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(54) Title: STRETCH FRAME FOR STRETCHING PROCESS

(57) Abstract: An apparatus comprising a frame and a pressure sensitive adhesive applied to at least a portion of the frame, where the pressure sensitive adhesive is arranged to bond a pre-stained film to the frame is disclosed. A method of making the apparatus also is disclosed. Also disclosed is a method of preparing a stretch frame for manufacturing electro-active polymer devices thereon.

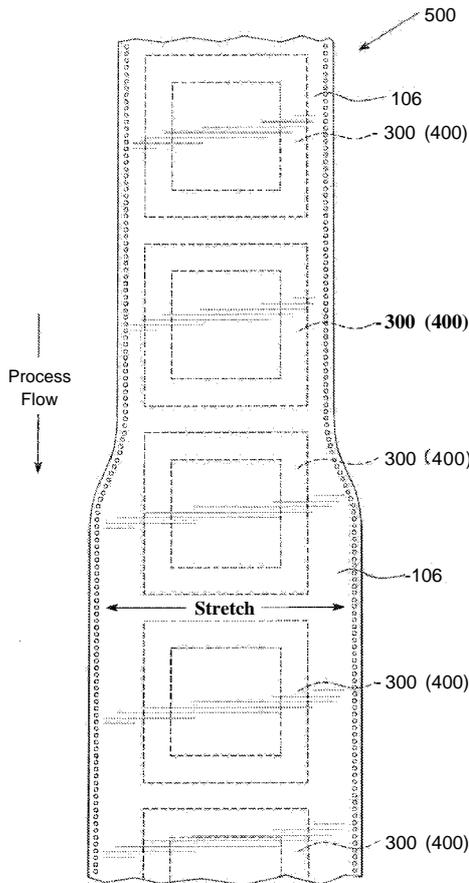


FIG. 12



MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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STRETCH FRAME FOR STRETCHING PROCESS

RELATED APPLICATIONS

This application claims the benefit, under 35 USC § 119(e), of U.S.

5 Provisional Application No.: 61/660,887 filed June 18, 2012 entitled "STRETCH
FRAME CONCEPT FOR RE-ENGINEERED STRETCHING **PROCESS**" the
entirety of which is incorporated herein by reference.

FIELD OF THE INVENTION

10 The present invention is directed in general to a stretch frame for a
stretching process during manufacturing and more specifically, to a stretch frame
for a stretching process during high volume manufacturing processes for
producing electroactive polymer cartridges and transducers.

BACKGROUND OF THE INVENTION

15 A tremendous variety of devices used today rely on actuators **of one** sort or
another to convert electrical energy **to** mechanical energy. Conversely, many
power generation applications operate by converting mechanical action into
electrical energy. Employed **to** harvest mechanical energy **in** this fashion, the
same **type** of device may be referred to as a generator. Likewise, when the
structure is employed to convert physical stimulus such as vibration or pressure
20 into an electrical signal **for** measurement purposes, it may be characterized as a
sensor. Yet, the term "transducer" may be used to **generically** refer **to** any **of the**
devices.

A number of design considerations favor the selection and use of advanced
dielectric elastomer materials, also referred to as "electroactive polymers", for the
25 fabrication of transducers. These considerations include potential force, power
density, power conversion/consumption, size, weight, cost, response time, duty
cycle, sendee requirements, environmental impact, etc. As such, in many
applications, electroactive polymer technology offers an ideal replacement for
piezoelectric, shape-memory alloy and electromagnetic devices such as motors
30 and solenoids.

An electroactive polymer transducer comprises two electrodes having
deformable characteristics and separated by a thin elastomeric dielectric material.

When a voltage difference is applied to the electrodes, the oppositely charged electrodes attract each other thereby compressing the polymer dielectric layer therebetween. As the electrodes are pulled closer together, the dielectric polymer film becomes **thinner** (the Z-axis component contracts) as it expands in the planar directions (along the X- and Y-axes), i.e., the displacement of the film is **in-plane**.
5 The electroactive polymer film may also be configured to produce movement in a direction orthogonal to the film structure (along the Z-axis), i.e., the displacement of the film is out-of-plane. U.S. Pat No. 7,567,681 discloses electroactive polymer film constructs which provide such **out-of-plane** displacement - also
10 referred to as surface deformation or as thickness mode deflection.

The material and physical properties **of the** electroactive polymer film may be varied and controlled to customize the deformation undergone by the transducer. More specifically, factors such as the relative elasticity between the polymer film and the electrode material, the relative thickness between the
15 polymer film and electrode material and/or the **varying** thickness of the polymer **film** and/or electrode material, the physical pattern of the polymer **film** and/or electrode material (**to** provide localized active and inactive areas), the tension or pre-strain placed on the electroactive polymer film as a whole, and the amount of voltage applied to or capacitance induced upon the film may be controlled and
20 varied to customize the features of the film when in an active mode.

Numerous applications exist that benefit from the advantages provided by such electroactive polymer films whether using the film alone or using it in an electroactive polymer actuator. One of the many applications involves the use of electroactive polymer transducers as actuators to produce **haptic**, tactile,
25 vibrational feedback (the communication **of information to a** user through forces applied to the user's body), and the like, in user interface devices. There are many **known** user interface devices which employ such feedback, typically **in** response to a force initiated by the user. Examples of user interface devices that may employ such feedback include keyboards, keypads, game controller, remote
30 control, touch screens, computer mice, trackballs, stylus sticks, joysticks, etc. The user interface surface can comprise any surface that a user manipulates, engages,

and/or observes regarding feedback or information from **the** device. Examples of such interface surfaces include, but are not limited **to**, a key (e.g., keys on a keyboard), a game pad or buttons, a display screen, etc.

The feedback provided by these types of interface devices is in the form of
5 physical sensations, such as vibrations, pulses, spring forces, etc., which a user senses either directly (e.g., via touching of the screen), indirectly (e.g., via a vibrational effect such as when a cell phone vibrates in a purse or bag) or
otherwise sensed (e.g., via an action of a moving body that creates a pressure disturbance sensed **by** the user). The proliferation of consumer electronic media
10 devices such as smart phones, personal media players, portable computing devices, portable gaming systems, electronic readers, etc., can create a situation where a sub-segment of customers would benefit or desire an improved haptic effect in the electronic media device. However, increasing feedback capabilities in every model of **an** electronic media device may not be justified due to increased
15 cost or increased profile of the device. Moreover, customers of certain electronic media devices may desire to temporarily improve the haptic capabilities of the electronic media device for certain activities.

Use of **electroactive** polymer materials in consumer electronic media devices as well as the numerous other commercial and consumer applications
20 highlights the need to increase production volume while maintaining precision and consistency of the films.

Present techniques for stretching and laminating films **to** produce electroactive polymer devices require many steps and require that the stretch frame is cleaned after each use, which is very labor intensive. The present
25 disclosure provides various stretch frames for producing electroactive polymer devices as described herein in the detailed description of the invention section of the present **disclosure**. The present disclosure also provides various stretching processing techniques for producing electroactive polymer devices as described herein **in** the detailed description of the invention section of the present disclosure.

SUMMARY OF THE INVENTION

Electroactive polymer devices that can be used with these designs include, but are not limited to planar, diaphragm, thickness mode, roll, and passive coupled devices (hybrids) as well as any type of electroactive polymer device described in
5 the commonly assigned patents and applications cited herein.

In one embodiment, an apparatus comprising a frame and a pressure sensitive adhesive (PSA) applied to at least a portion of the frame is provided. The pressure sensitive adhesive is arranged to bond a pre-strained film to the
frame.

10 In some variations, a method comprising providing a stretch frame, applying a pressure sensitive adhesive on at least a portion of the stretch frame, providing a film, stretching the film, and laminating the pre-strained film onto the pressure sensitive adhesive coating of the stretch frame is provided.

In other variations, a method of making a stretch frame is provided. The
15 method comprises providing a frame and applying a pressure sensitive adhesive on at least a portion of the frame. In one embodiment, the method further comprises the use of a release layer between the frame and the adhesive.

As noted above, there remains a need to mass produce such electroactive polymer devices while maintaining the performance characteristics obtained
20 through batch production or lower volume manufacturing processes.

The present disclosure provides stretch frames and stretching processes for producing electroactive polymer devices and reducing manufacturing cycle time, waste, and labor for cleaning conventional stretch frames after uses. Other
benefits include cost reduction, improvement in lamination integrity, enabling the
25 use of narrower frames, providing efficient use of silicone film, increasing throughput, and the film printing process after the film lamination process is made easier with thinner stretch frames.

These and other features, objects and advantages of the invention will become apparent to those persons skilled in the art upon reading the details of the
30 invention as more fully described below. In addition, variations of the processes and devices described herein include combinations of the embodiments or of

aspects of the embodiments where possible are within the scope of this disclosure even if those combinations are not explicitly shown or discussed.

BRIEF DESCRIPTION OF THE DRAWINGS.

5 The invention is best understood from the following detailed description when read in conjunction with the accompanying drawings. To facilitate understanding, the same reference numerals have been used (where practical) to designate similar elements are common to the drawings. Included in the drawings are the following:

10 Figs. 1A and 1B illustrate a top perspective view of a transducer before and after application of a voltage in accordance with one embodiment of the present invention;

Fig. 2A illustrates an exemplary electroactive polymer cartridge in accordance with one embodiment of the present invention;

15 Fig. 2B illustrates an exploded view of an electroactive polymer actuator, inertial mass and actuator housing in accordance with one embodiment of the present invention;

Fig. 3 illustrates a conventional stretch frame used in a conventional process;

20 Fig. 4 illustrates a sectional view of the conventional stretch frame shown in Fig. 3 taken along section 4—4;

Fig. 5 illustrates a flow diagram of a conventional process for stretching and laminating film onto the conventional stretch frame shown in Fig. 4;

Fig. 6 illustrates an exploded view of a reusable stretch frame according to one embodiment of the present invention;

25 Fig. 7 illustrates a sectional view of the reusable stretch frame shown in Fig. 6 taken along section 7—7;

Fig. 8 illustrates a pre-strained film laminated onto a pressure sensitive adhesive coating applied to the reusable stretch frame shown in Figs. 6 and 7 according to one embodiment of the present invention;

30 Fig. 9 illustrates an exploded view of a disposable stretch frame according to one embodiment of the present invention;

Fig. 10 illustrates a sectional view of the disposable stretch frame shown in Fig. 8 taken along section 10—10;

Fig. 11 illustrates a pre-strained film laminated onto a pressure sensitive adhesive coating applied to the disposable stretch frame shown in Figs. 9 and 10 according to one embodiment of the present invention;

Fig. 12 illustrates a schematic diagram of a stretcher for stretching film and laminating the pre-strained film on stretch frames according to one embodiment of the present invention;

Fig. 13 illustrates a flow diagram of a film stretching and laminating process according to one embodiment of the present invention;

Fig. 14 illustrates one embodiment of a semiautomatic stretcher being used to stretch film and to laminate the stretched film onto a stretch frame according to one embodiment of the present invention ; and

Fig. 15 illustrates one embodiment of a semiautomatic stretcher for stretching film and laminating the stretched film onto a stretch frame according to one embodiment of the present invention.

FIG. 16 illustrates a side view of the semiautomatic stretcher shown in Fig. 15.

Variation of the invention from that shown in the figures is contemplated.

DETAILED DESCRIPTION OF THE INVENTION

Examples of **electroactive** polymer devices and their applications are described, for example, in U.S. Pat Nos. 6,343,129; 6,376,971 ; 6,543,110; 6,545,384; 6,583,533; 6,586,859; 6,628,040; 6,664,718; 6,707,236; 6,768,246; 6,781,284; **6,806,621**; 6,809,462; 6,812,624; 6,876,135; 6,882,086; 6,891,317; 6,911,764; 6,940,221; 7,034,432; 7,049,732; 7,052,594; 7,062,055; 7,064,472; **7,166,953**; **7,199,501**; 7,199,501; 7,211,937; 7,224,106; 7,233,097; 7,259,503; 7,320,457; 7,362,032; 7,368,862; 7,378,783; 7,394,282; 7,436,099; 7,492,076; 7,521,840; 7,521,847; 7,567,681; 7,595,580; 7,608,989; **7,626,319**; 7,750,532; 7,761,981; 7,911,761; 7,915,789; 7,952,261; 8,183,739; 8,222,799; 8,248,750; and in U.S. Patent Application Publication Nos.; 2007/0200457; 2007/0230222;

201 1/0128239; and 2012/0126959, the entireties of which are incorporated herein by reference.

In various embodiments, the present invention provides a stretch frame for stretching film and / or laminating the stretched film onto the stretch frame. In various embodiments, the present invention provides a stretching process employing the stretch frame for stretching and / or laminating the stretched film. In one embodiment, a polymer film is stretched and / or laminated using the stretch frame and process according to the present disclosure to manufacture electroactive polymer devices. Embodiments of the stretch frame and stretching process according to the present disclosure can be used to stretch and laminate film to reduce manufacturing costs relative to conventional techniques by eliminating numerous processing steps and preclude the need for cleaning the stretch frames after each use, which can be labor intensive. Various embodiments of the present invention employ a unique coating stack to hold a pre-strained film tightly during manufacturing of electroactive polymer devices and to enable easy removal of film remnants left on the stretch frame after the devices are removed, e.g., cut out, from the stretch frame. In one embodiment, the stretch frames are disposable. In another embodiment, at least a portion of the stretch frame can be incorporated permanently into the transducer,

In one embodiment, a pressure sensitive adhesive (PSA) and release coat are applied to the stretch frame to hold a pre-strained film on the stretch frame and to enable easy removal of any pressure sensitive adhesive and / or film remnants from the stretch frame after each use, respectively. In addition to reducing manufacturing costs by decreasing the number of stretching and laminating steps and labor costs of cleaning stretch frames after each use, embodiments of the present invention also enable the use of narrower stretch frames, which provides additional printing area for an equally sized frame with the same outside dimensions, leading to increased manufacturing throughput.

For some electroactive polymer device configurations, the adhesives can be printed after film-to-film lamination. Conventional stretch frames that employ two aluminum stretch frames, it is difficult to build more than two layers of film

in a lamination due to the thickness of the stretch frames. Embodiments of the present invention provide thinner single stretch frames to simplify the stretching and / or lamination processes.

Films useful in embodiments of the present invention include, but are not
5 limited to those made from polymers such as silicone, polyurethane, **acrylate**, hydrocarbon rubber, olefin copolymer, polyvinylidene fluoride copolymer, fluoroelastomer styrenic copolymer, and adhesive elastomer.

Prior to describing the stretch frame and stretch / laminating process according to various embodiments **of the** present invention, the description now
10 turns to Figs. 1A and 1B, which illustrate an example of an **electroactive** polymer film or membrane 10 structure. A thin **elastomeric** dielectric film or layer **12** is sandwiched between compliant or stretchable electrode plates or layers 14 and 16, thereby forming a **capacitive** structure or film. The length "l" and width "w" of the dielectric layer, as well as that of the composite structure, are much **greater**
15 **than its** thickness "t". Preferably, the dielectric layer has a thickness in the range from about 10 μm to about 100 μm , with the total thickness of the structure in the range from about 15 μm to about 10 cm. The thickness of the dielectric layer in the transducer can be reduced during fabrication by stretching (or **pre-straining**) the dielectric film. The stretching can be uniaxial or biaxial. **In** biaxial pre-strain,
20 the stretch ratio may be equal in all directions or it can be anisotropic with stretching in one axis greater than in another.

It is additionally desirable to select the elastic modulus, thickness, and/or the geometry of electrodes 14, 16 such that the additional stiffness they contribute to the actuator is generally less than **the** stiffness of the dielectric layer **12**, which
25 has a relatively low modulus of elasticity, i.e., less than about 100 MPa and more preferably less than about 10 MPa, but is likely thicker than each of the electrodes. Electrodes suitable for use with these compliant capacitive structures are those capable of withstanding cyclic strains greater than about 1% without failure due to mechanical fatigue.

30 As seen in Fig. 1B, when a voltage is applied across the electrodes, the unlike charges in the two electrodes 14, 16 are attracted to each other and these

electrostatic attractive forces compress the dielectric film 12 (along the Z-axis). The dielectric film 12 is thereby caused to deflect **with** a change **in** electric field. As electrodes 14, **16** are compliant, they change shape **with** dielectric layer **12**. **In** the context of the present disclosure, "deflection" refers to any displacement, expansion, contraction, torsion, linear or area strain, or any other deformation of a portion of dielectric film **12**. Depending on the architecture, e.g., a frame, **in** which **capacitive** structure 10 is employed (collectively referred to as a "transducer"), this deflection may be used to produce mechanical work. Various different transducer architectures are disclosed and described in the above-identified patent references.

With a voltage applied, the transducer film 10 continues to deflect until mechanical forces balance the electrostatic forces driving the deflection. The mechanical forces include elastic restoring forces of the dielectric layer 12, the compliance or stretching **of the** electrodes **14, 16** and any external resistance provided by a device and/or load coupled to transducer 10. The resultant deflection **of the** transducer **10** as a result **of the** applied voltage may also depend on a number of other factors such as the dielectric constant of the **elastomeric** material and its size and stiffness. Removal of the voltage difference and the induced charge causes the reverse effects.

In some cases, the electrodes 14 and 16 may cover a limited portion **of** dielectric **film** 12 relative to the **total** area of the film. This may be done to prevent electrical breakdown around the edge of the dielectric or achieve customized deflections **in** certain portions thereof. Dielectric material outside an active area (the latter being a portion of the dielectric material having sufficient electrostatic force to enable deflection of that portion) may be caused to act as an external spring force on the active area during deflection. More specifically, material outside the active area may resist or enhance active area deflection by its contraction or expansion.

The dielectric film 12 may be pre-strained using the various embodiments of the stretch frame and process according to the present invention described herein. The **pre-strain** improves conversion between electrical and mechanical

energy, i.e., the pre-strain allows the dielectric film 12 to deflect more and provide greater mechanical work. Pre-strain of a film may be described as the change in dimension in a direction after pre-straining relative to the dimension in that direction before pre-straining. The pre-strain may include elastic deformation of the dielectric film and be formed, for example, by stretching the film in tension and fixing one or more of the edges while stretched, as indicated in Fig. 10. The pre-strain may be imposed at the boundaries of the film or for only a portion of the film and may be implemented by using a rigid frame or by stiffening a portion of the film.

10 The transducer structure of Figs. 1A and 1B and other similar compliant structures and the details of their constructs are more fully described in many of the referenced patents and publications disclosed herein.

Fig. 2A illustrates an exemplary electroactive polymer cartridge 12 having an electroactive polymer transducer film 26 placed between rigid frame 8 where the electroactive polymer film 26 is exposed in openings of the frame 8. The exposed portion of the film 26 includes two working pairs of thin elastic electrodes 32 on either side of the cartridge 12 where the electrodes 32 sandwich or surround the exposed portion of the film 26. The electroactive polymer film 26 can have any number of configurations. However, in one example, the electroactive polymer film 26 comprises a thin layer of elastomeric dielectric polymer (e.g., made of acrylate, silicone, urethane, thermoplastic elastomer, hydrocarbon rubber, fluoroelastomer, styrenic copolymer elastomer, or the like). When a voltage difference is applied across the oppositely-charged electrodes 32 of each working pair (i.e., across paired electrodes that are on either side of the film 26), the opposed electrodes attract each other thereby compressing the dielectric polymer layer 26 therebetween. The area between opposed electrodes is considered the active area. As the electrodes are pulled closer together, the dielectric polymer 26 becomes thinner (i.e., the Z-axis component contracts) as it expands in the planar directions (i.e., the X- and Y-axis components expand) (See Figs. 1B for axis references).

Furthermore, in variations where the electrodes contain conductive particles, like charges distributed across each electrode may cause conductive particles embedded within that electrode to repel one another, thereby contributing to the expansion of the elastic electrodes and dielectric films. In alternate variations, electrodes do not contain conductive particles (e.g., textured sputtered metal films). The dielectric layer 26 is thereby caused to deflect with a change in electric field. As the electrode material is also compliant, the electrode layers change shape along with dielectric layer 26. As stated hereinabove, deflection refers to any displacement, expansion, contraction, torsion, linear or area strain, or any other deformation of a portion of dielectric layer 26. This deflection may be used to produce mechanical work. As **shown**, the dielectric layer 26 can also include one or more mechanical output bars 34. The bars 34 can optionally provide attachment points for either an inertial mass (as described below) or for direct coupling to a substrate in the electronic media device.

In fabricating a transducer, an elastic film 26 can be stretched and held in a pre-strained condition usually by a rigid frame or stretch frame 8. In those variations employing a four-sided **frame**, the film can be stretched **bi-axially**. It has been observed that pre-strain improves the dielectric strength of the polymer layer 26, thereby enabling the use of higher electric fields and improving conversion between electrical and mechanical energy, i.e., the pre-strain allows the film to deflect more and provide greater mechanical work. Preferably, the electrode material is applied after **pre-straining** the polymer layer, but may be applied beforehand. The two electrodes provided on the same side of layer 26, referred to herein as same-side electrode pairs, i.e., electrodes on the top side of dielectric layer 26 and electrodes on a bottom side of dielectric layer 26, can be electrically isolated from each other. The opposed electrodes on the opposite sides of the polymer layer form two sets of **working** electrode pairs, i.e., electrodes spaced by the **electroactive** polymer film 26 form one working electrode pair and electrodes surrounding the adjacent exposed electroactive polymer film 26 form another working electrode pair. Each same-side electrode pair can have the same polarity, whereas the polarity of the electrodes of each

working electrode pair is opposite each other. Each electrode has an electrical contact portion configured for electrical connection to a voltage source.

Examples of electroactive polymer films can be found in the **commonly** assigned patents and patent applications disclosed and incorporated by reference
5 herein.

Now turning to Fig. 3, where a conventional stretch frame 100 used in a conventional process is illustrated. As shown, the conventional stretch frame 100 includes a top frame element 102 and a bottom frame 104 element. The top frame element 102 is slightly smaller than the bottom frame element 104. With
10 reference now to both Figs. 3 and 4, a **pre-strained** dielectric film 106 is sandwiched between the top and bottom frame elements 102, 104 of the stretch frame 100. An adhesive tape 108 may be employed to bond the **top** and bottom frame elements 102, 104 together. This holds the pre-strained film 108 in place for subsequent lamination and printing processes. Once **the** printing process is
15 completed, the individual electroactive polymer devices are removed, e.g., cut out (singulated), from the film 108 and removed from the stretch frame 100. The tape 108 and any film remnants must then be removed the stretch frame 100 before the stretch frame 100 can be reused. Removing the tape 108 and film remnants increases the **manufacturing** cycle time and adds labor costs for cleaning the
20 stretch frame after each use. Although the top and bottom stretch frame elements 102, 104 can be made of any suitable materials such as metals and rigid plastics, generally these components are made of **aluminum**.

Fig. 5 illustrates a flow diagram 200 of a conventional process for stretching and laminating film onto the conventional stretch frame **shown** in Fig.
25 4. This process 200 **will** now be described in conjunction with Figs. 3 and 4. The process 200 starts by providing 202 the bottom frame element 104. The film 106 is stretched 204 and laminated 206 onto the bottom frame element 104. The top frame element 102 is then provided and placed above the stretched **film** 106 and the bottom frame element 104. The tape 108 is applied to bond the top and
30 bottom frame elements 102, 104 to hold the pre-strained **film** 108 during the manufacturing steps. The electroactive **polymer** devices are manufactured using

the stretch frame 100. The devices are then removed 216 from the film 108, The excess film 108 is removed 218 and the tape 108 is removed and cleaned from the stretch frame 100.

Having described the film stretching and **laminating** process for
5 manufacturing electroactive polymer devices using a conventional stretch frame 100 and process 200, the disclosure now turns to Fig. 6, which illustrates an exploded view of a reusable stretch frame 300 according to one embodiment of the present invention and Fig. 7, which illustrates a sectional view of the stretch frame shown in Fig. 6 taken along section 7—7. As shown in Figs. 6 and 7, the
10 reusable stretch frame 300 according to one embodiment of the present invention comprises a bottom stretch frame element 302, a permanent, or long term, release coating 304 applied to a top portion of the stretch frame element 302, and a pressure sensitive adhesive 306 applied to the release coating 304. The release coating 304 is reusable and generally is applied once to the stretch frame element
15 302. Although the stretch frame element 302 can be made of any suitable material, the stretch frame element **302** is generally made of **aluminum**.

The reusable stretch frame 300 can be manufactured with thinner, narrower, stretch frame elements 302, which provides the additional advantage of increasing the pre-strained **film** 106 area available for printing the electroactive polymer components, for example. In other words, thinner or narrower stretch
20 frame elements 302 increase the ratio of print area over the overall area defined by the stretch frame element 302.

As shown in Fig. 8, the pre-strained film 106 is laminated onto the **pressure** sensitive adhesive material 306, which will hold the pre-strained film 106
25 **during** the **electroactive** polymer device manufacturing steps. Since the pre-strained film 106 is bonded to the stretch frame element 302 by the pressure sensitive adhesive 306, there is no need for a top stretch frame element 102 and tape 108 or other method to bond the top and bottom stretch frame elements 102, 104 as shown and described in connection with **Figs.** 3 and 4.

30 Fig. 9 illustrates an exploded view of a disposable stretch frame 400 according to one embodiment of the present invention. Fig. 10 illustrates a

sectional view of the stretch frame shown in Fig. 8 taken along section 10—10. The disposable stretch frame 400 comprises a stretch frame element 402 made of relatively inexpensive material (e.g., plastic) to make it economically feasible to make it disposable. A pressure sensitive adhesive 404 coating is applied to a top portion of the stretch frame element 402 but no release coating is necessary since the disposable stretch frame 400 will not be reused. Fig. 11 illustrates a pre-strained film 106 laminated onto the pressure sensitive adhesive 404 coating applied to the stretch frame element 402.

Another embodiment of this invention is that at least a portion of the disposable stretch frame can be incorporated into the structure of the transducer cartridge. For example, an adhesive coated polyethylene terephthalate (PET) film with apertures could be laminated onto a pre-strained dielectric film, processed through printing stations to add electrodes, and singulated into individual transducers by die-cutting through the entire materials stack. Using the disposable stretch frame material in the final product could reduce product cost by eliminating the steps used to print a frame in an electroactive polymer cartridge.

Although the reusable and disposable stretch frames 300, 400 are illustrated as having a generally rectilinear shape, the shape of these stretch frames 300, 400 should not be limited as such. In general, the stretch frames 300, 400 may be implemented using any suitable triangular, square, rectangular, rhomboidal, polygonal, circular, oval, irregular, or other suitable shape.

Fig. 12 illustrates a schematic diagram of a stretcher 500 for stretching film and laminating the pre-strained film on the stretch frames 300, 400 according to one embodiment of the present invention. The film 106 is initially rolled out and clamped on either side. As the film 106 advanced the clamps follow a track that widens and stretches the film 106. During the process, after the film 106 has been stretched, the film 106 is laminated onto the pressure sensitive adhesive coating applied to the reusable stretch frame 300 or the disposable stretch frame 400. After the pre-strained film 106 is laminated onto the stretch frames 300 (400), the frames are removed, e.g., cut out, from the film web and routed to an electroactive polymer device manufacturing stage, where the various components

of the electroactive polymer device are printed or applied to the **pre-strained** film **106** bonded to the stretch frame **300** (**400**).

The cleaning process is simple. After the device or plurality of devices is removed from the pre-strained film **106**, the pressure sensitive adhesive **306** and
5 film remnants are peeled easily from the release coating **304**. The reusable stretch frame **300** with the release coating **304** is reusable. For materials selection, consideration is given to **the** tack and peel adhesion properties of the pressure sensitive adhesive **306** as well as the release properties **of the** pressure sensitive adhesive **306**. **In** other words, the pressure sensitive adhesive **306** should not be
10 too easily released from the release coating **304** so it will remain during the manufacturing process, but should be easily released for the cleaning process. For making the release coating 306 permanent, an adhesion promoter can be applied to a portion of the stretch frame **300** prior to applying the release coating **304** thereon.

15 Various materials can be employed for the pressure sensitive adhesive 306 and the release coating **304**. In one embodiment the pressure sensitive adhesive **306** is a Dow Corning **2013** (a solvent-free silicone pressure sensitive adhesive that, when used **with SYL-OFF 4000** catalyst (a blend of **platinum** catalyst and vinyl functional silicone polymer), offers the ability to prepare pressure sensitive
20 constructions at low curing temperatures) material, among other materials, for example; the release coating 304 is a Dow Corning **SYL-OFF Q2-7785** (an **88%** active solids dispersion **of fluorofunctional** silicone polymer in heptane), among other materials, for example; and optionally, an adhesion promoter for the release coating **304** to aluminum stretch frame **302** is **NuSil CF2-135** (silicone primer),
25 among other materials, for example.

Other materials that may be employed for **the** pressure sensitive adhesive **304** include: Dow Coming **280A** (a dispersion of polydimethylsiloxane gum and resin diluted with xylene to **55%** silicone solids content.), Dow Corning **282** (a dispersion of **polydimethyldisiloxane** gum and resin diluted with xylene to **55%**
30 silicone solids content), Dow Corning **7355** (a dispersion of pQlydimethylsiloxane gum and resin diluted **with** xylene and toluene to **an** average **56.5** percent silicone

solids content.), **Dow** Coming 7358 (a dispersion of **polydimethylsiloxane** gum and resin diluted with xylene and toluene to an average 56.5 percent silicone solids content), Dow Corning 7388 (a dispersion of polydimethylsiloxane gum and resin diluted **with** xylene to 55% to 58% silicone solids content), Dow

5 Coming 7651, 7652, 7657, Dow Corning **SYL-OFF Q2-7566** (a dispersion of polydimethylsiloxane gum and resin diluted with xylene to 55% silicone solids content), Dow Corning SYL-OFF Q2-7735 (a peroxide-curable silicone pressure sensitive adhesive designed to provide low, stable release from liners made with Dow Corning SYL-OFF Q2-7785 Release Coating, while maintaining high

10 subsequent tack and adhesion properties; the adhesive is a dispersion of **siloxane** gum and silicone resin diluted **with** xylene to 55% silicone solids content), Dow Corning SYL-OFF Q2-7406 (a polydimethylsiloxane gum and resin dispersion). Momentive SILGRIP **PSA529** (silicone pressure sensitive adhesive), Momentive SILGRIP PSA590 (a silicone pressure sensitive adhesive based on a toluene

15 solution of **polysiloxane** gum and resin and supplied at 60% silicone solids and may be further diluted **with** aromatic, aliphatic or chlorinated solvents), Momentive SILGRIP PSA595 (a silicone pressure sensitive adhesive based on a xylene solution of polysiloxane gum and resin and supplied at 55% silicone solids and may be **further** diluted with aromatic, aliphatic or chlorinated solvents),

20 Momentive SILGRIP PSA6573A (a silicone pressure sensitive adhesive based on a toluene solution of **polysiloxane** gum and resin and supplied at 60% silicone solids and may be further diluted with aromatic, aliphatic or chlorinated solvents), Momentive SILGRIP PSA6574 (a silicone pressure sensitive adhesive based on a toluene solution of **phenyl** based polysiloxane gum and resin supplied at 55%

25 silicone solids and may be further diluted with aromatic, aliphatic or chlorinated solvents), NuSil **PSA-1 170** (a silicone based pressure sensitive adhesive), among other materials, for example. Other adhesives may also be employed that are not pressure sensitive adhesives such as hot-melt, liquid, thermal curing, **UV** curing, and B-staged adhesives. A wide range of adhesives can be used including

30 silicones, fluorosilicones, acrylates, polyurethanes, olefins, hydrocarbon rubbers, styrene copolymers, epoxies, hot-melt adhesives, pressure sensitive adhesives, thermal

curing adhesives, UV curing adhesives, liquid adhesives, and any combinations thereof, among other materials.

Materials that may be employed for the release coating 304 include: Momeniive FSR2000 (a fluorosilicone polymer containing platinum catalyst), epoxy silicone, fluoropolymer, fluorosilicone, among other materials, for example. The choice of the release coating is highly dependent on the materials used for the stretch frame, adhesive, and stretched dielectric film.

Additional materials that have been tested but have not performed as well as the above listed materials for a silicone film design include, for the release coating **304**: Magnaplate coatings including polymer-based LECTROFLUOR, TUFRAM surface enhancement coating, and TEFLON (polytetrafluoroethylene (PTFE) synthetic fluoropolymer of tetrafluoroethylene), mold release, EASE RELEASE 200, among other materials. These materials may find utility for other chemistries, however.

Portions of the surface of the stretch frame may be pre-treated prior to the application of the release coating to improve the formation and adhesion of a strong, durable release coating. Treatment agents include solvents, primers, coupling agents, and etchants. An exemplary adhesion promoter for a fluorosilicone release coating **304** to the aluminum stretch frame **302** is NuSil MED 1-161 (silicone primer specially formulated primer designed for use with platinum-cured systems where conventional silicone primers are insufficient.

Fig. 13 illustrates a flow diagram 600 of a film stretching and laminating process according to one embodiment of the present invention. As shown in Fig. 13, a stretch frame 300 (400) is provided 602 and a pressure sensitive adhesive 306 is applied thereto. In one embodiment, the reusable stretch frame **300** is made of aluminum, or other reusable material. The release coating 304 is applied to the aluminum reusable stretch frame 300 prior to its introduction into the process depicted in the flow diagram 600. When a disposable stretch frame 400 is employed, then the pressure sensitive adhesive 306 can be applied directly to the disposable stretch frame **400** material. Once the pressure sensitive adhesive 306 coating is applied, the film 106 stretched and the pre-strained film 106 is

laminated onto the stretch frame 300 (400). After lamination the stretch frame 300 (400) **with the pre-strained** film 106 is employed to manufacture 610 the electroactive polymer devices as described in connection with Figs 1A, IB, 2A, 2B. The devices are then removed, e.g., cut 612, from the pre-strained film 106
5 bonded to the stretch frame 300 (400) by the pressure sensitive adhesive 306. When a reusable stretch frame 300 is employed, the excess film 106 and the **pressure** sensitive adhesive 306 are simply peeled away from the release coating 304, making clean up easy and preparation of the stretch frame 300 **for** the next process run more efficient. When a disposable stretch **frame** 400 is employed, the
10 entire stretch frame 400 is disposed **of**.

Fig. 14 illustrates one embodiment **of a** semiautomatic stretcher 700 being used to stretch **film** 106 and to laminate the stretched film 106 onto a stretch frame 300 (400) according to one embodiment of the present invention. The semiautomatic stretcher 700 is being used **to** stretch the film 106 and for film-
15 frame lamination on **the film** stretcher 500 (as shown **in** Fig. 12). As shown in Fig. 14, an operator 702 is **in** the process of laminating the film 106 onto the frames 300 (400) that were coated with the pressure sensitive adhesive 306, **as** described in connection with Figs. 6-8. Although a manual lamination process is **shown**, embodiments of the present invention encompass a **fully** automatic
20 process where a roller **or** other means are employed to perform the lamination function. Also, the film 106 stretcher 500 can be advanced continuously or indexed by a single frame 300 (400) or a predetermined number of frames 300 (400).

Fig. 15 illustrates one embodiment of a semiautomatic stretcher 800 for
25 stretching film 106 with the film stretcher 500 (as shown in Fig. 12) and **laminating** the stretched film 106 onto a stretch frame 300 (400) according to one embodiment of the present invention. **FIG.** 16 illustrates a side view of the semiautomatic stretcher 800. With reference now to Figs. 15, and 16, the semiautomatic stretcher 800 comprises a base material roll 802, a machine
30 direction orientation roll 808, a first scrap winder 810, and a second scrap winder 812. The base material roll 802 comprises a dielectric film 106 layer sandwiched

between a polyethylene terephthalate layer 804 and a polyethylene (PE) interleave layer 806. In operation, as the base material roll 802 rotates the polyethylene terephthalate layer 804 is wound by the first scrap winder 810 and the PE interleave layer 806 is wound by the second scrap winder 812. The dielectric film layer 106 is advanced to the film stretcher 500 portion. A tape unwind spool 814 can be employed to apply tape 816 to the edges of the edges of the dielectric film 106 to reinforce the film 106 during the stretching phase.

As previously discussed, the various embodiments of the stretch frames 300 (400) and process 600 for stretching and laminating the film 106 onto the stretch frames 300 (400) provide several advantages over the conventional stretch frame 100 and process 200. Such advantages include, without limitation, cost reduction, improved lamination integrity, enables use of narrower frames to increase the film area available for printing, efficient use of silicone film, and increase throughput. Also, printing after the lamination process becomes easier with thinner stretch frames.

As for other details of the present invention, materials and alternate related configurations may be employed as within the level of those with skill in the relevant art. The same may hold true with respect to process-based aspects of the invention in terms of additional acts as commonly or logically employed. In addition, though the invention has been described in reference to several examples, optionally incorporating various features, the invention is not to be limited to that which is described or indicated as contemplated with respect to each variation of the invention. Various changes may be made to the invention described and equivalents (whether recited herein or not included for the sake of some brevity) may be substituted without departing from the true spirit and scope of the invention. Any number of the individual parts or subassemblies shown may be integrated in their design. Such changes or others may be undertaken or guided by the principles of design for assembly.

Also, it is contemplated that any optional feature of the inventive variations described may be set forth and claimed independently, or in combination with any one or more of the features described herein. Reference to

a singular item, includes the possibility that there are plural of the same items present. More specifically, as used herein and in the appended claims, the singular forms "a," "an," "said," and "the" include plural referents unless the specifically stated otherwise. In other words, use of the articles allow for "at least
5 one" of the subject item in the description above as well as the claims below. It is further noted that the claims may be drafted to exclude any optional element. As such, this statement is intended to serve as antecedent basis for use of such exclusive terminology as "solely," "only" and the like in connection with the recitation of claim elements, or use of a "negative" limitation. Without the use of
10 such exclusive terminology, the term "comprising" in the claims shall allow for the inclusion of any additional element - - irrespective of whether a given number of elements are enumerated in the claim, or the addition of a feature could be regarded as transforming the nature of an element set forth in the claims. Stated otherwise, unless specifically defined herein, all technical and scientific terms
15 used herein are to be given as broad a commonly understood meaning as possible while maintaining claim validity.

WHAT IS CLAIMED IS:

1. An apparatus comprising:
a frame; and
5 an adhesive applied to at least a portion of the frame,
wherein the adhesive is arranged to bond a pre-strained film to the frame.
2. The apparatus according to Claim 1, wherein the adhesive is a pressure
sensitive adhesive.
- 10 3. The apparatus according to one of Claims 1 and 2, wherein the adhesive
comprises a material selected from the group consisting essentially of silicones,
fluorosilicones, acrylates, polyurethanes, olefins, hydrocarbon rubbers, styrenic
copolymers, epoxies, hot-melt adhesives, pressure sensitive adhesives, thermal
15 curing adhesives, UV curing adhesives, liquid adhesives, and any combinations
thereof.
4. The apparatus according to Claim 1, further comprising a release coating
applied to at least a portion of the frame, wherein the adhesive is applied on top of
20 the release coating.
5. The apparatus according to Claim 4, wherein the release coating comprises
a material selected from the group consisting essentially of epoxy silicone,
fluoropolymer, fluorosilicone, polymer, and polytetrafluoroethylene, mold release,
25 and any combinations thereof.
6. The apparatus according to Claim 4, further comprising an adhesion
promoter, coupling agent, solvent, or etchant to improve the adhesion of release
coating to the frame.

7. The apparatus according to Claim 6, wherein the adhesion promoter comprises a silicone based primer,
8. A method of fabricating a polymer film device, the method comprising:
5 providing the apparatus according to any one of Claims 1 to 7;
providing a film;
stretching the film; and
laminating or bonding the pre-strained film onto the adhesive coating of
the frame.
- 10 9. The method according to Claim 8, further comprising manufacturing the electroactive polymer device on the pre-strained film.
10. The method according to Claim 9, further comprising removing the
15 electroactive polymer devices from the pre-strained film bonded to the frame by the adhesive.
11. The method according to Claim 10, further comprising incorporating at
least a portion of the frame into the electroactive polymer device.
- 20 12. The method according to Claim 8, further comprising applying a release coating onto at least a portion of the frame and applying the adhesive coating on top of the release coating.
- 25 13. The method according to Claim 12, further comprising applying an adhesion promoter to at least a portion of the stretch frame prior to applying the release coating thereon.
14. The method according to Claim 12, further comprising reusing the stretch
30 frame by removing at least a portion of the pre-strained film from the release coating.

15. A method of making a stretch frame, the method comprising:
providing a frame; and
applying a pressure sensitive adhesive on at least a portion of the frame,
- 5
16. The method according to Claim 15, further comprising applying a release coating on at least a portion of the frame prior to applying the pressure sensitive adhesive thereon.
- 10
17. The method according to Claim 16, further comprising applying an adhesion promoter on at least a portion of the frame prior to applying the release coating thereon.

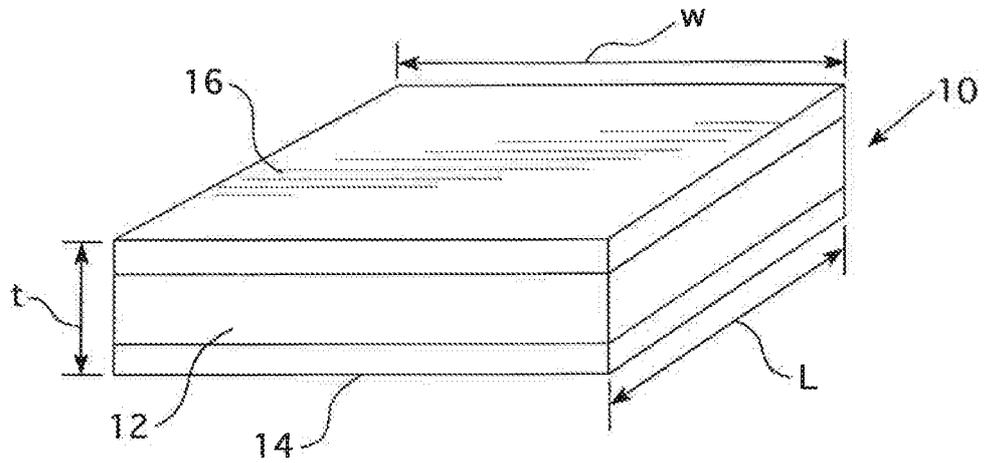


FIG. 1A

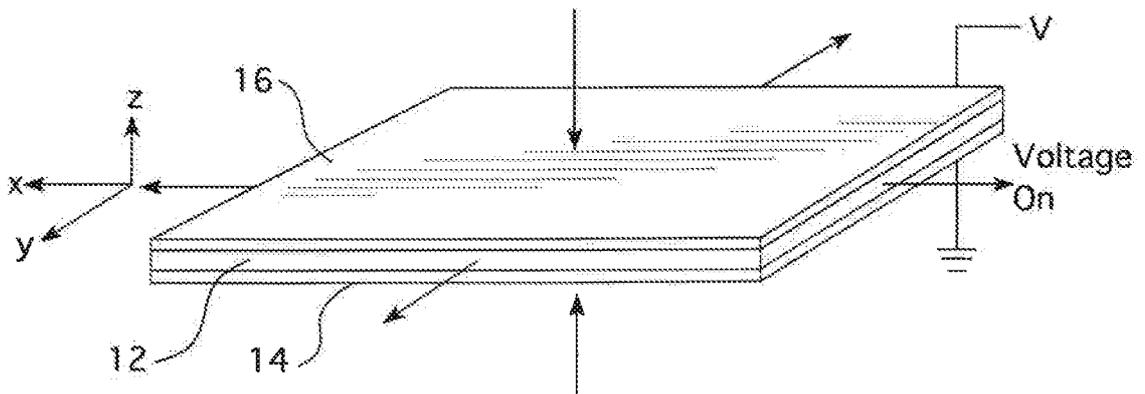


FIG. 1B

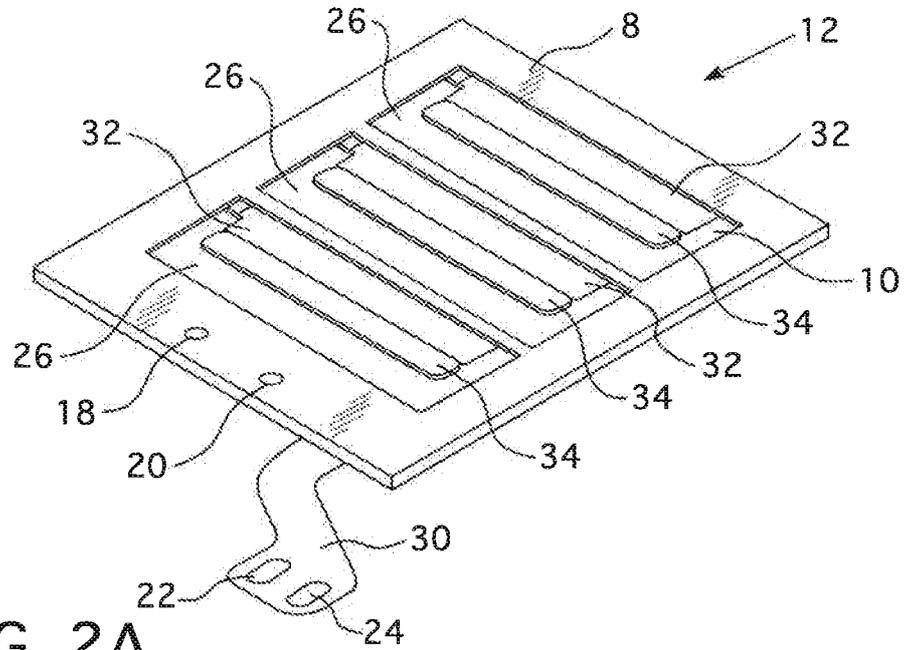


FIG. 2A

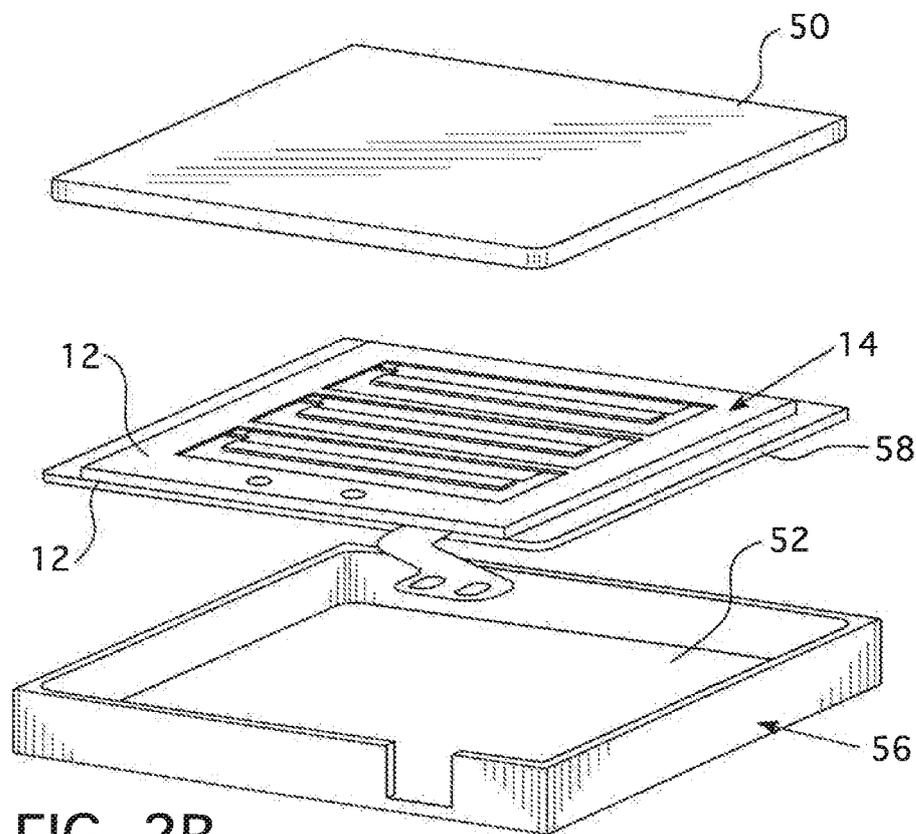


FIG. 2B

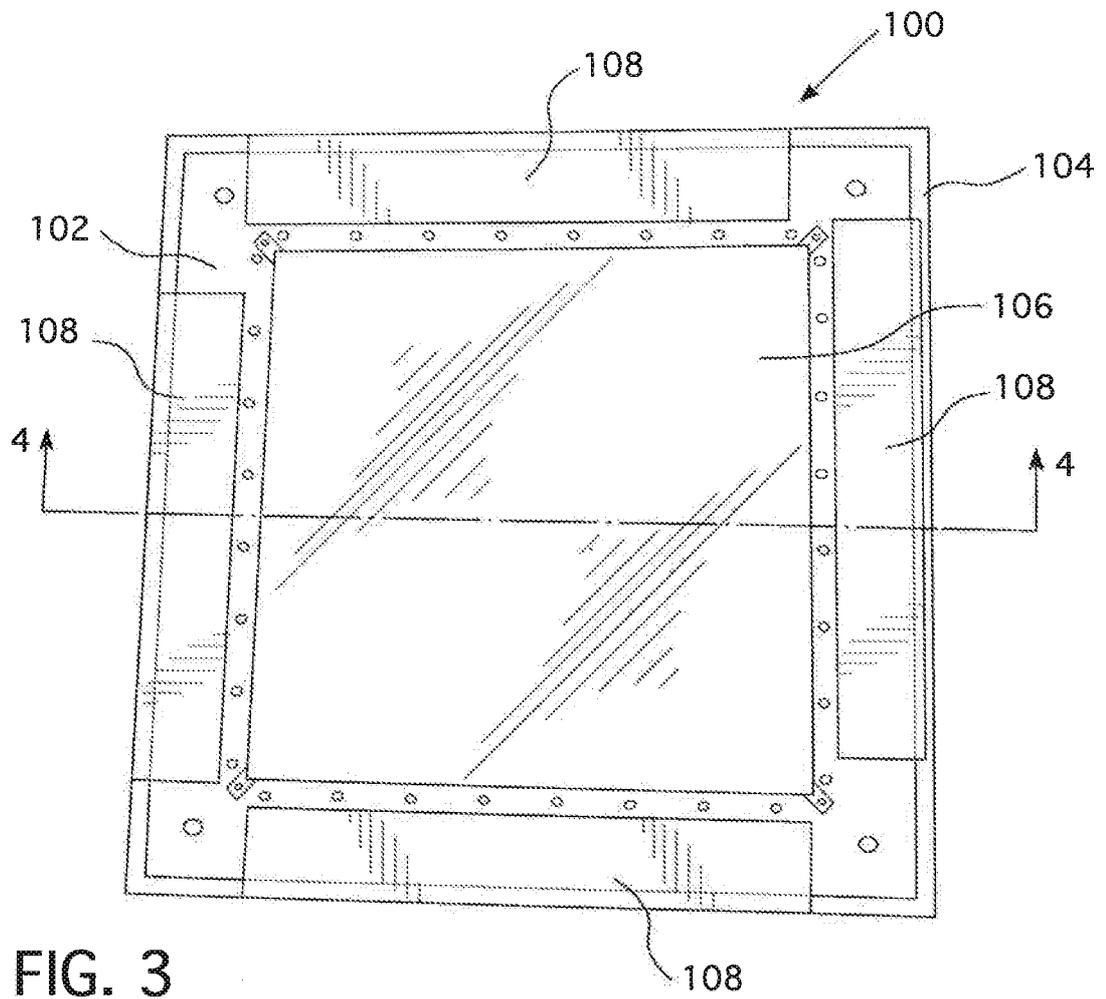


FIG. 3

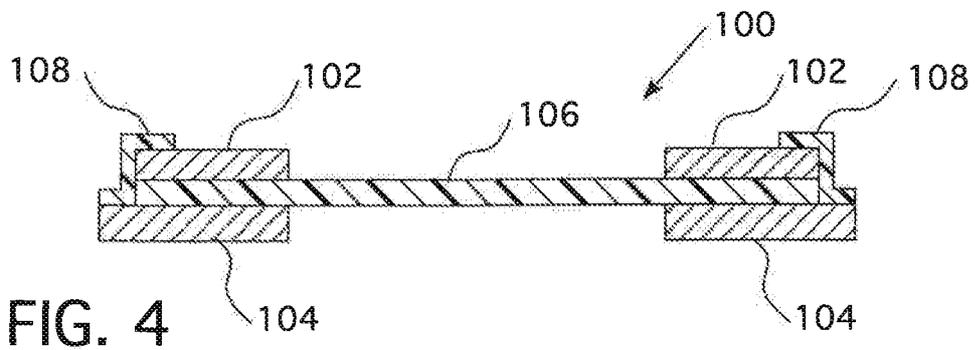


FIG. 4

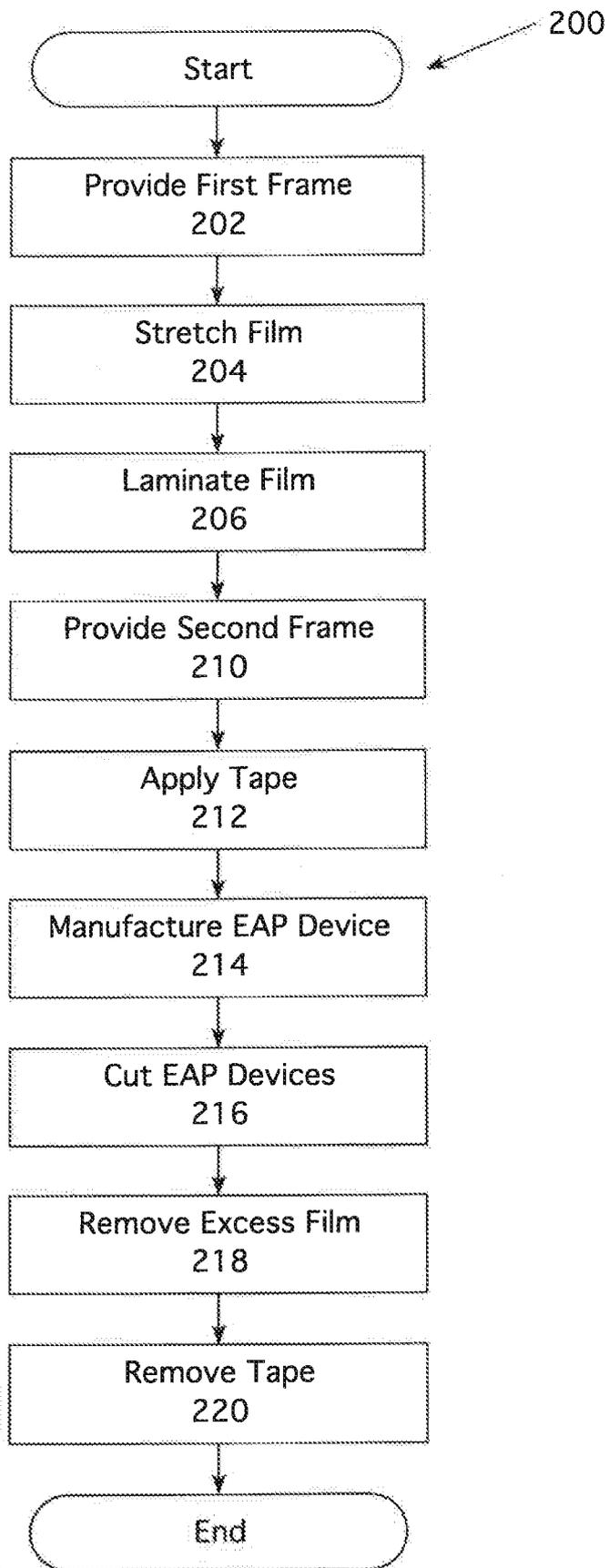


FIG. 5

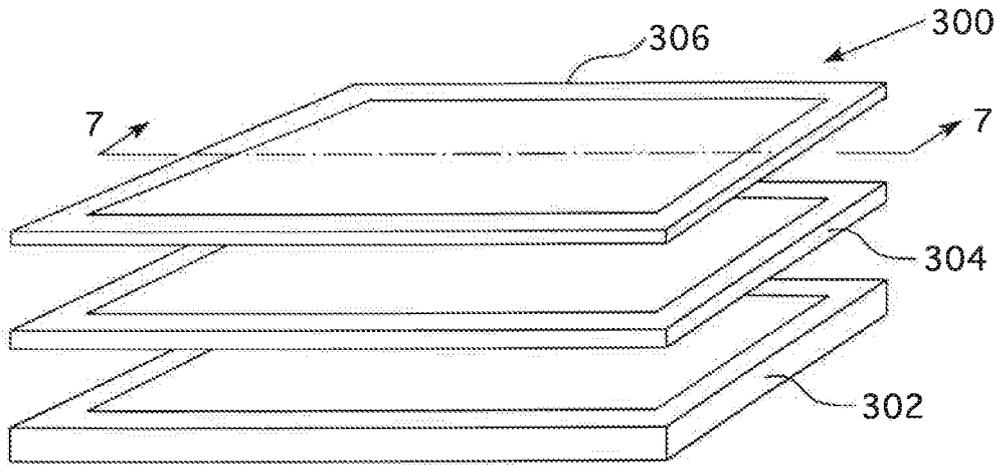


FIG. 6

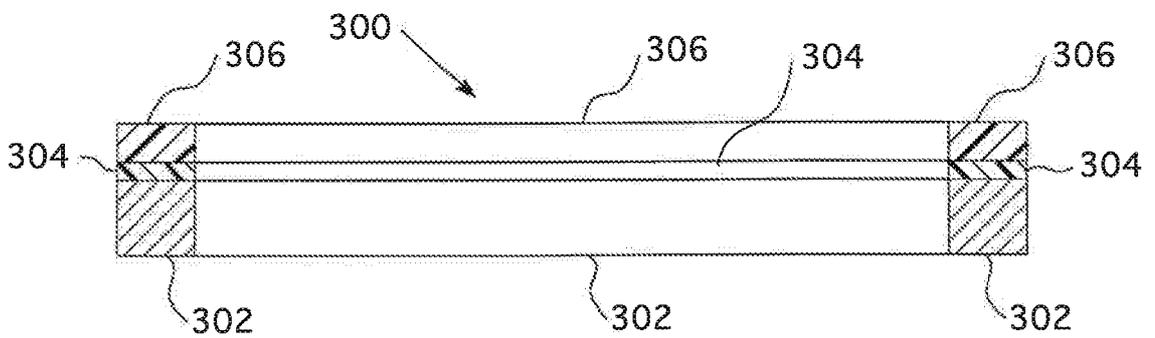


FIG. 7

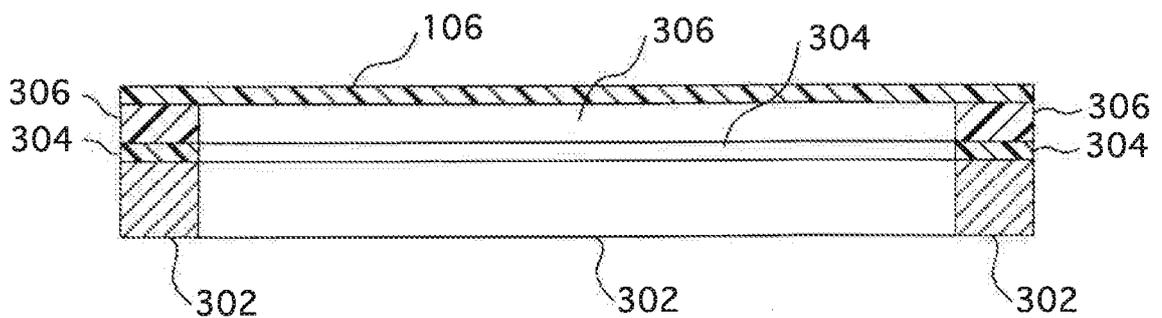


FIG. 8

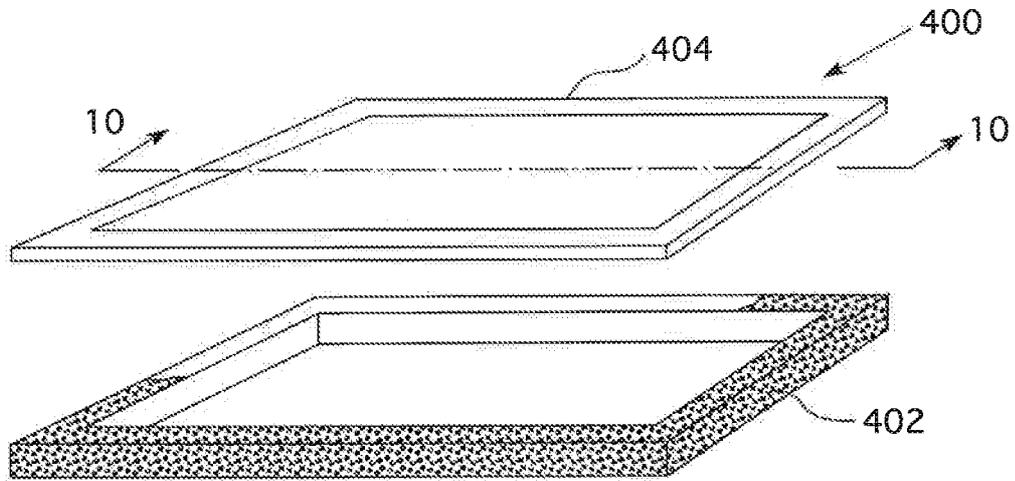


FIG. 9

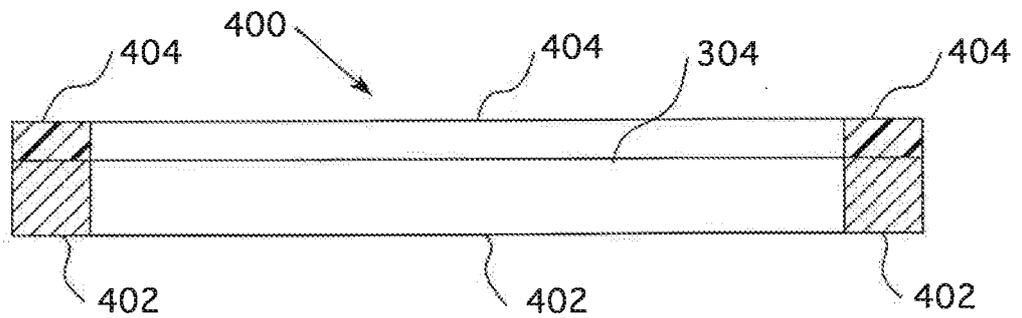


FIG. 10

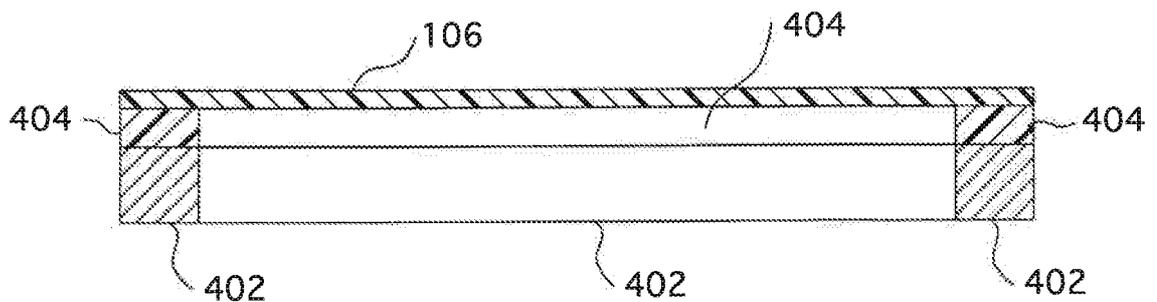


FIG. 11

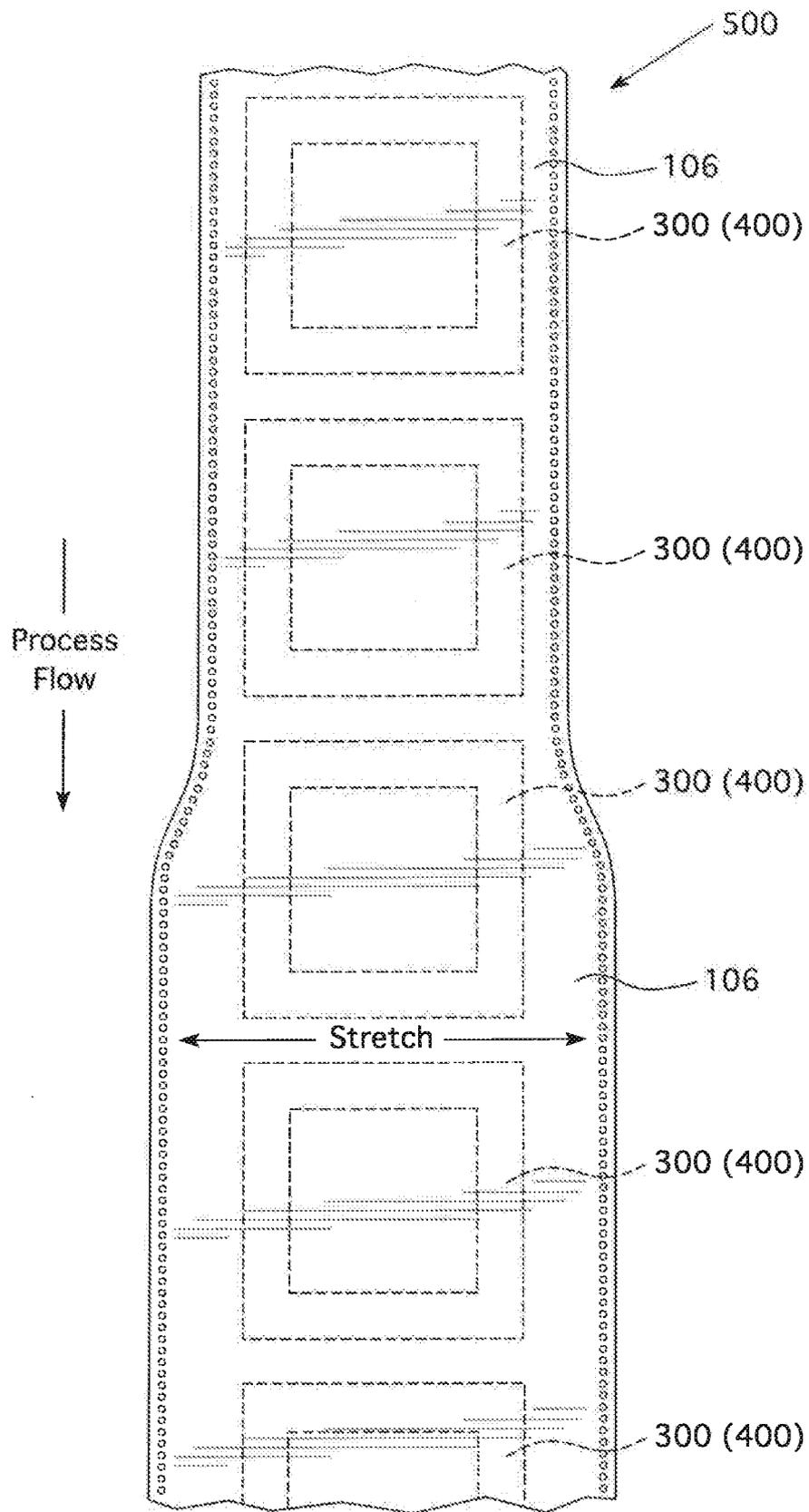


FIG. 12

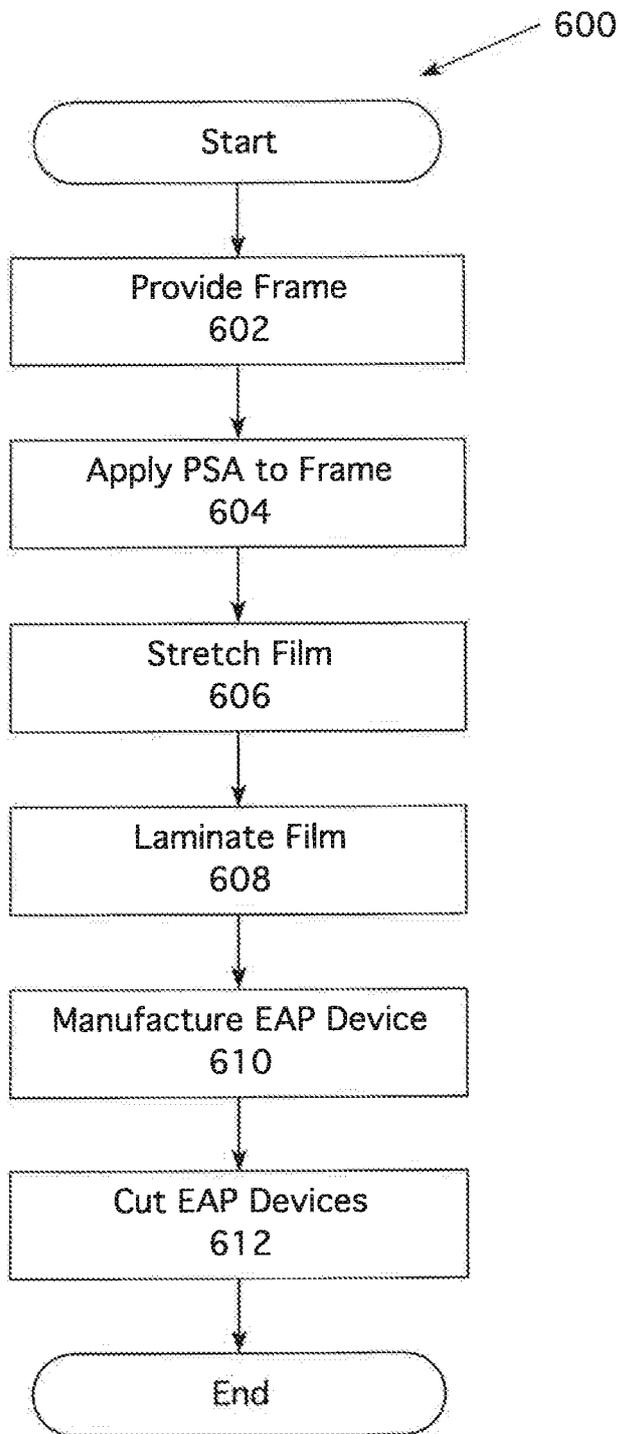


FIG. 13

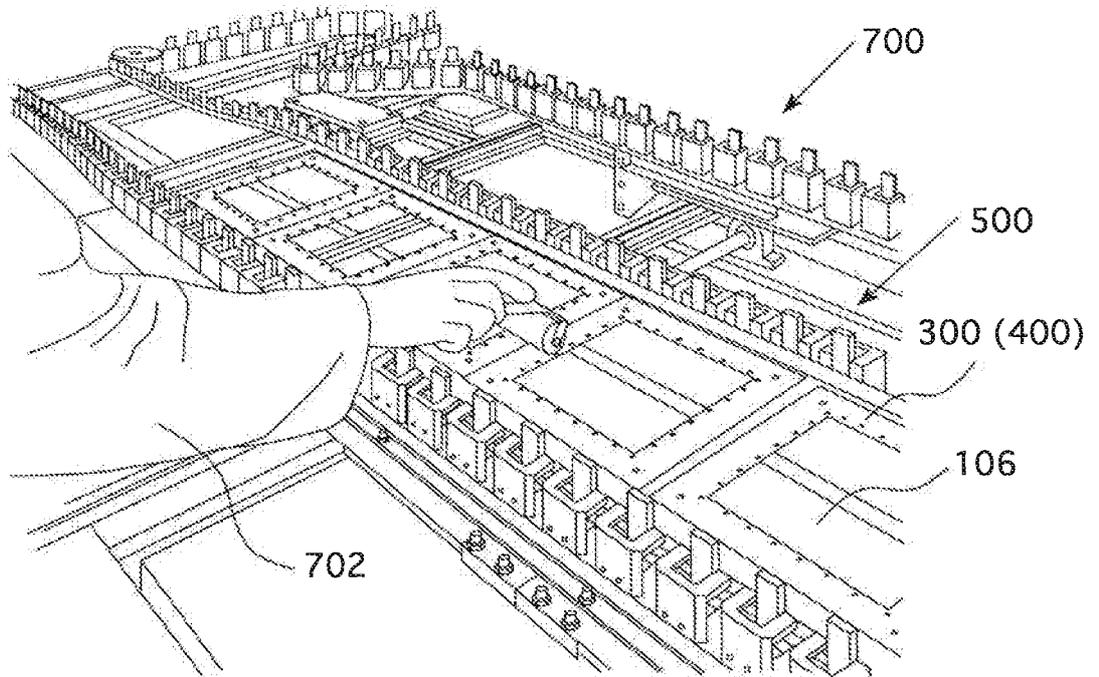


FIG. 14

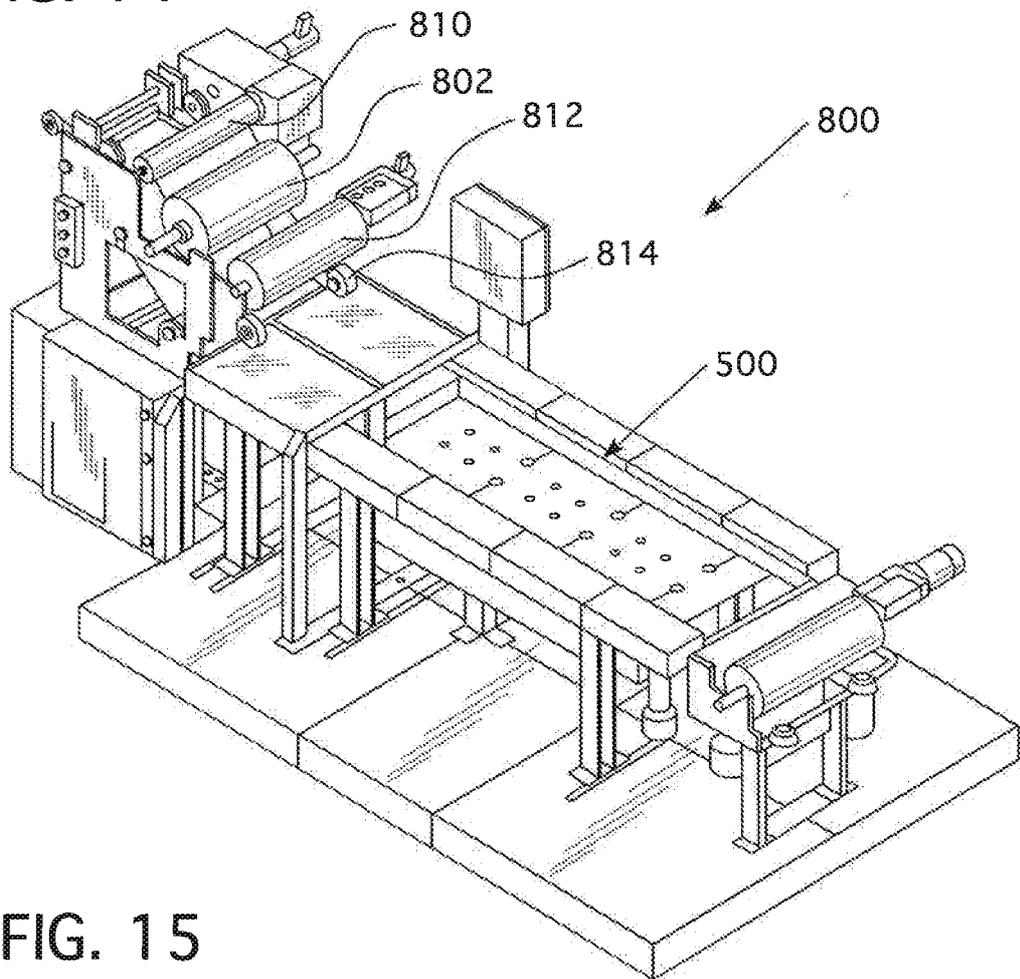


FIG. 15

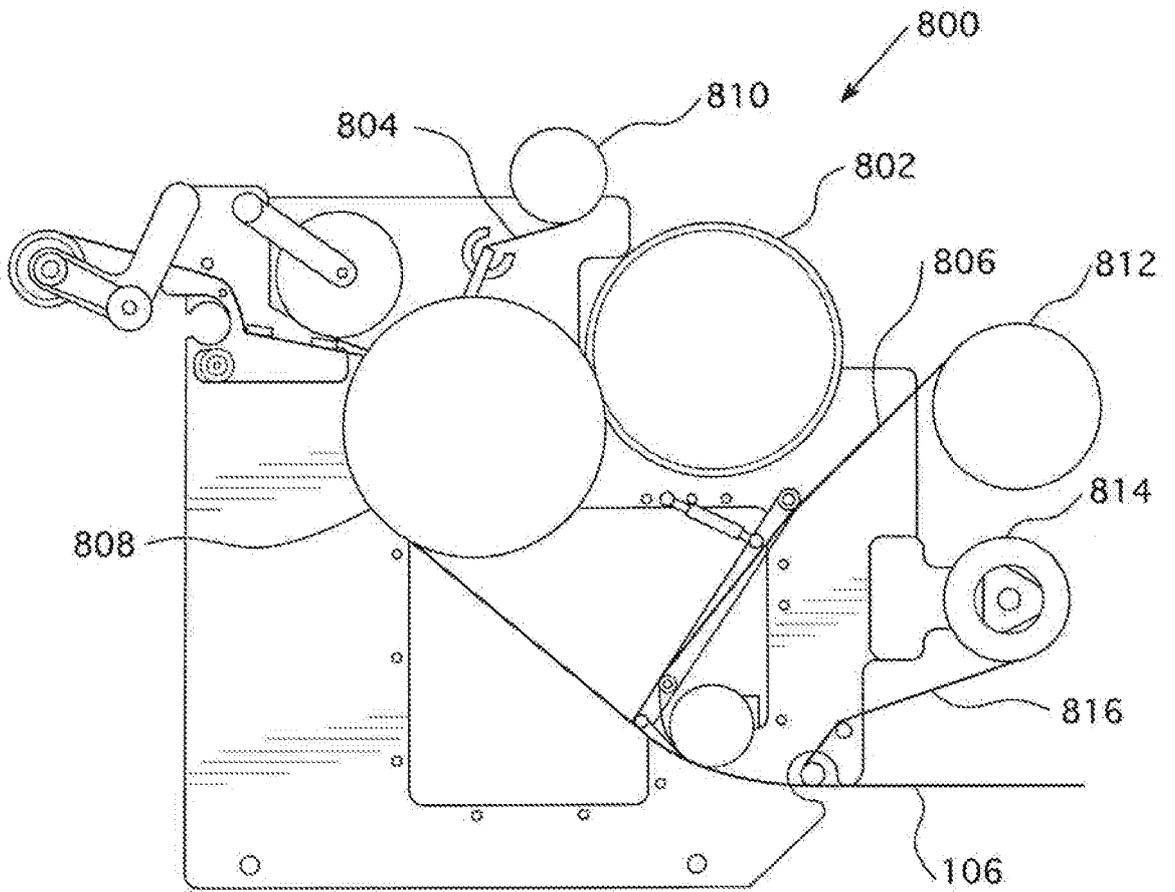


FIG. 16

A. CLASSIFICATION OF SUBJECT MATTER**H01L 41/08(2006.01)i, H04R 17/00(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01L 41/08; H04R 25/00; G03F 1/00; G03F 9/00; B32B 37/02; B32B 38/12; G03F 1/14; H04R 17/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & keywords: frame, adhesive, pre-strained, film, pressure sensitive adhesive, release coating, electroactive polymer device

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A		4-7 ,16 ,17
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A	US 7567681 B2 (RONALD E. PELRINE et al.) 28 July 2009 See abstract ; claim 1; and figures 1A, 1B.	1-7 ,15-17
A	JP 2006-178434 A (ASAHI KASEI ELECTRONICS CO. , LTD.) 06 July 2006 See abstract ; claims 1, 2; and figures 1, 2.	1-7 ,15-17

II Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

13 November 2013 (13.11.2013)

Date of mailing of the international search report

15 November 2013 (15.11.2013)

Name and mailing address of the ISA/KR


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