American Chemical Society

National Awards Nomination Packet

ACS Award in Polymer Chemistry:2018
for: Christopher Bowman

Received: 11/04/2015 *Cycle Year: 3*

"Times New Roman"

NOMINATOR:

Daniel Schwartz
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- Have you discussed this award nomination with the nominee? *Yes*

NOMINEE:

Christopher Bowman
Univ of Colorado, Chemical & Biological Eng
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ACS Current Member: Yes
Years of Service: 26
Date of birth: 01/01/1967
Present Position: James and Catherine Patten Endowed Chair
Industry: Academia

SAFETY PROTOCOLS:

- Does the nominee employ and require good safety protocols and practices in his/her laboratory? *Yes*

SUPPORTER 1

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SUPPORTER 2

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October 29, 2014

ACS Award in Polymer Chemistry
Nomination of Professor Christopher N. Bowman

Dear Committee Members:

Professor ***Christopher Bowman***, Distinguished Professor, Patten Endowed Chair, and Director of Materials Science and Engineering at the University of Colorado, is a preeminent scholar in the field of polymer chemistry, particularly in polymer networks and reactions therein, including implementation of thiol-based click chemistry and photopolymerizations. His is the most published and cited group in this area of polymer chemistry, and he has launched, re-launched or established fields that countless other groups have subsequently followed. His research elegantly spans contributions from the synthesis of new, functional monomers, development of novel polymerization reactions, understanding of the complex physical chemistry aspects of the reactions that underlie network formation and properties, and ultimate implementation of these polymers in applications that require the unique capabilities Bowman enables.

In polymer chemistry, Bowman has published more than 315 refereed journal articles; his papers have been cited more than 16,000 (Google Scholar, 12,750 in Web of Science) times (H-index 66/59, GS/WOS, 10/1/14); he has 13 patents issued and many more pending including seven distinct technologies that have been licensed or optioned to eight different companies. The breadth and depth of Bowman's research are evidenced by the variety of organizations that recognized his contributions, including the ACS's Cooperative Research Award, the MRS Outstanding Young Investigator, the Society for Biomaterials Clemson Award for Contributions to the Literature, the American Society for Engineering Education Curtis McGraw Award, and the AIChE Professional Progress, Allan Colburn, Wilhelm, and Charles Stine Awards.

His fundamental work on formation-structure-property relationships in photopolymerizations and networks includes detailed analysis of the reaction kinetics and mechanisms. He utilized this understanding coupled with chemical design principles to develop synthetic and materials approaches for enhancing polymer networks. Bowman combines understanding of materials and fundamental reaction processes with monomer synthesis to create polymers with dramatically-enhanced performance relative to current materials. Bowman's monomer design enabled him to develop novel chemistry approaches to subdiffraction photolithography (*Science*, 2009), ultrasensitive biodetection (*Nature Materials*, 2008) and polymer stabilized LCs (*Science*, 1997).

Bowman has focused extensively on synthesizing monomers that enable unique capabilities in polymers. As initially presented in his 2005 *Science* paper, by designing and synthesizing multipurpose monomers, Bowman launched the field of Covalent Adaptable Networks (CANs) (*Macromolecules,* 2010) for use in coatings that combine the benefits and attributes of

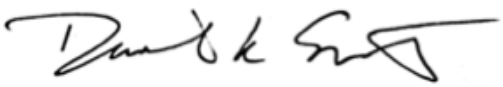
covalently crosslinked networks with those of physical networks to enable smart, adaptable networks while preserving all other mechanical and material characteristics (*Advanced Materials*, 2011).

Uniquely combining paradigms from synthetic chemistry with demand for enhanced performance polymers, Bowman's group focused on extending the click paradigm to photoinitiated reactions. Here, the powerful and useful characteristics of click reactions are dramatically expanded by photoinitiation, designing appropriate monomers, and considering a variety of previously unconsidered click reactions as polymerization reactions. Bowman started by pursuing radical-mediated thiol-ene click polymerizations in which his 2001 paper (*J Polym Sci, Polym Chem,* 2001 – 4th most cited article, excluding reviews, from >8000 published in JPS-Chem since 2001) helped to re-establish the thiol-ene reaction to the prominence it has today. Only 4 articles were published on thiol-ene reactions in 2000, but more than 250 have already been published in 2014! His leadership in the polymer click chemistry field is evidenced by his two review papers, one on thiol-ene radical reactions (*Angewandte Chemie,* 2010) and one on the broader library of thiol-X reactions (*Chemical Society Reviews*, 2010), which are both among the top 50 (5th and 34th, respectively, with 690 and 360 citations) most cited articles (WOS) from 125,000 articles published with "chemistry" as a topic since 2010.

Bowman has extended the click-photopolymerizations paradigm – formulating the first new photopolymerization reactions to arise in several decades. In one approach, enabled by his *Nature Chemistry* (2011) work, he developed a simple method for photoinitiating the most ubiquitous click reaction, i.e., the CuAAC reaction. Bowman has used this reaction to form high Tg, uniform, low stress triazole-containing polymer networks (*Advanced Materials,* 2013). Further, Bowman demonstrated the value of the thiol-yne reaction as a novel photopolymerization (*Macromolecules*, 2009 – the 12th most cited original research article in *Macromolecules* from > 6000 published since 2009) where he focused on the monomer synthesis, photopolymerization reaction, its mechanism and the applications of this highly capable reaction.

By creatively combining monomer synthesis and design with fundamental physical-chemical understanding and mechanistic evaluation, Christopher Bowman has led the polymer chemistry field in click-based reactions for forming and modifying networks; forming and implementing smart, adaptable polymer networks, and photopolymerization reactions. His work is not only field-leading, but field-defining, and he is an outstanding candidate for this prestigious award.

Sincerely,



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PROFESSIONAL EXPERIENCE

Distinguished Professor, University of Colorado, 11/12 – Present
Director, Materials Science and Engineering Program, 7/10 - Present
James and Catherine Patten Endowed Chair of Chemical and Biological Engineering, 7/07 – Present
Associate Dean for Research, College of Engineering and Applied Science, 8/07 – 7/09
Mel and Virginia Clark Professor of Chemical and Biological Engineering, University of Colorado, 7/05 – 6/07
Department Chair, Chemical and Biological Engineering, 8/03 – 6/07, 7/11 – 6/12
Courtesy Professor, Chemistry and Biochemistry, University of Colorado, 8/03 – Present
Clinical Professor of Dentistry, University of Colorado, Health Sciences Center, 1/01 – Present
Co-Director, Industry/University Cooperative Research Center for Fundamentals and Applications of Photopolymerizations, 1/00 – Present
Gillespie Professor, Chemical and Biological Engineering, University of Colorado, 8/99 – 7/05
Associate Professor, Chemical Engineering, University of Colorado, 8/95 – 8/99
Assistant Professor, Chemical Engineering, University of Colorado, 1/92 – 8/95

EDUCATION

Ph.D. in Chemical Engineering, August 1991, Purdue University
B.S. in Chemical Engineering (with Honors), May 1988, Purdue University

HONORS AND AWARDS

AIChE Professional Progress Award in Chemical Engineering, 2011
AIChE Materials Engineering and Science Division C.M.A. Stine Award, 2009
ACS, Div. of Polymeric Mtls Science and Engr Cooperative Research Award, 2007
American Institute of Chemical Engineers R.H. Wilhem Award, 2006
University of Colorado Faculty Fellowship, 2005-06
Society for Biomaterials Clemson University Award for Contributions to the Literature, 2005
College of Engineering Max S. Peters Outstanding Service Award, 2004
Univ. of Colorado Technology Transfer Office Physical Sciences Inventor of the Year, 2003

College of Engineering John and Mercedes Peebles Teaching Innovation Award, 2002
Department of Chemical Engineering Outstanding Undergraduate Teaching Award, 2002
American Institute of Chemical Engineers Allan P. Colburn Award, 2001
American Society of Engineering Education Curtis W. McGraw Award, 2000
Fellow, American Institute of Medical and Biological Engineers, 1999
Alfred P. Sloan Research Fellow, 1998 - 2000
Materials Research Society Outstanding Young Investigator Award, 1997
Camille Dreyfus Teacher-Scholar Award, 1996
University of Colorado Outstanding Faculty Graduate Advisor, 1995
National Science Foundation Presidential Faculty Fellowship, 1994 - 1999
Department of Chemical Engineering Outstanding Graduate Teaching Award, 1994

MISCELLANEOUS ACCOMPLISHMENTS

215 INVITED LECTURES PRESENTED BY CHRISTOPHER BOWMAN (1990-2014)

MORE THAN 350 NON-INVITED PRESENTATIONS HAVE BEEN GIVEN WITH CNB AS COAUTHOR

30 POST-DOCTORAL ASSOCIATES AND VISITING SCHOLARS SUPERVISED (6 CURRENT)

47 PHD THESES COMPLETED AND 12 CURRENT PHD STUDENTS SUPERVISED

>300 UNDERGRADUATE AND INDPENDENT STUDY RESEARCHERS SUPERVISED

SELECT ISSUED PATENTS (13 TOTAL, NUMEROUS OTHER APPLICATIONS)

1. A.S. Abuelyaman, J.D. Oxman, Y. Wang, C.N. Bowman, H.Y. Park, and C.J. Kloxin, "Disulfide Monomers Comprising Ehtylenically Unsaturated Groups Suitable for Dental Compositions," U.S. Patent No. 8,455,565, Issued June, 2013. Joint Patent with 3M Dental.
2. C.N. Bowman, H.Y. Park, C.J. Kloxin, A.S. Abuelyaman, J.D. Oxman, and Y. Wang, "Disulfide Monomers Comprising Ehtylenically Unsaturated Norbornyl Groups for Dental Compositions," U.S. Patent No. 8,431,626, Issued April, 2013. Joint Patent with 3M Dental.
3. C.N. Bowman and T.F. Scott, "Stress Relaxation in Crosslinked Polymers," U.S. Pat. No. 8,404,758, Issued March, 2013. Technology Licensed to 3M Corporation.
4. N.B. Cramer, H. Lu, J.W. Stansbury, and C.N. Bowman, "New Resin Systems for Dental Restorative Materials," U.S. Patent No. 8,192,673, June 5, 2012. Technology Optioned to Confi-Dental Products Company.
5. C.N. Bowman and T.F. Scott, "Stress Relaxation in Crosslinked Polymers," U.S. Pat. No. 7,943,680, Issued May 2011. Technology Licensed to 3M Corporation.
6. C.N. Bowman, H. Lu, J.W. Stansbury, "Novel Photopolymers and use in Dental Restorative Materials," US Patent No. 7,838,571, Issued November 2010. Technology optioned to Colorado Photopolymer Solutions.
7. C.N. Bowman, J. Stansbury, K.A. Berchtold, J. Nie, "(Meth)Acrylic and (Meth)Acrylamide Monomers Polymerizable, Compositions, and Polymers Obtained," US Pat. No. 7,498,394 B2, March 3, 2009.
8. C.N. Bowman, K.S. Anseth, A.R. Kannurpatti and M.D. Goodner, "Method and Material for Use With Dental Composites for Improving Conversion of Monomers to Polymers and Reducing Volume Shrinkage," U.S. Pat. No. 5,730,601, March 24, 1998.

SELECTED PUBLICATIONS (FROM 325 TOTAL REFEREED PUBLICATIONS)

1. M. Podgorski, S. Chatani, and C.N. Bowman, "Development of Step Growth Thiol-Vinyl Sulfone Polymer Networks," *Macromolecular Rapid Communications,* DOI: 10.1002/marc.201400260
2. W. Xi, H.Y. Peng, A. Aguirre-Soto, C.J. Kloxin, J.W. Stansbury, and C.N. Bowman, "Spatial and Temporal Control of Thiol-Michael Addition via Photocaged Superbase in Photopatterning and Two-Stage Polymer Networks Formation", *Macromolecules* (2014) DOI: 10.1021/ma501366f
3. J. Ma, X. Mu, C.N. Bowman, Y. Sun; M.L. Dunn; H.J. Qi, and D. Fang, "A Photoviscoplastic Model for Photo Activated Covalent Adaptive Networks," *Journal of Mechanics and Physics of Solids, 70,* 84-103 (2014).
4. H.Y. Peng, S.G. Bi, M.L. Ni, X.L. Xie, Y.G. Liao, X.P. Zhou, Z.G. Xue, J.T. Shu, Y. Wei, C.N. Bowman, and Y.W. Mai, *Journal American Chemical Society, 136,* 8855-8858 (2014).
5. S. Chatani, T. Gong, B. Earle, M. Podgorski, and C.N. Bowman, "Visible Light Thiol-Michael Addition Photopolymerization Reactions," *ACS Macro Letters, 3,* 315–318 (2014).
6. S. Chatani, C. Wang, M. Podgorski, and C.N. Bowman, "Triple Shape Memory Materials Incorporating Two Distinct Polymer Networks Formed by Selective Thiol-Michael Addition Reactions," *Macromolecules, 47,* 4949 – 4954 (2014).
7. J. Wydra, N.B. Cramer, J.W. Stansbury, and C.N. Bowman, "The reciprocity law concerning light dose -relationships applied to dental photopolymers: Theoretical analysis and experimental characterization," *Dental Materials, 30,* 605-612 (2014).
8. C. Fenoli, J. Wydra, and C.N. Bowman, "Controllable Reversible Addition Fragmentation Termination Monomers for Advances in Photochemically Controlled Covalent Adaptable Networks," *Macromolecules, 47,* 907 – 915 (2014).
9. M. Podgórski, D.P. Nair, S. Chatani, G. Berg, and C.N. Bowman, "Programmable mechanically assisted geometric deformations of glassy two-stage reactive polymeric materials," *ACS Applied Materials and Interfaces, 6,* 6111 – 6119 (2014).
10. J. Wydra, C. Fenoli, N.B. Cramer, and C.N. Bowman, "Influence of Small Amounts of Addition-Fragmentation Capable Monomers on Polymerization-induced Shrinkage Stress," *Journal of Polymer Science, Part A: Polymer Chemistry, 52,* 1315 – 1321 (2014).
11. M. Cole and C.N. Bowman, "Thiol-Ene functionalized siloxanes for use as elastomeric dental impression materials," *Dental Materials, 30,* 449 - 455 (2014).
12. W. Xi, T.F. Scott, C.J. Kloxin, and C.N. Bowman, "Click Chemistry in Materials Science," *Advanced Functional Materials, 24,* 2572 – 2590 (2014). (Cover taken from this article).
13. S. Chatani, C.J. Kloxin, and C.N. Bowman, "The Power of Light in Polymer Science: Photochemical Processes to Manipulate Polymer Formation, Structure and Properties," *Polymer Chemistry, 5,* 2187 (2014) DOI: 10.1039/C3PY01334K
14. A.A. Alzahrani, A.H. erbse, and C.N. Bowman, "Evaluation and development of novel photoinitiator complexes for photoinitiating the copper-catalyzed azide–alkyne cycloaddition reaction," *Polymer Chemistry, 5,* 1874 – 1882(2014) DOI: 10.1039/C3PY01064C.
15. C.R. Fenoli and C.N. Bowman, "Synthesis of Novel Trithiocarbonate and Allyl Sulfide Containing Monomers," *Polymer Chemistry, 5,* 62-68 (2014). (Cover Taken from Article)
16. D.P. Nair, M. Podgorski, S. Chatani, T. Gong, W. Xi, C.R. Fenoli, and C.N. Bowman, " The Thiol-Michael Addition Click Reaction: A Powerful and Widely Used Tool in Materials Chemistry," *Chemistry of Materials, 26,* 724 – 744 (2014).

17. S. Chatani, R.J. Sheridan, M. Podgorski, D.P. Nair, and C.N. Bowman, "Temporal Control of Thiol-Click Chemistry," *Chemistry of Materials, 25,* 3897-3901 (2013).
18. T. Gong, B.J. Adzima, and C.N. Bowman, "A Novel Copper Containing Photoinitiator, Copper(II) Acylphosphinate, and Its Application in Both the Photomediated CuAAC Reaction and in Atom Transfer Radical Polymerization," *Chemical Communications, 49,* 7950 – 7952 (2013).
19. C.J. Kloxin and C.N. Bowman, "Covalent Adaptable Networks: Smart, Reconfigurable, and Responsive Network Systems," *Chemical Society Reviews, 41,* 7161-7173 (2013).
20. T. Gong, B.J. Adzima, N. Baker, and C.N. Bowman, "Photopolymerization Reactions Using the Photoinitiated Copper (I)-Catalyzed Azide-Alkyne Cycloaddition (CuAAC) Reaction," *Advanced Materials, 25,* 2024 – 2028 (2013). (Cover Illustration Taken from This Article).
21. M.A. Cole, K.C. Jankousky, and C.N. Bowman, "Redox Initiation of Bulk Thiol-Ene Polymerizations," *Polymer Chemistry, 4,* 1167-1175 (2013).
22. W.X. Xi, M. Krieger, C.J. Kloxin, and C.N. Bowman, "A New Photoclick Reaction Strategy: Photo-Induced Catalysis of the Thiol-Michael Addition via a Caged Primary Amine," *Chemical Communications, 49,* 4504-4506 (2013).
23. S. Chatani, D.P. Nair, and C.N. Bowman, "Relative reactivity and selectivity of vinyl sulfones and acrylates towards the thiol-Michael addition reaction and polymerization," *Polymer Chemistry, 4,* 1048-1055 (2013).
24. M.A. Cole and C.N. Bowman, "Evaluation of Thiol-Ene Click Chemistry in Functionalized Polysiloxanes," *Journal Polymer Science, Polymer Chemistry, 51,* 1749-1757 (2013).
25. D.P. Nair, N.B. Cramer, J.C. Gaipa, M.K. McBride, E.M. Matherly, R.R. McLeod, R. Shandas, and C.N. Bowman, "Two Stage Reactive Polymer Network Forming Systems," *Advanced Functional Materials,* 22, 1502-1510 (2012).
26. H.Y. Park, C.J. Kloxin, A.S. Abuelyaman, J.D. Oxman, and C.N. Bowman, "Stress relaxation via addition-fragmentation chain transfer in high T_g, high conversion methacrylate-based systems," *Macromolecules, 45,* 5640 – 5646 (2012).
27. H.Y. Park, C.J. Kloxin, M.F. Fordney, and C.N. Bowman, "Stress Reduction and Tg Enhancement in Ternary Thiol-Yne-Methacrylate Systems via Addition-Fragmentation Chain Transfer," *Macromolecules, 45,* 5647 – 5652 (2012).
28. M.A. Cole, C.N. Bowman, "Synthesis and Characterization of Thiol-ene Functionalized Siloxanes and Evaluation of Their Crosslinked Network Properties", *Journal of Polymer Science, Part A – Polymer Chemistry 50,* 4325-4333 (2012).
29. H.Y. Park, C.J. Kloxin, A.S. Abuelyaman, J.D. Oxman, and C.N. Bowman, "Novel Dental Restorative Materials having Low Polymerization Shrinkage Stress via Stress Relaxation by Addition-Fragmentation Chain Transfer," *Dental Materials, 28,* 1113- 1119 (2012).
30. H.Y. Park, C.J. Kloxin, M.F. Fordney, and C.N. Bowman, "Stress Relaxation of Trithiocarbonate-Based Dental Composites," *Dental Materials, 28,* 888 – 893 (2012).
31. S. Ye, A. Setareh, I.R. Smith, N.B. Cramer, J.W. Stansbury, and C.N. Bowman, "Using Hyperbranched Oligomer Functionalized Glass Fillers to Reduce Shrinkage Stress," *Dental Materials, 28,* 1004-1011 (2012).
32. B.J. Adzima, Y. Tao, C.J. Kloxin, C. DeForest, K.S. Anseth, and C.N. Bowman, "Spatial and Temporal Control of the Copper Catalyzed Alkyne Azide Cycloaddition Reaction by Photoinitated Cu(II) Reduction," *Nature Chemistry, 3,* 256-259 (2011).
33. C.J. Kloxin, T.F. Scott, H.Y. Park, and C.N. Bowman, "Mechanopatterning on a Photoresponsive Elastomer," *Advanced Materials,* 23, 1977 (2011).

34. K.M. Schreck, D. Leung, and C.N. Bowman, “Hybrid Organic/Inorganic Thiol–Ene-Based Photopolymerized Networks,” *Macromolecules, 44,* 7520-7529 (2011).
35. N.B. Cramer. J.W. Stansbury and C.N. Bowman, "Recent Advances and Developments in Composite Dental Restorative Materials," *Journal of Dental Research*, 90, 402-416 (2011).
36. J.E. Boulden, N.B. Cramer, K.M. Schreck, C.L. Couch, C. Bracho-Troconis, J.W. Stansbury, and C.N. Bowman, “Thiol-ene-methacrylate Composites as Dental Restorative Materials,” *Dental Materials, 27,* 267-272 (2011).
37. C.J. Kloxin, T.F. Scott, B. Adzima, and C.N. Bowman, “Covalent Adaptable Networks (CANs): A Unique Paradigm in Crosslinked Polymers,” *Macromolecules, 43,* 2643-2653 (2010).
38. B. Adzima, C.J. Kloxin, and C.N. Bowman,” Externally Triggered Healing of a Thermoreversible Covalent Network via Self-limited Hysteresis Heating,” *Advanced Materials, 22,* 2784-2787 (2010).
39. H.Y. Park, C.J.Kloxin, T.F. Scott, and C.N. Bowman, “Covalent Adaptable Networks as Dental Restorative Resins: Stress Relaxation by Addition-fragmentation Chain Transfer in Allyl Sulfide-containing Resins,” *Dental Materials, 26,* 1010-1016 (2010).
40. C.E. Hoyle, A.B. Lowe, and C.N. Bowman, “Thiol-click Chemistry: A Multifaceted Toolbox for Small Molecular and Polymer Synthesis,” *Chemical Society Reviews, 39,* 1355-1387 (2010).
41. C.E. Hoyle and C.N. Bowman, “Thiol-Ene Click Chemistry,” *Angewandte Chemie International Edition, 49,* 1540-1573 (2010).
42. N.B. Cramer, C.A. Couch, K.M. Schreck, J.E. Boulden, R. Wydra, J.W. Stansbury, and C.N. Bowman, “Properties of Methacrylate-Thiol-Ene Formulations as Dental Restorative Materials,” *Dental Materials, 26,* 799-806 (2010).
43. N.B. Cramer, C.L. Couch, K.M. Schreck, J.A. Carioscia, J.E. Boulden, J.W. Stansbury and C.N. Bowman, “Investigation of Thiol-ene and Thiol-ene-methacrylate Based Resins as Dental Restorative Materials,” *Dental Materials, 26,* 21-18 (2010).
44. T.F. Scott, B.A. Kowalski, A.C. Sullivan, C.N. Bowman, R.R. McLeod, “Two-color Single-photon Photoinitiation and Photoinhibition for Subdiffraction Photolithography,” *Science, 324,* 913-917 (2009).
45. B.D. Fairbanks, M.P. Schwartz, A.E. Halevi, C.R. Nuttelman, C.N. Bowman, and K.S. Anseth, “A Versatile Synthetic Extracellular Matrix Mimic via Thiol-Norbornene Photopolymerization,” *Advanced Materials, 21,* 5005-5010 (2009).
46. B. Fairbanks, T. Scott, C. Kloxin, K. Anseth, and C.N. Bowman, “Thiol-Yne Photopolymerizations: Novel Mechanism, Kinetics and Step Growth Formation of Highly Crosslinked Networks,” *Macromolecules, 42,* 211-217 (2009).
47. B.D. Fairbanks, M.P. Schwartz, C.N. Bowman and K.S. Anseth, “Photoinitiated Polymerization of PEG-diacrylate with Lithium Phenyl1-2,4,6-trimethylbenzoylphosphinate: Polymerization Rate and Cytocompatibility,” *Biomaterials, 30,* 6702-6707 (2009).
48. H.D. Sikes, R.R. Hansen, L.M. Johnson, R. Jenison, J.W. Birks, K.L. Rowlen, and C.N. Bowman, “Using Polymeric Materials to Generate an Amplified Response to Molecular Recognition Events,” *Nature Materials, 7,* 52-56 (2008).
49. K.A. Berchtold, J. Nie, J.W. Stansbury, and C.N. Bowman, “Reactivity of Monovinyl (Meth)Acrylates Containing Cyclic Carbonates,” *Macromolecules, 41,* 9035-9043 (2008).

50. P. Johnson, J.W. Stansbury, and C.N. Bowman, "Kinetic Modeling of a Comonomer Photopolymerization System Using High Throughput Conversion Data," *Macromolecules, 41,* 230-237 (2008).
51. P.M. Johnson, J.W. Stansbury, and C.N. Bowman, "High-throughput Kinetic Analysis of Acrylate and Thiol-ene Photopolymerization Using Temperature and Exposure Time Gradients," *J. Polymer Science Part A: Polymer Chemistry, 46,* 1502-1509 (2008).
52. J.W. Stansbury, C.N. Bowman, and S.M., "Shining a Light on Dental Composite Restoratives," *Physics Today*, April 2008, 82-83 (2008).
53. H. Kilambi, J.W. Stansbury, and C.N. Bowman, "Deconvuluting the Impact of Inter-molecular and Intra-molecular Interactions on the Polymerization Kinetics of Ultra-rapid Mono(meth)acrylates," *Macromolecules 40,* 47-54 (2007).
54. J.A. Carioscia, L. Schneidewind, C. O'Brien, R. Ely, C. Feeser, N. Cramer, and C.N. Bowman, "Thiol-Norbornene Materials: Approaches to Develop High Tg Thiol-Ene Polymers," *J. Polymer Sci. A: Polymer Chemistry 45*, 5686-5696 (2007).
55. J.A. Carioscia, J.W. Stansbury, and C.N. Bowman, "Evaluation and Control of Thiol-ene/Thiol-epoxy Hybrid Networks," *Polymer 48*, 1526-1532 (2007).
56. P.M. Johnson, J.W. Stansbury, and C.N. Bowman, "Photopolymer Kinetics Using Light Intensity Gradients in High-throughput Conversion Analysis," *Polymer 48*, 6319-6324 (2007).
57. H. Kilambi, S.K. Reddy, L. Schneidewind, J.W. Stansbury, and C.N. Bowman, "Copolymerization and Dark Polymerization Studies of Novel Acrylic Monomers," *Polymer 48*, 2014-2021 (2007).
58. T.F. Scott, R.B. Draughon, and C.N. Bowman, "Actuation in Crosslinked Polymers via Photoinduced Stress Relaxation," *Advanced Materials, 18,* 2128-2132 (2006).
59. A.K. O'Brien and C.N. Bowman, "Impact of Oxygen on Photopolymerization Kinetics and Polymer Structure," *Macromolecules 39*, 2501-2506 (2006).
60. A.K. O'Brien and C.N. Bowman, "Modeling the Effect of Oxygen on Photopolymerization Kinetics," *Macromolecular Theory and Simulations 15*, 176-182 (2006). (Cover illustration for this issue was taken from this article.)
61. T.A. Scott, A. Schneider, W.D. Cook and C.N. Bowman, "Photoinduced Plasticity in Crosslinked Network," *Science 308*, 1615-1617 (2005).
62. O. Okay, S.K. Reddy, and C.N. Bowman, "Molecular Weight Development During Thiol-Ene Photopolymerizations," *Macromolecules, 38*, 4501 – 4511 (2005).
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64. H. Lu, J.W. Stansbury, and C.N. Bowman, "Impact of Curing Protocol on Conversion and Shrinkage Stress," *Journal of Dental Research, 84,* 822 – 826 (2005).
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66. J.A. Carioscia, H. Lu, J.W. Stansbury, and C.N. Bowman "Thiol-ene Oligomers as Dental Restorative Materials," *Dental Materials 21*, 1137-1143 (2005).
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SELECTED FUNDING OBTAINED

Dental Composites Based on Photoinitiated Thiol-Vinyl Sulfone Reactions, NIH U01 DE023777, 9/13 – 8/18, $2,250,000 (PI).

Cu-Catalyzed Azide-Alkyne Reactions for Novel Dental Composites, NIH U01 DE023774, 9/13 - 8/18, $2,400,000 (PI with Stansbury and Kloxin, co-PIs)

Thiol-X Click Foldamers for Polymer Affinity, DARPA Army Research Office, Contract # W911-NF-14-1-0605, 9/14 – 7/15, $123,954 (PI, Musgrave, co-PI).

Dynamic Artificial Cells Composed of Synthetic Biorthogonal Membranes, Army Research Office, MURI Program, 8/2013 – 7/2018, $1,150,000 (CNB's Portion, co-PI with N. Devaraj, PI)

Combining Reversible and Permanent Crosslinks in Thermosets for High Technology Applications, NSF DMR 1310528, 7/2013 – 6/2016, $345,000 (PI).

Photoinitiated Reactions in Covalent Adaptable Networks, NSF CBET 1264298, 5/2013 – 4/2016, $300,000.

Thio-Ether Nucleic Acids: Clicking Together Synthetic Poly(Nucleic Acids), NIH CA 174479, $424,210 (PI with Kloxin, co-PI).

Photo-Click: Photocatalysis, Photopolymerization and Photomodification via the Cu(I) Catalyzed Azide-Alkyne Reaction, NSF CHE 1214109, 6/1/2012 – 5/31/2015, $420,000.

Collaboration in the Development of Novel Polymerization Enhanced Immunofluorescence, NIH R21, 2/1/2011 – 1/31/2013, $408,596 (PI with Balasubramaniam and Berron, co-PIs).

Osteogenic Hydrogel Niches to Promote hMSC Migration and Differentiation, NIH R01, NIDCR, 12/10-11/15, approximately $1,625,000 total costs (co-PI with K. Anseth, PI).

Improved Resin Bonded Dental Restoratives Based on Nanogel-modified Adhesives, NIH/NIDCR Challenge Grant, 10/09-9/11, $1,000,000 (1RC1DE020480-01, co-PI with J.W. Stansbury, PI).

Development of Novel Thiol-Ene Methacrylate Composites for Dental Restorative Materials, NIH, 8/11/08-6/30/12, $1,431,416 (PI, Jeffrey Stansbury, co-PI).

Novel Crosslinked Polymers for Dental Restorations, National Institutes of Health, 4/1/06 – 3/31/11, $1,350,000, (PI with Prof. Jeffrey Stansbury, co-PI).

GOALI: Advanced Thiol-Ene Photopolymerizations, National Science Foundation, 9/06 – 9/10, $294,375 (PI with John Woods, co-PI).

Development of Novel Dental Resins and Composites, Confi-Dental Products, 3/15/05-1/31/2012, $384,000 (PI)

A National Science Foundation Industry / University Cooperative Research Center for Fundamentals and Applications of Photopolymerizations, In addition to NSF support numerous Companies Provide $40,000 per year, Total annual funding of approximately $500,000, 1/1/2000 - Present (co-Director with Prof. Alec Scranton, also co-Director).

High Amplification Detection of Genetic Cancer Markers, NIH 1R21 CA127884-01A1 Grant, 1/1/08-12/31/09, $305,460 (PI).

A MRSEC for Study of Ferroelectric Liquid Crystals, National Science Foundation, 9/02-8/08, $3,100,000 (co-PI with Prof. Noel Clark, PI, and David Walba, co-PI),

Development of Advanced Detection Technologies for Biochips, National Institutes of Health through InDevR, LLC, 12/04 – 11/06, $346,072 (CU/CNB portion, co-PI with Prof. Kathy Rowlen, PI).

Structure-Reactivity-Performance Interrelationships of Novel Photopolymerizable Monomers, Surface Specialties UCB, 12/03-11/06, $273,000 (PI).

Photopolymerized Gels for Cartilage Tissue Engineering, National Institutes of Health, 8/03-7/08, $766,308, (co-PI with Kristi Anseth, PI).

Low Shrinkage Dental Resins from SOC Oligomers, National Institutes of Health, 5/1/02 – 4/30/06, $ 900,000 (co-PI with Prof. Jeffrey Stansbury, PI).

Biofluidic Transport and Molecular Recognition in Polymeric Microdevices, DARPA, 1/02 – 2/05, $1,100,000 (co-PI with Prof. Robert Davis, PI, and Prof. Kristi Anseth, co-PI).

Novel Crosslinked Polymers for Dental Restorations, National Institutes of Health, 4/1/01 – 3/31/06, $1,400,000, (PI with Prof. Jeffrey Stansbury, co-PI).

Ferroelectric Liquid Crystals Materials Research Science and Engineering Center, National Science Foundation, 9/1/98 - 8/31/03, $4,000,000 (co-PI with Prof. Noel Clark, PI).

Novel Tissue Engineering Matrices with Controlled Microstructure, National Institutes of Health, 9/1/98 - 6/15/01, $500,000 (co-Pi with Prof. Kristi Anseth, PI).

Novel Crosslinked Polymers for Dental Restorations, 8/1/95-7/31/00, $464,254, National Institutes of Health, FIRST Award.

Presidential Faculty Fellowship Award, 10/1/94 - 9/30/00, $500,000, National Science Foundation.

ACS Award in Polymer Chemistry

Nomination of Christopher N. Bowman

20 Most Significant Publications and Patents

(Citations from Google Scholar)

1. A.A. Alzahrani, A.H. Erbse, and C.N. Bowman, "Evaluation and development of novel photoinitiator complexes for photoinitiating the copper-catalyzed azide–alkyne cycloaddition reaction," *Polymer Chemistry, 5,* 1874–1882 (2014). (11 citations)
2. D.P. Nair, M. Podgorski, S. Chatani, T. Gong, W. Xi, C.R. Fenoli, and C.N. Bowman, " The Thiol-Michael Addition Click Reaction: A Powerful and Widely Used Tool in Materials Chemistry," *Chemistry of Materials, 26,* 724 – 744 (2014). (29 citations)
3. T. Gong, B.J. Adzima, N. Baker, and C.N. Bowman, "Photopolymerization Reactions Using the Photoinitiated Copper (I)-Catalyzed Azide-Alkyne Cycloaddition (CuAAC) Reaction," *Advanced Materials, 25,* 2024 – 2028 (2013). (32 citations)
4. B.J. Adzima, Y. Tao, C.J. Kloxin, C. DeForest, K.S. Anseth, and C.N. Bowman, "Spatial and Temporal Control of the Copper Catalyzed Alkyne Azide Cycloaddition Reaction by Photoinitated Cu(II) Reduction," *Nature Chemistry, 3,* 256-259 (2011). (84 citations)
5. C.N. Bowman and T.F. Scott, "Stress Relaxation in Crosslinked Polymers," U.S. Pat. Nos. 8,404,758, Issued March, 2013, and 7,943,680 Issued May 2011. Technology Licensed to 3M Corporation with products currently being sold under this license.
6. C.E. Hoyle, A.B. Lowe, and C.N. Bowman, "Thiol-click Chemistry: A Multifaceted Toolbox for Small Molecular and Polymer Synthesis," *Chemical Society Reviews, 39,* 1355-1387 (2010). (441 citations)
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8. T.F. Scott, B.A. Kowalski, A.C. Sullivan, C.N. Bowman, R.R. McLeod, "Two-color Single-photon Photoinitiation and Photoinhibition for Subdiffraction Photolithography," *Science, 324,* 913-917 (2009). (138 citations).
9. B.D. Fairbanks, M.P. Schwartz, A.E. Halevi, C.R. Nuttelman, C.N. Bowman, and K.S. Anseth, "A Versatile Synthetic Extracellular Matrix Mimic via Thiol-Norbornene Photopolymerization," *Advanced Materials, 21,* 5005-5010 (2009). (155 citations).
10. B. Fairbanks, T. Scott, C. Kloxin, K. Anseth, and C.N. Bowman, "Thiol-Yne Photopolymerizations: Novel Mechanism, Kinetics and Step Growth Formation of Highly Crosslinked Networks," *Macromolecules, 42,* 211-217 (2009). (169 citations)
11. H.D. Sikes, R.R. Hansen, L.M. Johnson, R. Jenison, J.W. Birks, K.L. Rowlen, and C.N. Bowman, "Using Polymeric Materials to Generate an Amplified Response to Molecular Recognition Events," *Nature Materials, 7,* 52-56 (2008). (58 citations).
12. T.A. Scott, A. Schneider, W.D. Cook and C.N. Bowman, "Photoinduced Plasticity in Crosslinked Network," *Science 308,* 1615-1617 (2005). (207 citations)
13. N.B. Cramer and C.N. Bowman, "Kinetics of Thiol-ene and Thiol-acrylate Photopolymerizations using Real-Time FTIR," *Journal of Polymer Science, Part A: Polymer Chemistry, 39,* 3311 (2001). (274 citations)

14. L.G. Lovell, H. Lu, J.E. Elliott, J.W. Stansbury, and C.N. Bowman, “The Effect of Cure Rate on the Mechanical Properties of Dental Resins,” *Dental Materials, 17*, 504 (2001). (244 citations)
15. H. Ma, R.H. Davis, and C.N. Bowman, “A Novel Sequential Photoinduced Living Graft Polymerization,” *Macromolecules, 33*, 331 (2000). (256 citations)
16. A.T. Metters, K.S. Anseth, and C.N. Bowman, “Fundamental Studies of a Novel, Biodegradable PEG-*b*-PLA Hydrogel,” *Polymer, 41*, 3993 (2000). (222 citations)
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18. C.A. Guymon, E.N. Hoggan, T.P. Rieker, N.A. Clark, D.M. Walba, and C.N. Bowman, “Effects of Monomer Structure on Their Organization and Polymerization in a Smectic Liquid Crystal,” *Science, 275*, 57-59 (1997). (95 citations)
19. K.S. Anseth, L.M. Kline, T.A. Walker, K.J. Anderson, C.N. Bowman, "Reaction Kinetics and Volume Relaxation During Polymerizations of Multiethylene Glycol Dimethacrylates," *Macromolecules, 28*, 2491 (1995). (187 citations)
20. K.S. Anseth, C.M. Wang, and C.N. Bowman, "Kinetic Evidence of Reaction Diffusion During the Polymerization of Multi (Meth)Acrylate Monomers," *Macromolecules, 27*, 650-655 (1994). (262 citations)

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October 25, 2014

ACS Award in Polymer Chemistry

Members of the Selection Committee:

Professor Christopher Bowman is the most outstanding candidate of which I am aware for the **ACS Polymer Chemistry Award**. As a former awardee, I am happy to enthusiastically recommend him. Chris is an international leader in not just one aspect of polymer chemistry, but rather three distinct areas: photopolymerization, thiol-click reactions, and smart polymer networks. His contributions are unparalleled – though I only have space to address two! Unique to Chris's approach is his integration of synthesis of monomers combined with unique polymerizations and detailed physical-chemical analyses to design materials of great practical value while simultaneously advancing fundamental research.

Chris is the unchallenged leader in photopolymerization. Unlike others in the field, Chris has truly worked on the chemistry aspect of these polymerizations – using molecular design and careful experimental analysis to create novel, functional monomers and unique experimental approaches to enhanced understanding and improved performance. Arguably, it had been several decades since any new photopolymerization reaction was developed – but in the last five years, Chris has introduced two highly capable photopolymerizations – the radical-mediated thiol-yne polymerization (*Macromolecules*, 2009) and the photoinitiated cooper-catalyzed azide-alkyne reaction (*Nature Chemistry*, 2011; *Advanced Materials*, 2013). Each paper is among the most highly cited papers in those journals since publication. His two wavelength approach combines a photoinitiator and photoinhibitor to enable feature formation at sizes well below the diffraction limit (*Science*, 2009), while his work on polymerization-based biodetection used creative design of a macroinitiator and monomer for ultrasensitive biodetection (*Nature Materials*, 2008).

Chris's leadership on the understanding and implementation of thiol-based click reactions, particularly the thiol-ene, thiol-yne and thiol-Michael addition reactions, is unprecedented. His 2010 reviews in this area (*Angewandte Chemie*, *Chemical Society Reviews*) already have close to 1400 citations and both rank among the top articles published in the entire chemistry field (#1 and #7, respectively out of >10000 polymer chemistry articles within 5 years). His analysis of the mechanisms underlying these reactions (e.g., *Macromolecules*, 2001) relaunched this approach and its now critical role in polymer chemistry. He has subsequently translated these reactions to the design of innovative dental materials (*Dental Materials*, 2005), tissue engineering matrices (*Advanced Materials*, 2009), shape memory materials (*Advanced Functional Materials*, 2012), and in additive manufacturing (*Macromolecular Rapid Communications*, 2012).

In summary, the breadth and depth, creativity and leadership of Professor Chris Bowman across several areas of synthetic and physical polymer chemistry makes him *the* clear choice for the ACS Award in Polymer Chemistry.

Sincerely,

Kris Matyjaszewski
J.C. Warner University Professor of Natural Sciences

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October 23, 2014

To the Awards Committee of the ACS Award in Polymer Chemistry

I am delighted to second the nomination of Professor **Christopher N. Bowman** for the 2016 ACS Award in Polymer Chemistry. Chris Bowman is one of the most original and innovative polymer scientists in the world today. His originality and far reaching discoveries have revolutionized polymer synthesis, polymerization kinetics and applications. His work has had **major impact** in polymer synthesis, characterization, structure and morphology of highly crosslinked polymers, structure and behavior of membranes and molecular design of new biomaterials, especially dental materials. With a systematic effort to study the kinetics and reaction engineering aspects of multi-functional polymerizations, he studied UV polymerizations often accompanied by volume shrinkage and showed new methods to reduce or avoid shrinkage during polymerization.

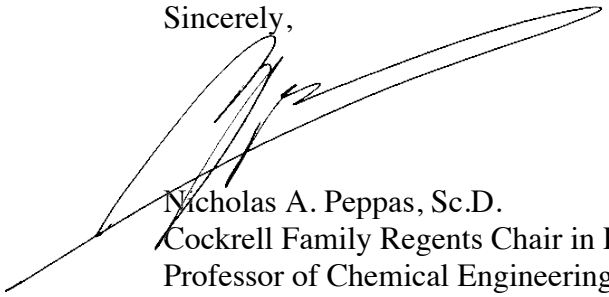
Chris' work shows that it is possible to simulate the gelation process in multi-functional polymerization reactions in the presence of microcyclization processes by taking in consideration diffusion-controlled phenomena. He is also a leader in click chemistry and has applied these techniques to the development of a variety of new polymers. Indicative of this acceptance of his work is that he had received about 16,400 citations and an H factor of 68.

Bowman has implemented successfully various physical models and has made significant contributions to the molecular design of biomaterials for specific applications, especially with his pioneering work on new thiolene-based polymers. He has concentrated on the design of dental materials where the need of precise three-dimensional network structures without unreacted functionalities is paramount.

Indicative of Bowman's impact to science and his recognition by his peers is that Chris Bowman is the only chemical engineer to have received three national AIChE awards (out of 8) before the age of 40: the 2001 Allan P Colburn Award, the 2006 W H Wilhelm Award from AIChE for his contributions to polymerization kinetics and the 2009 Professional Progress Award. He is also the recipient of the 2001 ASEE Curtis McGraw Award, 1997 MRS Young Investigator Award, and the Presidential Faculty Fellow (PFF), Camille and Henry Dreyfus Teacher-Scholar and Alfred Sloan Fellowship Awards.

Clearly, Chris Bowman is a **leading polymer researcher of our generation**. He is an exceptional candidate for the 2016 ACS Polymer Chemistry Award.

Sincerely,



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