. The ultrasonic blade **210** may be fabricated from a material suitable for transmission of ultrasonic energy as previously described with respect to the ultrasonic blade **120**.

(107) FIG. **20** is a top perspective view of one embodiment of an ultrasonic blade **230**. The ultrasonic blade **230** is generally well-suited for cutting, coagulating, and reshaping tissue. In one embodiment the ultrasonic blade **230** may be configured as an ultrasonic surgical elevator blade

generally well-suited to separate muscle tissue from bone. Nevertheless, the ultrasonic blade **230** may be employed in various other therapeutic procedures. The ultrasonic blade **230** has a blade body **232** that has a generally flat planar tapered top surface portion **234**, a generally flat planar bottom surface **238** (FIG. **21**), and an offset edge portion **236** with a cutting edge **239** well-suited for dissecting tissue against bone. The ultrasonic blade **230** may be fabricated from a material suitable for transmission of ultrasonic energy as previously described with respect to the ultrasonic blade **120**. The blade body **232** may comprise a substantially elongated treatment region, generally designated as **240**, and a neck or transition portion **242** that protrudes from a proximal end **132** of the treatment region **240**. The neck portion **242** may be attached to the ultrasonic transmission waveguide **104** by a stud, weld, glue, quick connect, or other known attachment methods, for example. In alternative embodiments, the ultrasonic blade **230** and the waveguide **104** may be formed as a single unitary body. In either configuration, the ultrasonic transmission waveguide **104** amplifies the mechanical vibrations transmitted to the ultrasonic blade **230** as is well known in the art. Accordingly, the ultrasonic blade **230** is adapted to couple to the ultrasonic surgical instrument **100**, which may be employed with the above-described ultrasonic system **10**.

(108) FIG. **21** illustrates a use of one embodiment of the ultrasonic blade **230** shown in FIG. **20**. The ultrasonic blade **230** comprises the generally planar treatment region **240** with a generally flat planar top surface **234**, a generally flat planar bottom surface **238**, and an offset edge portion **236** with a cutting edge **239**. The cutting edge **239** is suitable to dissect muscle tissue **244** from a bone **246**.

(109) The ultrasonic blades **120**, **150**, **180**, **210**, **230** described above each have a length "L" that is substantially equal to an integral multiple of one-half system wavelengths (λ/2). The distal end **134** of the ultrasonic blades **120**, **150**, **180**, **210**, **230** may be disposed near an antinode in order to provide the maximum longitudinal excursion of the distal end **134**. When the transducer assembly is energized, the distal end **134** of the ultrasonic blade **120**, **150**, **180**, **210**, **230** may be configured to move in the range of, for example, approximately 10 to 500 microns peak-to-peak, and preferably in the range of about 30 to 150 microns at a predetermined vibrational frequency range. As previously discussed, a suitable vibrational frequency range may be about 20 Hz to 120 kHz and a well-suited vibrational frequency range may be about 30-70 kHz and one example operational vibrational frequency may be approximately 55.5 kHz.

(110) Other embodiments may comprise multiple end effectors **50** attached distally to a common ultrasonic transmission waveguide **104**. The end effectors **50** may provide a variety of tissue effects that are similar to those discussed above with respect to the ultrasonic blades **120**, **150**, **180**, **210**, **230**. As discussed above, the ultrasonic blades **120**, **150**, **180**, **210**, **230** may be separable (and of differing composition) from the waveguide **104**, and coupled by, for example, a stud, weld, glue, quick connect, or other known methods. A quick connect coupling may provide lower cost and ease of use of multiple ultrasonic blades **120**, **150**, **180**, **210**, **230** in one procedure.

(111) As described above, an end effector or blade of an ultrasonic surgical instrument can be vibrated along a longitudinal axis to treat tissue, for example. In various circumstances, such instruments can be preferably configured such that they do not vibrate in any other direction, such as axes which are transverse to the longitudinal axis, for example. Such transverse vibration may make the surgical instrument inefficient and may require additional power to operate the surgical instrument, for example. In at least one circumstance, such transverse vibration may be created and/or amplified by an imbalanced asymmetrical configuration of the blade. In various embodiments of the present invention, an end effector or blade of an ultrasonic surgical instrument can be configured such that such transverse vibration is reduced or eliminated. For example, in at least one embodiment, the blade can include an asymmetrical configuration which can be balanced with respect to at least one axis which is transverse to the longitudinal vibrational axis of the surgical instrument, as described in greater detail below.

(112) In various embodiments, referring to FIGS. **56-59**, an ultrasonic surgical instrument blade,

such as blade **680**, for example, can include blade body **682** having a generally flat top surface, or side, **684** and a generally flat bottom surface, or side, **686**. Although surfaces, or sides, **684** and **686** can be generally flat or planar, they can comprise any suitable configuration including curved and/or curvilinear configurations, for example. The top and bottom surfaces **684**, **686** can be substantially parallel and can extend along the longitudinal or central axis **127**. The blade body **682** may comprise a substantially elongated treatment region, generally designated as **688**, and a neck or transition portion **690** that protrudes from a proximal end **632** of the treatment region **688**. The neck portion **690** may be attached to the ultrasonic transmission waveguide **104** (FIG. **1**) by a stud, weld, glue, quick connect, or other known attachment methods, for example. In alternative embodiments, the ultrasonic blade **680** and the ultrasonic transmission waveguide **104** may be formed as a single unitary body. In either configuration, the ultrasonic transmission waveguide **104** can amplify the mechanical vibrations transmitted to the ultrasonic blade **680** as is well known in the art.
(113) In various embodiments, blade **680** can include a notch **692** (hook shaped in the illustrated embodiment) which is defined at the distal end **634** of the treatment region **688**. The notch **692** can extend inwardly into the blade body **682**, as illustrated in FIGS. **57** and **59**, wherein the notch **692** can comprise a cutting edge **694** configured to incise tissue, for example. In various embodiments, referring to FIG. **58**, the blade **680** can further include cutting edge **696** which can also be configured to incise tissue, for example. In at least one embodiment, the cross-section of blade **680**, again referring to FIG. **58**, can be configured such that blade **680** is balanced, or at least substantially balanced, with respect to axis **669**. In various embodiments, the cross-section can be defined by a plane, such as plane **673**, for example, wherein plane **673** can be perpendicular to longitudinal axis **127** and wherein axis **669** can lie within the plane **673**. In at least one embodiment, the cross-section of blade **680** can include a body, or central, portion **675** and a cutting, or step, portion **679**, extending from central portion **675**. In various embodiments, axis **669** may be referred to as a centerline of the blade, or a portion of the blade, although such use is not intended to communicate that the blade, or a portion of the blade, is necessarily symmetrical. Often, such a reference can be used to refer to an axis, or datum, which is utilized to determine or measure whether a symmetrical and/or asymmetrical blade, or a portion of a blade, is balanced with respect thereto.
(114) In various embodiments, referring to the cross-section of blade **680** illustrated in FIG. **60**, the sides of central portion **675** can be defined by surfaces **684** and **686**, for example, wherein surfaces **684** and **686** can define a width (w) therebetween. Although the width of central portion **675** is substantially constant in the illustrated exemplary embodiment, the width of central portion **675** can have any suitable configuration, including configurations which comprise identical, or at least substantially identical, portions on the opposite sides of transverse axis **669**, for example. In at least one such embodiment, central portion **675** can include a first mass M.sub.B1 positioned on a first side of transverse axis **669** and a second mass M.sub.B2 positioned on a second side of said transverse axis, wherein M.sub.B, can be equal, or at least substantially equal, to M.sub.B2. In various embodiments, again referring to FIG. **60**, M.sub.B1 can comprise the area defined by h and w/2 and, similarly, M.sub.B2 can comprise the area defined by l.sub.2 and w/2. In at least one embodiment, l.sub.1 can equal, or at least substantially equal, l.sub.2. In various alternative embodiments, however, M.sub.B1 may not be equal to M.sub.B2. In at least one such embodiment, l.sub.1 may not equal l.sub.2. In various embodiments, though, the mass of blade **680** may be balanced in another manner as described in greater detail below.
(115) In various embodiments, referring to FIG. **60**, step portion **679** of the cross-section can comprise first surface **681** and second surface **683**, wherein cutting edge **696** can be positioned intermediate first surface **681** and second surface **683**. In at least one embodiment, step portion **679** can include, similar to the above, a first mass M.sub.S1, defined by A.sub.1, positioned on the first side of axis **669** and a second mass M.sub.S2, defined by A.sub.2, positioned on the opposite, or

second, side of axis **669**, wherein M.sub.S1 can be equal, or at least substantially equal, to M.sub.S2. In at least one such embodiment, step portion **679** can include a center of gravity **685**, wherein center of gravity **685** can be positioned along transverse axis **669**. Although various embodiments having a symmetrical step portion **679** are possible, step portion **679** can include an asymmetric configuration with respect to transverse axis **669**. In at least one such embodiment, cutting edge **696** may not lie along, or be co-planar with, axis **669** wherein, as a result, blade **680** can include a cutting edge which is positioned closer to one of sides **684** and **686** without creating a mass imbalance with respect to axis **669**. In at least one embodiment, referring to FIG. **60**, cutting edge **696** can be positioned a distance x with respect to second side **686**, for example, such that blade **680** is balanced as described in greater detail below. Owing to the closer proximity of the cutting edge with respect to one side of the blade, the cutting edge may be more visible to the surgeon thereby facilitating the proper use of the surgical instrument.

(116) In various embodiments, further to the above, M.sub.S1 may not be equal to M.sub.S2. In at least one such embodiment, though, the masses of central portion **675** and step portion **679**, for example, can be arranged such that the mass of blade **680** is still balanced with respect to transverse axis **669**, for example. More particularly, M.sub.S1, M.sub.S2, M.sub.B1, and M.sub.B2 can be selected such that M.sub.B1+M.sub.S1 is equal, or at least substantially equal, to M.sub.B2+M.sub.S2. In such embodiments, as a result, the total mass of blade **680** on the first side of axis **669** can be equal, or at least substantially equal, to the total mass of blade **680** on the second side of axis **669**. Furthermore, in various embodiments, the mass of blade **680** can be arranged such that the moment of force and the moment of inertia of masses M.sub.S1, M.sub.S2, M.sub.B1, and M.sub.B2 are balanced as well. Generally, the moment of force of a mass is proportional to the product of the mass and the distance between the center of gravity of the mass and a datum, or axis. Also, generally, the moment of inertia of a mass is proportional to the product of the mass and the square of the distance between the center of gravity of the mass and a datum, or axis. Referring to the illustrated embodiment of FIG. **60**, masses M.sub.S1, M.sub.S2, M.sub.B1, and M.sub.B2 can be positioned so as to balance, or at least substantially balance, the moment of force and the moment of inertia of blade **680** with respect to transverse axis **669**, for example.

(117) In various embodiments, again referring to FIG. **60**, step portion **679**, as described above, can include first and second surfaces and a cutting edge **696** positioned therebetween. In at least one embodiment, step portion **679** can further include an edge height, s, which can define the distance between cutting edge **696** and first portion **697** of step portion **679**. More particularly, in at least one embodiment, step portion **679** can include first portion **697** and cutting portion **699** which are separated by datum **695**, wherein edge height s can define the distance between the top of first portion **697**, i.e., cutting edge **696**, and datum **695**. Stated another way, referring to FIG. **60**A, edge height s can be defined as the distance between the top of a right triangle defined by area A.sub.4 and the top of a right triangle defined by the combined areas of A.sub.1 and A.sub.3. In at least one embodiment, further to the above, A.sub.1 can equal A.sub.2, and A.sub.2 can equal A.sub.3+A.sub.4. In various embodiments where second surface **683** is parallel to axis **669**, the edge height s can equal the length of second surface **683**. In various other embodiments where second surface **683** is not parallel to axis **669**, the edge height s can equal the length of the projection of second surface **683** onto axis **669**. In various embodiments, cutting edge **696** can lie in a first plane **693**, datum **695** can lie in a second plane which is parallel to the first plane, and wherein the step height s can define the distance between the first and second planes.

(118) In various embodiments, first surface **681** and second surface **683** can be arranged such that an angle α, or edge angle, is defined therebetween wherein the edge angle can be any suitable angle such as approximately 35 degrees or approximately 65 degrees, for example. During various experimental uses of such surgical blades, it was observed that surgical blades having smaller edge angles, i.e., angles closer to zero degrees, transected tissue faster than surgical blades having larger edge angles, i.e., angles closer to 90 degrees. It was also observed, though, that such blades were to

able to seal, or produce hemostasis within, the edges of the tissue as the tissue was being transected regardless of the edge angle selected. Such a result was deemed to be surprising and, advantageously, it is believed that the edge angle of the blades disclosed herein can be selected to facilitate a desired cutting rate without affecting the hemostasis of the tissue. Furthermore, it was also determined by the experimental uses of such surgical blades that a relationship for producing hemostasis within porcine tissue can comprise:

(119) $1.26 - 0.0102^{*} a - 1.14^{*} h + 8.14w$

wherein a represents the longitudinal amplitude of the blade, wherein w represents the width of the blade, similar to the above, and wherein h represents the height of the blade. In various embodiments, this relationship for producing hemostasis can be equated to zero, values for two of variables a, h, and w can be selected or input into the relationship, and the relationship can then be utilized to determine a value for the third variable. In at least one circumstance, this relationship was used to determine a suitable range of widths for the blade, w, which can be between approximately 0.040″ and approximately 0.070″, depending on the level of hemostasis required from a particular blade. A width of approximately 0.060″ was selected for one actual example.

(120) In at least one embodiment, second surface **683** of step portion **679** can be parallel, or at least substantially parallel, to first side **684** and/or second side **686** of central portion **675**. In various embodiments, first surface **681** can lie within a plane which is transverse to second surface **683** and first side **684**, for example. Although portions of the exemplary embodiment of step portion **679** in FIG. **60** are illustrated as right triangles having straight sides, step portion **679** can include any suitable configuration which is balanced, or at least substantially balanced, with respect to transverse axis **669**, for example. In at least one embodiment, such balancing can be achieved by positioning the center of gravity of the step portion along the centerline of the blade. In various embodiments, a blade, such as blade **680**, for example, can be balanced such that the relationship of:

(121) $\frac{x^2}{2*\tan\alpha} + \frac{(w-x)}{2}\left(\frac{x}{\tan\alpha} - s\right) - \left(\frac{w}{2}\right)^2 \frac{1}{\tan\alpha}$ or, correspondingly: (1)

$$\left[\frac{x^2}{2} * (\tan\alpha)^{-1} + \frac{(w-x)}{2}\left(x * (\tan\alpha)^{-1} - s\right) - \left(\frac{w}{2}\right)^2 (\tan\alpha)^{-1}\right]$$

$$\frac{x^2}{2} * (\tan\alpha)^{-1} + \frac{(w-x)}{2}\left(x * (\tan\alpha)^{-1} - s\right) - \left(\frac{w}{2}\right)^2 (\tan\alpha)^{-1}$$

is equal to, or at least substantially equal to, zero, wherein w is the width of the body portion of the blade, such as central portion **675**, for example, wherein α is the edge angle defined between the first and second surfaces of the step portion, such as surfaces **681** and **683**, for example, wherein s is the edge height of the step portion which can be defined as outlined above, and wherein x is the distance between a side of the body portion, such as second side **686**, and the cutting edge of the step portion, such as cutting edge **696**, for example.

(122) In various embodiments, suitable values for variables w, s, and a can be selected and relationship (1) can be manipulated to determine a value for variable x. In at least one such embodiment, relationship (1) is equated to zero and the selected values for variables w, s, and a are substituted into relationship (1) to determine the value for variable x. In such circumstances, variable x is dependent upon the selection of the values for w, s, and α. If a blade, such as blade **680**, for example, is constructed in accordance with the selected values of w, s, and α and the determined value for x, then blade **680** will be balanced, or at least substantially balanced, with respect to transverse axis **669**, for example. As outlined above, the values for variables w, s, and α can be selected for various reasons. For example, the value for variable w, i.e., the width of the body portion of the blade, can be selected such that the blade can fit through an endoscope, for example. In various embodiments, the value for variables s and a, i.e., the height and edge angle of step portion **679**, can be selected to improve or optimize the manufacturability of the blade. In addition to or in lieu of the above, the values for variable w, s, and/or α can be selected to optimize the cutting performance of the blade, for example.

(123) Although relationship (1) may be utilized to set variable x as a dependent variable,

relationship (1) may be utilized to set at least one of the other above-described variables as a dependent variable. In at least one such embodiment, for example, relationship (1) can be equated to zero and selected values for variables w, s, and x can be substituted into relationship (1) to determine a value for variable α. Similarly, relationship (1) can be equated to zero and selected values for variables w, a, and x can be substituted into relationship (1) to determine a value for variable s, for example. A similar approach can be undertaken to determine a value for variable w. Further to the above, in various embodiments, an ultrasonic surgical blade can be configured such that, for any given values of s and w, the relationship of:

(124) $$A * x^2 * (\tan\alpha)^{-1} + B * x * (\tan\alpha)^{-1} + C * (\tan\alpha)^{-1} + D * x + E \quad (2)$$

$$A * x^2 * (\tan\alpha)^{-1} + B * x * (\tan\alpha)^{-1} + C * (\tan\alpha)^{-1} + D * x + E$$

is equal, or at least substantially equal, to zero, wherein A, B, C, D, and E are constants. In various alternative embodiments, an ultrasonic surgical blade can be configured such that, for any given values of s and α, the relationship of:

(125) $$A * x^2 + B * x + C * x * w + D * w + E * w^2 + F \quad (3)$$

is equal, or at least substantially equal, to zero, wherein A, B, C, D, E, and F are constants. In various further embodiments, an ultrasonic surgical blade can be configured such that, for any given values of w and α, the relationship of:

(126) $$A * x^2 + B * x + C * x * s + D * s + E \quad (4)$$

is equal, or at least substantially equal, to zero, wherein A, B, C, D, and E are constants.

(127) In various embodiments, the above-described approaches for balancing an ultrasonic surgical blade can be utilized to balance, or at least substantially balance, various alternative surgical blades as outlined in greater detail below. In at least one embodiment, owing to the relationship between mass and kinetic energy, the energy imparted by such blades can also be balanced. More specifically, if the mass of a blade is balanced with respect to a datum or centerline of a blade, the kinetic energy produced by the blade, when it is motivated, will also be balanced with respect to the datum or centerline. In such circumstances, as a result, the surgical blade can be configured to deliver a uniform energy profile to the targeted tissue, for example. In various embodiments, a balanced, or at least substantially balanced, blade can provide a uniform, or at least substantially uniform, pressure profile to the targeted tissue. In at least one embodiment, a blade can be considered to be substantially balanced if the mass on the first side of the cross-section centerline is within approximately 10 percent of the mass on the second side of the centerline. In such embodiments, although the blade is not mass balanced, any transverse vibrations produced by the unbalanced blade may not substantially affect the performance of the blade. In at least one embodiment, a blade can be considered substantially balanced if the cutting edge, such as cutting edge **696**, for example, is positioned within approximately 10 percent of the calculated distance for x, for example. Further to the above, although methods of balancing the mass of a blade with respect to one axis have been described herein, such methods can be utilized to balance the mass of a blade with respect to two or more axes.

(128) In at least one embodiment, referring to FIG. **61**, blade **780** can include a central portion **775** having first side **784** and second side **786**. Blade **780** can further include two step portions **779** which, in various embodiments, can be positioned on opposite sides of central portion **775**. In such embodiments, as a result, blade **780** can comprise two cutting edges **796** which can be configured to transect tissue, for example. In various embodiments, further to the above, each step portion **779** can be balanced with respect to axis **769**, wherein axis **769** can be transverse to longitudinal axis **127**. In various alternative embodiments, although not illustrated, step portions **779** can be arranged such that, although each step portion **779** may be imbalanced with respect to axis **769**, step portions **779** can balance, or offset, one another. In at least one additional embodiment, referring to FIG. **62**, blade **880** can include central portion **875** and two step portions **879** wherein, similar to the above,

portions **875** and **879** can be balanced with respect to transverse axis **869**. In at least one further embodiment, referring to FIG. **63**, blade **980** can include a central portion **975** having first side **984** and second side **986**. Blade **980** can further include two step portions **979** wherein, similar to the above, portions **975** and **979** can be balanced with respect to transverse axis **969**. In at least one more embodiment, referring to FIG. **64**, blade **1080** can include central portion **1075** and two step portions **1079** wherein portions **1075** and **1079** can be balanced with respect to transverse axis **1069**.

(129) FIGS. **22-24** illustrate one embodiment of an ultrasonic blade **250** comprising a protective sheath **252**. The ultrasonic blade **250** is generally well-suited for cutting, coagulating, and reshaping tissue. The protective sheath **252** is generally well suited for glidingly engaging the surface of the bone to prevent damage to the bone and the ultrasonic blade **250** while the ultrasonic blade **250** removes muscle tissue from the bone and to dissipate thermal energy generated by the ultrasonic blade **250**. FIG. **22** illustrates a partial cross-sectional view of one embodiment of an ultrasonic blade **250** comprising a protective sheath **252** taken along the longitudinal axis. FIG. **23** is a bottom view of the ultrasonic blade **250** taken along line **23-23**. FIG. **24** is a cross-sectional view of the ultrasonic blade **250** and the protective sheath **252**. The ultrasonic blade **250** comprises a body **254** having a substantially planar top surface **256** a generally rounded cutting edge **258** and an atraumatic surface **259** for bone contact and atraumatic use along the bone region configured to prevent the cutting edge **136** from cutting into bone tissue. In one embodiment the cutting edge **258** may be configured as an ultrasonic surgical elevator blade generally well-suited to separate muscle tissue from bone. A lateral cutting edge **264** suitable for dissecting tissue is positioned on one side of the body **254** and an atraumatic edge **266** suitable to coagulate tissue may be positioned laterally along an opposite side of the body **254**. The body also comprises a generally flat planar bottom surface **268** adjacent to the protective sheath **252**. An air gap **262** may separate the bottom surface **268** from the protective sheath **252** for cooling purposes, for example. The protective sheath **252** comprises a substantially arcuate lateral bottom surface **260** with a flat portion in the center thereof.

(130) FIG. **25** illustrates a use of one embodiment of an ultrasonic surgical instrument **270** removing muscle tissue **244** from bone **246**. The ultrasonic surgical instrument **270** comprises the ultrasonic blade **250** described above. The ultrasonic blade **250** comprises the atraumatic bone protective sheath **252**. As used herein, atraumatic means designed to avoid injury. In one embodiment, the atraumatic bone protective sheath **252** extends longitudinally below the ultrasonic blade **250** to the handpiece housing of the ultrasonic surgical instrument **270** to act between the bottom surface of the ultrasonic blade **268** and the bone **246** to avoid injuring the bone **246** while coagulating, reshaping, or removing muscle tissue **244** from the bone **246** as described above. The air gap **262** provides a path for irrigation fluid to pass between the bottom surface **268** of the ultrasonic blade **250** and the protective sheath **252** to dissipate thermal energy generated by the ultrasonic blade **250** while cutting. In one embodiment, the protective sheath **252** may be rigidly and fixedly attached or mounted to the bottom surface **268** of the ultrasonic blade **250** in any suitable manner to reduce design complexity and cost. In other embodiments, the protective sheath **252** may be fixedly mounted to other substantially rigid portions of the ultrasonic surgical instrument **270**. In alternative embodiments, the protective sheath **252** may be user deployable (e.g., retractable).

(131) The protective sheath **252** reduces thermal heating effects that may result from the ultrasonic blade **250** contacting the bone **246**. The process of removing the muscle tissue **244** from the bone **246** during posterior spine access may be a lengthy procedure. Accordingly, there is a concern that the high temperatures may build and cause breakage of the ultrasonic blade **250**, spread of excessive lateral thermal heating, damage to the bone **246**, damage to the muscle **244**, and/or damage to nerve tissue. Accordingly, the bottom surface **268** of the ultrasonic blade **250** is shielded or protected by the protective sheath **252** and can rest against the surface of the bone **246** while the active portion or the cutting edge **258** of the ultrasonic blade **250** applies energy to the muscle

tissue **244**, resulting in good surgical technique of dissecting muscle tissue from bone (e.g., the spine). This protective sheath **252** also shields the ultrasonic blade **250** from contacting metal retractors and thus minimizes the risk of breaking the blade **250**. Reducing the risk of breaking the ultrasonic blade **250** reduces instrument exchange during a surgical procedure because there is less concern for retracting instruments to avoid breaking the ultrasonic blade **250**. In addition, the protective sheath **252** may enable more directed energy between the blade and a clamp arm (not shown).

(132) The protective sheath **252** may be formed of any suitable polymeric material and may be formed on or attached to the ultrasonic blade **250** using a variety of techniques. Generally, the protective sheath **252** may be formed of any material suitable to shield the ultrasonic blade **250** from contacting bone or metal objects while cutting and minimizing the risk that of breaking the ultrasonic blade **250**. In addition, the protective sheath **252** may be formed of a material and may be attached to the ultrasonic blade **250** in a manner that is suitable to decrease the thermal energy created by the ultrasonic blade **250** to spread from the bottom surface **268** thereof. In one embodiment, the protective sheath **252** may be formed by coating the bottom surface **268** of the ultrasonic blade **250** with a polymeric material. The protective sheath **252** may be formed of a variety of high temperature lubricious polymers. For example, the protective sheath **252** may be formed of any number of fluorinated polymers such as Tetrafluoroethylene or Polytetrafluoroethylene, such as Teflon® by DuPont. In another embodiment, the protective sheath **252** may be formed as separate rigid polymeric component permanently attached (e.g., affixed, mounted) to the bottom surface **268** of the ultrasonic blade **250**. The protective sheath **252** may be attached to the bottom surface **268** of the ultrasonic blade **250** with physical snaps, adhesives, and/or insert/molding. In yet another embodiment, the protective sheath **252** may be formed as a separate rigid polymeric component mounted to a rigid portion of the ultrasonic instrument **270** and shield the bottom surface **268** of the ultrasonic blade **250** without physically contacting the bottom surface **268** of the ultrasonic blade **250**. This provides the air gap **262** between the bottom surface **268** of the ultrasonic blade **250** and the separate rigid polymeric protective sheath **252**. The air gap **262** enables irrigation fluid to travel between the protective sheath **252** and the bottom surface **268** of the ultrasonic blade **250** to assist in cooling the blade. In one embodiment, irrigation may be provided within the protective sheath to assist in cooling the ultrasonic blade **250** from ultrasonically induced thermal effects. For example, in one embodiment a protective sheath may be configured to act as an irrigation conduit along the bottom surface of the ultrasonic blade to provide directed irrigation for surgical regions as well as providing a cooling effect to the ultrasonic blade during use (FIGS. **52-55**). In various other embodiments, the protective sheath **252** may be user deployable and/or retractable by the user. Thus the user may deploy the protective sheath **252** to shield the bottom surface **268** of the ultrasonic blade **150** from the bone **246** or may retract the protective sheath **252** when desired to enable back-cutting. In other embodiments, the protective sheath **252** may be configured to assist in the mechanical dissection or removal of the muscle tissue **244** from the bone **246**. For example, the protective sheath **252** may be configured in the shape and style to accommodate a conventional curette or cobb blade with sharp cutting edges **258**, **264**. The sheath also may be employed as a fulcrum along the bottom surface **268** of the ultrasonic blade **250** while still enabling distal and lateral tissue effects by exposing the cutting edge **258** of the ultrasonic blade **250**.

(133) FIG. **26** illustrates a use of one embodiment of the ultrasonic surgical blade **230** shown in FIGS. **20**, **21** comprising one embodiment of a protective sheath **272**. The protective sheath **272** is positioned adjacent to the bottom surface **238** of the ultrasonic surgical blade **230**. The protective sheath **272** protects the bone **246** as the cutting edge **239** dissects the muscle tissue **244** from the bone **246**. An air gap **274** between the protective sheath **272** and the bottom surface **238** of the ultrasonic blade **230** provides a path for irrigation fluid to pass therebetween to dissipate thermal energy generated by the ultrasonic blade **230** while cutting. The protective sheath **272** may be

formed of any polymeric material as previously discussed with respect to FIGS. **22-25**.
(134) FIGS. **27-31** illustrate one embodiment of an ultrasonic surgical instrument **280** comprising an end effector **304**. FIG. **27** is a top perspective view of one embodiment of the ultrasonic surgical instrument **280**. FIG. **28** is a cross-sectional view of the ultrasonic surgical instrument **280** shown in FIG. **27** taken along the longitudinal axis of the ultrasonic surgical instrument **280**. FIG. **29** is a bottom view of the ultrasonic surgical instrument **280** taken along lines **29-29**. FIG. **30** is a cross-sectional view of the ultrasonic surgical instrument **280** taken along lines **30-30**. FIG. **31** is cross-sectional view of the ultrasonic surgical instrument **280** taken along lines **31-31**. With reference now to FIGS. **27-31**, the ultrasonic surgical instrument **280** comprises an outer tubular member or outer tube **282** that extends from the handpiece assembly **456** (FIGS. **41-44**). The outer tube **282** has a substantially circular cross-section and a longitudinal opening or aperture **302** to receive an inner tubular member or inner tube **312**. The outer tube **282** has a substantially circular cross-section and may be fabricated from stainless steel. It will be recognized that the outer tube **282** may be constructed from any suitable material and may have any suitable cross-sectional shape. Located at the distal end of the ultrasonic surgical instrument **280** is an end effector **304** for performing various tasks, such as, for example, grasping tissue, cutting tissue and the like. It is contemplated that the end effector **304** may be formed in any suitable configuration.
(135) The end effector **304** comprises a non-vibrating clamp arm assembly **284**, an ultrasonic blade **286**, and a protective sheath **288**. The clamp arm assembly **284** comprises a tissue pad **300**. The non-vibrating clamp arm assembly **284** is to grip tissue or compress tissue against the ultrasonic blade **286**, for example.
(136) The ultrasonic blade **286** is generally well-suited for cutting, coagulating, and reshaping tissue. In one embodiment the ultrasonic blade **286** may be configured as an ultrasonic surgical elevator blade generally well-suited to separate muscle tissue from bone. Nevertheless, the ultrasonic blade **286** may be employed in various other therapeutic procedures. The ultrasonic blade **286** comprises a cutting edge **324** at a distal portion and in other embodiments may comprise one or more lateral cutting edges and/or lateral atraumatic dull, smooth or curved edges. The ultrasonic blade **286** comprises a bottom surface **322** adjacent to the protective sheath **288** such that the protective sheath **288** shields the bottom surface **322** from contacting other surfaces. The ultrasonic blade **286** may be coupled to the ultrasonic transmission waveguide **104** or may be formed as a unitary piece therewith. The ultrasonic instrument **280** may be employed with the ultrasonic system **10**.
(137) The protective sheath **288** is generally well suited for glidingly engaging the surface of the bone to prevent damage to the bone while the ultrasonic blade **286** removes muscle tissue from bone and to dissipate thermal energy generated by the ultrasonic blade **286** while cutting. In the embodiment, the protective sheath **288** may be fixedly coupled to the ultrasonic blade **286** or to the outer tube **282** and is not user deployable. An air gap **320** between the bottom surface **322** of the ultrasonic blade **286** and the protective sheath **288** provides a path for irrigation fluid to pass therebetween to dissipate thermal energy generated by the ultrasonic blade **286**. The protective sheath **288** comprises the proximal partially circumferentially extending portion **310** that overlaps and fixedly engages the outer tube **282**. As previously discussed, the proximal partially circumferentially extending portion **310** comprises multiple projections **318** to engage apertures **316** formed in the outer tube **282**. In one embodiment, the protective sheath **288** may be fixedly attached to the outer sheath **282** by way of the multiple projections **318** engaging the apertures **316** formed in the outer tube **282**. As shown in FIG. **30**, the protective sheath **288** comprises a curved substantially arcuate bottom surface **314** to slidingly engage bone. The curved bottom surface **314** comprises a convex portion **315** at a distal end and a concave portion **317** at a proximal end. The protective sheath **288** may be formed of any polymeric material as previously discussed with respect to FIGS. **22-25**.
(138) The end effector **304** is illustrated in a clamp open position. The clamp arm assembly **284** is

preferably pivotally mounted to the distal end of the outer tube **282** at pivot points **290**A, B such that the clamp arm assembly **284** can rotate in the direction shown by arrows **294**, **298**. The clamp arm assembly **284** preferably includes clamp arms **306**A, B and corresponding pivot pins **291**A, B on either side to engage the pivot points **290**A, B. The distal end of the inner tube **312** comprises fingers or flanges **313**A and **313**B (not shown) that extend therefrom. The fingers **313**A, B have corresponding openings **313**A and **313**B (not shown) to receive posts **315**A and **315**B (not shown) of the clamp arms **306**A, B. When the inner tube **312** is moved axially, the fingers **313**A, B move axially forwardly or rearwardly and engage the corresponding posts **315**A, B of the clamp arms **306**A, B to open and close the clamp arm assembly **284**. For example, when the inner tube **312** moves axially rearwardly or is retracted towards the proximal end in the direction indicated by arrow **292**, the clamp arm assembly **284** opens in the direction indicated by arrow **294**. When the inner tube **312** moves axially or is advanced towards to the distal end in the direction indicated by arrow **296** the clamp arm assembly **284** closes in the direction indicated by arrow **298**. The outer tube **282** remains fixed and the apertures **316** are configured to receive the projecting members **318** from the partially circumferentially extending portion **310** of the protective sheath **288**. The proximal partially circumferentially extending portion **310** of the protective sheath **288** is thus fixedly mounted to the outer tube **282**. In one embodiment, the proximal partially circumferentially extending portion **310** of the protective sheath **288** may be formed of similar materials as the protective sheath **288** or may be formed of other substantially rigid materials.

(139) The clamp arm **306** includes the tissue pad **300** attached thereto for squeezing tissue between the ultrasonic blade **286** and the clamp arm assembly **300**. The tissue pad **300** is preferably formed of a polymeric or other compliant material and engages the ultrasonic blade **286** when the clamp arm **306** is in its closed position. Preferably, the tissue pad **300** is formed of a material having a low coefficient of friction but which has substantial rigidity to provide tissue-grasping capability, such as, for example, TEFLON, a trademark name of E. I. Du Pont de Nemours and Company for the polymer polytetraflouroethylene (PTFE). The tissue pad **300** may be mounted to the clamp arm **300** by an adhesive, or preferably by a mechanical fastening arrangement. Serrations **308** are formed in the clamping surfaces of the tissue pad **300** and extend perpendicular to the axis of the ultrasonic blade **286** to allow tissue to be grasped, manipulated, coagulated and cut without slipping between the clamp arm **306** and the ultrasonic blade **286**.

(140) FIGS. **32-35** are cross-sectional views of various embodiments of ultrasonic surgical instruments **350**, **352**, **354**, **356** taken along the longitudinal axis. The ultrasonic surgical instruments **350**, **352**, **354**, **356** comprise respective fixedly attached protective sheaths **358**, **364**, **370**, **376**. As previously discussed, fixedly attached means that the protective sheaths are not deployable and remain in the position shown in FIGS. **32-35** during use of the instruments **350**, **352**. As shown in FIGS. **32-35**, the ultrasonic surgical instrument **350**, **352**, **354**, **356** each comprise the outer tube **282** that extends from a handpiece assembly (e.g., the handpiece assembly **60** shown in FIG. **1**). The outer tube **282** has a substantially circular cross-section and a longitudinal opening or aperture **302** to receive the inner tube **312**. Located at the distal end of the ultrasonic surgical instrument **350** is an end effector **304** for performing various tasks, such as, for example, grasping tissue, cutting tissue and the like. It is contemplated that the end effector **304** may be formed in any suitable configuration. The ultrasonic surgical instrument **350**, **352**, **354**, **356** may be employed with the ultrasonic system **10**.

(141) The end effector **304** comprises the non-vibrating clamp arm assembly **284**, an ultrasonic blade **286**, and a protective sheath **354**. The clamp arm assembly **284** is preferably pivotally attached to the distal end of the outer tube **282** at the pivot point **290**. The clamp arm assembly **284** comprises a tissue pad **300**. As previously discussed, the ultrasonic blade **286** may be coupled to the ultrasonic transmission waveguide **104** or may be formed as a unitary piece therewith and may be actuated by the ultrasonic system **10**.

(142) The protective sheaths **358**, **364**, **370**, **376** are generally well suited for glidingly engaging the

surface of the bone to prevent damage to the bone while the ultrasonic blade **286** removes muscle tissue from the bone and to dissipate thermal energy generated by the ultrasonic blade **286** while cutting. The protective sheaths **358**, **364**, **370**, **376** may be fixedly coupled to the ultrasonic blade **286** or to the outer tube **282** and are not user deployable. An air gap **320** between the bottom surface **322** of the ultrasonic blade **286** and the fixed protective sheaths **358**, **364**, **370**, **376** provides a space for irrigation fluid to pass therebetween to dissipate thermal energy generated by the ultrasonic blade **286** while cutting. In the embodiments illustrated in FIGS. **32-35**, the fixedly mounted protective sheaths **358**, **364**, **370**, **376** each comprise the proximal partially circumferentially extending portion **310** that overlaps and fixedly engages the outer tube **282**. As previously discussed, the proximal partially circumferentially extending portion **310** comprises multiple projections **318** to engage the apertures **316** formed in the outer tube **282** and thus the protective sheaths **358**, **364**, **370**, **376** are fixedly secured within the outer tube **282**. The alternative embodiments, the fixed protective sheaths **358**, **364**, **370**, **376** may be attached to an inner tube positioned within the outer tube **282**. The fixed protective sheaths **358**, **364**, **370**, **376** each comprise a distal portion comprising respective tapered bodies **384**, **388**, **392**, **398** that extend longitudinally beyond the distal portion of the ultrasonic blade **286** to protect the distal cutting edge **324** of the ultrasonic blade **286**. In other embodiments, the tapered bodies **384**, **388**, **392**, **398** may extend laterally to protect longitudinal portions of the ultrasonic blade **286**. The fixed protective sheaths **358**, **364**, **370**, **376** each comprise respective substantially planar sheet portions **359**, **365**, **371**, **377** extending longitudinally between the distal tapered bodies **384**, **388**, **392**, **398** and the proximal partially circumferentially extending portion **310** to shield the bottom surface **322** of the ultrasonic blade **286**. The protective sheaths **358**, **364**, **370**, **376** may be formed of any polymeric material as previously discussed with respect to FIGS. **22-25**.

(143) As shown in FIG. **32**, the fixed protective sheath **358** comprises the tapered body **360** at a distal end that extends longitudinally beyond the distal end of the ultrasonic blade **286**. The tapered body **360** comprises a substantially planar top surface **362** and a substantially planar bottom surface **382** that taper from a proximate end to a blunt distal end **384**.

(144) As shown in FIG. **33**, the fixed protective sheath **364** comprises the tapered body **366** at a distal end that extends longitudinally beyond the distal end of the ultrasonic blade **286**. The tapered body **366** comprises a substantially planar top surface **368** and a substantially planar bottom surface **386** that taper from a proximate end to a blunt distal end **388**. The substantially planar top and bottom surfaces **368**, **386** have corresponding radiused contoured surfaces that meet the blunt surface **388**.

(145) As shown in FIG. **34**, the fixed protective sheath **370** comprises the tapered body **378** at a distal end that extends longitudinally beyond the distal end of the ultrasonic blade **286**. The tapered body **378** comprises a curved top surface **374** and a curved bottom surface **390** that taper from a proximate end to a sharp distal end **392**.

(146) As shown in FIG. **35**, the fixed protective sheath **376** comprises the tapered body **378** at a distal end that extends longitudinally beyond the distal end of the ultrasonic blade **286**. The tapered body **378** comprises a substantially planar top surface **396** and a substantially curved bottom surface **394** that taper from a proximate end to a sharp distal end **398**.

(147) FIGS. **36-37** are cross-sectional views of one embodiment of an ultrasonic surgical instrument **400** taken along the longitudinal axis. The ultrasonic surgical instrument **400** may be employed with the ultrasonic system **10**. The ultrasonic surgical instrument **400** comprises a deployable protective sheath **402**. In one embodiment, the deployable protective sheath **402** may be deployed by a user during a surgical procedure. Deployable means that the deployable protective sheath **402** may be advanced to a distal end in the direction indicated by arrow **404** to be put into use and may be retracted to a proximate end in the direction indicated by arrow **406** when it is to be taken out of use. The deployable protective sheath **402** comprises a distal portion **401** that substantially shields the bottom surface **322** of the ultrasonic blade **286** when it is deployed. The

deployable protective sheath **402** comprises a proximate portion **403** that extends to the handpiece assembly (e.g., the handpiece assembly **60** shown in FIG. **1**) where it is coupled to a protective sheath deploying and retracting mechanism. The distal portion **401** may be formed slightly thicker then the proximal portion **403**. The deployable protective sheath **402** may be formed of any polymeric material as previously discussed with respect to FIGS. **22-25**. In one embodiment, the proximal portion **403** may be formed of the same material as the distal portion **401** of the deployable protective sheath **402**. In other embodiments, the proximal portion **403** may be formed of a different more durable material than the distal portion **401** of the deployable protective sheath **402** to withstand repeated deployments and retractions. For example, the proximal portion **403** may be formed of metal or other durable material to withstand the moderate forces required to hold the deployable protective sheath **402** in place during deployment, retraction, and use.

(148) The ultrasonic surgical instrument **400** comprises the outer tube **282** that extends from the handpiece assembly **456**. The outer tube **282** has a substantially circular cross-section and a longitudinal opening or aperture **302** to receive the inner tube **312**. Located at the distal end of the ultrasonic surgical instrument **350** is an end effector **304** for performing various tasks, such as, for example, grasping tissue, cutting tissue and the like. It is contemplated that the end effector **304** may be formed in any suitable configuration. The end effector **304** comprises the non-vibrating clamp arm assembly **284**, an ultrasonic blade **286**, and the deployable protective sheath **402**. The clamp arm assembly **284** is preferably pivotally attached to the distal end of the outer tube **282** at the pivot point **290**. The clamp arm assembly **284** comprises a tissue pad **300**. As previously discussed, the ultrasonic blade **286** may be coupled to the ultrasonic transmission waveguide **104** or may be formed as a unitary piece therewith.

(149) When the deployable protective sheath **402** is advanced in the direction indicated by arrow **404**, it is generally well suited for glidingly engaging the surface of the bone to prevent damage to the bone while the ultrasonic blade **286** removes muscle tissue from the bone and to dissipate thermal energy generated by the ultrasonic blade **286** while cutting. The deployable protective sheath **402** also is well suited to shield the bottom surface of the blade **322** from contact with other objects. The deployable protective sheath **402** may be retracted in the direction indicated by arrow **406** when it is not needed. When the deployable protective sheath **402** is deployed, the air gap **320** between the bottom surface **322** of the ultrasonic blade **286** and the protective sheath **402** provides a space for irrigation fluid to pass therebetween to dissipate thermal energy generated by the ultrasonic blade **286** while cutting. In one embodiment, the deployable protective sheath **402** may retract within the inner tube **312**.

(150) FIGS. **38-39** are cross-sectional views of one embodiment of an ultrasonic surgical instrument **410** taken along the longitudinal axis. The ultrasonic surgical instrument **410** comprises a deployable protective sheath **412**. In one embodiment, the deployable protective sheath **412** may be deployed by a user during a surgical procedure. Deployable means that the deployable protective sheath **412** may be advanced to a distal end in the direction indicated by arrow **404** to be put in use and may be retracted to a proximate end in the direction indicated by arrow **406** to be put out of use. The deployable protective sheath **402** comprises a distal portion **407** that substantially covers the bottom surface **418** of the ultrasonic blade **414** when it is deployed. The deployable protective sheath **412** comprises a proximate portion **405** that extends to a handpiece assembly (e.g., the handpiece assembly **60** shown in FIG. **1**) where it is coupled to a protective sheath deploying and retracting mechanism. The distal portion **407** may be formed slightly thicker then the proximal portion **405**. The distal portion comprises a vertically extending projection **420** to protect the cutting edge **416** of the ultrasonic blade **414**. The projection **420** is adapted to engage and compress the bottom surface of the ultrasonic blade **414** when it is retracted. The deployable protective sheath **402** may be formed of any polymeric material as previously discussed with respect to FIGS. **22-25**. In one embodiment, the proximal portion **405** may be formed of the same material as the distal portion **407** of the deployable protective sheath **412**. In other embodiments,

the proximal portion **405** may be formed of a different more durable material than the distal portion **407** of the deployable protective sheath **412** to withstand repeated deployments and retractions. For example, the proximal portion **405** of the deployable protective sheath **412** may be formed of metal or other durable material to withstand the moderate forces required to hold the deployable protective sheath **412** in place during deployment, retraction, and use.

(151) The ultrasonic surgical instrument **410** comprises the outer tube **282** that extends from the handpiece assembly **456**. The outer tube **282** has a substantially circular cross-section and a longitudinal opening or aperture **302** to receive the inner tube **312**. Located at the distal end of the ultrasonic surgical instrument **350** is an end effector **304** for performing various tasks, such as, for example, grasping tissue, cutting tissue and the like. It is contemplated that the end effector **304** may be formed in any suitable configuration. The end effector **304** comprises the non-vibrating clamp arm assembly **284**, an ultrasonic blade **414** with a distal chisel-shaped cutting edge **416**, and the deployable protective sheath **412**. The clamp arm assembly **284** is preferably pivotally attached to the distal end of the outer tube **282** at the pivot point **290**. The clamp arm assembly **284** comprises a tissue pad **300**. As previously discussed, the ultrasonic blade **286** may be coupled to the ultrasonic transmission waveguide **104** or may be formed as a unitary piece therewith.

(152) When the deployable protective sheath **412** is advanced in the direction indicated by arrow **404**, it is generally well suited for gliding along the surface of the bone to prevent damage to the bone while the ultrasonic blade **414** removes muscle tissue from the bone. The deployable protective sheath **412** may be retracted in the direction indicated by arrow **406** when it is not needed. When the deployable protective sheath **412** is deployed, the air gap **320** between the bottom surface **418** of the ultrasonic blade **414** and the protective deployable sheath **412** provides a space for irrigation fluid to pass therebetween. The protective deployable sheath **412** retracts inside the inner tube **312**.

(153) FIG. **40** is cross-sectional view of one embodiment of an ultrasonic surgical instrument **430** taken along the longitudinal axis. The ultrasonic surgical instrument **430** may be employed with the ultrasonic system **10**. The ultrasonic surgical instrument **430** comprises a fixedly attached protective sheath **432**. As previously discussed, fixedly attached means that the protective sheath is not deployable and remains in the position shown in FIG. **40** for the usable life of the instrument **430**. As shown in FIG. **40**, the ultrasonic surgical instrument **430** comprises the outer tube **282** that extends from the handpiece assembly **456**. The outer tube **282** has a substantially circular cross-section and a longitudinal opening or aperture **302** to receive the inner tube **312**. Located at the distal end of the ultrasonic surgical instrument **350** is an end effector **304** for performing various tasks, such as, for example, grasping tissue, cutting tissue and the like. It is contemplated that the end effector **304** may be formed in any suitable configuration.

(154) The end effector **304** comprises the non-vibrating clamp arm assembly **284**, an ultrasonic blade **286**, and a protective sheath **432**. The clamp arm assembly **284** is preferably pivotally attached to the distal end of the outer tube **282** at the pivot points **290**A, B. The clamp arm assembly **284** comprises a tissue pad **300**. As previously discussed, the ultrasonic blade **286** may be coupled to the ultrasonic transmission waveguide **104** or may be formed as a unitary piece therewith.

(155) The protective sheath **432** is generally well suited for glidingly engaging the surface of the bone to prevent damage to the bone while the ultrasonic blade **286** removes muscle tissue from the bone and to dissipate thermal energy generated by the ultrasonic blade **286** while cutting. The protective sheath **432** is also well suited to shield the bottom surface **322** of the blade **286**. The protective sheath **432** may be fixedly coupled to the ultrasonic blade **286** or to the outer tube **282** by way of projections **318** (FIGS. **27-31**) and apertures **316** and is not user deployable. An air gap **320** between the bottom surface **322** of the ultrasonic blade **286** and the fixed protective sheath **432** provides a space for irrigation fluid to pass therebetween to dissipate thermal energy generated by the ultrasonic blade **286** while cutting. The fixed protective sheath **432** comprises the proximal

partially circumferentially extending portion **310** that overlaps and fixedly engages the outer tube **282**. As previously discussed, the proximal partially circumferentially extending portion **310** comprises the multiple projections **318** to engage the apertures **316** formed in the outer tube **282**. The fixed protective sheath **432** is attached to the outer tube **282**. The fixed protective sheath **432** comprises discrete projections or bumps **434** formed on a top surface **436** thereof. There may be one or multiple bumps **434** formed on the top surface **436** of the protective sheath **432**. The bumps **434** decrease the contact surface area between the ultrasonic blade **286** and the protective sheath **432**, which may occur during a procedure when the protective sheath is used as a fulcrum. This may reduce the heat or thermal energy generated by the ultrasonic blade **286** and the load on the ultrasonic blade **286**. The protective sheath **432** may be formed of any polymeric material as previously discussed with respect to FIGS. **22-25**.

(156) FIGS. **41-43** illustrate one embodiment of an ultrasonic system **400**. FIG. **41** is a side view of the ultrasonic system **400**. One embodiment of the ultrasonic system **400** comprises the ultrasonic signal generator **12** coupled to the ultrasonic transducer **14**, a hand piece housing **452**, and an end effector **304** (shown in FIG. **27**) forming an ultrasonic instrument **456**. The ultrasonic instrument **456** comprises a curved lever member **454** coupled to the protective sheath **402** to move the protective sheath **402** axially. The ultrasonic instrument **456** also comprises a slideable member **458**B coupled to the inner tube **312**. The slideable member **458**B moves axially within a slot that defines walls **460**B formed in the hand piece housing **452** to actuate the end effector **304**.

(157) FIG. **42** is a cross-sectional side view of the ultrasonic system **456** shown in FIG. **41** and a cross-sectional view of various tube assemblies to couple the hand piece housing **452** with an end effector. As shown in FIG. **42**, the curved lever member **454** is pivotally mounted to the hand piece housing **452** at pivot point **462** such that it can rotate in the direction indicated by arrows **463**A, B. Link members **464**A and **464**B (not shown) are pivotally coupled at a proximate end to pivot points **466**A and **466**B (not shown) and at a distal end to pivot points **468**A and **468**B (not shown). When the curved lever member **454** is rotated about the pivot point **462** in the direction indicated by arrow **463**A the sheath **402** moves axially in the direction indicated by arrow **465**A in its deployed position. When the curved lever member **454** is moved in the direction indicated by arrow **463**B the sheath **402** moves axially in the direction indicated by arrow **465**B n its retracted position.

(158) FIG. **43** is a bottom cross-sectional view of the ultrasonic instrument **456** shown in FIG. **41**. As shown in FIG. **43**, the slideable members **458**A, B are held in a locked position by respective springs **472**A, B which engage and compress the slideable members **458**A, B against an interior portion of the hand piece housing **452**. The interior portion of the hand piece housing **452** comprises rows of serrated edges **474**A, B formed along inner portions of the walls **460**A, B defined by the slot. Notched members **480**A, B are mounted to flanges formed on the slideable members **458**A, B and are configured to engage the respective serrated edges **474**A, B formed in the respective walls **460**A, B. Bodies **470**A, B are formed integrally with the inner tube **312** or are attached to thereto. When a force is applied in the direction indicated by arrows **476**, B against the respective springs **472**A, B, the slideable members **458**A, B can be moved axially as indicated by arrows **478**A, B. Thus the inner tube **312** moves axially to actuate the clamp arm assembly **284** of the end effector **304**.

(159) In alternative embodiments, the ultrasonic instrument **456** may be adapted and configured such that the curved lever member **454** is coupled to the inner tube **312** and the slideable members **458**A, B are coupled to the protective sheath **402**. Accordingly, rotating the curved lever member **454** moves the inner tube **312** axially to actuate the end effector **304**. And the slideable members **458**A, B can be used to axially deploy and retract the protective sheath **402**.

(160) FIGS. **44-51** illustrate one embodiment of an ultrasonic system **500**. FIG. **44** is a side view of the ultrasonic instrument **506** with the deployable protective sheath **402** in a stowed or retracted position. FIG. **45** is a top view of the ultrasonic instrument **506** with the deployable protective sheath **402** in the stowed or retracted position taken along line **45-45** in FIG. **44**. FIG. **46** is a side

view of the ultrasonic instrument **506** with the deployable protective sheath **402** in a deployed position. FIG. **47** is a top view of the ultrasonic instrument **506** in the deployed position taken along line **47-47** in FIG. **46**.

(161) With reference to FIGS. **44-47**, one embodiment of the ultrasonic instrument **500** is coupled to an ultrasonic signal generator **12** and comprises an ultrasonic transducer **14**, a hand piece housing **502**, and an end effector **504** forming an ultrasonic instrument **506**. The ultrasonic instrument **506** comprises a slideable member **508** coupled to the deployable protective sheath **402** in any suitable manner as previously discussed. The slideable member **508** moves axially within a slot **510** formed in the hand piece housing **502** to actuate or deploy/retract the deployable protective sheath **402**. The slideable member **508** is shown in the deployable protective sheath **402** retracted or stowed position. When the slideable member **508** moves axially in the direction indicated by arrow **514** the deployable protective sheath **402** also moves axially in the same direction to its retracted or stowed position. When the slideable member **508** moves axially in the direction indicated by arrow **516** the deployable protective sheath **402** also moves axially in the same direction to its deployed position. Once deployed, the deployable protective sheath **402** may be locked in place with any suitable locking mechanism. An air gap **518** provides a path for irrigation fluid to cool the ultrasonic blade **512** while cutting. The end effector **504** comprises an ultrasonic blade **512** coupled to the ultrasonic transducer **14** by the ultrasonic transmission waveguide **104** as previously discussed. The fixed outer tube **282** (or sheath) shields the surgeon and the patient from unintended contact with the ultrasonic blade **512** and the ultrasonic transmission waveguide **104**.

(162) FIG. **48** is a more detailed side view of the ultrasonic instrument **506** with the deployable protective sheath **402** in a stowed or retracted position. FIG. **49** is a more detailed top view of the ultrasonic instrument **506** with the protective sheath **402** in the stowed or retracted position taken along line **49-49** in FIG. **48**. FIG. **50** is a more detailed side view of the ultrasonic instrument **506** with the deployable protective sheath **402** in a deployed position. FIG. **51** is a more detailed top view of the ultrasonic instrument **506** in the deployed position taken along line **51-51** in FIG. **50**.

(163) With reference to FIGS. **44-51**, the deployable protective sheath **402** is user deployable by moving the slideable member **508** in the direction indicated by arrow **516**. The distal end of the deployable protective sheath **402** may be formed of any polymeric material as previously discussed with respect to FIGS. **22-25**. The proximal end of the deployable protective sheath **402** may be formed of metal or other durable material to withstand the moderate forces required to hold the deployable protective sheath **402** in place during deployment, retraction, and use.

(164) FIG. **50** shows the deployable protective sheath **402** in the deployed position in a substantially relaxed state as indicated by the air gap **518** between the deployable protective sheath **402** and the ultrasonic blade **512**. Thus, in a stress free state, the deployable protective sheath **402** does not contact the ultrasonic blade **512**. When the deployable protective sheath **402** is used as a fulcrum, however, it may contact the ultrasonic blade **512** for some period of time. However, when the pressure is released on the ultrasonic instrument **500**, the deployable protective sheath **402** is sufficiently resilient to return to its initial position, thus restoring the air gap **518** between the protective sheath **412** and the ultrasonic blade **512**. If needed, a separate spring may be added to the deployable protective sheath **402** to ensure that it no longer contacts the ultrasonic blade **512** once the pressure is released. In the illustrated embodiment, the deployable protective sheath **402** is shown to be smaller than the outline of the ultrasonic blade **512**. This enables the user to cut tissue with the distal tip and both edges of the ultrasonic blade **512** when the deployable protective sheath **402** is deployed. In alternate embodiments, the deployable protective sheath **402** may also cover some or all of the three edges of the ultrasonic blade **512**.

(165) FIGS. **52-55** illustrate one embodiment of an ultrasonic surgical instrument **550** comprising an end effector **552**. The ultrasonic surgical instrument may be employed with the ultrasonic system **10**. FIG. **52** is a top perspective view of one embodiment of the ultrasonic surgical instrument **550**. FIG. **53** is a partial cross-sectional view of the ultrasonic surgical instrument **550**

shown in FIG. **52** taken along the longitudinal axis of the ultrasonic surgical instrument **550**. FIG. **54** is a cross-sectional view of the ultrasonic surgical instrument **550** taken along lines **54-54** shown in FIG. **53**. FIG. **55** is a top view of the ultrasonic surgical instrument **550**.

(166) With reference now to FIGS. **52-55**, the ultrasonic surgical instrument **550** comprises an outer member or outer tube **282** that extends from the handpiece assembly **60** or **456** (FIG. **1** or FIGS. **41-44**). The outer tube **282** has a substantially circular cross-section and a longitudinal opening or aperture **302** to receive an inner member or an inner tube **312**. The outer tube **282** has a substantially circular cross-section and may be fabricated from stainless steel. It will be recognized that the outer tube **282** may be constructed from any suitable material and may have any suitable cross-sectional shape. Located at the distal end of the ultrasonic surgical instrument **550** is an end effector **552** for performing various tasks, such as, for example, grasping tissue, cutting tissue and the like. It is contemplated that the end effector **304** may be formed in any suitable configuration.

(167) The end effector **552** comprises a non-vibrating clamp arm assembly **284**, an ultrasonic blade **286**, and a protective sheath **554**. The end effector **552** is illustrated in a clamp open position and operates in a manner discussed above. The clamp arm assembly **284** comprises a tissue pad **300**. The non-vibrating clamp arm assembly **284** is to grip tissue or compress tissue against the ultrasonic blade **286**, for example. The protective sheath **552** defines a chamber **556** in fluid communication with irrigation channels or tubes **558**A, B to receive irrigation fluid from the irrigation channels **558**A, B. The irrigation channels **558**A, B couple to conventional irrigation devices by way of ports **560**A, B (not shown) at the proximate end of the ultrasonic instrument **550**. The irrigation channels **558**A, B deliver irrigation fluid to the chamber **556** to dissipate thermal energy generated by the ultrasonic blade **286** while cutting and carrying away pieces cut bone and tissue. Irrigation may be controlled manually by way of a control button on the handpiece or automatically wherein each time the ultrasonic instrument **550** is powered on a irrigation fluid release cam may be activated to release the irrigation fluid.

(168) The ultrasonic blade **286** is generally well-suited for cutting, coagulating, and reshaping tissue. In one embodiment the ultrasonic blade **286** may be configured as an ultrasonic surgical elevator blade generally well-suited to separate muscle tissue from bone. Nevertheless, the ultrasonic blade **286** may be employed in various other therapeutic procedures. The ultrasonic blade **286** comprises a cutting edge **324** at a distal portion and may comprise cutting edges extending longitudinally along the sides of the ultrasonic blade **286**. The ultrasonic blade **286** comprises a bottom surface **322** adjacent to the protective sheath **554**. The ultrasonic blade **286** may be coupled to the ultrasonic transmission waveguide **104** or may be formed as a unitary piece therewith.

(169) The protective sheath **554** is generally well suited for glidingly engaging the surface of the bone to prevent damage to the bone while the ultrasonic blade **286** removes muscle tissue from the bone and to dissipate thermal energy generated by the ultrasonic blade **286** while cutting. The protective sheath **554** may be fixedly coupled to the ultrasonic instrument **550** or may be user deployable. In the illustrated embodiment, the protective sheath **550** is fixedly mounted to the outer tube **282** as previously discussed. The protective sheath **288** comprises the proximal partially circumferentially extending portion **310** that overlaps and fixedly engages the outer tube **282**. As previously discussed, the proximal partially circumferentially extending portion **310** comprises multiple projections to engage the apertures **316** formed in the outer tube **282**. When fixedly attached, the protective sheath **554** may be attached to the outer tube **282**. When the protective sheath **554** is deployed, it may be attached to an inner tube received within the inner tube **312** that is slidingly engaged to a deployment mechanism on the handpiece portion of the ultrasonic instrument **550** as previously discussed. The protective sheath **554** comprises a bottom surface **560** to slidingly engage bone. The protective sheath **554** may be formed of any polymeric material as previously discussed with respect to FIGS. **22-25**.

(170) The devices disclosed herein can be designed to be disposed of after a single use, or they can

be designed to be used multiple times. In either case, however, the device can be reconditioned for reuse after at least one use. Reconditioning can include any combination of the steps of disassembly of the device, followed by cleaning or replacement of particular pieces, and subsequent reassembly. In particular, the device can be disassembled, and any number of the particular pieces or parts of the device can be selectively replaced or removed in any combination. Upon cleaning and/or replacement of particular parts, the device can be reassembled for subsequent use either at a reconditioning facility, or by a surgical team immediately prior to a surgical procedure. Those skilled in the art will appreciate that reconditioning of a device can utilize a variety of techniques for disassembly, cleaning/replacement, and reassembly. Use of such techniques, and the resulting reconditioned device, are all within the scope of the present application.
(171) Preferably, the various embodiments described herein will be processed before surgery. First, a new or used instrument is obtained and if necessary cleaned. The instrument can then be sterilized. In one sterilization technique, the instrument is placed in a closed and sealed container, such as a plastic or TYVEK bag. The container and instrument are then placed in a field of radiation that can penetrate the container, such as gamma radiation, x-rays, or high-energy electrons. The radiation kills bacteria on the instrument and in the container. The sterilized instrument can then be stored in the sterile container. The sealed container keeps the instrument sterile until it is opened in the medical facility.
(172) It is preferred that the device is sterilized. This can be done by any number of ways known to those skilled in the art including beta or gamma radiation, ethylene oxide, steam.
(173) Although various embodiments have been described herein, many modifications and variations to those embodiments may be implemented. For example, different types of end effectors may be employed. Also, where materials are disclosed for certain components, other materials may be used. The foregoing description and following claims are intended to cover all such modification and variations.
(174) Any patent, publication, or other disclosure material, in whole or in part, that is said to be incorporated by reference herein is incorporated herein only to the extent that the incorporated materials does not conflict with existing definitions, statements, or other disclosure material set forth in this disclosure. As such, and to the extent necessary, the disclosure as explicitly set forth herein supersedes any conflicting material incorporated herein by reference. Any material, or portion thereof, that is said to be incorporated by reference herein, but which conflicts with existing definitions, statements, or other disclosure material set forth herein will only be incorporated to the extent that no conflict arises between that incorporated material and the existing disclosure material.

Claims

1. An ultrasonic surgical system, comprising: a housing assembly; a shaft assembly extending from the housing assembly, wherein the shaft assembly comprises: an outer tube; and an inner tube movable relative to the outer tube; an ultrasonic waveguide extending through the shaft assembly; an end effector, comprising: an ultrasonic blade extending from the ultrasonic waveguide; and a clamp arm moveable relative to the ultrasonic blade between an open position and a closed position, wherein the clamp arm is movable based on movement of the inner tube relative to the outer tube; and a protective sheath configured to shield a portion of the ultrasonic blade, wherein the protective sheath is moveable between a retracted position and a deployed position; wherein the housing assembly comprises: a housing; a lever operably coupled to the housing and the protective sheath, wherein the protective sheath is movable between the retracted position and the deployed position based on movement of the lever relative to the housing; and an actuator operably coupled to the inner tube, wherein the actuator is moveable between a first position and a second position,

and wherein the clamp arm is configured to move toward the closed position based on movement of the actuator toward the second position.
2. The ultrasonic surgical system of claim 1, wherein the housing assembly defines a slot, and wherein the actuator is movable within the slot.
3. The ultrasonic surgical system of claim 1, wherein the housing comprises serrated edges, wherein the actuator comprises a notched member, and wherein the actuator is prevented from moving between the first position and the second position based on the notched member engaging the serrated edges.
4. The ultrasonic surgical system of claim 3, wherein the housing assembly further comprises a spring configured to bias the notched member into engagement with the serrated edges.
5. The ultrasonic surgical system of claim 1, wherein the housing assembly further comprises a link pivotably coupled to the lever and the protective sheath.
6. The ultrasonic surgical system of claim 1, wherein the protective sheath is configured to move toward the retracted position based on movement of the lever toward the housing.
7. The ultrasonic surgical system of claim 1, wherein the actuator is slidable between the first position and the second position.
8. An ultrasonic surgical system, comprising: a housing assembly; a shaft assembly extending from the housing assembly, wherein the shaft assembly comprises: an outer tube; and an inner tube movable relative to the outer tube; an ultrasonic waveguide extending through the shaft assembly; an end effector, comprising: an ultrasonic blade extending from the ultrasonic waveguide; and a clamp arm pivotable relative to the ultrasonic blade between an open position and a closed position, wherein the clamp arm is movable based on movement of the inner tube relative to the outer tube; and wherein the housing assembly comprises: a housing, defining: a first slot on a first lateral side thereof; and a second slot of a second lateral side thereof; a first actuator operably coupled to the inner tube, wherein the first actuator is axially moveable through the first slot; and a second actuator operably coupled to the inner tube, wherein the second actuator is axially moveable through the second slot, and wherein the clamp arm is configured to move between the open position and the closed position based on cooperative movement of the first actuator and the second actuator through the first slot and the second slot, respectively.
9. The ultrasonic surgical system of claim 8, wherein each of the first actuator and the second actuator are moveable between a locked configuration and an unlocked configuration.
10. The ultrasonic surgical system of claim 9, wherein the inner tube defines a longitudinal axis, and wherein the first actuator and the second actuator are moveable toward their respective unlocked configurations based on movement of the first actuator and the second actuator toward the longitudinal axis.
11. The ultrasonic surgical system of claim 10, wherein the housing assembly further comprises: a first spring configured to bias the first actuator toward a first locked configuration; and a second spring configured to bias the second actuator toward a second locked configuration.
12. The ultrasonic surgical system of claim 11, wherein the housing comprises: first serrated edges, wherein the first actuator comprises a first member, and wherein the first member is configured to engage the first serrated edges based on the first actuator being in the first locked configuration; and second serrated edges, wherein the second actuator comprises a second member, and wherein the second member is configured to engage the second serrated edges based on the second actuator being in the second locked configuration.
13. The ultrasonic surgical system of claim 8, further comprising a protective sheath configured to shield a portion of the ultrasonic blade, wherein the protective sheath is moveable between a retracted position and a deployed position.
14. The ultrasonic surgical system of claim 13, wherein the housing assembly further comprises a lever operably coupled to the housing and the protective sheath, and wherein the protective sheath is movable between the retracted position and the deployed position based on pivotable movement

of the lever relative to the housing.

15. An ultrasonic surgical system, comprising: a housing assembly; a shaft assembly extending from the housing assembly, wherein the shaft assembly comprises: an outer tube; and an inner tube movable relative to the outer tube, wherein the inner tube defines a longitudinal axis; an ultrasonic waveguide extending through the shaft assembly; an end effector, comprising: an ultrasonic blade extending from the ultrasonic waveguide; and a clamp arm moveable relative to the ultrasonic blade between an open position and a closed position, wherein the clamp arm is movable based on movement of the inner tube relative to the outer tube; and a protective sheath configured to shield a portion of the ultrasonic blade, wherein the protective sheath is moveable between a retracted position and a deployed position; wherein the housing assembly comprises: a housing; a lever operably pivotably to the housing, wherein pivotable movement of the lever is configured to effect a first action of the ultrasonic surgical system; and a actuator, wherein axial movement of the actuator along the longitudinal axis is configured to effect a second action of the ultrasonic surgical system, and wherein the actuator is prevented from effecting the second action of the ultrasonic surgical system absent a force being applied to the actuator in a direction toward the longitudinal axis.

16. The ultrasonic surgical system of claim 15, wherein: the housing comprises serrated edges; the actuator comprises a member; and engagement of the member with the serrated edges prevents the actuator from axially moving along the longitudinal axis between a first position and a second position.

17. The ultrasonic surgical system of claim 16, wherein the housing assembly further comprises a spring configured to bias the member into engagement with the serrated edges absent the force.

18. The ultrasonic surgical system of claim 15, wherein: the first action of the ultrasonic surgical system comprises moving the protective sheath between the retracted position and the deployed position; and the second action of the ultrasonic surgical system comprises moving the clamp arm between the open position and the closed position.

19. The ultrasonic surgical system of claim 15, wherein: the first action of the ultrasonic surgical system comprises moving the clamp arm between the open position and the closed position; and the second action of the ultrasonic surgical system comprises moving the protective sheath between the retracted position and the deployed position.