US012383465B2

(12) **United States Patent**
Smith et al.

(10) **Patent No.: US 12,383,465 B2**
(45) **Date of Patent: Aug. 12, 2025**

(54) **CASSETTE BAGS FOR TRANSPORTING BIOMATERIALS**

(71) Applicant: **Cryoport, Inc.**, Brentwood, TN (US)

(72) Inventors: **Steffen Smith**, View Park, CA (US); **Mike Dybicz**, Nashville, TN (US); **Brittany Roberts**, Brentwood, TN (US); **Bobby Onel**, Laguna Beach, CA (US)

(73) Assignee: **Cryoport, Inc.**, Brentwood, TN (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 568 days.

(21) Appl. No.: **17/853,715**

(22) Filed: **Jun. 29, 2022**

(65) **Prior Publication Data**

US 2024/0000662 A1 Jan. 4, 2024

(51) **Int. Cl.**
A61J 1/16 (2023.01)
A61J 1/14 (2023.01)

(52) **U.S. Cl.**
CPC ***A61J 1/16*** (2013.01); ***A61J 1/1412*** (2013.01); ***A61J 1/1468*** (2015.05)

(58) **Field of Classification Search**
CPC A61J 1/16; A61J 1/1468; A61J 1/1412
USPC 206/438
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,719,347	A	7/1929	Weinstein	
3,717,005	A	2/1973	McGrew et al.	
3,948,409	A	4/1976	Ovchinnikov et al.	
3,955,749	A	5/1976	Turkenkopf	
4,306,425	A	12/1981	Sitte et al.	
4,313,558	A	2/1982	Benham	
4,411,138	A	10/1983	Leithauser et al.	
4,455,842	A	6/1984	Granlund	
4,542,826	A	9/1985	Adams	
4,572,363	A	2/1986	Alpern	
4,694,655	A	9/1987	Seidel et al.	
4,729,494	A	3/1988	Peillon et al.	
4,790,141	A	12/1988	Glascock	
5,566,821	A	10/1996	Brown	
5,954,202	A	9/1999	Mellon	
6,206,194	B1	3/2001	Beneroff et al.	
6,419,088	B1 *	7/2002	Barrois	B65D 25/107 206/570
6,467,642	B2	10/2002	Mullens et al.	

(Continued)

FOREIGN PATENT DOCUMENTS

CN	2412849	Y	1/2001
CN	200794335	U	10/2018

(Continued)

OTHER PUBLICATIONS

USPTO; Non-Final Office Action dated Dec. 2, 2011 in U.S. Appl. No. 12/658,641.

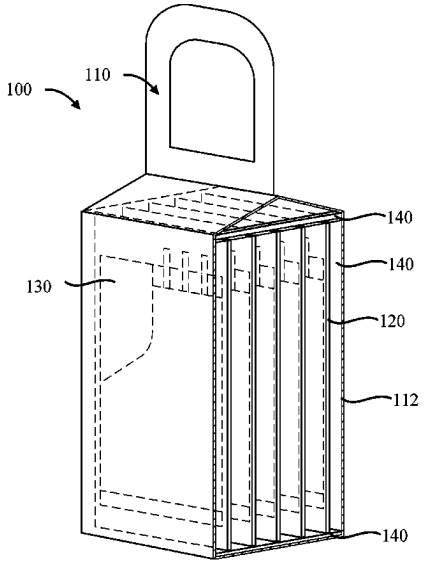
(Continued)

Primary Examiner — Jacob K Ackun
(74) *Attorney, Agent, or Firm* — Snell & Wilmer L.L.P.

(57) **ABSTRACT**

An envelope is configured to hold, support, and protect an article such as a blood bag during transportation under fic temperatures. The envelope includes a single piece component (e.g., a monolithic component), including multiple panels that are configured to fold to form an enclosure that surrounds the article such as the blood bag for support and protection of the article such as the blood bag.

26 Claims, 6 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

6,539,360	B1	3/2003	Kadaba	
6,913,389	B2	7/2005	Kannankeril	
7,627,926	B2	12/2009	Williams	
7,881,987	B1	2/2011	Hart	
8,220,107	B2	7/2012	Williams	
8,371,449	B2	2/2013	Simon et al.	
8,397,343	B2	3/2013	Williams	
8,904,810	B2	12/2014	Schabron et al.	
9,292,824	B1	3/2016	Freeman	
9,378,442	B2	6/2016	Barnings	
10,987,276	B2	4/2021	Mongrenier	
11,124,354	B2	9/2021	Waltermire	
11,691,788	B1	7/2023	Smith	
2001/0039807	A1	11/2001	Mogil	
2002/0099567	A1	7/2002	Joao	
2002/0102992	A1	8/2002	Koorapaty	
2002/0119880	A1	8/2002	Hogberg	
2002/0144926	A1	10/2002	Rutledge	
2002/0167500	A1	11/2002	Gelbman	
2003/0137968	A1	7/2003	Lareau et al.	
2004/0215532	A1	10/2004	Boman	
2004/0236635	A1	11/2004	Publicover	
2005/0046584	A1	3/2005	Breed	
2005/0171738	A1	8/2005	Kadaba	
2005/0234785	A1	10/2005	Burman	
2005/0246192	A1	11/2005	Jauffred et al.	
2006/0080819	A1	4/2006	McAllister	
2006/0168644	A1	7/2006	Richter et al.	
2007/0009119	A1	1/2007	Pohle et al.	
2007/0028642	A1	2/2007	Glade et al.	
2007/0095722	A1	5/2007	Messinger	
2007/0268138	A1	11/2007	Chung et al.	
2008/0094209	A1	4/2008	Braun	
2008/0162304	A1	7/2008	Ourega	
2008/0208158	A1	8/2008	Goodman	
2008/0291033	A1	11/2008	Aghassipour	
2009/0014537	A1	1/2009	Gelbman	
2009/0293524	A1	12/2009	Vezina et al.	
2009/0314835	A1	12/2009	Jackson	
2010/0025274	A1	2/2010	Stopek	
2010/0080168	A1	4/2010	Fukuyama	
2010/0204558	A1	8/2010	Zocchi	
2010/0299278	A1	11/2010	Kriss et al.	
2011/0031304	A1	2/2011	Phillips	
2011/0176749	A1	7/2011	Race	
2011/0216178	A1	9/2011	Carpenter	
2014/0144800	A1	5/2014	Delorme et al.	
2014/0319022	A1	10/2014	Chu	
2015/0069072	A1	3/2015	Kelley	
2015/0284145	A1	10/2015	Arimoto et al.	
2016/0046410	A1	2/2016	Nakamura	
2016/0229622	A1	8/2016	Booska	
2017/0073146	A1	3/2017	Kuhn	
2017/0255856	A1*	9/2017	Murdoch	G06K 19/07773
2019/0119027	A1	4/2019	Itou et al.	
2019/0175448	A1*	6/2019	Obrad	B65D 81/03
2020/0369435	A1	11/2020	Greenwood et al.	
2021/0315201	A1	10/2021	McCormick	
2023/0225942	A1	7/2023	Smith	
2023/0227209	A1	7/2023	Smith	
2023/0320933	A1	10/2023	Smith	
2023/0339653	A1	10/2023	Smith	

FOREIGN PATENT DOCUMENTS

CN	210259426	U	4/2020
EP	1642749	A1	4/2006
EP	3409260	A1	12/2018
JP	2006-051968	A	2/2005
JP	2007-275568	A	10/2007
JP	3958213		5/2018
WO	1999-058425	A1	11/1999
WO	2002053967		11/2002
WO	2007-028647	A1	3/2007
WO	2008041663	A1	4/2008
WO	2021-248238	A1	12/2021

OTHER PUBLICATIONS

USPTO; Final Office Action dated Aug. 14, 2012 in U.S. Appl. No. 12/658,641.
USPTO; Non-Final Office Action dated Sep. 11, 2015 in U.S. Appl. No. 12/658,641.
USPTO; Non-Final Office Action dated Dec. 11, 2012 in U.S. Appl. No. 12/852,413.
USPTO; Final Office Action dated May 10, 2012 in U.S. Appl. No. 12/852,413.
USPTO; Advisory Action dated Jul. 31, 2012 in U.S. Appl. No. 12/852,413.
USPTO; Non-Final Office Action dated Jun. 18, 2014 in U.S. Appl. No. 12/852,413.
USPTO; Non-Final Office Action dated Jun. 17, 2016 in U.S. Appl. No. 12/852,413.
USPTO; Final Office Action dated Nov. 29, 2016 in U.S. Appl. No. 12/852,413.
USPTO; Non-Final Office Action dated Jul. 25, 2017 in U.S. Appl. No. 14/589,768.
USPTO; Final Office Action dated Feb. 7, 2018 in U.S. Appl. No. 14/589,768.
USPTO; Non-Final Office Action dated Jun. 19, 2018 in U.S. Appl. No. 14/589,768.
USPTO; Final Office Action dated Dec. 27, 2018 in U.S. Appl. No. 14/589,768.
USPTO, Non Final Office Action dated Jul. 10, 2020 in U.S. Appl. No. 15/841,170.
USPTO, Notice of Allowance dated Oct. 30, 2020, in U.S. Appl. No. 15/841,170.
PCT; International Search Report dated May 31, 2002 in International Application No. PCT/US2001/049684.
PCT; International Search Report dated Jun. 28, 2010 in International Application No. PCT/US2010/023252.
PCT; Written Opinion of International Search Authority dated Jun. 28, 2010 in International Application No. PCT/US2010/023252.
PCT; International Preliminary Report on Patentability dated Mar. 22, 2013 in International Application No. PCT/US2010/023252.
PCT; International Search Report & Written Opinion dated Apr. 24, 2019 in PCT Application No. US2018/065509.
PCT; International Preliminary Report on Patentability dated Jun. 16, 2020 in PCT Application No. US2018/065509.
Electronic Reusable Paper, http://www2.parc.com /hsl/projects/gyricon/, (Oct. 2005).
PCT; International Search Report and Written Opinion of the International Searching Authority dated Oct. 5, 2023 for Application No. PCT/US2023/025748.
PCT; International Search Report and Written Opinion of the International Searching Authority dated Jun. 29, 2023 for Application No. PCT/US2023/015267.
USPTO; Non-Final Office Action dated Jan. 25, 2024 in U.S. Appl. No. 17/580,094.
USPTO; Notice of Allowance dated Feb. 17, 2023 in U.S. Appl. No. 17/580,044.
USPTO; Restriction Requirment dated Mar. 5, 2024 in U.S. Appl. No. 17/889,275.
KIPO; International Search Report and Written Opinion dated May 2, 2023 in PCT application No. PCT/US2023/010113.
KIPO; International Search Report and Written Opinion dated Apr. 24, 2023 in PCT application No. PCT/US2022/053024.
USPTO; Non-Final Office Action dated Jun. 21, 2024 in U.S. Appl. No. 17/889,275.
USPTO; Notice of Allowance dated Jun. 13, 2024 in U.S. Appl. No. 17/580,094.
PCT; International Preliminary Report on Patentability (IPRP) dated Aug. 2, 2024 in Application Serial No. PCT/US2023/010113.
PCT; International Preliminary Report on Patentability (IPRP) dated Aug. 2, 2024 in Application Serial No. PCT/US2022/053024.

(56) **References Cited**

OTHER PUBLICATIONS

USPTO; Notice of Allowance dated Jun. 12, 2024 in U.S. Appl. No. 18/217,289.
PCT; International Preliminary Report on Patentability (IPRP) dated Oct. 17, 2024 in Application Serial No. PCT/PCT/US2023/015267.
USPTO; Notice of Allowance dated Sep. 3, 2024 in U.S. Appl. No. 17/580,094.

* cited by examiner

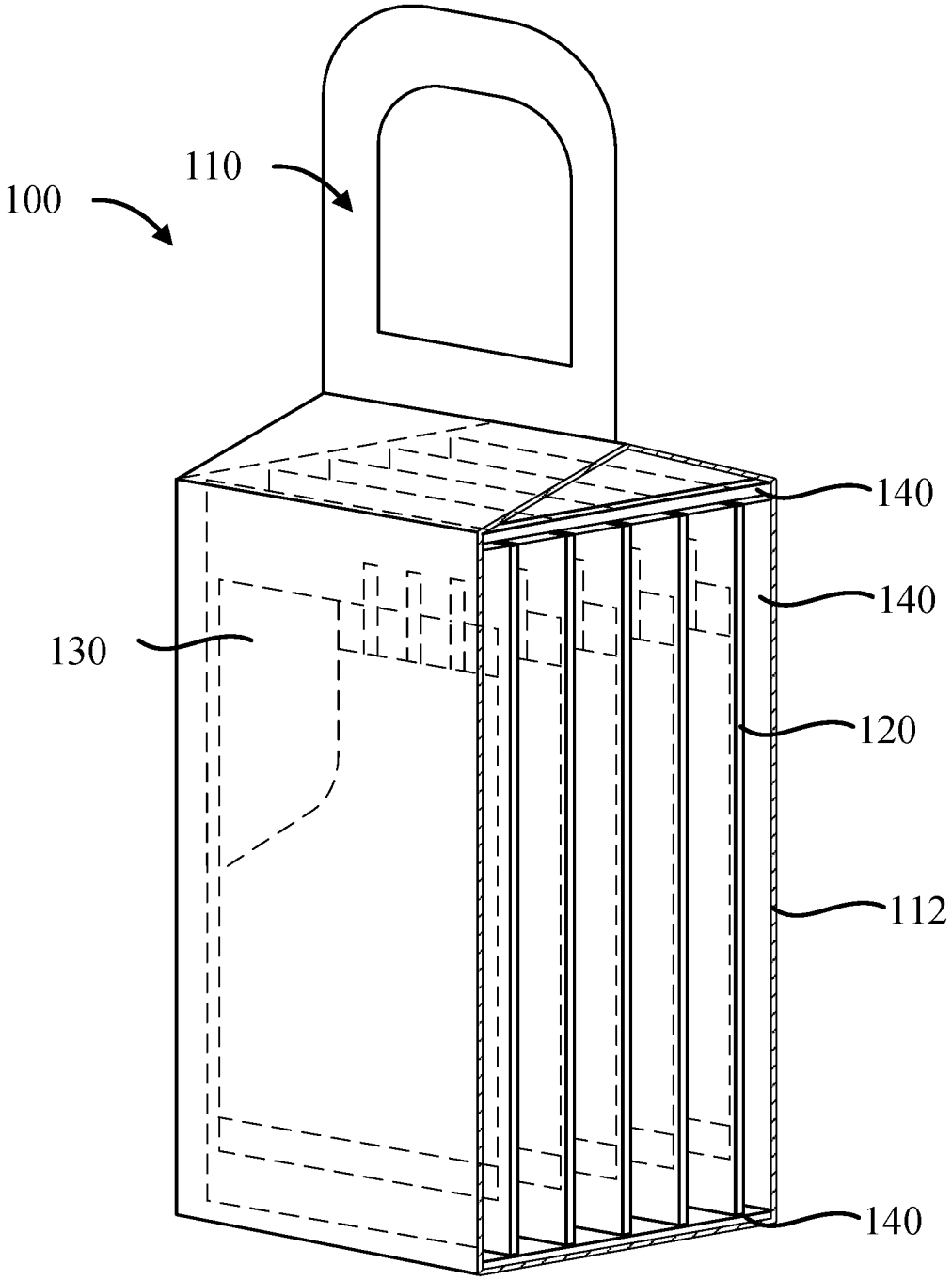


FIG. 1

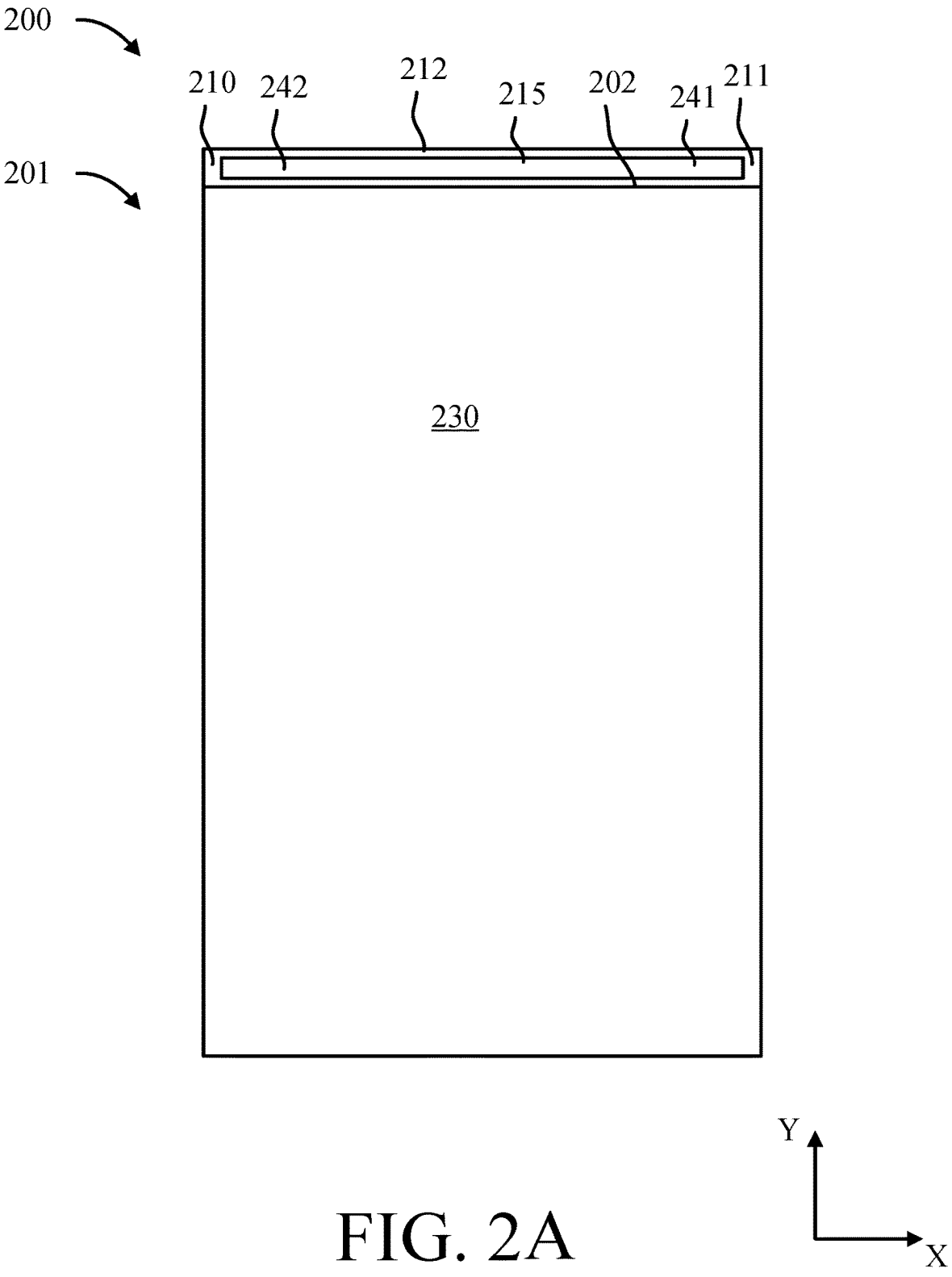


FIG. 2A

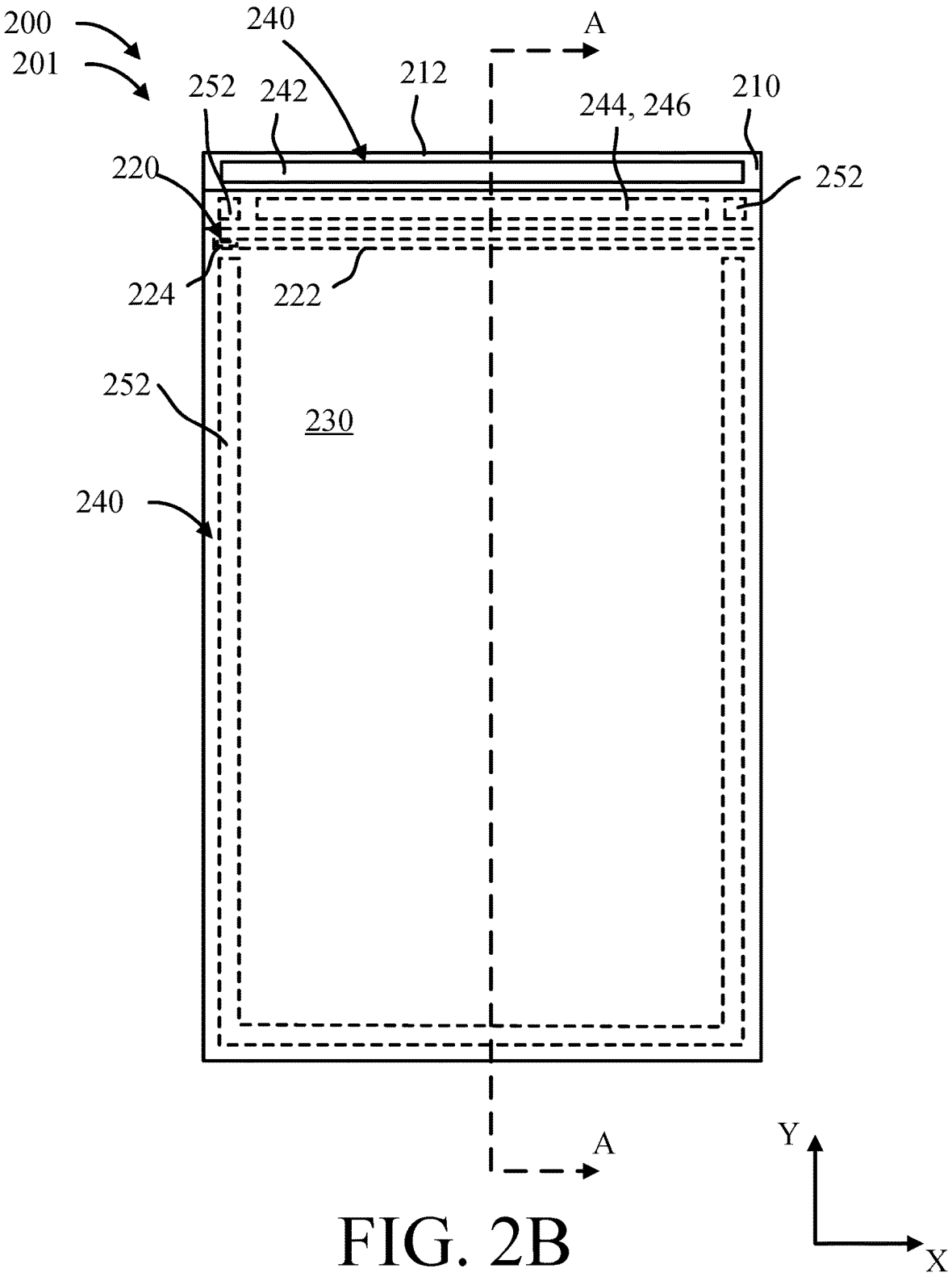
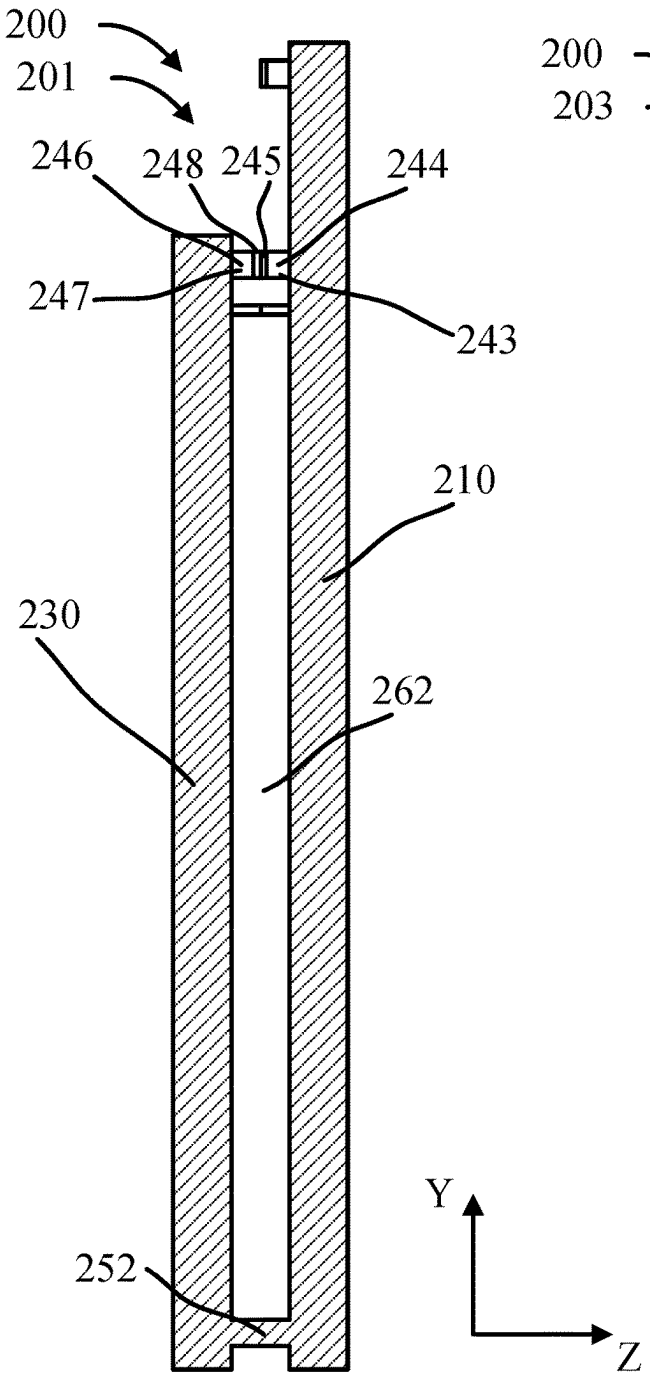

200
201
240
A
252
242
212
244, 246
210
220
252
224
222
252
230
240
A
Y
X

FIG. 2B



SECT. A-A

FIG. 2C

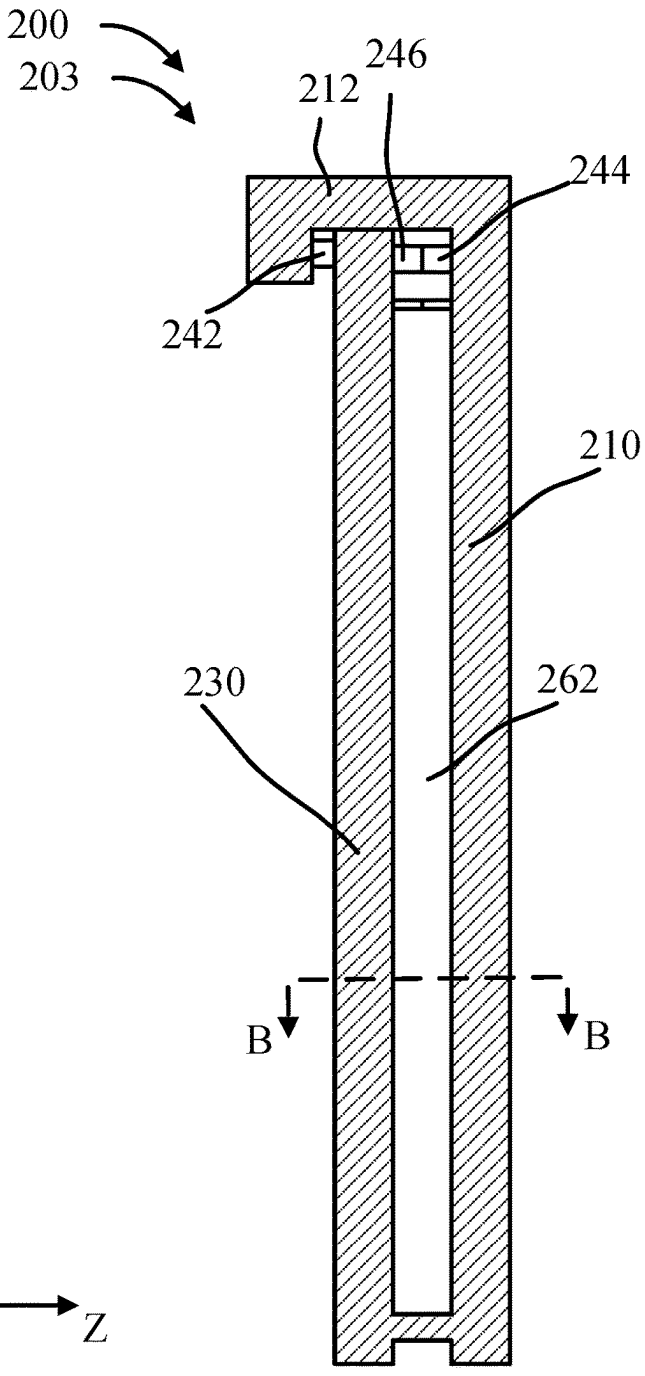


FIG. 2D

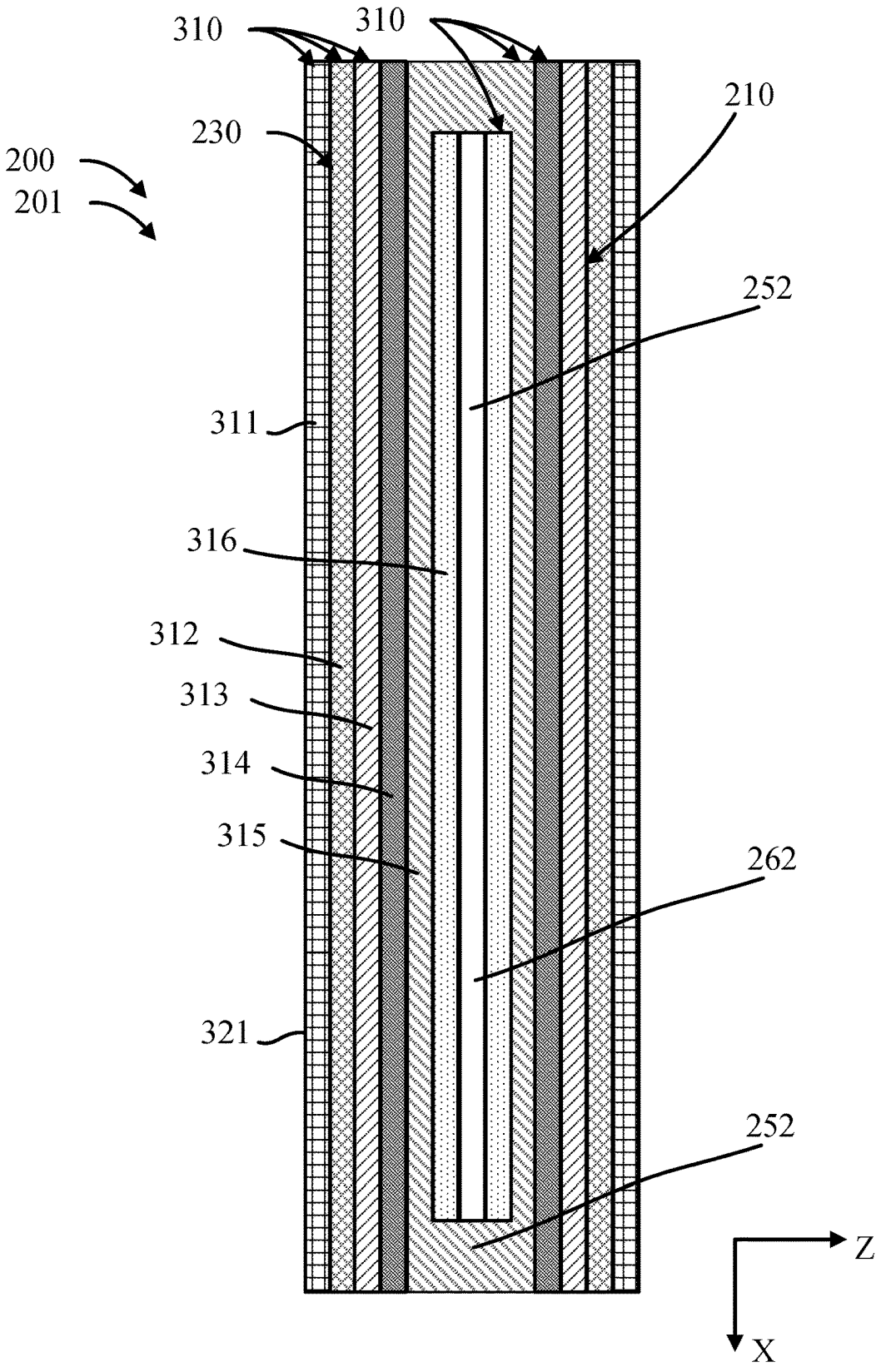

310
310
210
230
200
201
252
311
316
312
313
314
315
262
321
252
Z
X

FIG. 2E

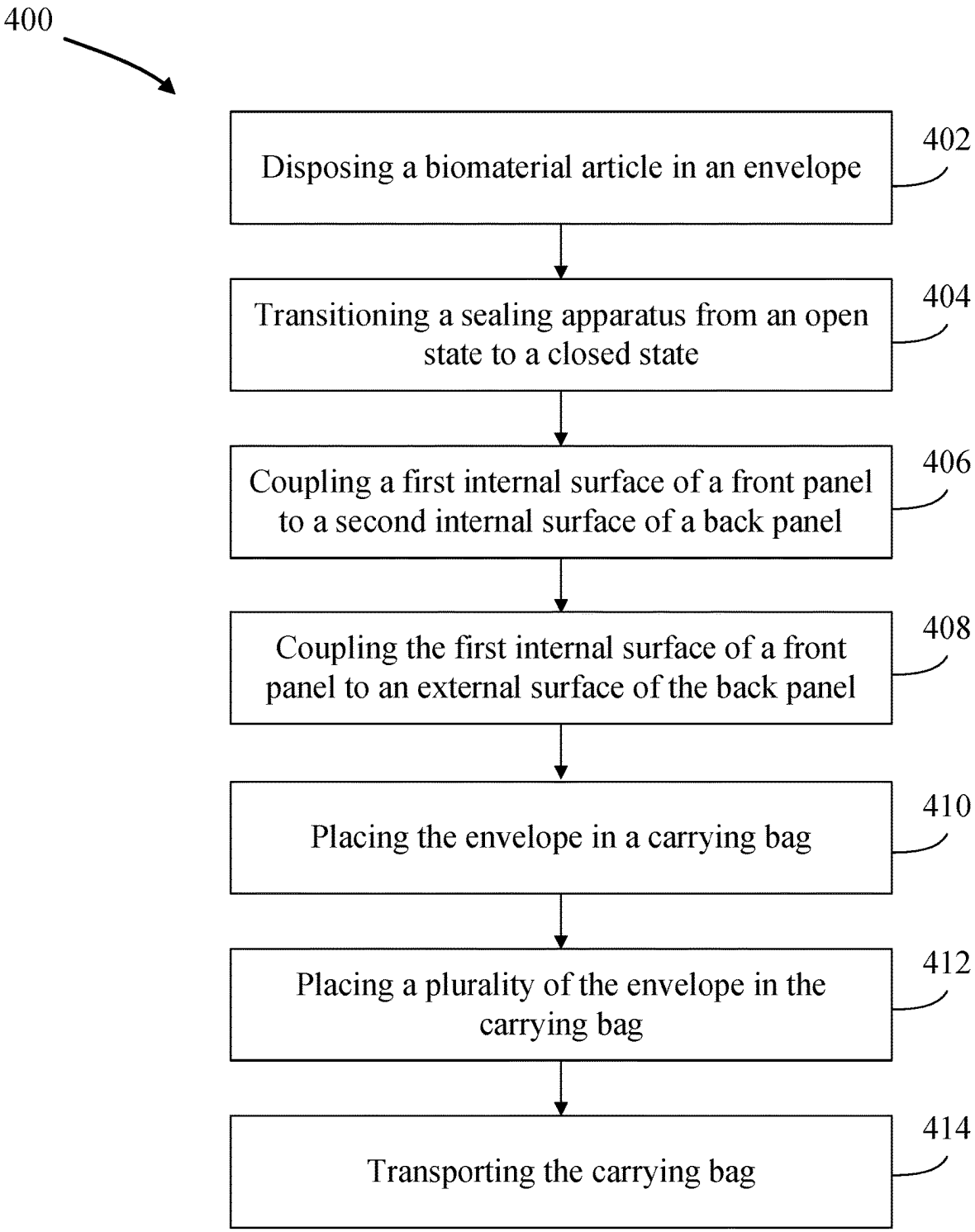

400
Disposing a biomaterial article in an envelope
402
Transitioning a sealing apparatus from an open state to a closed state
404
Coupling a first internal surface of a front panel to a second internal surface of a back panel
406
Coupling the first internal surface of a front panel to an external surface of the back panel
408
Placing the envelope in a carrying bag
410
Placing a plurality of the envelope in the carrying bag
412
Transporting the carrying bag
414

FIG. 3

CASSETTE BAGS FOR TRANSPORTING BIOMATERIALS

FIELD

This specification relates to a system, device or apparatus for cryogenically storing, transporting and/or shipping a liquid, such as blood, under cryogenic temperatures.

DESCRIPTION OF THE RELATED ART

Medical practitioners or professions may refrigerate or freeze blood for storage and/or transportation to a medical facility. When transporting blood, the blood may be refrigerated and stored in a blood bag. Less-dense blood plasma is often frozen at cryogenic temperatures. At cryogenic temperatures, the blood bags may shatter during transport because the storage devices that store the blood bags are brittle at cryogenic temperatures. Blood bag manufacturers may provide an overwrap bag that is made of material that is more cryogenically friendly, i.e., less brittle, and does not shatter at cryogenic temperatures. The overwrap bag is placed over the blood bag and contains the blood within the blood bag if the blood bag shatters. The overwrap bag, however, does not prevent the blood bag from shattering and does not maintain the integrity and usability of the blood that has been released.

Often, the blood bag is placed into a metallic case for transport. The metallic case holds the blood bag while in storage and during transportation. The metallic case holds the shape of the blood bag and protects the blood bag from external damage, such as cuts and punctures. The metal case, however, does not protect the blood bag from shocks and vibrations. Any impact to the metallic case also causes the blood bag to slide and impact the inner surfaces of the case which may cause the blood bag to become damaged.

Accordingly, there is a need for a system, device or apparatus to protect an article such as a blood bag from shock and vibration during storage and transfer.

SUMMARY

In general, one aspect of the subject matter described in this specification is embodied in an envelope to contain an article, for instance, a blood bag envelope. The blood bag envelope is configured to hold, support, and protect a blood bag. The envelope includes a plurality of layers between an internal cavity and an external environment. Each layer in the plurality of layers is configured to protect, hold, and/or support the blood bag disposed within the cavity, in accordance with various embodiments.

An envelope for transporting an object is disclosed herein. In various embodiments, the envelope comprises: a front panel comprising a first plurality of layers; a back panel comprising a second plurality of layers, the back panel coupled to the front panel via a first seal; a sealing apparatus disposed between the front panel and the back panel, the sealing apparatus configured to transition from an open state to a closed state, the sealing apparatus and the first seal defining a cavity of the envelope in response to being in the closed state; a first sealing mechanism disposed between the front panel and the back panel, the first sealing mechanism disposed outside of the cavity; and a second sealing mechanism coupled to an internal surface of the front panel.

In various embodiments, the first sealing mechanism and the second sealing mechanism comprise a double sided tape. The first sealing mechanism and the second sealing mechanism can each comprise a protective layer coupled to one side of the double sided tape.

In various embodiments, the first sealing mechanism is configured to couple the front panel to the back panel after the sealing apparatus is closed. The second sealing mechanism can be configured to couple to an external surface of the back panel. A portion of the front panel can form a crease along a top edge of the envelope in response to coupling the second sealing mechanism to the back panel.

In various embodiments, the first plurality of layers and the second plurality of layers each comprise: an exterior layer comprising a polymeric material; an interior layer comprising an absorbent material; and a barrier layer disposed between the exterior layer and the interior layer.

In various embodiments, the first plurality of layers and the second plurality of layers each comprise a first tie layer disposed between the exterior layer and the barrier layer. The first plurality of layers and the second plurality of layers can each comprise sealant layer, the sealant layer at least partially defining the first seal.

An envelope for transporting an object is disclosed herein. In various embodiments, the envelope comprises: a front panel and a back panel each comprising: an interior layer defining an internal surface, the internal surface at least partially defining a cavity of the envelope; an exterior layer disposed outward from the interior layer; a barrier layer disposed between the interior layer and the exterior layer; a sealant layer disposed between the barrier layer and the interior layer; a first tie layer disposed between the exterior layer and the barrier layer; and a second tie layer disposed between the sealant layer.

In various embodiments, a first portion of the sealant layer of the front panel is bonded to a second portion of the sealant layer of the back panel to form a first seal. The envelope can further comprise a sealing apparatus disposed between the front panel and the back panel, the sealing apparatus configured to transition from an open state to a closed state, the sealing apparatus and the first seal defining a cavity of the envelope in response to being in the closed state.

In various embodiments, the first tie layer couples the exterior layer to the barrier layer. The second tie layer can couple the sealant layer to the barrier layer. The sealant layer can be configured to protect the barrier layer.

A method of shipping a biomaterial article is disclosed herein. In various embodiments, the method comprises: disposing the biomaterial article in an envelope, the envelope comprising an interior layer, an exterior layer, a barrier layer disposed between the interior layer and the exterior layer, and a sealant layer disposed between the interior layer and the barrier layer; transitioning a sealing apparatus from an open state to a closed state to create a first seal of a cavity defined by the sealing apparatus and a manufacturing seal; coupling a first internal surface of a front panel of the envelope to a first internal surface of a back panel of the envelope via a first sealing mechanism to create a second seal; and coupling the first internal surface of the front panel of the envelope to an external surface of the back panel of the envelope to create a third seal.

In various embodiments, a crease is formed at a top edge of the envelope in response to coupling the first internal surface to the external surface.

In various embodiments, the method further comprises placing the envelope in a carrying bag. The method can further comprise placing a plurality of the envelope in the carrying bag, each envelope in the plurality of the envelope having a respective biomaterial article disposed therein. The method can further comprise transporting the carrying bag.

BRIEF DESCRIPTION OF THE DRAWINGS

Other systems, methods, features, and advantages of the present invention will be apparent to one skilled in the art upon examination of the following figures and detailed description. Component parts shown in the drawings are not necessarily to scale and may be exaggerated to better illustrate the important features of the present invention.

FIG. **1** illustrates a perspective cross-sectional view of a blood bag transport assembly, in accordance with various embodiments;

FIG. **2**A illustrates a back view of an envelope for use in a transport assembly, in accordance with various embodiments;

FIG. **2**B illustrates a front view of an envelope for use in a blood bag transport assembly, in accordance with various embodiments;

FIG. **2**C illustrates a cross-sectional view of an envelope for use in a blood bag transport assembly in a manufactured state, in accordance with various embodiments;

FIG. **2**D illustrates a cross-sectional view of an envelope for use in a blood bag transport assembly in an assembled state, in accordance with various embodiments;

FIG. **2**E illustrates a cross-sectional view of an envelope for use in a blood bag transport assembly, in accordance with various embodiments;

FIG. **3** illustrates a method of transporting a biomaterial article, in accordance with various embodiments.

DETAILED DESCRIPTION

Disclosed herein are systems, apparatuses and devices for transporting and storing an article such as a blood bag. The system, apparatus or device may include a plurality of envelopes ("envelopes") disposed in a sealed bag ("bag") that stores and transports a plurality of articles (such as blood bags) (i.e., each envelope in the plurality of envelopes includes a blood bag in the plurality of bags). Particular embodiments of the subject matter described in this specification may be implemented to realize one or more of the following advantages.

The envelopes disclosed herein are made from a plurality of layers. Each layer in the plurality of layers can, alone and/or in combination, withstand cryogenic temperatures. That is, the envelopes are resistant to brittleness and are not as susceptible to shattering at cryogenic temperatures. The envelopes disclosed herein are configured to absorb any shocks to the envelope, and thus, protects the article from vibrations, drops, impacts, or other shocks. The envelopes disclosed herein can be produced cheaper than typical blood bag transport envelopes, in accordance with various embodiments. The envelopes disclosed herein can be produced with fewer components relative to typical blood bag transport envelopes, in accordance with various embodiments. As disclosed herein, "cryogenic temperatures" refers to temperatures below −180° C. (93K or −292° F.).

Other benefits and advantages include an ease of manufacture and an ease of assembly prior to shipping a blood bag, in accordance with various embodiments. In this regard, the envelopes disclosed herein can be coupled together in a relatively easy manner via a "manufacturing seal" as described further herein. In this regard, two flat sheets can be joined together to form a manufactured state of the envelopes disclosed herein. After being loaded with an cryogenic article (e.g., a blood bag), a first seal can seal the article from an external environment (e.g., a slider zipper or a press to close zipper), and a second seal can provide redundant sealing (e.g., an adhesive, a double-sided tape, or the like). In this regard, prior to shipment of the cryogenic article, the article can easily be loaded and sealed within the envelope, in accordance with various embodiments.

Referring now to FIG. **1**, a perspective cross-sectional view of a blood bag transport assembly **100** is illustrated, in accordance with various embodiments. The blood bag transport assembly **100** comprises a carrying bag **110**, a plurality of envelopes **120**, a plurality of blood bags **130**, and absorbent material layers **140**. Each envelope in the plurality of envelopes **120** is configured to house a blood bag in the plurality of blood bags **130**. In this regard, each envelope in the plurality of envelopes **120** is configured to protect and/or support a respective blood bag in the plurality of blood bags **130** during transportation of the blood bag transport assembly **100**.

In various embodiments, absorbent material layers **140** may at least partially surround the plurality of envelopes **120**. For instance, at least a portion of the absorbent material layers **140** may be arranged abutting an internal perimeter of the carrying bag **110**. The plurality of envelopes **120** may be received into an area defined by the internal perimeter of the carrying bag **110**. Thus, one or more absorbent material layer **140** may be adjacent both an envelope **120** and a wall of the internal perimeter of the carrying bag **110**. More specifically, one or more absorbent material layer **140** may be interstitial between the envelope **120** and the wall of the internal perimeter of the carrying bag **110**. In various embodiments, adjacent envelopes in the plurality of envelopes **120** may be separated by absorbent material layers **140** disposed between the adjacent envelopes. In this regard, the plurality of envelopes **120** may be dampened in all directions by absorbent material layers **140** during transport of the blood bag transport assembly **100** (i.e., mechanically dampened from shock and vibration of the carrying bag **110** that may occur during transport). Thus, each blood bag in the plurality of blood bags **130** may be dampened by a respective envelope in the plurality of envelopes **120** as described further herein, as well as being dampened by the absorbent material layers **140** disposed within a cavity **112** defined by the carrying bag **110** as described further herein.

Referring now to FIG. **2**A, a back planar view of an envelope **200** is illustrated in connection with X-Y-Z axes and in accordance with various embodiments. The envelope **200** may be utilized in a blood bag transport assembly **100** from FIG. **1** (e.g., as one of the plurality of envelopes **120**). The envelope **200** may be made of a plurality of layers as described further herein and may be configured to withstand cryogenic temperatures without shattering or breaking. The envelope **200** may hold, enclose and protect different sizes of blood bags, such as a 50-ml blood bag, a 250-ml blood bag, and/or a 500-ml blood bag, or the like.

In various embodiments, the envelope **200** is in a manufactured state **201** prior to transporting an article (e.g., a blood bag or the like). In the manufactured state **201**, a front panel **210** is coupled to a back panel **230** by an adhesive (e.g., an epoxy, tape, etc.) as described further herein. A "manufactured state" as described herein, refers to a configuration of the envelope **200** after the envelope **200** is manufactured. For example, the envelope **200** is manufactured to form a manufactured state, then sealed after being loaded with an article (e.g., a blood bag) to form an assembled state. The "assembled state" as described further herein, refers to a configuration of the envelope **200** after the envelope **200** is fully sealed (i.e., after a blood bag, or other cryogenic article, is placed in a cavity of the envelope **200** while the envelope **200** is in the manufactured state **201**). In

the "assembled state", the envelope **200** can provide redundant sealing to prevent any potential leak of material (i.e., a blood bag) disposed therein during transport, as described further herein.

In various embodiments, the front panel **210** defines a top edge panel **212**. In various embodiments, after an object for transport (e.g., a blood bag or the like), is disposed in an opening **202** of the envelope **200** into an internal cavity, the top edge panel **212** may be folded over the opening **202** and coupled to the back panel **230** as described further herein. In this regard, the front panel **210** may comprise a sealing mechanism **242** (e.g., a double-sided tape, an epoxy, or the like), disposed on an inner surface **211** of the front panel **210**. In various embodiments, the sealing mechanism **242** is a double-sided tape. For example, the sealing mechanism **242** can comprise double sided transfer tape, such as that sold by 3M Company, headquartered in Saint Paul Minnesota, and sold under the name 3M™ Scotch® ATG Transfer Tape **969**. However, the present disclosure is not limited in this regard, and various sealing mechanisms **242** are within the scope of this disclosure.

In various embodiments, in response to the sealing mechanism **242** being a double sided tape, a protective layer **241** may be disposed on the adhesive (i.e., to protect the adhesive properties of the double sided tape prior to use). In this regard, the protective layer **241** may be disposable after removing the protective layer **241** from the double sided tape, in accordance with various embodiments.

Referring now to FIG. **2**B, a back planar view of the envelope **200** from FIG. **2**A is illustrated with dashed lines indicating elements of the envelope **200** that are hidden from the back planar view. the envelope **200** further comprises an assembly sealing system **240**. The assembly sealing system **240** comprises a sealing apparatus **220** disposed between the front panel **210** and the back panel **230**. In various embodiments, the sealing apparatus **220** may comprise a track **222** and a zipper **224**. Although described as having a track **222** and zipper **224**, the present disclosure is not limited in this regard. For example, the sealing apparatus can comprise a press-to-close zipper and still be within the scope of this disclosure. The sealing apparatus **220** is configured to provide an initial assembly seal in the assembled state from a cavity (e.g., cavity **262** as shown in FIGS. **2**C-D) defined between the back panel **230** and the front panel **210** as describe further herein.

In various embodiments, the sealing apparatus **220** is configured to transition from an open state to a closed state. In this regard, in an open state, a portion of the track **222** on the front panel **210** is separated from a portion of the track **222** on the back panel **230**. In a closed state, the portion of the track **222** on the front panel **210** is coupled to the portion of the track **222** on the back panel **230**.

The envelope **200** further comprises a manufacturing sealing system **250**. The manufacturing sealing system **250** is configured to create a manufacturing seal around a perimeter of the envelope **200**. The manufacturing sealing system **250** comprises a manufacturing seal **252** disposed between the front panel **210** and the back panel **230** along a perimeter of the envelope **200** (i.e., extending along a first side of the envelope from the sealing apparatus **220** in a negative Y-direction to a bottom left corner, from the bottom left corner along a bottom side of the envelope in a positive X-direction to a bottom right corner, from the bottom right corner in a positive Y-direction to the sealing apparatus **220**). In this regard, the cavity (e.g., cavity **262** from FIGS. **2**C-D) can be defined by the manufacturing seal **252** and the sealing apparatus **220**, in accordance with various embodiments.

In various embodiments, the assembly sealing system **240** further comprises a sealing mechanism **244** disposed on the front panel **210** and a sealing mechanism **246** disposed on the back panel **230**. The sealing mechanisms **244**, **246** can be disposed vertically (i.e., in the Y-direction) between the sealing apparatus **220** and the top edge panel **212**. The sealing mechanisms **244**, **246** can be in accordance with the sealing mechanism **242**. In this regard, the sealing mechanisms **244**, **246** can each comprise a double sided tape and a protective layer. In this regard, the protective layer may be removed after an object for transport (e.g., a blood bag **130** from FIG. **1**) is disposed therein. Then, the double sided tape can seal a top portion of the envelope **200** (i.e., a vertical end of the envelope). Thus, the sealing mechanisms **244**, **246** may remain unexposed until the article for transport (e.g., a blood bag) is disposed in the internal cavity (e.g., cavity **262** from FIGS. **2**C-D) of the envelope and the sealing mechanisms **244**, **246** are to be used for an additional seal. The sealing mechanisms **242**, **244**, **246** can provide redundant sealing with the sealing apparatus **220** to prevent any leakage in response to an object being transported breaking (e.g., a blood bag **130** from FIG. **1** being punctured or torn). Although described herein has having a sealing mechanism **244** disposed on the front panel **210** and the sealing mechanism **246** disposed on the back panel **230** opposite the sealing mechanism **244**, the present disclosure is not limited in this regard. For example, a single sealing mechanism (e.g., sealing mechanism **244** or sealing mechanism **246**) can be disposed on an internal surface of one of the front panel **210** or the back panel **230** and still be within the scope of this disclosure. In various embodiments, by having two sealing mechanisms **244**, **246** disposed opposite each other, a stronger seal can be obtained relative to a single sealing mechanism, in accordance with various embodiments.

Referring now to FIG. **2**C, a cross-sectional view of the envelope **200** in a manufactured state along section A-A in FIG. **2**B prior to sealing the envelope **200** is illustrated, with like numerals depicting like elements, in accordance with various embodiments. As shown, the manufacturing seal **252** bonds the front panel **210** to the back panel **230** and at least partially defines the cavity **262**, in accordance with various embodiments. In various embodiments, FIG. **2**C is not to scale and is sized for illustrative purposes. In this regard, at a bottom edge of the envelope **200** proximal the manufacturing seal **252**, the front panel **210** would be nearly touching the back panel **230** in response to being joined by the manufacturing seal **252**.

In various embodiments, prior to assembly (as shown in FIG. **2**C), sealing mechanism **244** comprises a double sided tape **243** and a protective layer **245** in a similar manner to sealing mechanism **242** described previously herein. Similarly, the sealing mechanism **246** can comprise a double sided tape **247** and a protective layer **248**. In this regard, while shipping the envelope **200** in the manufactured state, the adhesive on an otherwise exposed side of the double sided tape **243**, **245** can remain protected (i.e., maintain its adhesive properties). Thus, after loading an article for transport in the cavity **262**, the sealing apparatus **220** can be described in a manner described previously herein, then the protective layers **241**, **245**, **247** can be removed from their respective sealing mechanisms **242**, **244**, **246**, the double sided tape **243** can be coupled to the double sided tape **245**, and the top edge panel **212** can be folded over the back panel **230** and be coupled to an external surface of the back panel **230** by the sealing mechanism **242** to form the assembled state **203** as shown in FIG. **2**D.

In various embodiments, in the assembled state **203** of FIG. **2**D, the envelope **200** comprises redundant sealing between the cavity **262** and the top edge panel **212** (e.g., via the sealing apparatus **220** and the sealing mechanisms **244**, **246**). Additionally, in accordance with various embodiments, the envelope **200** includes a seal between the external surface of the back panel **230** and an internal surface of the top edge panel **212**. Thus, a crease defined by a fold of the top edge panel **212** over the back panel **230** can further act as a seal and essentially provide four levels of assembly sealing between the cavity **262** and an external environment. As such, any leak from an article being transported can be maintained within the envelope **200**, preventing potentially hazardous or harmful material from reaching the external environment.

Referring now to FIG. **2**E, a cross-sectional view of the envelope **200** from FIG. **2**D along section line B-B is illustrated, in accordance with various embodiments, with like numerals depicting like elements. In various embodiments, the envelope **200** comprises a plurality of layers **310**. The plurality of layers **310** include an external layer **311**, an internal layer **316**, and intermediate layers **312**, **313**, **314**, **315**. Although described with various intermediate layers **312**, **313**, **314**, **315**, the present disclosure is not limited in this regard. For example, any of intermediate layers **312**, **313**, **314**, **315** can be used on their own, in combination with other intermediate layers **312**, **313**, **314**, **315**, and in any order between the external layer **311** and the internal layer **316**.

In various embodiments, by having the plurality of layers **310**, the elements to manufacture the envelope **200** in the manufactured state from FIGS. **2**A-C can be a relatively simple process. For example, as shown in FIGS. **2**A-C, in the manufactured state, the front panel **210** is coupled to the back panel **230** via the manufacturing seal **252**. In this regard, two flat panels (e.g., the front panel **210** and the back panel **230** can be pressed together and the manufacturing seal **252** (e.g., an adhesive) cured to bond the front panel **210** to the back panel **230**. In contrast, other support mechanisms for carrying cryogenic articles (e.g., blood bags) typically utilize metallic cassette racks that add weight, are more expensive to manufacture, and are more expensive to ship.

In various embodiments, the external layer **311** comprises a polymeric material (e.g., acrylonitrile butadiene siren (ABS), chlorinated polyvinyl chloride (CPVC), high-density polyethylene (HDPE), polybutylene (PB-1), polyethylene (PE, MDPE, HDPE, etc.), polyethylene of raised temperature (PE-RT), cross-linked polyethylene (PEX), polypropylene (PP), polyvinylidene difluoride (PVDF), un-plasticized polyvinyl chloride (UPVC)) that is able to withstand cryogenic temperatures). The external layer **311** can be configured to provide a dimensional-stable print surface. By having a dimensional-stable print surface, ink disposed on an external surface **321** of the external layer **311** can be protected. In various embodiments, the external layer **311** can provide additional material integrity to the envelope **200**.

In various embodiments, the internal layer **316** can comprise a desiccant layer. In various embodiments, the desiccant layer protects the contents within the envelope from humidity changes. In various embodiments, the desiccant layer provides high moisture absorption relative to typical envelopes. For example, the internal layer **316** can comprise an absorbent polymer material capable of absorbing between 25 times and 1,000 times its own weight in water. In various embodiments, the internal layer **316** comprises a superabsorbent polymer. However, the present disclosure is not limited in this regard. In various embodiments, the internal layer **316** is configured to provide additional burst strength to the envelope **200**. In various embodiments, the internal layer **316** can be Therapak™ absorbent material, such as that sold under the trademark Therapak™ 10312 by Avantor Clinical Services based in Chorley Lancashire, United Kingdom.

In various embodiments, disposed between the external layer **311** and the internal layer **316** is a barrier layer (e.g., intermediate layer **313**). In various embodiments, the barrier layer is configured to provide chemical resistance from an external environment. In this regard, the barrier layer is configured to prevent chemicals from infiltrating the cavity **262** with the cryogenic article (e.g., a blood bag), disposed therein. In various embodiments, the barrier layer is configured to prevent moisture, light, and/or oxygen from infiltrating the cavity **262** as well. In various embodiments, the barrier layer is made of a high-density polyethylene (HDPE) material, such as that sold under the trademark Tyvek® 1073B by Dupont de Numours, Inc. based in Wilmington, Delaware. However, the present disclosure is not limited in this regard. For example, the barrier layer can be made of any polymeric material (e.g., acrylonitrile butadiene siren (ABS), chlorinated polyvinyl chloride (CPVC), high-density polyethylene (HDPE), polybutylene (PB-1), polyethylene (PE, MDPE, HDPE, etc.), polyethylene of raised temperature (PE-RT), cross-linked polyethylene (PEX), polypropylene (PP), polyvinylidene difluoride (PVDF), un-plasticized polyvinyl chloride (UPVC)), and still be within the scope of this disclosure.

In various embodiments, disposed between the external layer **311** and the internal layer **316** is a sealant layer (e.g., intermediate layer **315**). In various embodiments, the sealant layer is configured to provide heat sealable capability to the envelope **200**. In various embodiments, the sealant layer can comprise a polymeric material such as a thermoplastic polyurethane (TPU) that melts and welds to itself when heated to approximately 200° C. (**400**). In this regard, the sealant layer **315** can be exposed along a perimeter of the envelope **200** and act as the manufacturing seal **252**. Thus, when exposed to heat, the sealant layer (e.g., intermediate layer **315**) of the back panel **230** bonds itself to the sealant layer (e.g., intermediate layer **315**) of the front panel **210** to form the envelope **200** in the manufactured state. In various embodiments, the sealant layer can provide additional burst strength to the envelope **200**, further protecting the article (e.g., a blood bag) from external forces during transportation. In various embodiments, the sealant layer is configured to seal the article within the cavity **262**. In various embodiments, the sealant layer can protect the barrier layer (e.g., intermediate layer **315**).

In various embodiments, disposed between the external layer **311** and the barrier layer (e.g., intermediate layer **313**) is a tie layer (e.g., intermediate layer **312**). In various embodiments, the tie layer can comprise an adhesive resin (e.g., ethylene-vinyl acetate (EVA), Ethylene-methyl acrylate (EMA), Ethylene-acrylic acid (EAA), Ethylene-grafted-maleic anhydride (AMP), or the like). In this regard, the tie layer can be configured to bond the external layer **311** to the barrier layer. In various embodiments, the tie layer can also provide an additional layer of protection for the barrier layer (e.g., intermediate layer **313**).

In various embodiments, disposed between the sealant layer (e.g., intermediate layer **315**) and the barrier layer (e.g., intermediate layer **313**) is a second tie layer (e.g., intermediate layer **314**). In various embodiments, the second tie layer is in accordance with the first tie layer. For example,

the second tie layer can comprise an adhesive resin (e.g., ethylene-vinyl acetate (EVA), Ethylene-methyl acrylate (EMA), Ethylene-acrylic acid (EAA), Ethylene-grafted-maleic anhydride (AMP), or the like). In various embodiments, the second tie layer is different than the first tie layer. In this regard, tie layers can adhere to different polymeric materials relative to other polymeric materials. For example, EVA or EMA can adhere well to HDPE, LDPE, PP, PS, and/or PVDC, EAA can adhere well to PA, PET, Ionomers, LDPE, EVA, EMA, and/or AI, and AMP can adhere well to PA, AI, EVOH, and/or cellulose.

Referring now to FIG. **3**, a method **400** of transporting a plurality of biomaterial articles (e.g., blood bags **130** from FIG. **1**) is illustrated, in accordance with various embodiments. The method **400** comprises disposing a biomaterial article (e.g., a blood bag **130** from FIG. **1**) in an envelope (e.g., envelope **200** from FIGS. **2**A-E) (block **402**). The envelope **200** is in a manufactured state (e.g., FIGS. **2**A-D) during block **402**. In this regard, the sealing apparatus **220** is in an open state, and the blood bag can be placed in the cavity **262** of the envelope **200** in block **402**.

In various embodiments, the method **400** further comprises transitioning the sealing apparatus **220** from the open state to a closed state (block **404**). In this regard, the zipper **224** can slide across the track **222** and couple a track on the back panel **230** to a track on the front panel **210** to create a first seal of the cavity **262** from an external environment of the envelope **200**.

In various embodiments, the method **400** further comprises coupling a first internal surface of a front panel **210** to a second internal surface of a back panel **230** (block **406**). In various embodiments, the front panel **210** can be coupled to the back panel **230** in block **406** via the sealing mechanism **244** and/or sealing mechanism **246**. In this regard, the sealing mechanisms **244**, **246** can be coupled to each other to form a second seal between the cavity **262** and the external environment. In various embodiments, a single sealing mechanism **244** or **246** can couple to an opposite surface and still be within the scope of this disclosure.

In various embodiments, the method **400** can further comprise coupling the first internal surface of the front panel **210** to an external surface of the back panel **230** (block **408**). In this regard, a top edge panel **212** of the front panel **210** can be folded over a top edge of the back panel **230** creating a crease along the top edge of the back panel **230** as shown in FIG. **2**E, and the first internal surface of the top edge panel **212** can be coupled to the external surface of the back panel **230** creating additional seals of the cavity **262** from the external environment (e.g., a seal along the crease and/or a seal from coupling first internal surface to the external surface via the sealing mechanism **242**).

In various embodiments, the method **400** further comprises placing the envelope **200** in a carrying bag **110** (block **410**) and placing a plurality of the envelope **200** (loaded in accordance with blocks **402**-**408**) in the carrying bag (block **412**). In this regard, a plurality of loaded envelopes **200** can be placed in the carrying bag **110** to be transported together. The method **400** further comprises transporting the carrying bag (block **414**).

Exemplary embodiments of the methods/systems have been disclosed in an illustrative style. Accordingly, the terminology employed throughout should be read in a non-limiting manner. Although minor modifications to the teachings herein will occur to those well versed in the art, it shall be understood that what is intended to be circumscribed within the scope of the patent warranted hereon are all such embodiments that reasonably fall within the scope of the advancement to the art hereby contributed, and that that scope shall not be restricted, except in light of the appended claims and their equivalents.

What is claimed is:

1. An envelope for transporting an object, the envelope comprising:

a front panel comprising a first plurality of layers;

a back panel comprising a second plurality of layers, the back panel coupled to the front panel via a first seal;

a sealing apparatus disposed between the front panel and the back panel, the sealing apparatus configured to transition from an open state to a closed state, the sealing apparatus and the first seal defining a cavity of the envelope in response to being in the closed state;

a first sealing mechanism disposed between the front panel and the back panel, the first sealing mechanism disposed outside of the cavity; and

a second sealing mechanism coupled to an internal surface of the front panel.

2. The envelope of claim **1**, wherein the first sealing mechanism and the second sealing mechanism comprise a double sided tape.

3. The envelope of claim **2**, wherein the first sealing mechanism and the second sealing mechanism each comprise a protective layer coupled to one side of the double sided tape.

4. The envelope of claim **1**, wherein the first sealing mechanism is configured to couple the front panel to the back panel after the sealing apparatus is closed.

5. The envelope of claim **4**, wherein the second sealing mechanism is configured to couple to an external surface of the back panel.

6. The envelope of claim **5**, wherein a portion of the front panel forms a crease along a top edge of the envelope in response to coupling the second sealing mechanism to the back panel.

7. The envelope of claim **1**, wherein the first plurality of layers and the second plurality of layers each comprise:

an external layer comprising a polymeric material;

an internal layer comprising an absorbent material; and

a barrier layer disposed between the external layer and the internal layer.

8. The envelope of claim **7**, wherein the first plurality of layers and the second plurality of layers each comprise a first tie layer disposed between the external layer and the barrier layer.

9. The envelope of claim of claim **7**, wherein the first plurality of layers and the second plurality of layers each comprise a sealant layer, the sealant layer at least partially defining the first seal.

10. An envelope for transporting an object, the envelope comprising:

a front panel and a back panel each comprising:

an internal layer defining an internal surface, the internal surface at least partially defining a cavity of the envelope;

an external layer disposed outward from the internal layer;

a barrier layer disposed between the internal layer and the external layer;

a sealant layer disposed between the barrier layer and the internal layer;

a first tie layer disposed between the external layer and the barrier layer; and

a second tie layer disposed between the sealant layer.

11. The envelope of claim 10, wherein a first portion of the sealant layer of the front panel is bonded to a second portion of the sealant layer of the back panel to form a first seal.

12. The envelope of claim 11, further comprising a sealing apparatus disposed between the front panel and the back panel, the sealing apparatus configured to transition from an open state to a closed state, the sealing apparatus and the first seal defining a cavity of the envelope in response to being in the closed state.

13. The envelope of claim 10, wherein the first tie layer couples the external layer to the barrier layer.

14. The envelope of claim 13, wherein the second tie layer couples the sealant layer to the barrier layer.

15. The envelope of claim 14, wherein the sealant layer is configured to protect the barrier layer.

16. A method of shipping a biomaterial article, the method comprising:

disposing the biomaterial article in an envelope, the envelope comprising an internal layer, an external layer, a barrier layer disposed between the internal layer and the external layer, and a sealant layer disposed between the internal layer and the barrier layer;

transitioning a sealing apparatus from an open state to a closed state to create a first seal of a cavity defined by the sealing apparatus and a manufacturing seal;

coupling a first internal surface of a front panel of the envelope to a first internal surface of a back panel of the envelope via a first sealing mechanism to create a second seal; and

coupling the first internal surface of the front panel of the envelope to an external surface of the back panel of the envelope to create a third seal.

17. The method of claim 16, wherein a crease is formed at a top edge of the envelope in response to coupling the first internal surface to the external surface.

18. The method of claim 16, further comprising placing the envelope in a carrying bag.

19. The method of claim 18, further comprising placing a plurality of the envelope in the carrying bag, each envelope in the plurality of the envelope having a respective biomaterial article disposed therein.

20. The method of claim 19, further comprising transporting the carrying bag.

21. An envelope for transporting an object, the envelope comprising:

an internal layer defining an internal surface, the internal surface at least partially defining a cavity of the envelope;

an external layer disposed outward from the internal layer;

a barrier layer disposed between the internal layer and the external layer;

a sealant layer disposed between the barrier layer and the internal layer;

a first tie layer disposed between the external layer and the barrier layer; and

a second tie layer disposed between the sealant layer.

22. The envelope of claim 21, further comprising a sealing system including a plurality of sealing apparatuses.

23. The envelope of claim 21, wherein the external layer comprises a polymeric material, and wherein the internal layer comprises a desiccant layer.

24. The envelope of claim 23, wherein the first tie layer and the second tie layer comprise an adhesive resin.

25. The envelope of claim 24, wherein the barrier layer comprises a second polymeric material different from the external layer, and wherein the sealant layer comprises a third polymeric material different from the barrier layer and the external layer.

26. The envelope of claim 21, wherein the envelope is configured to be resistant to brittleness and shattering at cryogenic temperatures.

* * * * *