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[54] **POLYMER-LITHIUM BATTERIES AND IMPROVED METHODS FOR MANUFACTURING BATTERIES**

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[52] **U.S. Cl.** **429/124**; 429/130; 429/162; 429/246; 429/306; 29/623.3; 29/623.4

[58] **Field of Search** 429/124, 127, 429/130, 162, 192, 246, 306; 29/623.3, 623.4, 623.5

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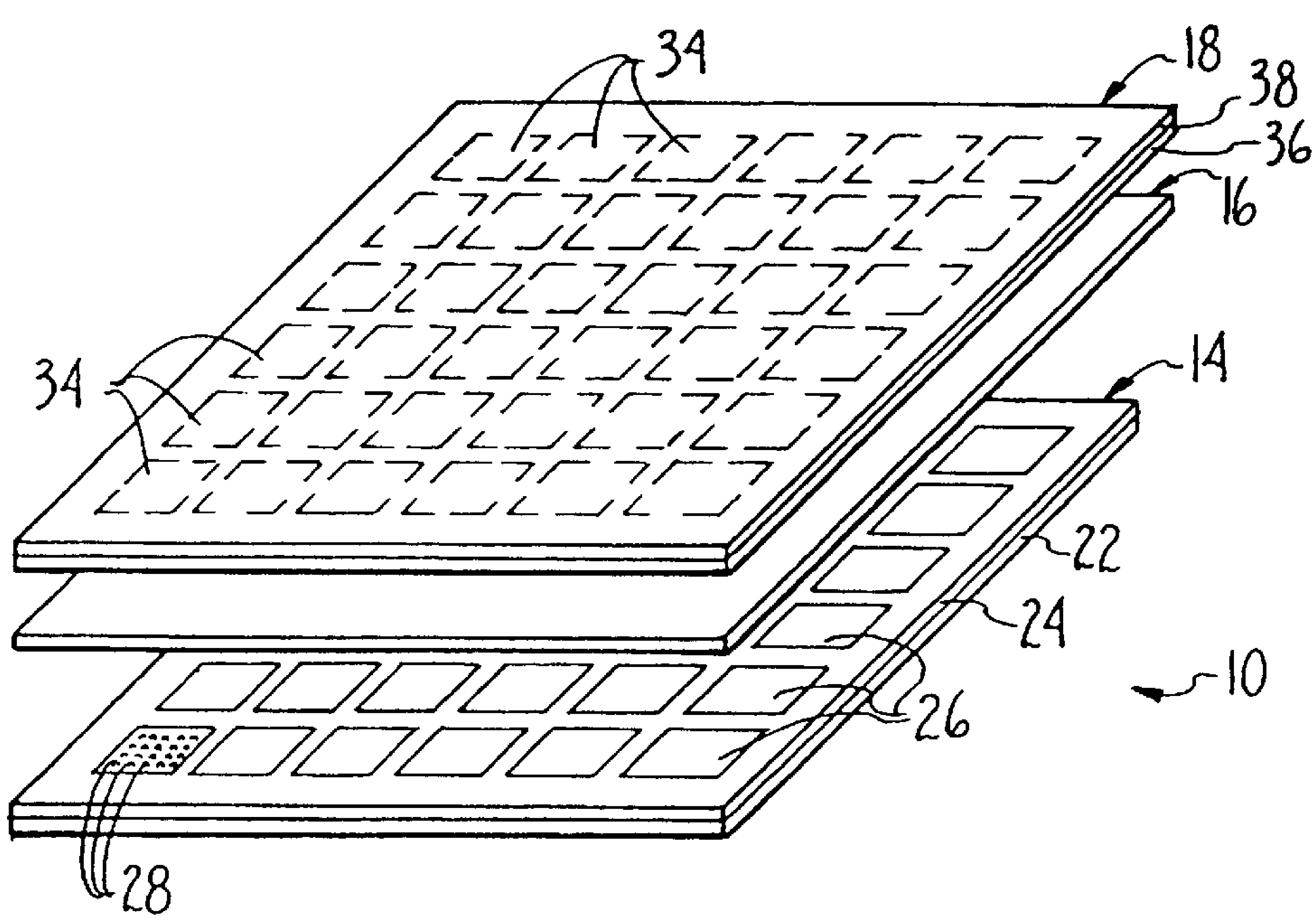
Attorney, Agent, or Firm—Trask, Britt & Rossa

[57] **ABSTRACT**

Improved polymer batteries and improved methods of manufacturing such polymer batteries are provided. One improved method of manufacture involves the formation of a laminated array structure that includes a number of individual battery cells. After formation of the laminated array the individual batteries are singulated from the array by cutting, shearing or stamping. Other manufacturing improvements include the use of a printing process (e.g. stenciling) to form the cathodes, the use of permanent mask layers to contain and insulate the cathodes and anodes, and the use of a molten lithium deposition process for forming the anodes.

70 Claims, 5 Drawing Sheets



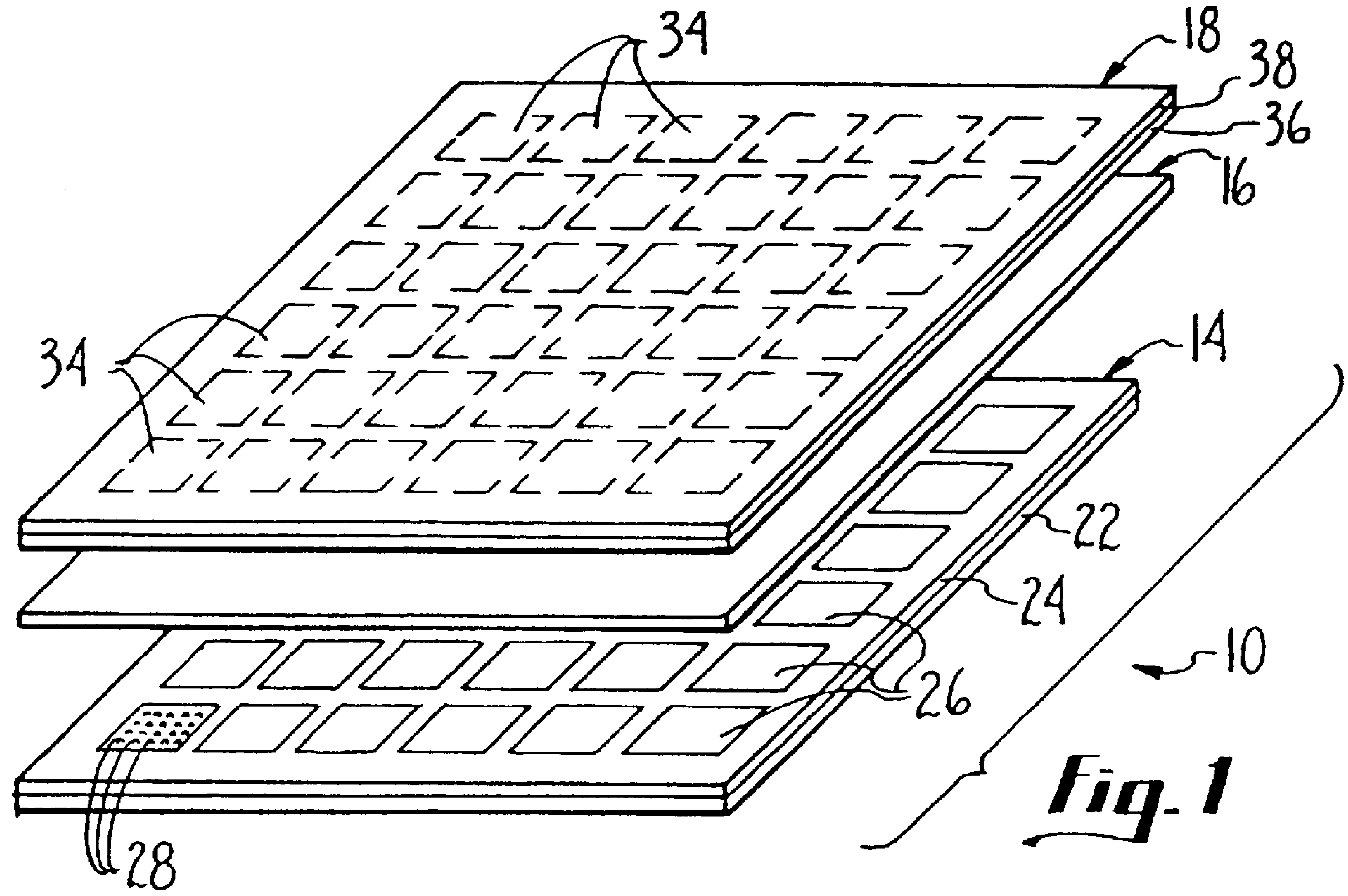


Fig. 1

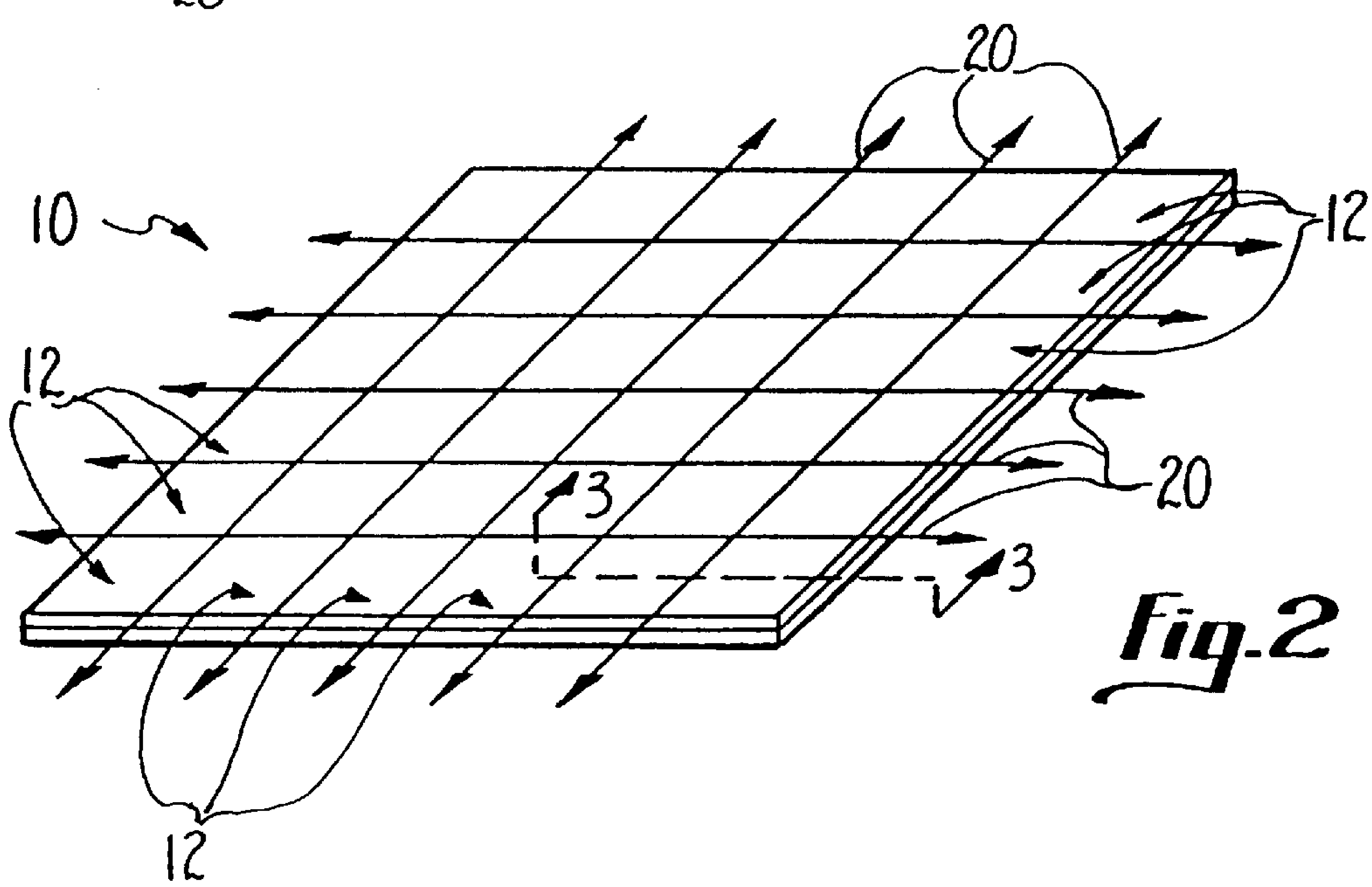
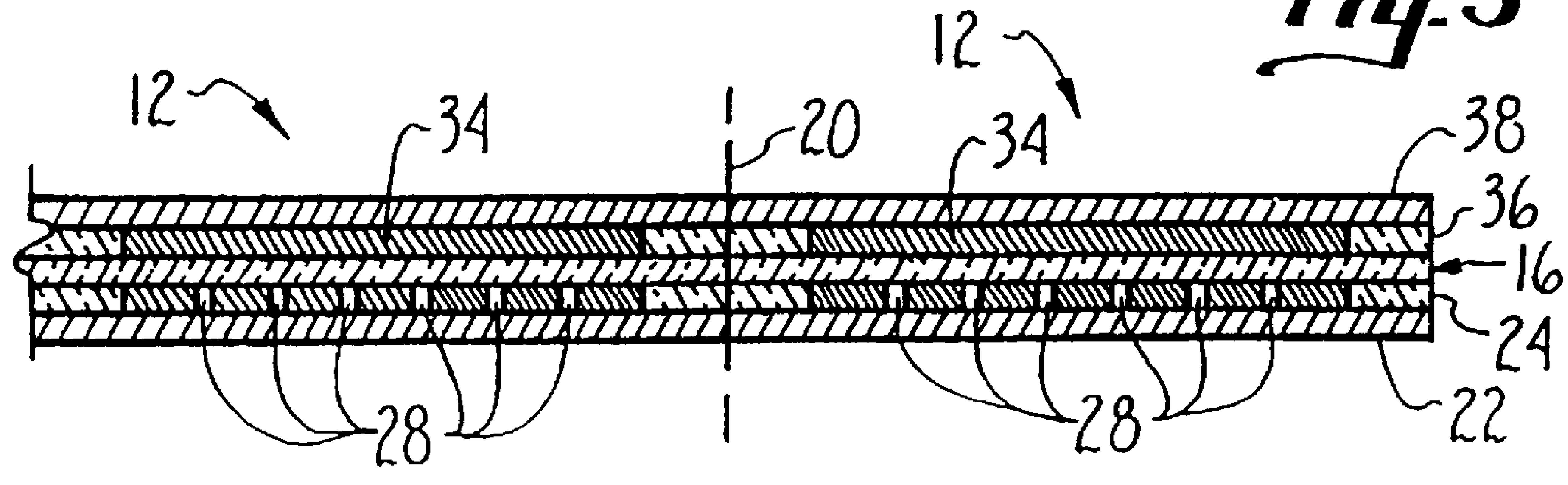


Fig. 2

Fig. 3



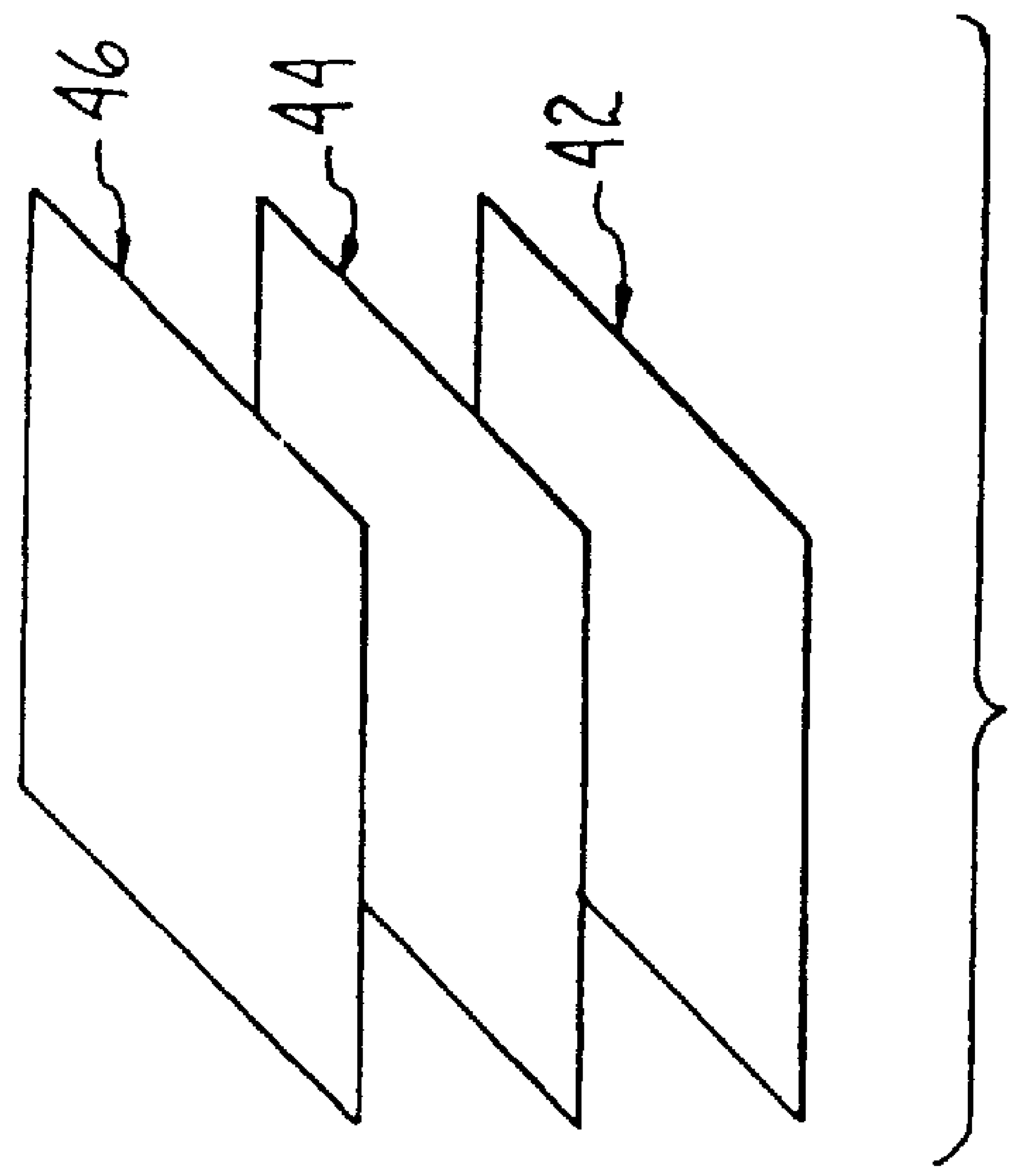


Fig. 4A

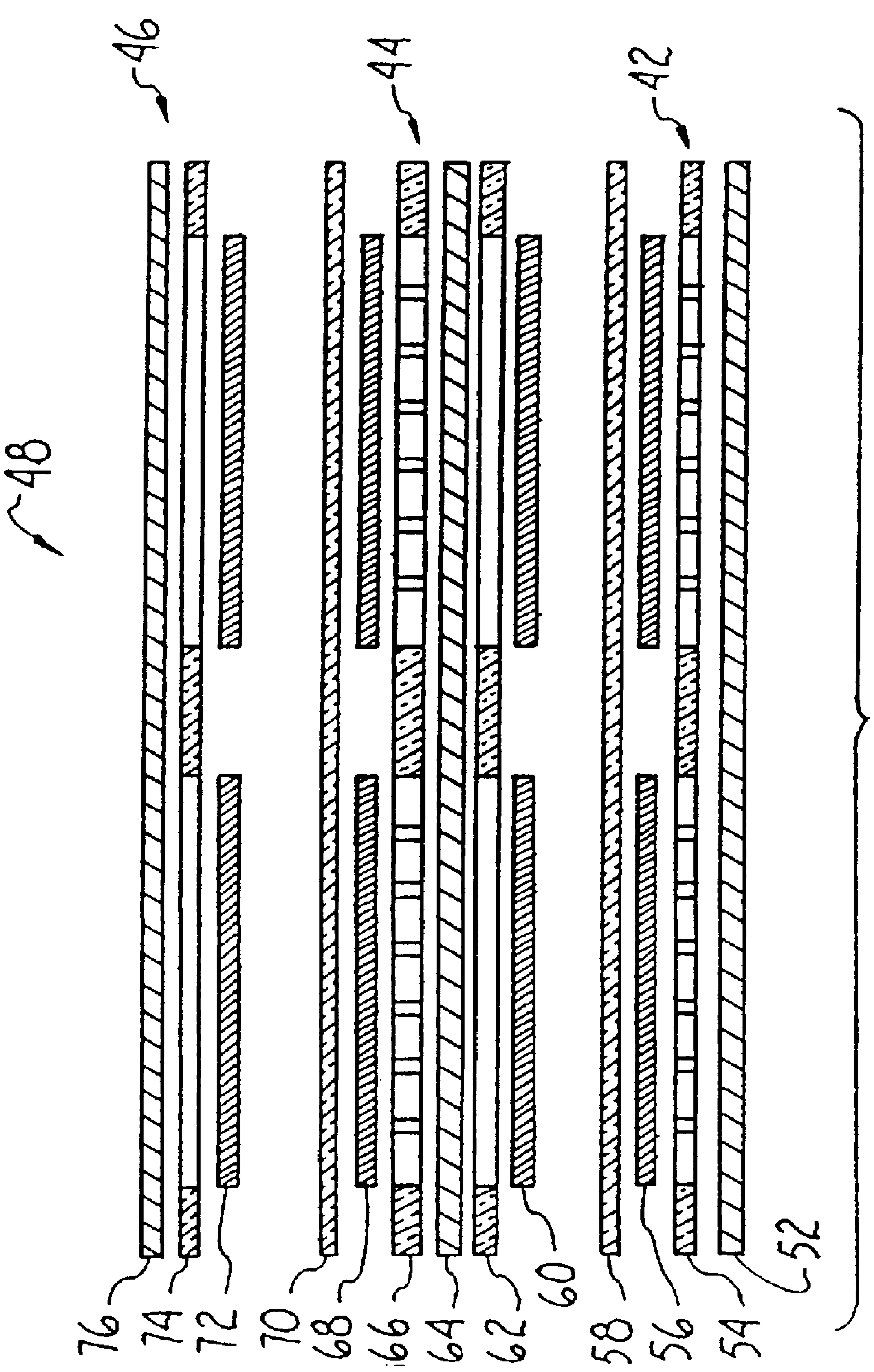


Fig. 4

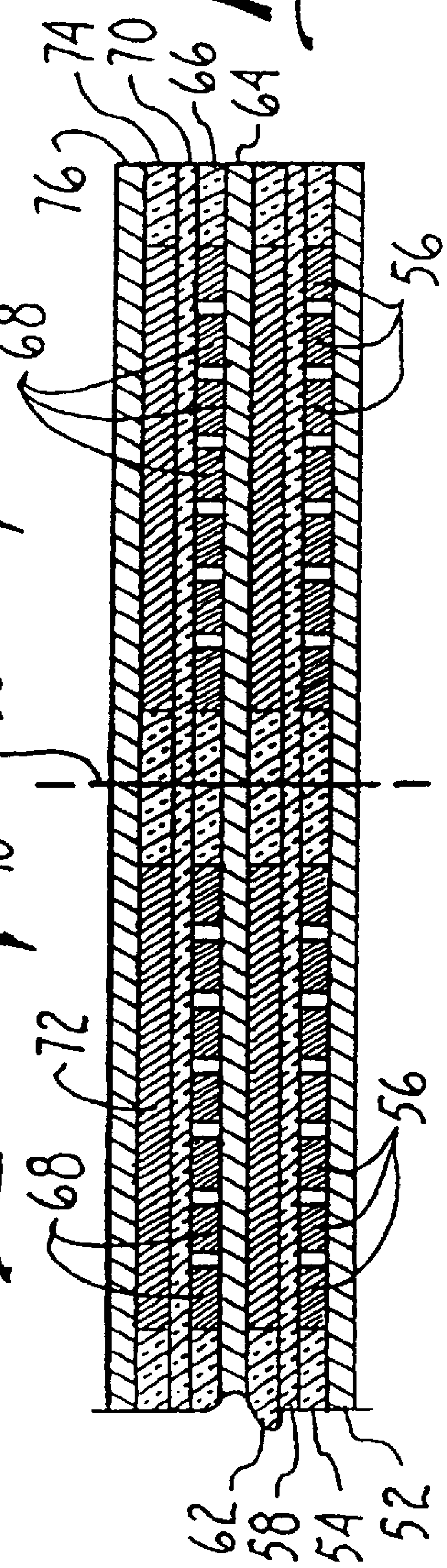


Fig. 5

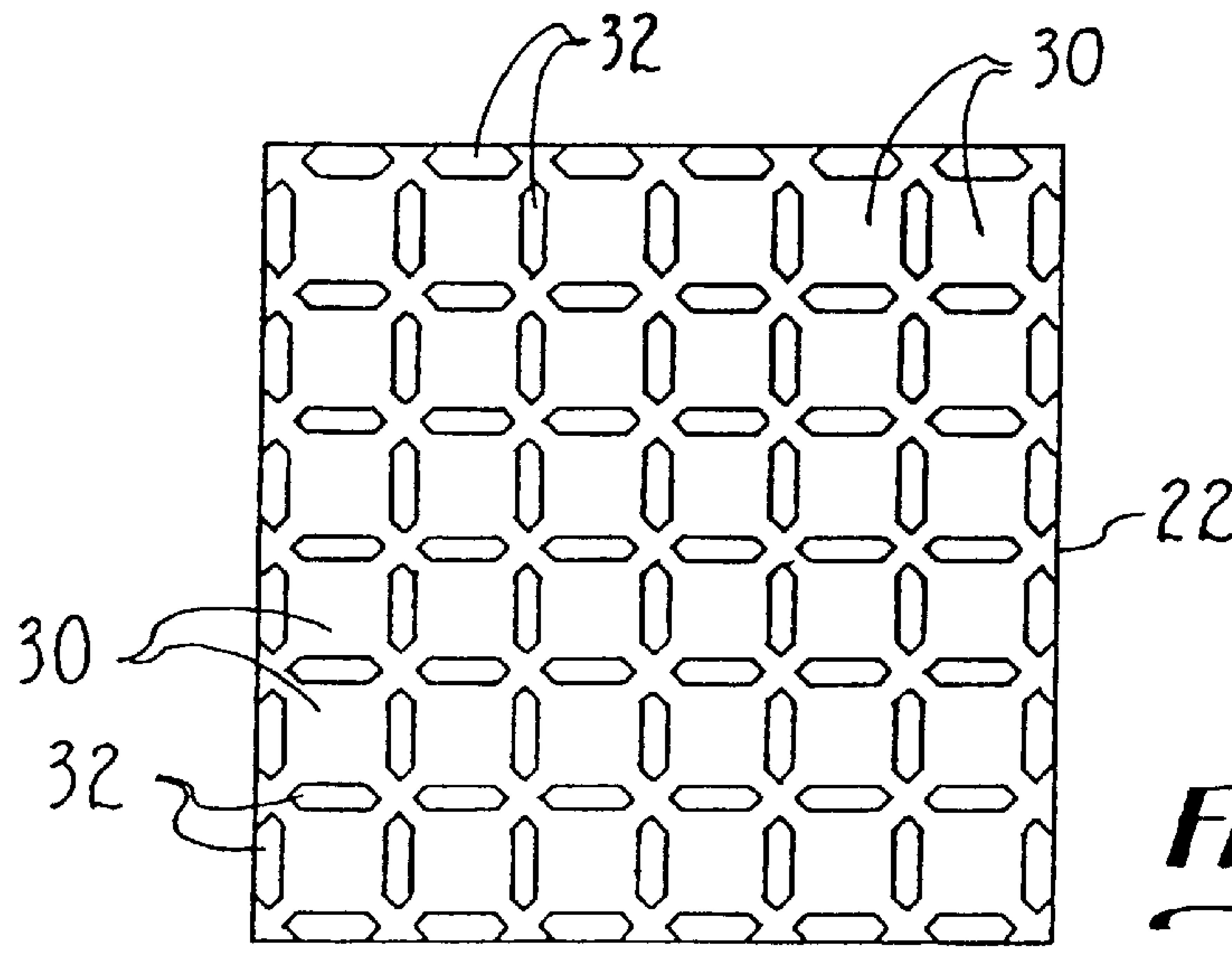


Fig. 6A

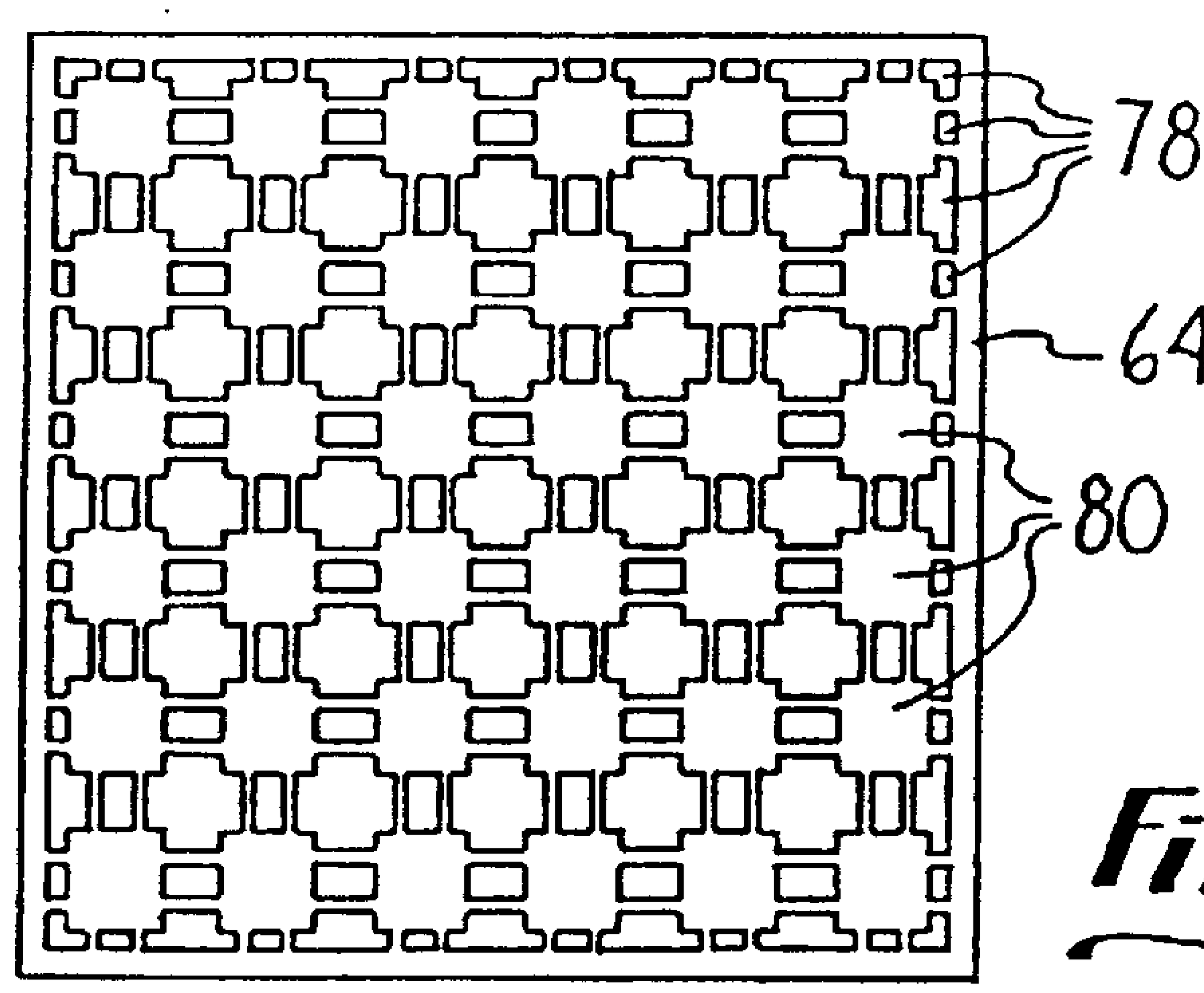


Fig. 6B

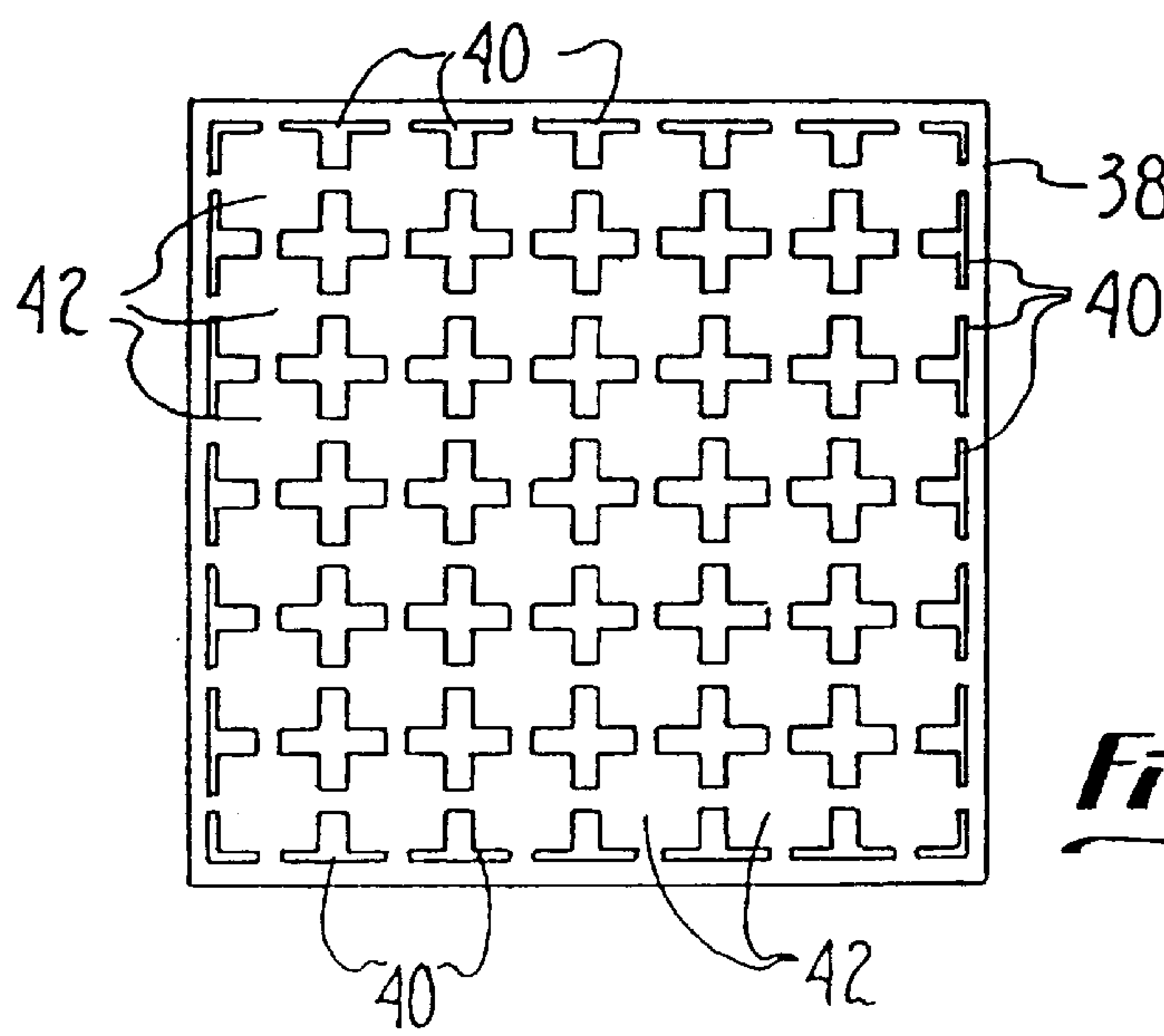


Fig. 6C

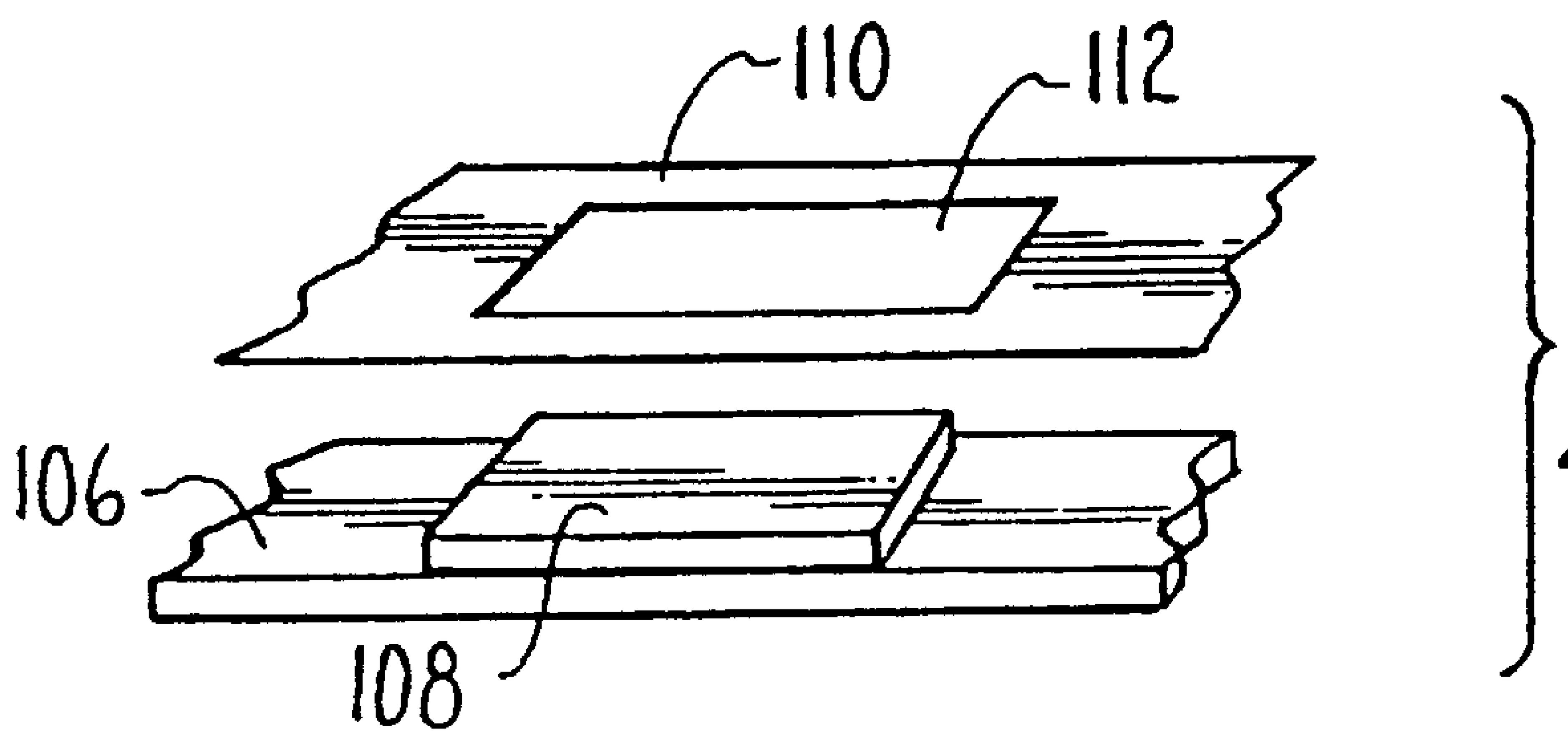


Fig. 7

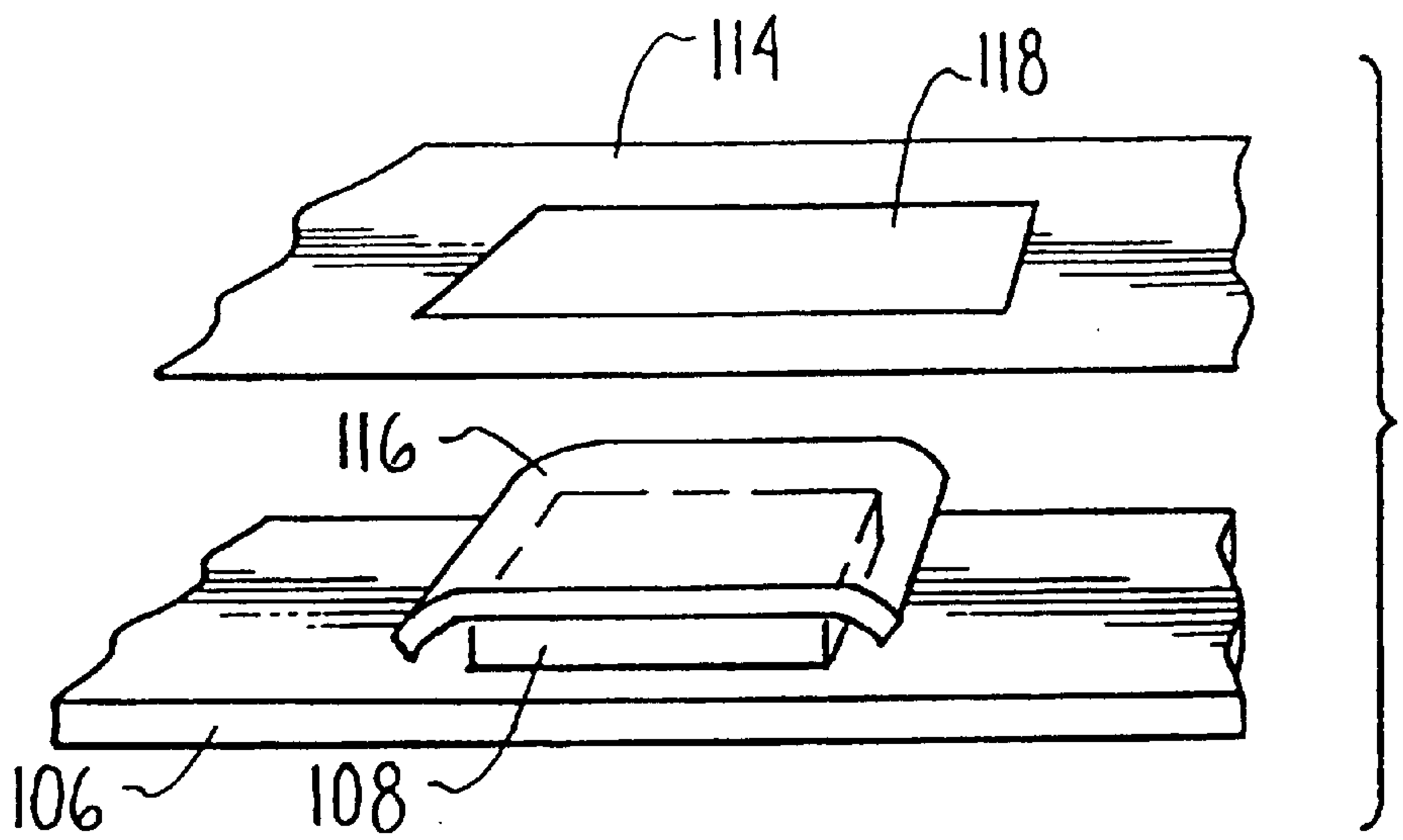


Fig. 8

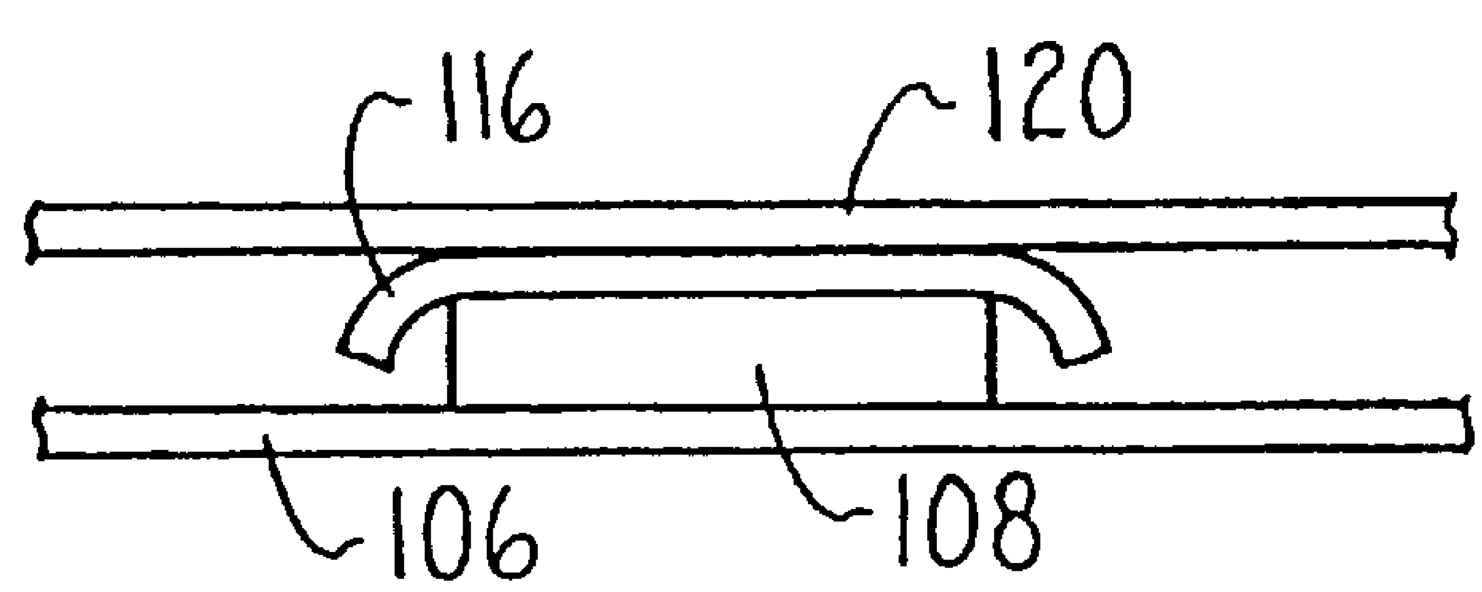


Fig. 9

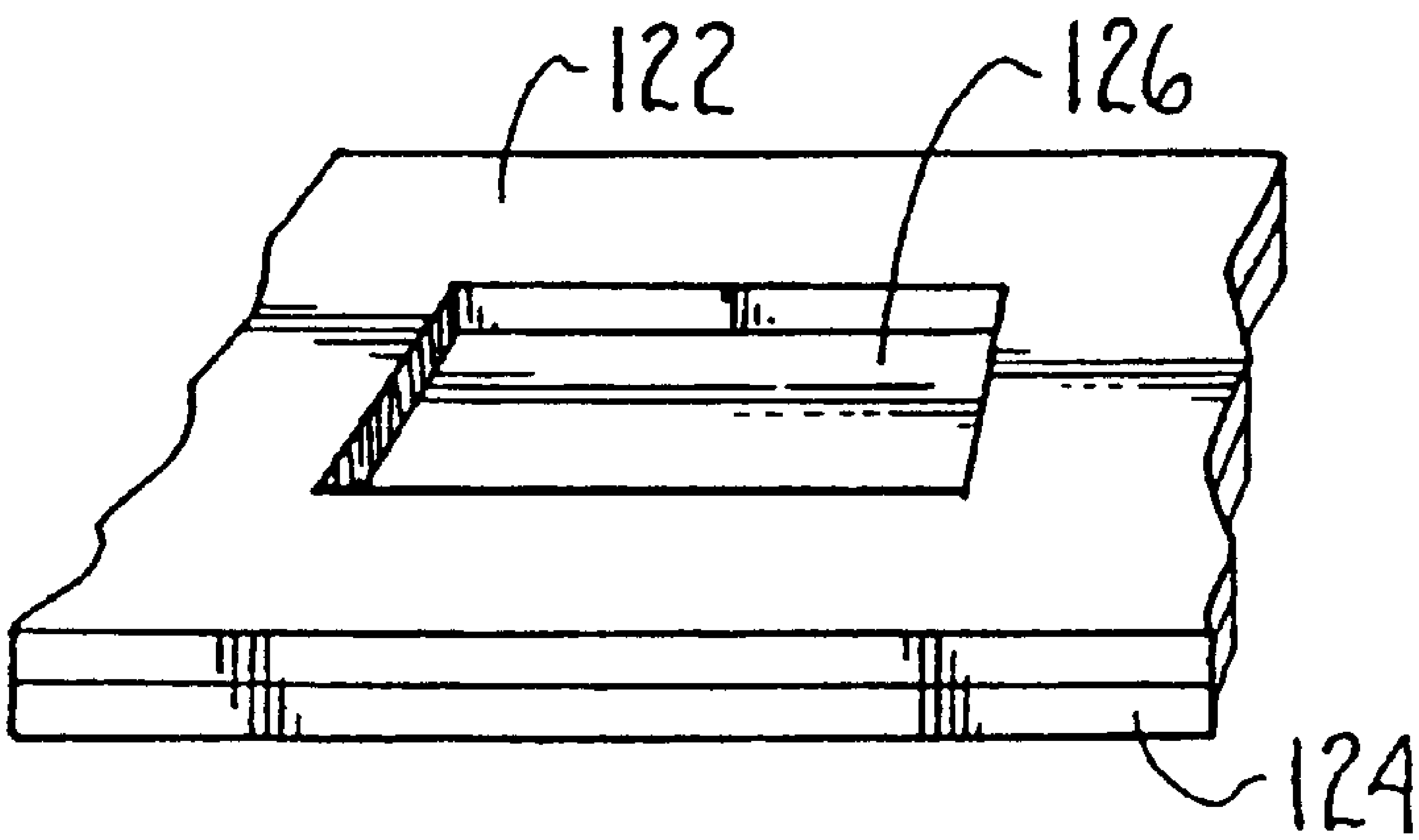


Fig. 10A

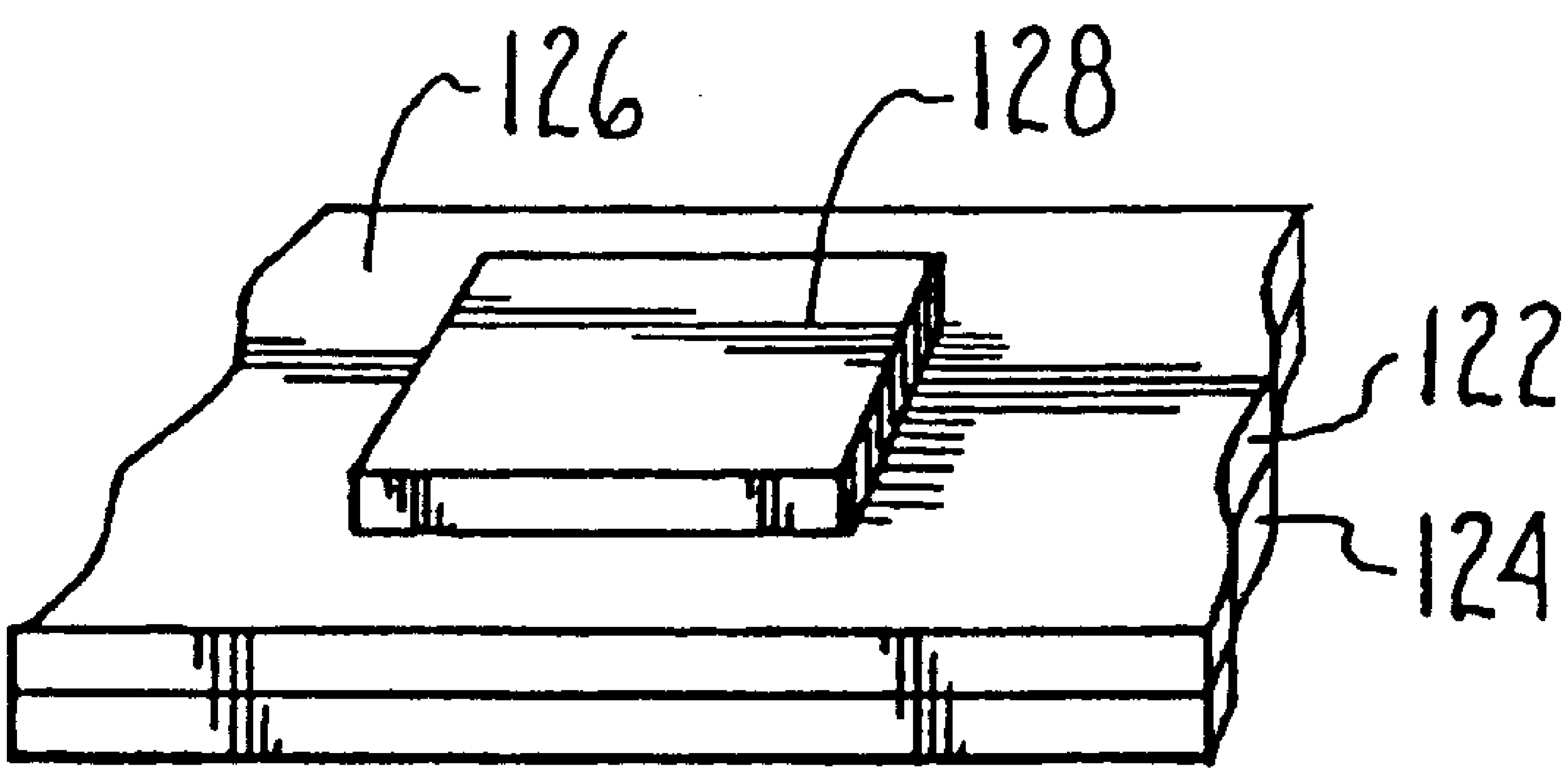


Fig. 10B

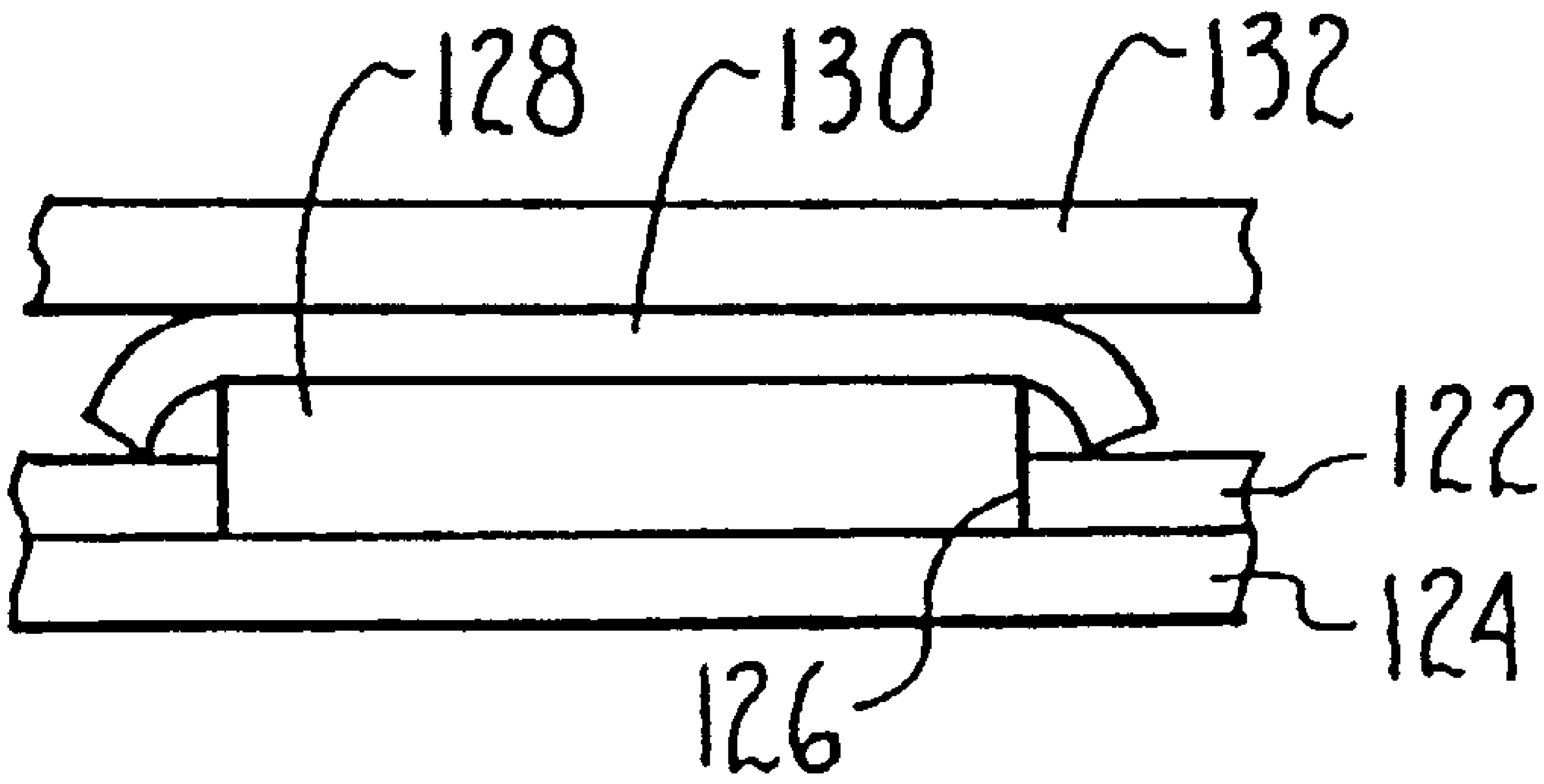


Fig. 10C

POLYMER-LITHIUM BATTERIES AND IMPROVED METHODS FOR MANUFACTURING BATTERIES

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

CROSS REFERENCES TO RELATED APPLICATIONS

This application is related to copending application filed Jun. 2, 1993 and entitled "Package and Method for Fabricating a Battery Employing An Alkali-Metal Anode and Polymer Film Inks".

FIELD OF THE INVENTION

This invention relates generally to batteries and more particularly to thin batteries constructed with polymer films. Specifically, the invention is directed to improved polymer batteries and improved methods for making polymer batteries.

BACKGROUND OF THE INVENTION

Advancements in semiconductor technology have led to the production of large scale integrated circuits which have brought about a revolution in the electronics industry. Microelectronic components are now widely used in the production of a variety of electronic devices (e.g. portable computers, calculators, watches, cordless telephones, radios, tape recorders, security systems). Development of such portable electronic devices has brought about the evolution of batteries as miniature power supplies. This new generation of batteries must produce higher energy per unit volume and superior discharge characteristics as compared to traditional batteries.

The technology related to thin solid state batteries in particular, is being increasingly developed. Typically this type of thin battery is constructed with an alkali metal anode, a non-aqueous electrolyte, and cathodes of nonstoichiometric compounds. Lithium is most often used as an anode material because it has a low atomic weight and is highly electronegative. Such thin batteries have a high energy density, a long shelf life and operate efficiently over a wide range of temperatures.

In the past thin batteries have been manufactured by forming and assembling the anode, electrolyte, and cathode of a battery cell as separate components. This is a relatively labor intensive procedure that involves the intricate assembly of a number of discrete components. In particular, the stamping and handling of individual discs of lithium is costly and difficult, because lithium is expensive and highly reactive.

This has led to the development of continuous manufacturing processes in which the components of a thin battery are constructed using polymeric films. Such thin polymer batteries may include anodes, electrolytes and cathodes formed as a continuous film of a polymeric material. As an example, U.S. Pat. No. 4,621,035 to Bruder, describes a lithium battery that includes a lithium anode formed by laminating lithium to a conductive polymer.

These polymer battery components are typically manufactured by extruding or drawing down suitable materials, such as lithium, onto a flexible polymeric material. In general, this is a relatively complex manufacturing technique which requires relatively complicated and expensive manufacturing equipment. Furthermore, many of the difficulties in manufacturing such polymer batteries are related to handling and assembling the lithium anodes, the cathodic polymers and the electrolytic polymers. These problems are compounded because most prior art manufacturing procedures typically involve the formation of one battery cell at a time.

The present invention is directed to improved polymeric battery structures and improved methods for assembling such polymeric batteries. These improvements lower the manufacturing costs, increase the manufacturing efficiencies and provide improved batteries.

Accordingly, it is an object of the present invention to provide improved polymeric battery structures and particularly improved polymer-lithium batteries. It is a further object of the present invention to provide improved methods for manufacturing polymeric batteries. It is a further object of the present invention to provide improved battery structures that can be manufactured in multiple units and then singulated into individual batteries. It is yet another object of the present invention to provide improved thin polymeric batteries that are high in energy, reliable, light weight and relatively inexpensive to manufacture.

SUMMARY OF THE INVENTION

In accordance with the present invention, improved polymer batteries and improved methods for manufacturing polymer batteries are provided. In an illustrative method of manufacture, a laminated array structure having multiple battery cells (e.g. thirty six) is assembled. The laminated array may be formed by assembling separate stacks for the different components of a battery. For a single cell battery these separate stacks may include, a cathode stack, a separator/electrolyte stack, and an anode stack. Following formation of the laminated array, the individual battery cells are singulated from the array to form the individual batteries.

The laminated array includes multiple battery cells formed by a layered structure that includes; a cathode substrate layer including a patterned cathode mask; a cathode layer formed by depositing a patterned cathodic material onto the cathode substrate layer to form cathodes insulated by the cathode mask; a separator/electrolyte layer in contact with the cathode layer; an anode substrate layer including a patterned anode mask; and an anode layer in contact with the separator/electrolyte layer formed by applying a molten anode material such as lithium to an anode substrate to form anodes separated by the anode mask. Following assembly of the laminated array, the individual batteries may be singulated from the array by a suitable technique such as cutting, shearing or die stamping.

The individual batteries have a laminated structure that includes a cathode substrate (i.e. a current collector), a cathode supported and insulated by the cathodic mask, a separator/electrolyte layer, an anode supported and insulated by the anode mask, and an anode substrate. Furthermore, the laminated array my be formed with more than one stack of cells (e.g. base stack, center stack, top stack) to form a stacked or multi-cell battery structure which provides higher battery voltages.

Such a method of manufacturing batteries using a laminated array and the resultant laminated battery structures are characterized by the following novel and improved features:

1. Discrete, deposited patterns of cathode material (in an array form) are used to minimize electrical shorting of the anode to the cathode during formation of individual battery

cells and singulation of the individual battery cells from the array. A preferred method of depositing the cathode material is using a printing process such as pin transfer, screen or stencil printing.

2. The use of permanent mask layers in battery cell fabrication to minimize electrical shorting during formation and singulation of the individual battery cells.

3. The use of permanent mask layers in battery cell fabrication to act as a containment system for the cathode and anode materials.

4. The use of an integral support system (i.e. “studs” provided by the mask layers) that can prevent the separator/electrolyte material from being compressed or pushed into contact with the current collector or displacing the cathode material. This is particularly advantageous on larger or more flexible cells.

5. Staggered, etched or die cut patterns can be used for the anode and cathode substrates (i.e. current collectors) to prevent or minimize electrical shorting during battery cell formation and singulation of the batteries from the array.

6. A thin film of molten lithium (e.g. lithium solder) may be deposited onto a polymer or metallic support film, in either a solid or a discrete pattern (through the use of masks and/or patterned support films) for use as an anode material in polymer-lithium batteries.

7. A higher voltage, “stacked” array of battery cells may be produced using mask layers (or patterning both sides of a single support structure) such that lithium can be clad to one side and the cathode material deposited on the opposite side.

In an alternate embodiment of the invention, a single cell battery structure may be formed by using stenciling techniques instead of conventional extrusion techniques. As an example, a cathode material may be stenciled onto a current collector layer (e.g. copper) using a first stencil. Next, a second stencil slightly larger than the first, and thicker, can be placed over the cathode material pattern without touching it, and an electrolyte layer can be drawn across the cathode and deposited. Next, an anode material can be applied to the electrolyte layer to complete the battery structure.

These and other objects, features and advantages of the invention will be apparent from the following more particular description of the preferred embodiments of the invention as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an exploded perspective view of a laminated array constructed in accordance with the invention that contains multiple battery cells that will be singulated from the array to form individual batteries;

FIG. **2** is a perspective view of the assembled laminated array showing the singulation step for separating the individual battery cells to form a number of individual batteries;

FIG. **3** is a partial cross sectional view through the laminated array taken along section line **3**—**3** of FIG. **2** showing adjacent battery cells prior to singular ion of the battery cells;

FIG. **4** is an exploded cross sectional view showing the construction of adjacent cells of a laminated array constructed in accordance with the invention for a stacked battery configuration;

FIG. **4**A is an exploded perspective view showing the assembly of the separate panels of a laminated array constructed in accordance with the invent ion for a stacked battery configuration;

FIG. **5** is a partial cross sectional view showing adjacent cells of the laminated array shown in FIG. **4** after assembly;

FIG. **6**A shows a suitable pattern for a cathode substrate layer for the laminated array shown in FIGS. **4** and **5**;

FIG. **6**B shows a suitable pattern for a separator layer for the laminated array shown in FIGS. **4** and **5**;

FIG. **6**C shows a suitable pattern for an anode substrate layer for the laminated array shown in FIGS. **4** and **5**;

FIGS. **7**, **8**, and **9** are perspective views showing the assembly of a battery cell using stenciling techniques; and

FIGS. **10**A–**10**C are perspective views showing the assembly of a battery cell constructed using stenciling techniques.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIGS. **1**–**3**, the assembly of a laminated array **10** constructed in accordance with the invention is shown. The laminated array **10** includes a plurality of separate battery cells **12** (FIGS. **2** and **3**) that upon formation of the laminated array **10** are singulated to form a plurality of individual batteries. In the illustrative embodiment the laminated array **10** has a square shape and is formed with thirty six separate battery cells **12**. Alternately the laminated array may include a lesser or greater number of battery cells.

As shown in FIG. **1**, the laminated array **10** is formed in three separate stacks including, a cathode stack **14**, a separator/electrolyte stack **16** and an anode stack **18**. These stacks **14**, **16**, **18** can be assembled separately and then lightly pressed together to complete the laminated array **10**. The individual battery cells **12** can then be separated or singulated from the laminated array **10** and suitable leads can be formed to the cathode and anodes of the completed battery cells.

The singulation step is represented schematically in FIG. **2** by the cut lines **20**. Singulation can be accomplished by cutting, shearing, die stamping or any other suitable method of separating the individual batteries **12** from the laminated array **10**.

The cathode stack **14** includes a cathode substrate **22**, a cathode mask **24**, and cathodes **26** formed on the substrate **22** and separated by the cathode mask **24**. The substrate **22** functions as a current collector for the cathodes **26** in the separated battery cells **12**. As such, the cathode substrate **22** is preferably formed of a conductive material, such as a metal foil (e.g. copper), or a conductive polymer. The cathode substrate **22** may be formed of a solid sheet (i.e. panel) of material or it my be patterned in a configuration that shapes the final battery cells **12**. One representative pattern for the cathode substrate **22** is shown in FIG. **6**A and includes solid metal areas **30** and die cut/etched areas **32**. Each battery cell **12** occupies the generally square solid metal areas **30**. The cathode substrate **22** may also include suitable openings (not shown) for connecting leads to the cathodes **26**.

The cathode mask **24** is formed of an insulating material. The cathode mask **24** functions as a containment system for the cathodes **26**. In addition the cathode mask **24** insulates the cathodes **26** and protects the cathodes **26** structurally and environmentally. Furthermore, the cathode mask **24** provides a webbing between the individual battery cells **12** of the laminated array **10** to reduce the potential of shorting between the cells **12** during singulation of the battery cells **12**. The cathode mask **24** may also serve as a pattern for deposition of the cathodes **26** on the cathode substrate **22**.

The cathode mask **24** may formed of a thin dielectric material such as an insulating tape (e.g. Kapton tape), or a dielectric paste (e.g. insulating polymer thick film dielectric inks such as DuPont 5014). These materials can be formed in a pattern to retain and insulate the cathodes **26**. Moreover, the cathode mask **24** may be patterned to accommodate the shape of the battery cells **12** and the pattern of the cathode substrate **22**. In the illustrative embodiment the cathode mask **24** is patterned in squares (36 squares) for the cathodes **26** substantially as shown in FIG. **1**. The cathode mask **24** may be formed and patterned in advance as a separate structure by any suitable technique (e.g. die cutting, etching). Alternately, the cathode mask **24** may be formed around the cathodes **26** after formation of the cathodes **26** on the cathode substrate **22**.

As clearly shown in FIG. **3**, the cathode mask **24** is preferably formed with studs **28** (or standoffs) that will support the separator/electrolyte layer **16** in the completed battery cells **12**. The studs **28** also function to prevent the separator/electrolyte layer **16** from being physically pushed through the cathodes **26** to the substrate **22**. Moreover, the cathode mask **24** and studs **28** support the cathodes **26** and prevent shorting during the singulation process.

The cathodes **26** are formed by depositing a suitable cathode active material onto the cathode substrate **22**. A preferred method of forming the cathodes **26** on the cathode substrate **22** is with a printing process such as a pin-transfer, screen or stencil printing processes. Such pin transfer, screen or stencil printing processes are capable of depositing materials in high volumes and in discrete or irregular patterns. In addition, such printing processes can be performed with relatively inexpensive equipment using relatively simple manufacturing procedures. Furthermore, pin-transfer, screen or stencil printing allows quick changes to be made in the thickness and shape of the deposited materials by changing the pin-array, pin head size, printing screen or stencil with minimal investment in time and equipment. Moreover, such printing process can be used in conjunction with a deposition pattern defined by the cathode mask **24**.

Screen and stencil printing are commonly used in the electronics or graphic arts industry to print thick film inks or solder paste. Typically, a squeegee traverses across a patterned screen or stencil to force the material to be deposited through the screen or stencil openings to provide a printed pattern. Equipment commonly used include screen printing machines are available from MPM Corporation, DEK and Presco.

The cathodes **26** may be formed of any suitable cathode active material that can be deposited and patterned on the cathode substrate **22**. As an example, the cathodes **26** can be formed of a cathode active material (e.g. iodine) and a polymer (e.g. poly-2-vinylpyridine) that react to form a conductive depolarizer. Such a cathode material can be formulated to flow under the heat and pressure of a pin-transfer, screen or stencil printing process in a desired pattern. Other suitable cathode materials include MnO_2, PbI_2, I_2, $NbSe_2$, $NbSe_3$, MoS_2, MoS_3, TiS_2, TiS_3, $TaSe_3$, TaS_2, V_6O_{13}, CoO_2, and MoO_2.

The separator/electrolyte stack **16** is formed of a material that will function as a solid electrolyte for the completed battery cells **12**. The separator/electrolyte stack **16** thus functions as the medium of transfer of ions between the anodes **34** and cathodes **26** of the battery cells **12**. Depending on the cathodic active material that is used, the separator/electrolyte stack **16** may be formed of a suitable solid layer of material. As an example, for a lead iodide cathode **26** the separator/electrolyte stack **16** may be formed from a mixture of lithium iodide and conductivity enhancing alumina. For an iodine cathode, a separator/electrolyte stack **16** my be formed of solid lithium iodide.

Still referring to FIGS. **1–3**, the anode stack **18** includes the lithium anodes **34**, an anode mask **36**, and an anode substrate **38**. The anode substrate **38** is preferably formed of a thin metal foil (e.g. copper, stainless steel, nickel). The substrate **38** my be a solid metal foil or may be patterned to save material, prevent shorting and to accommodate the shape of the battery cells **12**. One representative pattern for the anode substrate **38** is shown in FIG. **6**C and includes die cut/etched areas **40** and solid metal areas **42**. The anodes **34** in the completed battery cells **12** rest on the solid metal areas **42**.

To form the lithium anodes **34** on the anode substrate **38**, molten lithium can be applied to the anode substrate **38** as a patterned solder. Lithium has a relatively low melting point and can therefore be deposited as solder in a suitable pattern. Such a lithium solder manufacturing technique can be used to deposit the pattern of lithium anodes **34** on the anode substrate **38** in much the same way as solders are applied to printed circuit boards. As an example, lithium can be deposited in a square pattern substantially as shown in FIG. **1** onto an anode substrate **38** formed of copper.

The molten lithium deposition may be done similar to wave soldering printed circuit board assemblies. A substrate may be run on a conveyor and across a molten wave of lithium. Lithium melts around 180° C. but because of its highly reactive nature to air in general and moisture in particular, it must be contained in a protective environment such as argon. Typical wave soldering equipment for printed circuit boards is available form Technical Devices, Inc.

Such a solder process can be used in lieu of physically bonding lithium foil to a substrate **38** formed of a different metal foil. Roll bonding lithium foil to another foil is an extremely difficult process with the thin, fragile (84 psi tensile strength) nature of lithium foil. Furthermore, molten lithium can be applied as an extremely thin film; in many cases, far less than 1 mil. This is particularly advantageous as rolled lithium foils are extremely difficult and costly to produce at thicknesses less than 1.5 mils.

Moreover, with lithium anodes **34** formed as a thin film, much less lithium is used in each battery cell **12**. This is important for some applications (e.g. airline transported products) because the amount of lithium per battery cell or product is limited due to its inherent, hazardous, reactive nature.

The anode mask **36** may be formed of a dielectric material patterned into a desired shape substantially as previously described for the cathode mask **24**. The anode substrate **38** and anode mask **36** form an insulating and supporting webbing between the individual anodes **34** of the battery cells **12**. This helps to reduce the possibility of the battery cells **12** shorting together during singulation (e.g. diecutting or shearing) of the individual battery cells **12** from the laminated array **10**. As with the cathode mask **24**, the anode mask **36** my be formed as a separate structure or following formation of the patterned anodes **34**.

Using the process of the invention, battery cells **12** can be manufactured as single cells as shown in FIGS. **1–3**. The process of the invention can also be used however, to manufacture stacked or multiple cell batteries. A method of constructing stacked multiple cell batteries is shown in FIGS. **4**, **4A**, and **5**. A pair of adjacent stacked multiple cell batteries **40** separated by a cut line **50** are shown in FIG. **5**.

As before, the stacked batteries **40** can be manufactured in a laminated array **48**. AS shown in FIG. **4**, a laminated array **48** includes a base stack **42**, a middle stack **44**, and a top stack **46**. Moreover, each separate stack **42**, **44**, **46** is substantially similar in construction to the single cell laminated stack **10** previously described. Each separate stack **42**, **44**, **46** may be manufactured separately and then lightly pressed together as shown in FIG. **4**A to complete the assembly.

With reference to FIG. **4**, the base battery stack **42** includes a cathode substrate **52**, a cathode mask **54**, a cathode layer **56**, and a separator/electrolyte layer **58**. The middle stack **44** includes a lithium anode layer **60**, an anode mask **62**, a metal separator layer **64**, a cathode mask **66**, a cathode layer **68**, and a separator/electrolyte layer **70**. The top stack **46** includes a second lithium anode layer **72**, a second anode mask **74** and a second anode substrate **76**.

The separator layer **64** of the middle stack **44** is patterned on one side (upper) with an cathode material and on an opposite side (lower) with anode material. As shown in FIG. **6**B, the separator layer **64** can be formed of a solid metal foil having solid metal areas **80** and die cut or etched areas **78**. The construction and function of each of the remaining layers is substantially as previously described.

Alternate Embodiments

Referring now to FIGS. **7**–**9** the assembly of a thin battery using stenciling techniques is shown. Such stenciling techniques may be used in the assembly of a single cell battery as shown or in the assembly of a multicell laminated array (e.g. , (**10**) FIG. **1**, (**48**) FIG. **4**) as previously described.

Initially and as shown in FIG. **7**, a cathode **108** is stenciled onto a current collector **106** using a stencil **110**. The stencil **110** is formed of a thin material having an opening **112** sized to form the cathode **108**. In addition the thickness of the cathode **108** can be controlled by the thickness of the stencil **110**. Following formation of the cathode **108**, and as shown in FIG. **8**, another stencil **114** is used to form a solid electrolyte **116** over the cathode **108**. The opening **118** in the stencil **114** for forming the electrolyte **116**, is slightly larger than the cathode **108** such that the electrolyte **116** overlaps opposite edges of the cathode **108** substantially as shown. In addition, the thickness of the electrolyte **116** can be controlled by the thickness of the template **114**. Following formation of the electrolyte **116**, and as shown in FIG. **9**, an anode **120** is formed over the electrolyte.

Referring now to FIGS. **10**A–**10**C, another method of assembling a battery using stenciling techniques is shown. As shown in FIG. **10**A an insulating paint **122** is applied to a substrate **124** to form the current collector. In place of an insulating paint, a tape such as a "Kapton" tape or a polymer thick film insulating dielectric material may be used. The insulating paint **122** (or tape or polymer dielectric) includes an opening **126** for forming the cathode **128**. Next, as shown in FIG. **10**B, the cathode **128** is deposited into the opening **126**. As shown the cathode **128** is thicker than the depth of the opening **126**. Next, as shown in FIG. **10**C, the battery cell is completed by formation of a solid electrolyte **130** and anode **132**.

Using the disclosed stenciling techniques battery cells can be made simply, quickly and relatively inexpensively. Moreover, such stenciling techniques can be used to make individual testable battery cells or to make an array of cells as previously described.

Although the invention has been described in terms of preferred embodiments, as will be apparent to those skilled in the art, other applications of the inventive concepts disclosed herein are possible. It is intended therefore that the following claims include such alternate embodiments.

What is claimed is:

1. A method for manufacturing thin batteries, comprising:

forming a cathode layer by depositing a cathode material onto a cathode substrate in a pattern to form cathodes;

separating the cathodes with an insulating cathode mask;

forming a separator/electrolyte layer of a solid electrolyte material in contact with the cathodes;

forming an anode layer by depositing an anode material as a patterned solder on an anode substrate to form anodes for contact with the separator/electrolytic layer;

separating the anodes with an insulated anode mask;

combining the separate layers together to form a laminated array structure containing multiple battery cells; and

singulating individual battery cells from the laminated array structure.

2. The method as claimed in claim **1** and wherein the cathode layer is formed by depositing a cathode material on the cathode substrate in a discrete pattern using a printing process.

3. The method as claimed in claim **2** and wherein the anode material is lithium.

4. The method as claimed in claim **1** and further comprising forming a second cathode layer, a second separator/electrolyte layer and a second anode layer to form multiple stacked battery cells.

5. The method as claimed in claim **1** and wherein the cathode substrate comprises a patterned metal foil.

6. The method as claimed in claim i and wherein the cathode layer is formed by depositing a cathode material on the cathode substrate using a stencil to pattern the cathode material.

7. The method as claimed in claim **1** and wherein the cathode layer is formed by depositing an insulating paint having a pattern of openings on the cathode substrate and then depositing the cathode material into the openings.

8. The method as claimed in claim **1** and wherein singulating the individual battery cells is by cutting, shearing or stamping.

9. A method of manufacturing thin polymer batteries by forming a laminated array containing multiple battery cells by the steps comprising;

forming a cathode substrate layer of a conductive material;

forming cathodes for the battery cells by depositing a cathode material in a discrete pattern on the cathode substrate layer and separating the cathodes with a cathode mask;

placing a separator/insulator layer in contact with the cathodes;

forming an anode substrate layer of a conductive material;

forming anodes for the battery cells by depositing a molten anode material in a discreet pattern on the anode substrate layer and separating the anodes with an anode mask;

placing the anodes in contact with the separator/insulator layer; and

singulating the individual battery cells from the laminated array.

10. The method as claimed in claim **9** and wherein the cathode material is deposited on the cathode substrate using a printing process.

11. The method as claimed in claim **10** and wherein the printing process uses stencils to pattern the cathode material.

12. The method as claimed in claim **11** and wherein the anodes are formed by depositing molten lithium solder in a pattern on the anode substrate.

13. The method as claimed in claim **12** and wherein the cathode substrate is formed of a sheet of patterned metal.

14. The method as claimed in claim **12** and wherein the laminated array is formed with more than one layer of anodes and more than one layer of cathodes to form stacked battery cells.

15. The method as claimed in claim **12** and wherein the cathode mask is formed with studs to prevent the cathodes from being compressed and shorted.

16. The method as claimed in claim **12** and wherein the anode substrate is formed of a sheet of patterned metal.

17. A method of forming a thin battery comprising the steps of:

providing a cathode substrate layer;

depositing a cathode material on the substrate layer using a first stencil formed with a first opening and printing the cathode material through the first opening onto the substrate layer to form a cathode;

depositing an electrolytic material on the cathode using a second stencil formed with a second opening and printing the electrolytic material through the second opening onto the cathode; and

forming an anode on the electrolytic material.

18. The method as claimed in claim **17** and wherein the second opening is larger than the first opening and the electrolytic material overlaps opposite sides of the cathode.

19. A thin battery comprising:

a cathode substrate formed of a conductive material;

a cathode deposited in a discrete pattern on the cathode substrate by depositing a cathode material on the cathode substrate using a printing process;

a cathode mask formed on the cathode substrate for separating and insulating the cathode said cathode mask including studs to prevent compression and shorting of the cathode;

a separator/electrolyte layer in contact with the cathode;

an anode deposited in a discrete pattern on a conductive anode substrate in contact with the separator/electrolyte layer and formed by depositing a molten anode material onto the anode substrate; and

an anode mask formed on the anode substrate for separating and insulating the anode.

20. The thin battery as claimed in claim **19** and wherein the printing process for depositing the cathode material uses stencils.

21. The thin battery as claimed in claim **19** and wherein the anode is formed of lithium applied as a patterned solder.

22. The thin battery as claimed in claim **19** and wherein the printing process for depositing the cathode material uses insulating paint deposited onto the cathode substrate.

23. The thin polymer battery as claimed in claim **19** and wherein the battery further comprises:

a second cathode formed of a cathode material deposited on the anode substrate by a printing process and insulated by a second cathode mask;

a second separator/electrolyte layer in contact with the second cathode; and

a second anode in contact with the second separator/electrolyte layer and formed of an anode material deposited on a second anode substrate.

24. The thin polymer battery as claimed in claim **19** and wherein a plurality of identical batteries are assembled in a laminated array and then singulated from the array.

25. The thin battery as claimed in claim **19** and wherein the separator/electrolyte layer is stenciled onto the cathode.

26. A method for manufacturing batteries comprising:

depositing a cathode layer onto a cathode substrate in a pattern to form cathodes;

separating the cathodes with an insulating cathode mask;

depositing an anode layer on an anode substrate in a pattern to form anodes;

separating the anodes with an insulated anode mask;

providing a separator/electrolyte layer between said cathodes and said anodes; and

combining the separate layers together to form a laminated array structure containing multiple battery cells.

27. The method as claimed in claim 26 and further including singulating individual battery cells from the laminated array structure.

28. The method as claimed in claim 26 and wherein the cathode layer is formed by depositing a cathode material on the cathode substrate in a discrete pattern using a printing process.

29. The method as claimed in claim 26, and wherein the anode material is lithium.

30. The method as claimed in claim 26 and further comprising forming a second cathode layer, providing a second separator/electrolyte layer and forming a second anode layer to form multiple stacked battery cells.

31. The method as claimed in claim 26 and wherein the cathode substrate comprises a patterned metal foil.

32. The method as claimed in claim 26 and wherein the cathode layer is formed by depositing a cathode material on the cathode substrate using a stencil to pattern the cathode material.

33. The method as claimed in claim 26 and wherein the cathode layer is formed by depositing an insulating paint having a pattern of openings on the cathode substrate and then depositing the cathode material into the openings.

34. The method as claimed in claim 27 and wherein singulating the individual battery cells is by cutting shearing or stamping.

35. A method of manufacturing batteries comprised of a laminated array containing multiple battery cells comprising

providing a cathode substrate layer of a conductive material;

depositing a cathode material in a pattern to form cathodes on the cathode substrate layer and separating the cathodes with a cathode mask;

placing a separator/insulator layer in contact with the cathodes;

providing an anode substrate layer of a conductive material;

depositing an anode material in a pattern to form anodes on the anode substrate layer and separating the anodes with an anode mask; and

placing the anodes in contact with the separator/insulator layer.

36. The method as claimed in claim 35 and further including singulating the individual battery cells from the laminated array.

37. The method as claimed in claim 35 and wherein the cathode material is deposited on the cathode substrate layer using a printing process.

38. The method as claimed in claim 37 and wherein the printing process uses stencils to pattern the cathode material.

39. The method as claimed in claim 35 and wherein the anodes are formed by depositing molten lithium solder in a pattern on the anode substrate layer.

40. The method as claimed in claim 35 and wherein the cathode substrate layer is formed of a sheet of patterned metal.

41. The method as claimed in claim 35 and wherein the laminated array is formed with more than one layer of anodes and more than one layer of cathodes to form stacked battery cells.

42. The method as claimed in claim 35 and wherein the cathode mask is formed with studs to prevent the cathodes from being compressed and shorted.

43. The method as claimed in claim 35 and wherein the anode substrate layer is formed of a sheet of patterned metal.

44. A method of forming a battery comprising the steps of:

providing a cathode substrate layer;

depositing a cathode material on the cathode substrate layer using a printing process to form a cathode;

depositing an electrolytic material on the cathode using a printing process; and

forming an anode on the electrolytic material.

45. The method as claimed in claim 44 and wherein said depositing a cathode material includes using a first stencil formed with a first opening and printing the cathode material through the first opening onto the cathode substrate layer and said depositing an electrolytic material includes using a second stencil formed with a second opening and printing the electrolytic material through the second opening onto the cathode.

46. The method as claimed in claim 45 and wherein the second opening is larger than the first opening and the electrolytic material overlaps opposite sides of the cathode.

47. A battery comprising:

a cathode substrate comprised of a conductive material;

a cathode on the cathode substrate;

a cathode mask on the cathode substrate separating and insulating the cathode, said cathode mask including studs;

a separator/electrolyte layer in contact with the cathode;

an anode on a conductive anode substrate in contact with the separator/electrolyte layer; and

an anode mask on the anode substrate separating and insulating the anode.

48. The battery as claimed in claim 47 and wherein the anode is comprised of lithium.

49. The battery as claimed in claim 47 and wherein the battery further comprises:

a second cathode on the anode substrate and insulated by a second cathode mask;

a second separator/electrolyte layer in contact with the second cathode; and

a second anode in contact with the second separator/electrolyte layer on a second anode substrate.

50. The battery as claimed in claim 47 and further including a plurality of substantially identical batteries assembled in a laminated array.

51. A method of forming a battery comprising the steps of:

providing an anode substrate layer;

depositing an anode material on the anode substrate layer using a printing process to form at least one anode;

depositing an electrolytic material on the at least one anode using a printing process; and

forming at least one cathode on the electrolytic material.

52. The method as claimed in claim 51 and wherein said depositing an anode material includes using a first stencil formed with a first opening and printing the anode material through the first opening onto the anode substrate layer and said depositing an electrolytic material includes using a second stencil formed with a second opening and printing the electrolytic material through the second opening onto the anode.

53. The method as claimed in claim 52 and wherein the second opening is larger than the first opening and the electrolytic material overlaps opposite sides of the anode.

54. A battery, comprising:

a cathode substrate;

a anode substrate;

a cathode on said cathode substrate;

a cathode mask on said cathode substrate, said cathode mask including a plurality of studs to prevent compression and shorting of said cathode;

a separator/electrolyte layer in contact with said cathode; and

an anode on said anode substrate and in contact with said separator/electrolyte layer.

55. The battery of claim 54, further including an anode mask on said anode substrate.

56. The battery of claim 55, wherein said anode mask includes a plurality of studs to prevent compression and shorting of said anode.

57. The battery as claimed in claim 54 and wherein the anode is comprised of lithium.

58. The battery as claimed in claim 54 and wherein the battery further comprises:

a second cathode on the anode substrate and insulated by a second cathode mask;

a second separator/electrolyte layer in contact with the second cathode; and

a second anode in contact with the second separator/electrolyte layer on a second anode substrate.

59. The battery as claimed in claim 54 and further including a plurality of substantially identical batteries assembled in a laminated array.

60. A method for manufacturing batteries, comprising:

forming a pattern of cathodes on a cathode substrate;

separating the cathodes with an insulating cathode mask;

forming a pattern of anodes on an anode substrate;

separating the anodes with an insulated anode mask; and

providing a separator/electrolyte layer between and in contact with said cathodes and said anodes.

61. The method as claimed in claim 60 and wherein the cathodes are formed by depositing a cathode material on the cathode substrate in a discrete pattern using a printing process.

62. The method as claimed in claim 60, and wherein the anodes are formed from lithium.

63. The method as claimed in claim 60 and further comprising forming a second pattern of cathodes providing a second separator/electrolyte layer and forming a second pattern of anodes to form multiple stacked battery cells.

64. The method as claimed in claim 60 and wherein the cathode substrate comprises a patterned metal foil.

65. The method as claimed in claim 60 and wherein the cathode layer is formed by depositing a cathode material on the cathode substrate using a stencil to pattern the cathode material.

66. The method as claimed in claim 60 and wherein the cathodes are formed by depositing an insulating paint having a pattern of openings on the cathode substrate and then depositing a cathode material into the openings.

67. A method for manufacturing batteries, comprising:

providing a conductive separator layer having a first side and it second side;

forming a plate of cathodes an said first side of said separator layer;

forming a pattern of anodes on said second side of said separator layer;

providing a cathode substrate over said cathodes; and

providing an anode substrate over said anodes.

68. The method of claim 67, further including separating said cathodes with an insulating cathode mask.

69. The method of claim 67, further including separating said anodes with an insulating anode mask.

70. The method as claimed in claim 67 and wherein the separator comprises a metal foil.

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