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(54) **RECEPTACLES FOR INKJET DEPOSITED PLED/OLED DEVICES AND METHOD OF MAKING THE SAME**

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(57) **ABSTRACT**

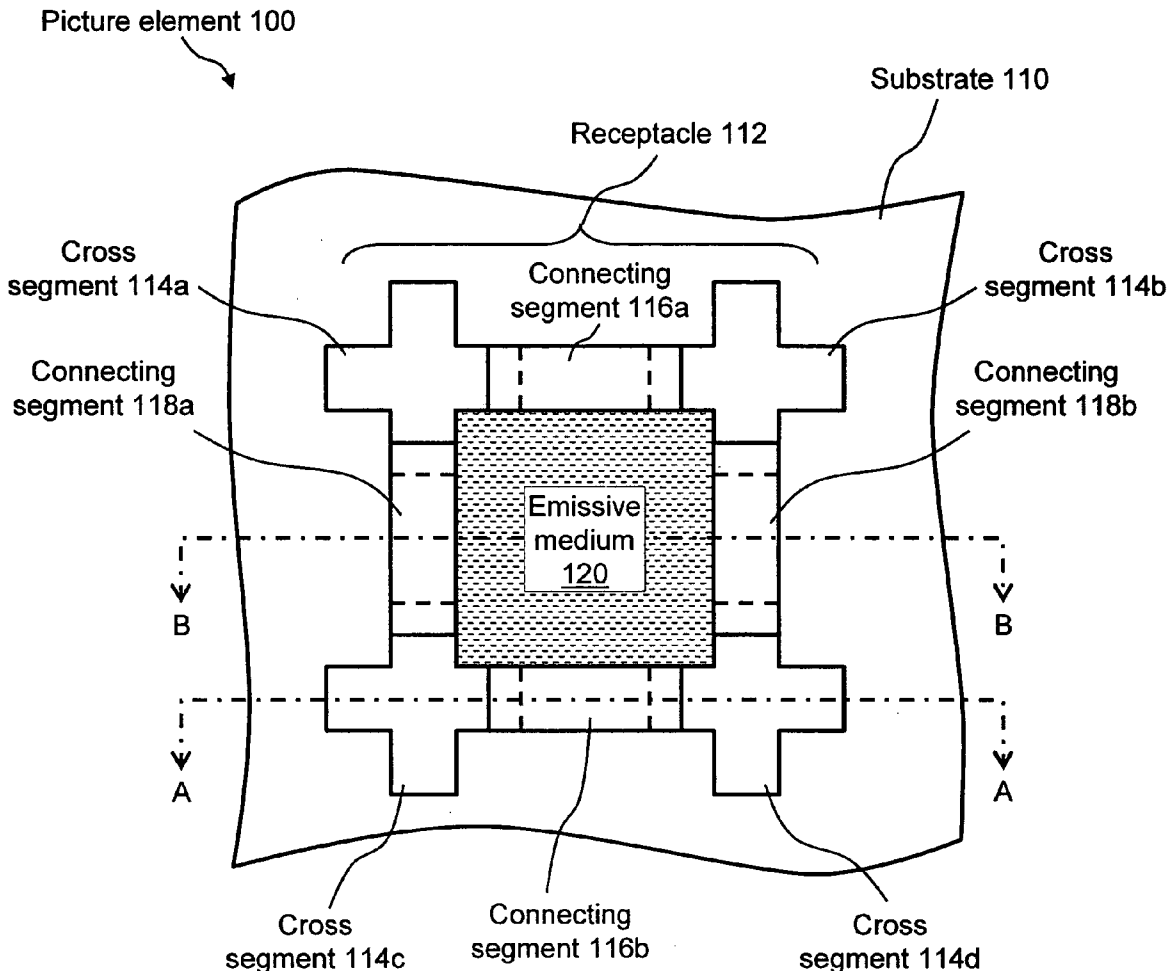
Evaporated receptacles for inkjet deposited polymeric light-emitting diode (PLED)/organic light-emitting diode (OLED) and a method of making the same. The evaporated receptacles are formed via a shadow mask vacuum deposition process. The method of forming a light-emitting display includes forming an electrode on a substrate, forming a receptacle structure over the electrode via a shadow mask vacuum deposition process, and delivering a quantity of polymeric solution, which contains a light-emitting material, into the receptacle via a standard inkjet deposition process.

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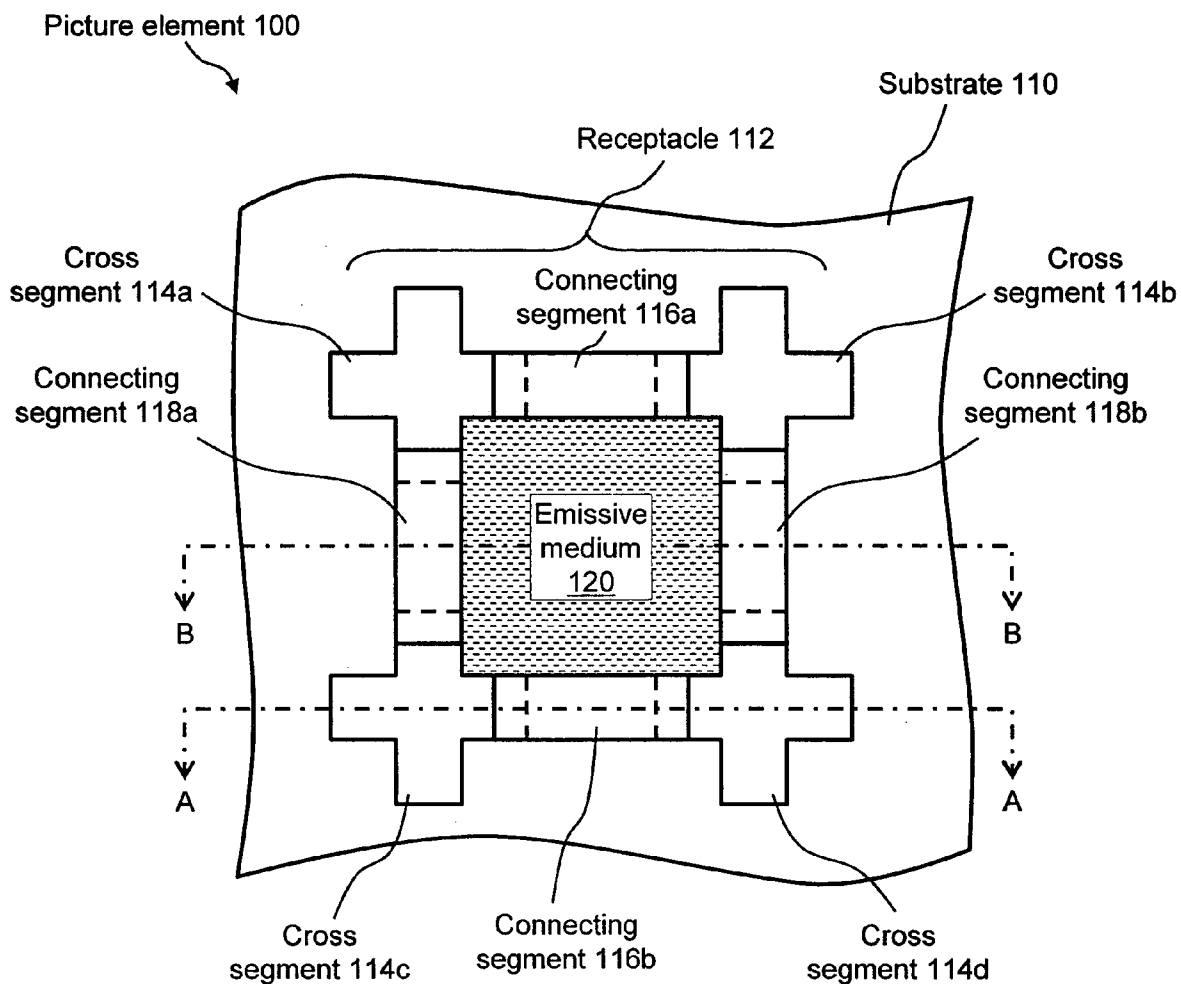
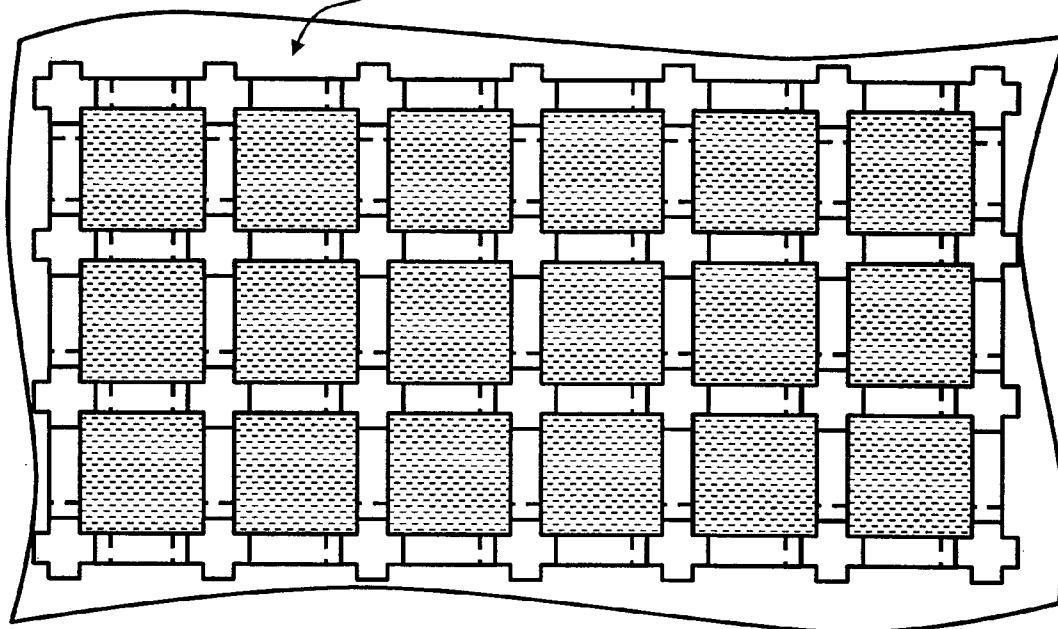


FIG. 1

Light-emitting display 200

Picture elements 100



Substrate 110

FIG. 2

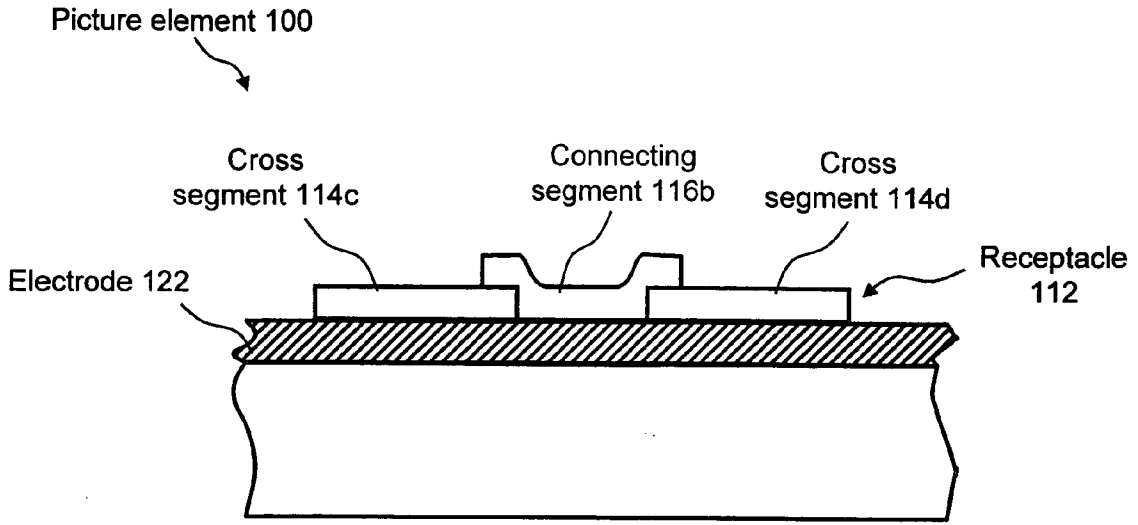


FIG. 3A

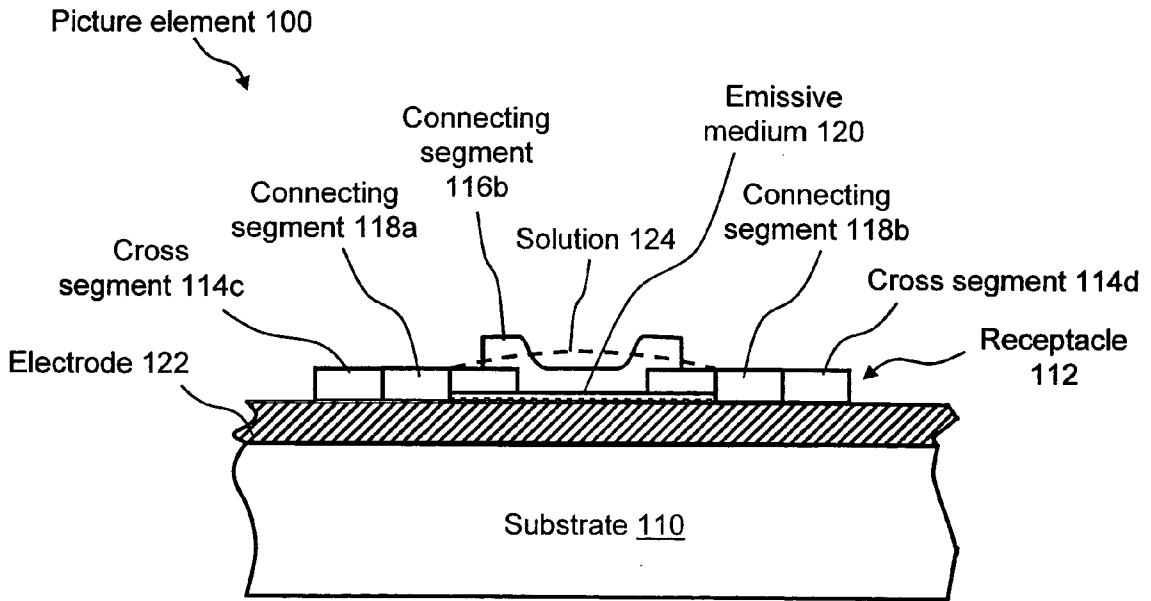


FIG. 3B

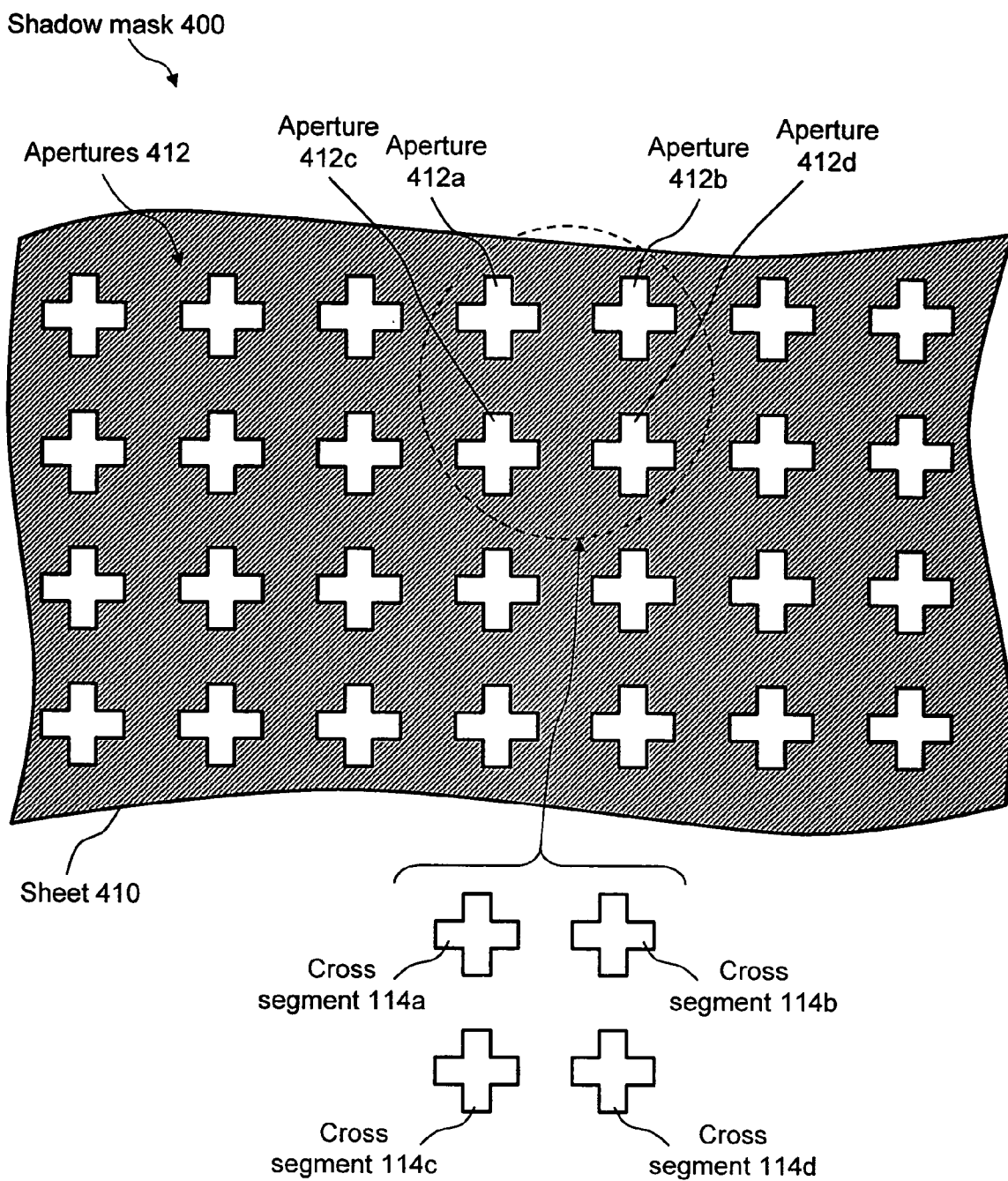


FIG. 4

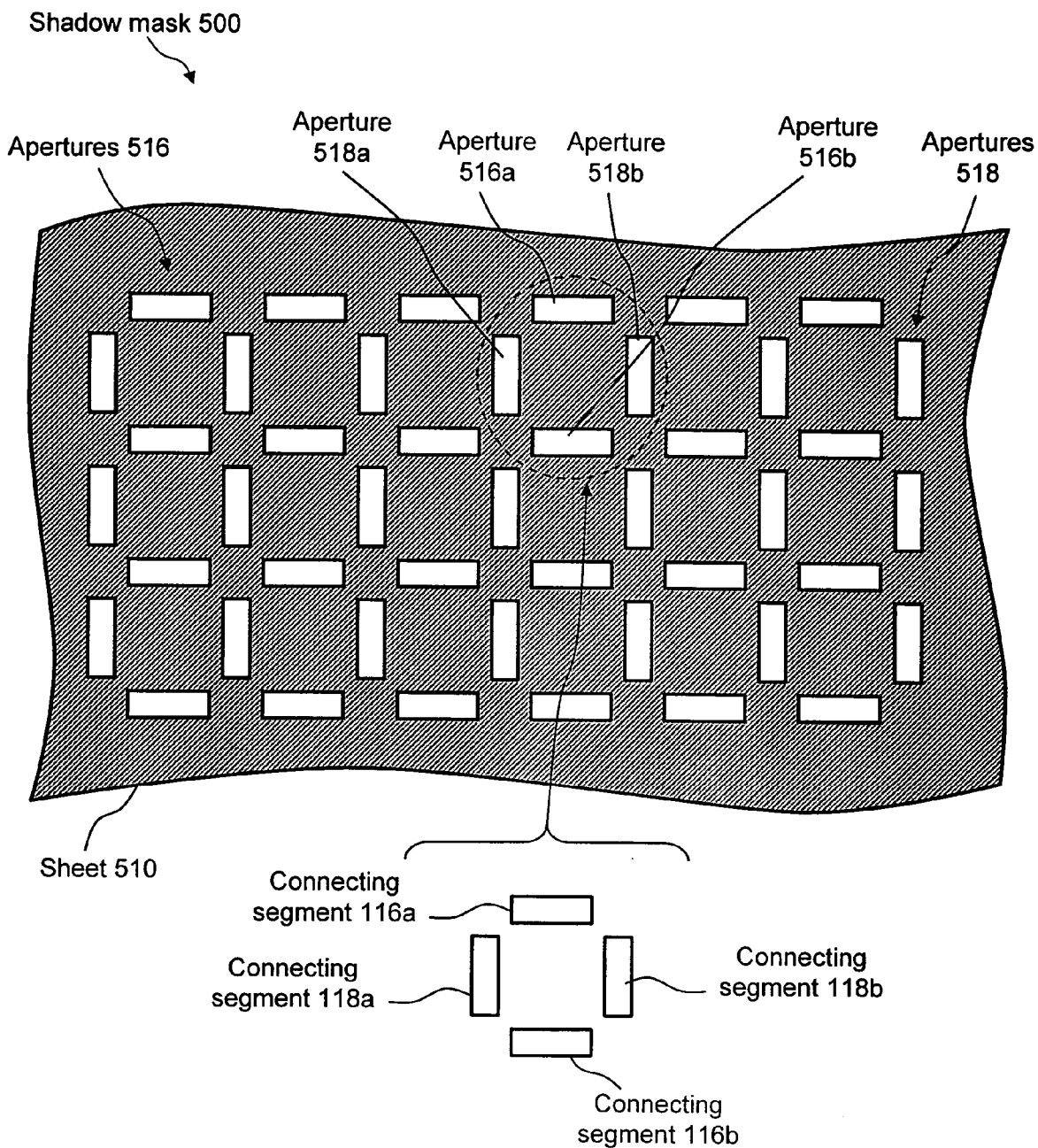


FIG. 5

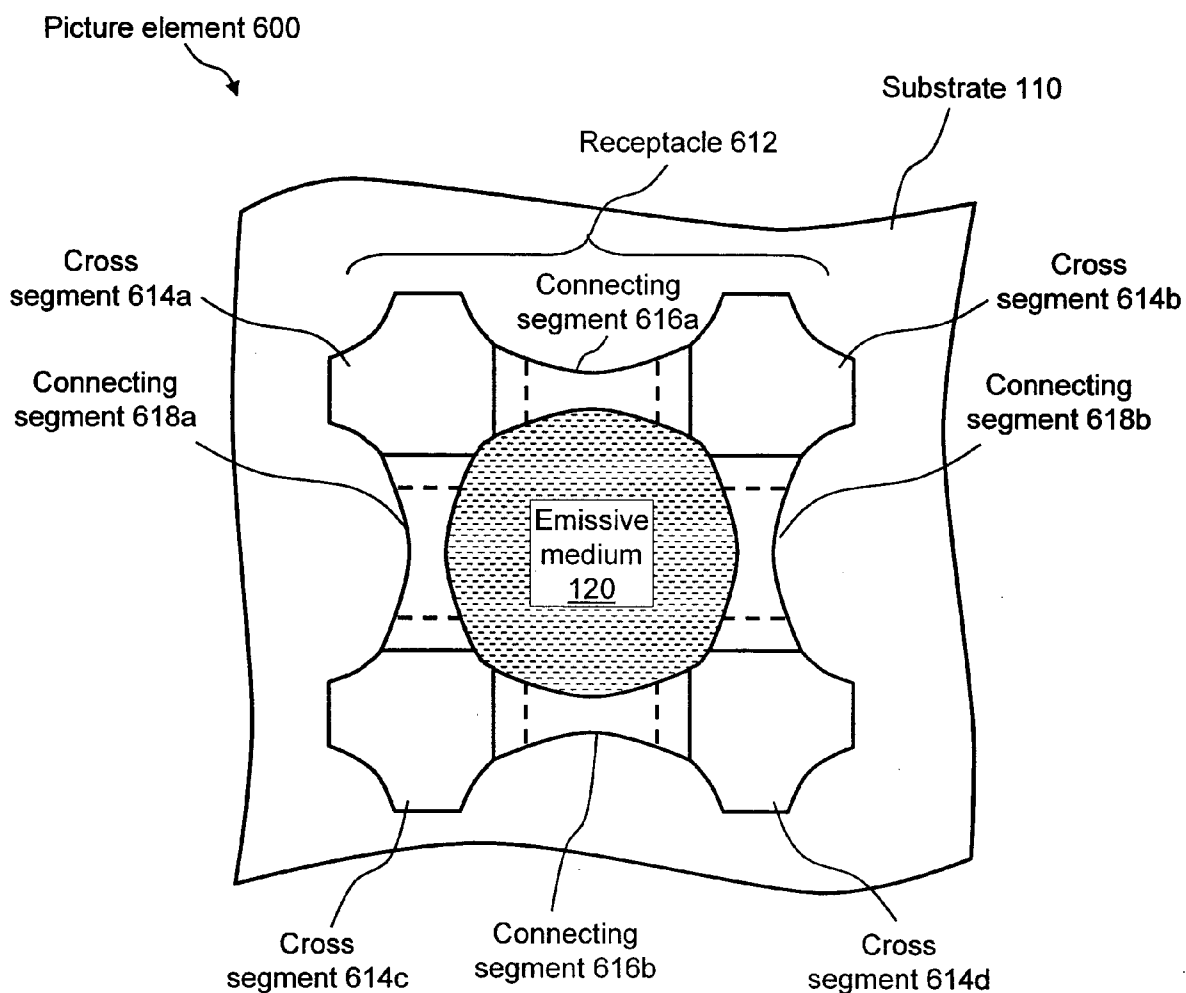


FIG. 6

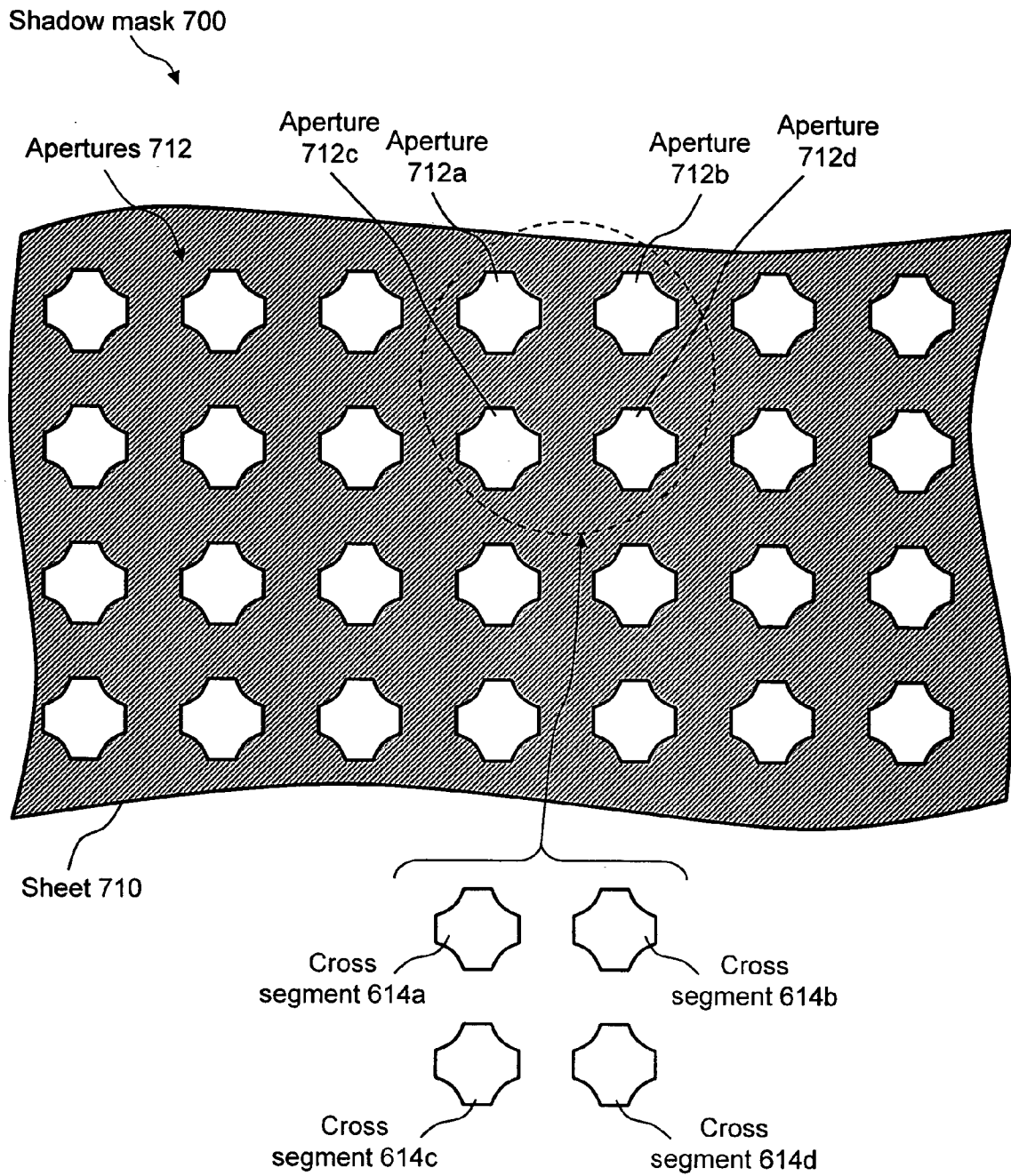


FIG. 7

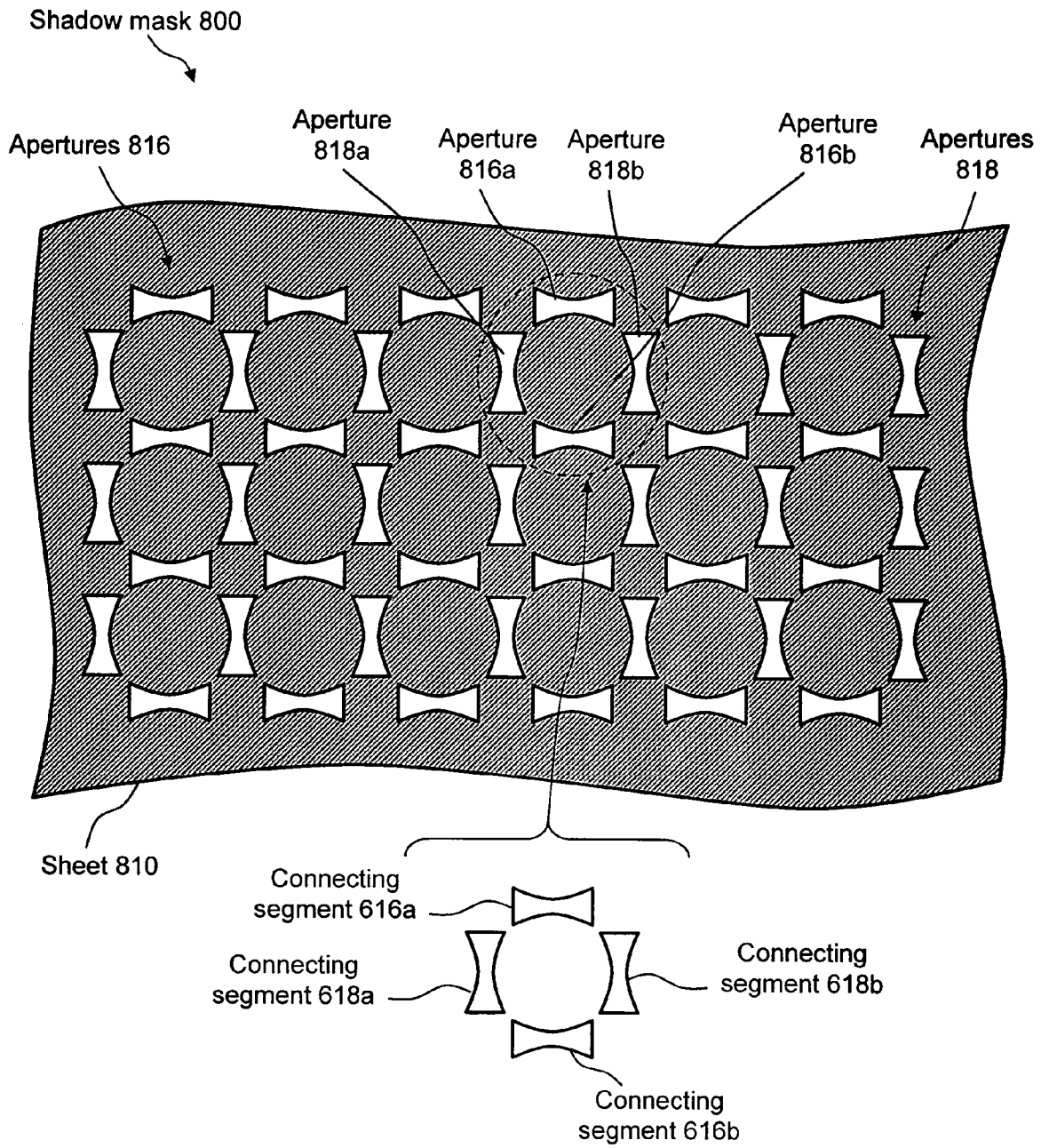


FIG. 8

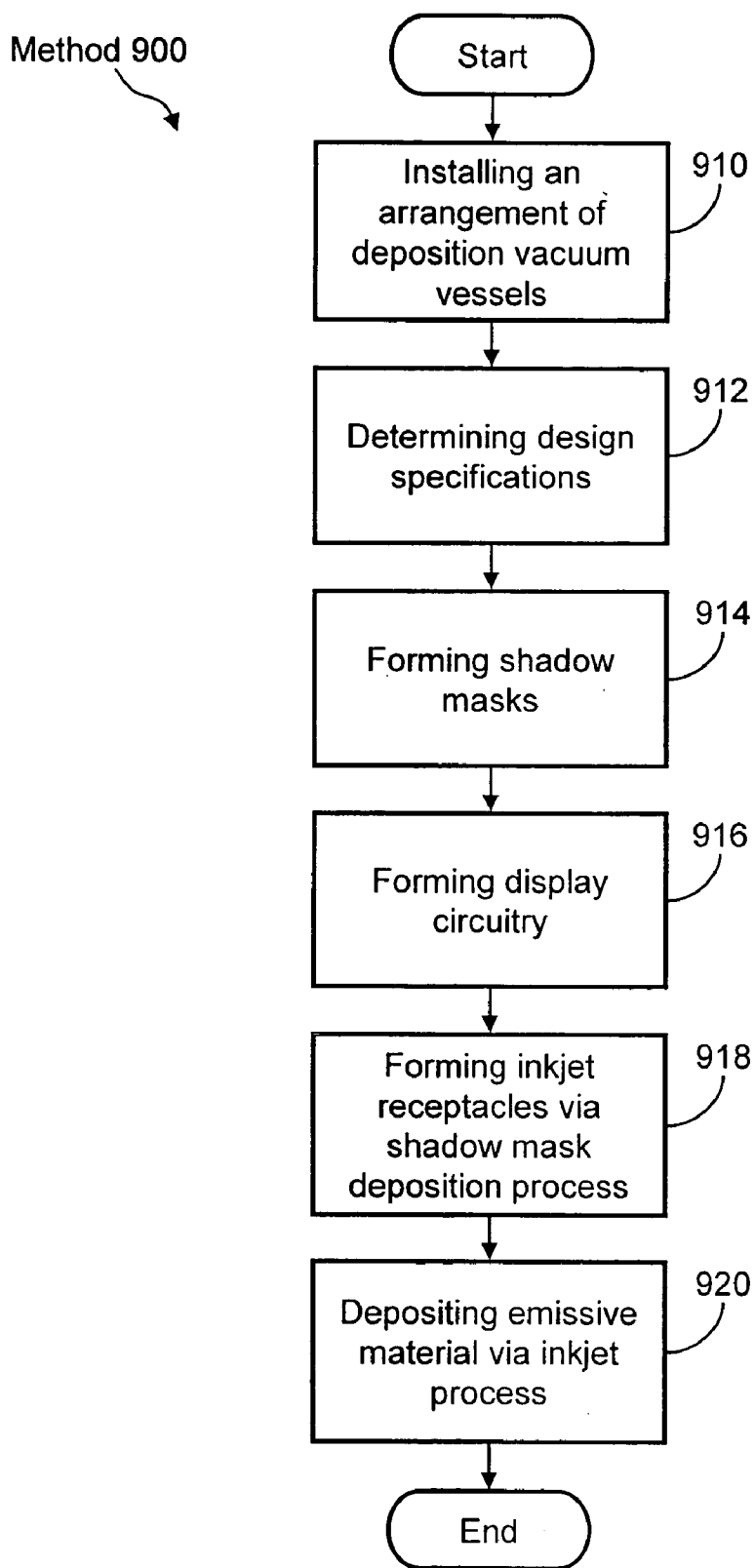


FIG. 9

**RECEPTACLES FOR INKJET DEPOSITED
PLED/OLED DEVICES AND METHOD OF
MAKING THE SAME**

FIELD OF THE INVENTION

[0001] The present invention relates to an inkjet deposition process for forming polymeric light-emitting diode (PLED) or organic light-emitting diode (OLED) displays. In particular, the invention relates to forming evaporated receptacles for inkjet deposited PLED/OLED devices.

BACKGROUND OF THE INVENTION

[0002] An organic light-emitting diode (OLED) is a light-emitting diode (LED) made of semiconducting organic polymers. These devices promise to be much cheaper to fabricate than inorganic LEDs. Varying amounts of OLEDs can be deposited in arrays on a screen by use of simple "printing" methods to create a graphical color display, for use as television screens, computer displays, portable system screens, and in advertising and information board applications. OLED panels may also be used as lighting devices.

[0003] One of the great benefits of an OLED display over the traditional liquid crystal displays found in computer monitors is that OLED displays do not require a backlight in order to function. This means that they draw far less power and can be used with small portable devices, which have mostly made use of monochrome, low-resolution displays, in order to conserve power. This also means that they are able to last for long periods of time on a single battery charge.

[0004] There are two main directions in OLED technology. The first OLED technology was developed by Eastman Kodak Company (Rochester, N.Y.) and is usually referred to as "small-molecule" OLED. The production of small-molecule displays requires a vacuum deposition process, which makes the production process expensive and inflexible. A second OLED technology, developed by Cambridge Display Technology (Cambridge, UK), is a polymer-based OLED technology, which is sometimes referred to as PLED technology. Although development of PLED technology lags behind the development of small-molecule OLED technology by several years, it promises some advantages. For example, the organic electroluminescent materials can be applied on the substrate by a technique derived from commercial inkjet printing, which means that PLED displays can be made in a very flexible and inexpensive way.

[0005] Producing a multi-color organic display is not an easy task. While the use of inkjet printing techniques for forming PLED displays has found some acceptance in forming displays with larger feature sizes, the technique has, so far, depended on a complex and costly photolithography process for forming the receptacles upon the display substrate. The receptacles, or wells, are structures that are formed upon a substrate into which, in the case of a PLED display, the droplets of polymer solution are collected during an inkjet deposition process. What is needed is a simpler and less costly process for forming receptacles upon a display substrate for use in a subsequent inkjet deposition process that delivers the polymer solvent thereon for completing the display fabrication.

[0006] One exemplary method of forming a light-emitting display by use of an inkjet deposition process is found in

reference to U.S. Pat. No. 6,767,774, entitled, "Producing Multi-color Stable Light-Emitting Organic Displays." The '774 patent describes a polymer or organic light-emitting display that may be formed on a substrate by patterning the light-emitting material by use of a screen printing technique. In this way, displays may be formed economically and overcome the difficulties associated with photoprocessing light-emitting materials. A binary optic material may be selectively incorporated into sol gel coatings and coated over light-emitting elements formed from the light-emitting material. A tricolor display may be produced by use of a light-emitting material that produces a single color.

[0007] While the '774 patent describes a suitable method of forming a light-emitting display by use of an inkjet deposition process, it makes no mention of providing simpler or more inexpensive ways to form the receptacle structures upon a substrate for use in the inkjet deposition process.

[0008] It is therefore an object of the invention to provide a simplified and inexpensive process for forming receptacles upon a display substrate for use in a subsequent inkjet deposition process for forming a large-area PLED/OLED display.

[0009] It is another object of this invention to provide a method of using a shadow mask vacuum deposition process for forming receptacles upon a display substrate for use in a subsequent inkjet deposition process.

BRIEF SUMMARY OF THE INVENTION

[0010] The present invention relates to evaporated receptacles for inkjet deposited PLED/OLED device and a method of making such devices. In accordance with one aspect of the invention, a light-emitting display is made by forming a substrate with an electrode disposed thereon, forming a receptacle structure over the electrode via a shadow mask vacuum deposition process, and delivering a quantity of polymeric solution, which contains a light-emitting material, into the receptacle via a standard inkjet deposition process.

[0011] The present invention avoids the use of a complex and costly photolithography process for forming the receptacles upon the display substrate. As a result, the combination of using a shadow mask vacuum deposition process to form the inkjet receptacles and the use of an inkjet deposition process to deliver the light-emitting material provides a less complex and more cost-effective way to make polymer displays of any desired dimension.

[0012] Other features and advantages of the present invention will become more apparent from the detailed description of exemplary embodiments provided below with reference to the accompanying drawings in which:

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] **FIG. 1** illustrates a top view of a picture element in accordance with a first embodiment of the invention.

[0014] **FIG. 2** illustrates an example light-emitting display formed of a plurality of picture elements of the present invention.

[0015] **FIG. 3A** illustrates a cross-sectional view of the picture element of the present invention taken along line A-A of **FIG. 1**.

[0016] **FIG. 3B** illustrates a cross-sectional view of the picture element of the present invention taken along line B-B of **FIG. 1**.

[0017] **FIG. 4** illustrates a top view of an exemplary shadow mask for forming an arrangement of receptacle cross segments via a shadow mask vacuum deposition process in accordance with a first embodiment of the invention.

[0018] **FIG. 5** illustrates a top view of an exemplary shadow mask for forming an arrangement of receptacle connecting segments via a shadow mask vacuum deposition process in accordance with a first embodiment of the invention.

[0019] **FIG. 6** illustrates a top view of a picture element in accordance with a second embodiment of the invention.

[0020] **FIG. 7** illustrates a top view of an exemplary shadow mask for forming an arrangement of receptacle cross segments via a shadow mask vacuum deposition process in accordance with a second embodiment of the invention.

[0021] **FIG. 8** illustrates a top view of an exemplary shadow mask for forming an arrangement of receptacle connecting segments via a shadow mask vacuum deposition process in accordance with a second embodiment of the invention.

[0022] **FIG. 9** illustrates a flow diagram of a method of making inkjet receptacles via a shadow mask vacuum deposition process and using same in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0023] **FIG. 1** illustrates a top view of a picture element **100** in accordance with a first embodiment of the invention. Picture element **100** is a representative pixel of a flat-panel display, such as a PLED or OLED display. Picture element **100** includes a substrate **110** upon which is formed a receptacle **112**. Receptacle **112** is formed by an arrangement of evaporated segments. Receptacle **112** is formed of a plurality of cross segments **114** arranged on a grid that are interconnected via a plurality of connecting segments **116** and connecting segments **118**, which form the walls of receptacle **112** for retaining liquid solvent during an inkjet deposition process.

[0024] In this example, receptacle **112** is formed of a cross segment **114a**, a cross segment **114b**, a cross segment **114c**, and a cross segment **114d**, arranged on a grid as shown in **FIG. 1**. Cross segments **114a** and **114b** are interconnected via a connecting segment **116a** to form a first wall of receptacle **112**; cross segments **114c** and **114d** are interconnected via a connecting segment **116b** to form a second wall of receptacle **112**; cross segments **114a** and **114c** are interconnected via a connecting segment **118a** to form a third wall of receptacle **112**; and cross segments **114b** and **114d** are interconnected via a connecting segment **118b** to form a fourth wall of receptacle **112**.

[0025] Deposited within the walls of receptacle **112** that are formed by the combination of cross segments **114**, connecting segments **116**, and connecting segments **118** is a quantity of emissive medium **120**.

[0026] Substrate **110** is formed of any standard substrate material that is suited for a shadow mask evaporation process, such as metal foil, plastic, or glass.

[0027] Cross segments **114**, connecting segments **116**, and connecting segments **118** of receptacle **112** are formed of via a shadow mask evaporation process. The material for forming cross segments **114**, connecting segments **116**, and connecting segments **118** is an organic hydrophobic material that is suited for use with an inkjet deposition process and also suited for use with a shadow mask evaporation manufacturing process. While the literal definition of the word "hydrophobic" is roughly to repel water, for the purposes of this disclosure "hydrophobic" shall mean that the adhesiveness to a polymeric solution, which contains a light-emitting material, is low (affinity). By contrast, while the literal definition of the word "hydrophilic" is roughly to attract water, for the purposes of this disclosure "hydrophilic" shall mean that the adhesiveness to a polymeric solution, which contains a light-emitting material, is high (affinity). Both expressions are used for the sake of convenience as a comparison to clarify the degree of affinity against the polymeric solution.

[0028] Examples of organic hydrophobic materials for forming cross segments **114**, connecting segments **116**, and connecting segments **118** of receptacle **112** are (poly) vinyl alcohol, (poly)acrylate or polyimide. The design objective is for the solid material forming cross segments **114**, connecting segments **116**, and connecting segments **118** of receptacle **112** to have a surface energy higher than the surface tension of the polymeric solution deposited therein and, thus, the structure forming receptacle **112** repels the polymeric solution. Further details of the formation of cross segments **114**, connecting segments **116**, and connecting segments **118** of receptacle **112** via the shadow mask evaporation process are found in reference to **FIGS. 4 and 5**.

[0029] Emissive medium **120** is representative of a light emissive solid polymer layer that is deposited via a standard inkjet process whereby a volume of solvent with polymeric material dissolved therein is deposited within receptacle **112** and allowed to dry, which leaves only a solid layer of light emissive material. Commercially available polymeric solvents are, for example, Xylene; Toluene; benzene compounds, such as trimethylbenzene, chlorobenzene; dichlorobenzene supplied by Shell Chemical Corporation (Houston, Tex.); or proprietary mixtures including these chemicals, such as supplied by Dow Corning Corporation (Midland, Mich.).

[0030] **FIG. 2** illustrates an example of a light-emitting display **200** formed of a plurality of picture elements **100**, as described in **FIG. 1**. Receptacles **112** of picture elements **100** are formed upon substrate **110** via a shadow mask vacuum deposition process. Subsequently, emissive medium **120** is deposited within receptacles **112** via a standard inkjet process in order to complete the formation of light-emitting display **200**. Further details of the inkjet process are found in reference to **FIGS. 3A and 3B**.

[0031] **FIG. 3A** illustrates a cross-sectional view of picture element **100** taken along line A-A of **FIG. 1**. Cross segments **114c** and **114d** and connecting segment **116b** are deposited atop an electrode **122**, which is a portion of the circuitry of picture element **100** that is deposited atop substrate **110**. Cross segments **114c** and **114d** are intercon-

nected with connecting segment **116b** to form a continuous wall of receptacle **112**. Connecting segment **116b** is deposited, such that it overlaps slightly atop cross segment **114c** on one end and overlaps slightly atop cross segment **114d** on its opposing end, so that it fills the gap between cross segments **114c** and **114d** in order to form a continuous wall, as shown in **FIG. 3A**.

[0032] Electrode **122** is formed of an electrically conductive hydrophilic material, such as indium-tin oxide (ITO), as commonly used in bottom emitting PLED displays, or metal, such as nickel covered with a thin (5-50 angstrom thickness) nickel oxide formed by exposure of the nickel film to plasma in the presence of oxygen. The design objective is for the solid material forming electrode **122** to have a surface energy lower than the surface tension of the polymeric solution deposited thereon and, thus, electrode **122** attracts the polymeric solution.

[0033] **FIG. 3B** illustrates a cross-sectional view of picture element **100** taken along line B-B of **FIG. 1**. **FIG. 3B** shows that emissive medium **120** is bounded by the well structure of receptacle **112** that is formed by the combination of cross segments **114**, connecting segment **116**, and connecting segments **118**. **FIG. 3B** further shows receptacle **112** filled with a solution **124**, which is representative of a polymeric solution, as described in reference to **FIG. 1**.

[0034] For simplicity **FIGS. 3A** and **3B** are shown without the electronic active matrix circuit, which is typically positioned between electrode **122** and substrate **110**.

[0035] With reference to **FIGS. 1, 2, 3A, and 3B**, cross segments **114**, connecting segments **116**, and connecting segments **118** of receptacle **112**, are formed via a shadow mask evaporation system, such as described in reference to U.S. Patent Application No. 2003/0228715, entitled, "Active Matrix Backplane for Controlling Controlled Elements and Method of Manufacture Thereof," assigned to Amedeo Corporation (Pittsburgh, Pa.), which is incorporated herein by reference. The '715 patent application describes an electronic device formed from electronic elements deposited on a substrate. The electronic elements are deposited on the substrate by the advancement of the substrate through a plurality of deposition vacuum vessels that have at least one material deposition source and a shadow mask positioned therein. The material from at least one material deposition source positioned in each deposition vacuum vessel is deposited on the substrate through the shadow mask that is positioned in the deposition vacuum vessel, in order to form on the substrate a circuit formed of an array of electronic elements. The circuit is formed solely by the successive deposition of materials on the substrate.

[0036] Cross segments **114**, connecting segments **116**, and connecting segments **118** of receptacle **112** are formed with a thickness of, for example, 2 microns and with a width as is practical, depending on the pitch of picture elements **100** upon substrate **110**. For example, the width of the walls of each receptacle **112** formed by cross segments **114**, connecting segments **116**, and connecting segments **118** may be in the range of 10 to 20 micrometers.

[0037] With continuing reference to **FIGS. 1, 2, 3A, and 3B**, during a standard inkjet deposition process, a printhead sweeps across the area of a target display, such as light-emitting display **200** of **FIG. 2**, and delivers droplets of

solution **124** of a predetermined volume into the receptacles **112** thereof. By doing so, each receptacle **112** is filled or slightly overfilled to a uniform level with a predetermined quantity of solution **124**, as shown in **FIG. 3B**. The droplets of solution **124** are repelled by the hydrophobic material that forms the walls of each receptacle **112**, while, at the same time, the droplets of solution **124** are pulled into each receptacle **112** by the surface energy of the hydrophilic material of electrode **122**. In this way, each droplet of solution **124** is drawn to its intended location within each picture element **100** of the target display, such as light-emitting display **200** of **FIG. 2**. The display then experiences a drying event, whereby the liquid within solution **124** evaporates and leaves behind only the solids within solution **124** as a thin, solid, uniform layer of emissive material, i.e., emissive medium **120**.

[0038] **FIG. 4** illustrates a top view of an exemplary shadow mask **400** for forming an arrangement of cross segments **114** of a plurality of receptacles **112** via a shadow mask vacuum deposition process in accordance with a first embodiment of the invention. Shadow mask **400** includes a sheet **410** formed of, for example, nickel, chromium, steel, copper, Kovar, or Invar. Kovar and Invar are materials with a low coefficient of thermal expansion (CTE) known commercially as KOVAR™ or INVAR™ and are supplied, for example, by ESPICorp Inc. (Ashland, Oreg.). Formed within sheet **410** is a pattern of apertures **412**, which are openings of a predetermined size, shape, and location, for forming an arrangement of cross segments **114**. With reference to **FIGS. 1 and 4**, shadow mask **400** includes, for example, an aperture **412a** for forming cross segment **114a**, an aperture **412b** for forming cross segment **114b**, an aperture **412c** for forming cross segment **114c**, and an aperture **412d** for forming cross segment **114d**.

[0039] The location of apertures **412** are set on a pitch, as determined by an associated layout of picture elements **100** for a given display design. More specifically, the pitch of apertures **412** is dependent on the number of pixels per inch of a given display design. For example, the pitch of apertures **412** may be in the range of 100 to 500 μm , which equates to 250 to 50 pixels per inch, respectively.

[0040] Shadow mask **400** is suitable for use in a vacuum vessel of one deposition stage of an evaporation system. An example of a shadow mask evaporation system and method for forming cross segments **114**, connecting segments **116**, and connecting segments **118** of receptacle **112** is described in reference to the '715 patent application.

[0041] Optionally, one or more shadow masks, such as shadow mask **400**, in one or more successive deposition stages, respectively, of an evaporation process may be required for forming the full arrangement of cross segments **114** for any given display design, depending on the pitch of the design. The requirement is that the structural integrity and strength of the shadow masks, such as shadow mask **400**, be suitably maintained with any given layout of apertures **412**.

[0042] **FIG. 5** illustrates a top view of an exemplary shadow mask **500** for forming an arrangement of connecting segments **116** and connecting segments **118** of a plurality of receptacles **112** via a shadow mask vacuum deposition process in accordance with a first embodiment of the invention. Shadow mask **500** includes a sheet **510** formed of, for

example, nickel, chromium, steel, copper, Kovar, or Invar. Formed within sheet **510** is a pattern of apertures **516** and apertures **518**, which are openings of a predetermined size, shape, and location, for forming an arrangement of connecting segments **116** and **118**, respectively. With reference to **FIGS. 1 and 5**, shadow mask **500** includes, for example, an aperture **516a** for forming connecting segment **116a**, an aperture **516b** for forming connecting segment **116b**, an aperture **518a** for forming connecting segment **118a**, and an aperture **518b** for forming connecting segment **118b**.

[0043] The location of apertures **516** and **518** are set on a pitch, as determined by an associated layout of picture elements **100** for a given display design. More specifically, the pitch of apertures **516** and **518** is dependent on the number of pixels per inch of a given display design. For example, the pitch of apertures **516** and **518** may be in the range of 100 to 500 μm , which equates to 250 to 50 pixels per inch, respectively.

[0044] Shadow mask **500** is suitable for use in a vacuum vessel of one deposition stage of an evaporation system. An example of a shadow mask evaporation system and method for forming cross segments **114**, connecting segments **116**, and connecting segments **118** of receptacle **112** is described in reference to the '715 patent application.

[0045] Optionally, one or more shadow masks, such as shadow mask **500**, in one or more successive deposition stages, respectively, of an evaporation process may be required for forming the full arrangement of connecting segments **116** and **118** for any given display design, depending on the pitch of the design, for example, a shadow mask that includes only apertures **516** and another shadow mask that includes only apertures **518**. The requirement is that the structural integrity and strength of the shadow masks, such as shadow mask **500**, be suitably maintained with any given layout of apertures **516** and/or apertures **518**.

[0046] **FIG. 6** illustrates a top view of a picture element **600** in accordance with a second embodiment of the invention. Picture element **600** is a representative pixel of a flat-panel display, such as a PLED or OLED display. Picture element **600** includes substrate **110**, upon which is formed a receptacle **612**. Receptacle **612** is formed by an arrangement of evaporated segments and is formed of a plurality of cross segments **614**, arranged on a grid, that are interconnected via a plurality of connecting segments **616** and connecting segments **618**, which form the walls of receptacle **612** for retaining liquid solvent during an inkjet deposition process.

[0047] In this example, receptacle **612** is formed of a cross segment **614a**, a cross segment **614b**, a cross segment **614c**, and a cross segment **614d**, arranged on a grid, as shown in **FIG. 6**. Cross segments **614a** and **614b** are interconnected via a connecting segment **616a** to form a first wall of receptacle **612**; cross segments **614c** and **614d** are interconnected via a connecting segment **616b** to form a second wall of receptacle **612**; cross segments **614a** and **614c** are interconnected via a connecting segment **618a** to form a third wall of receptacle **612**; and cross segments **614b** and **614d** are interconnected via a connecting segment **618b** to form a fourth wall of receptacle **612**.

[0048] Deposited within the walls of receptacle **612** that are formed by the combination of cross segments **614**, connecting segments **616**, and connecting segments **618** is a quantity of emissive medium **120**.

[0049] Cross segments **614**, connecting segments **616**, and connecting segments **618** of receptacle **612** are formed via a shadow mask evaporation process. The material for forming cross segments **614**, connecting segments **616**, and connecting segments **618** is an organic hydrophobic material that is suited for use with an inkjet deposition process and also suited for use with the shadow mask evaporation manufacturing process, as described in **FIG. 1**. Further details of the formation of cross segments **614**, connecting segments **616**, and connecting segments **618** of receptacle **612** via the shadow mask evaporation process are found in reference to **FIGS. 7 and 8**.

[0050] As compared with picture element **100** of **FIG. 1**, picture element **600** illustrates an example alternative shape for a receptacle of a display. More specifically, picture element **100** of **FIG. 1** results in emissive medium **120** forming in a square shape, whereas picture element **600** of **FIG. 6** results in emissive medium **120** forming in a circular shape. The shape of the receptacles of the present invention are not limited to square or circular; any desired shape or geometry, such as rectangular, square, circular, or oval, is within the scope of this invention.

[0051] **FIG. 7** illustrates a top view of an exemplary shadow mask **700** for forming an arrangement of cross segments **614** of a plurality of receptacles **612** via a shadow mask vacuum deposition process in accordance with a second embodiment of the invention. Shadow mask **700** includes a sheet **710** formed of, for example, nickel, chromium, steel, copper, Kovar, or Invar. Formed within sheet **710** is a pattern of apertures **712**, which are openings of a predetermined size, shape, and location, for forming an arrangement of cross segments **614**. With reference to **FIGS. 6 and 7**, shadow mask **700** includes, for example, an aperture **712a** for forming cross segment **614a**, an aperture **712b** for forming cross segment **614b**, an aperture **712c** for forming cross segment **614c**, and an aperture **712d** for forming cross segment **614d**.

[0052] The location of apertures **712** are set on a pitch, as determined by an associated layout of picture elements **600** for a given display design. More specifically, the pitch of apertures **712** is dependent on the number of pixels per inch of a given display design. For example, the pitch of apertures **712** may be in the range of 100 to 500 μm , which equates to 250 to 50 pixels per inch, respectively.

[0053] Shadow mask **700** is suitable for use in a vacuum vessel of one deposition stage of an evaporation system. An example shadow mask evaporation system and method for forming cross segments **614**, connecting segments **616**, and connecting segments **618** of receptacle **612** is described in reference to the '715 patent application.

[0054] Optionally, one or more shadow masks, such as shadow mask **700**, in one or more successive deposition stages, respectively, of an evaporation process may be required for forming the full arrangement of cross segments **614** for any given display design, depending on the pitch of the design. The requirement is that the structural integrity and strength of the shadow masks, such as shadow mask **700**, be suitably maintained with any given layout of apertures **712**.

[0055] **FIG. 8** illustrates a top view of an exemplary shadow mask **800** for forming an arrangement of connecting

segments **616** and connecting segments **618** of a plurality of receptacles **612** via a shadow mask vacuum deposition process in accordance with a second embodiment of the invention. Shadow mask **800** includes a sheet **810** formed of, for example, nickel, chromium, steel, copper, Kovar, or Invar. Formed within sheet **810** is a pattern of apertures **816** and apertures **818**, which are openings of a predetermined size, shape, and location, for forming an arrangement of connecting segments **616** and **618**, respectively. With reference to **FIGS. 6 and 8**, shadow mask **800** includes, for example, an aperture **816a** for forming connecting segment **616a**, an aperture **816b** for forming connecting segment **616b**, an aperture **818a** for forming connecting segment **618a**, and an aperture **818b** for forming connecting segment **618b**.

[0056] The location of apertures **816** and **818** are set on a pitch, as determined by an associated layout of picture elements **600** for a given display design. More specifically, the pitch of apertures **816** and **818** is dependent on the number of pixels per inch of a given display design. For example, the pitch of apertures **816** and **818** may be in the range of 100 to 500 μm , which equates to 250 to 50 pixels per inch, respectively.

[0057] Shadow mask **800** is suitable for use in a vacuum vessel of one deposition stage of an evaporation system. An example shadow mask evaporation system and method for forming cross segments **614**, connecting segments **616**, and connecting segments **618** of receptacle **612** is described in reference to the '715 patent application.

[0058] Optionally, one or more shadow masks, such as shadow mask **800**, in one or more successive deposition stages, respectively, of an evaporation process may be required for forming the full arrangement of connecting segments **616** and **618** for any given display design, depending on the pitch of the design, for example, a shadow mask that includes only apertures **816** and another shadow mask that includes only apertures **818**. The requirement is that the structural integrity and strength of the shadow masks, such as shadow mask **800**, be suitably maintained with any given layout of apertures **816** and/or apertures **818**. Additionally, the deposition sequence of the receptacle components is not critical and can be altered without material change to the resultant receptacles.

[0059] **FIG. 9** illustrates a flow diagram of a method **900** of making inkjet receptacles via a shadow mask vacuum deposition process and using same in accordance with the invention. With continuing reference to **FIGS. 1 through 8**, method **900** includes the following steps.

[0060] At step **910**, an arrangement of deposition vacuum vessels is installed in a serial arrangement to form a shadow mask vacuum deposition system, such as described in reference to the '715 patent application.

[0061] At step **912**, the design specifications of the specific light emissive display to be formed via the shadow mask vacuum deposition system are determined.

[0062] At step **914**, a set of shadow masks, such as shadow masks **400**, **500**, **700**, or **800**, for forming receptacles, such as a plurality of receptacles **112** or **612**, suitable for use with an inkjet printing deposition process are formed. The plurality of apertures within each shadow mask is arranged according to the predetermined pattern for each segment of the receptacle structure.

[0063] At step **916**, circuitry associated with the display is formed upon a substrate, such as substrate **110**, via any well-known manufacturing process. The outmost layer is an arrangement of electrodes, such as electrodes **122**, formed of an electrically conductive hydrophilic material, as described in reference to **FIG. 3A**.

[0064] At step **918**, an arrangement of receptacle structures is formed upon a substrate, such as a plurality of receptacles **112** or **612** upon substrate **110**. The receptacles are formed via one or more shadow mask vacuum deposition events by use of the set of shadow masks of step **914** within the shadow mask vacuum deposition system of step **910**. More specifically, a hydrophobic material, as described in reference to **FIG. 1**, is deposited upon the hydrophilic electrodes to form the structure of the receptacles.

[0065] At step **920**, a solution, such as solution **124**, which is a solvent with a polymer dissolved therein, is deposited within the receptacles formed at step **918** via a standard inkjet deposition process. During the inkjet deposition process, a printhead sweeps across the area of the target display, such as light-emitting display **200** of **FIG. 2**, and delivers droplets of solution **124** of a predetermined volume into the receptacles **112** thereof. By doing so, each receptacle **112** is filled or slightly overfilled to a uniform level with a predetermined quantity of solution **124**, as shown in **FIG. 3B**. The droplets of solution **124** are repelled by the hydrophobic material that form the walls of each receptacle **112**, while, at the same time, the droplets of solution **124** are pulled into each receptacle **112** by the surface energy of the hydrophilic material of electrode **122**. In this way, each droplet of solution **124** is drawn to its intended location within each picture element **100** of the target display, such as light-emitting display **200** of **FIG. 2**. The display then experiences a drying event, whereby the liquid within solution **124** evaporates and leaves behind only the solids within solution **124** as a thin, solid, uniform layer of emissive material, i.e., emissive medium **120**. Method **900** ends.

[0066] Although the invention has been described in detail in connection with the exemplary embodiments, it should be understood that the invention is not limited to the above disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alternations, substitutions, or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Accordingly, the invention is not limited by the foregoing description or drawings, but is only limited by the scope of the appended claims.

What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. A system for providing an electronic display assembly, comprising:

a substrate;

at least one receptacle structure disposed over the substrate, the receptacle structure being formed by employing a shadow mask aligned with a surface of the substrate; and

a light-emissive material contained in the receptacle structure.

2. The system of claim 1, wherein the receptacle structure has a predetermined configuration that allows a predeter-

mined volume of a light-emissive material to be contained within the receptacle structure.

3. The system of claim 1, wherein the receptacle structure comprises a plurality of cross segments disposed on a grid over the substrate, and a plurality of connecting segments for interconnecting the cross segments.

4. The system of claim 1, wherein the light-emissive material is an inkjet deposited light-emissive material.

5. The system of claim 1, further comprising at least one electrode disposed on the substrate and under the receptacle structure.

6. An electronic display assembly, comprising:

a substrate;

an electrode formed on the substrate;

a plurality of receptacles provided over the substrate, the receptacles being formed by employing deposition of material through a shadow mask aligned with a surface of the substrate; and

an emissive medium provided within the plurality of receptacles formed by employing deposition through the shadow mask.

7. The electronic display assembly of claim 6, wherein the emissive medium forms an active display element.

8. The electronic display assembly of claim 7, wherein the active display element is a light-emitting device.

9. An organic light-emitting diode, comprising:

a substrate;

an electrode formed on the substrate;

at least one receptacle provided over the substrate, the at least one receptacle being formed by employing deposition of material through a shadow mask aligned with a surface of the substrate; and

a light emissive polymer provided within the at least one receptacle formed by employing deposition through the shadow mask.

10. A receptacle structure for containing a light-emissive material of a light-emitting display, the receptacle structure being formed by a process comprising the steps of:

employing a first shadow mask provided in a first deposition vacuum vessel to deposit a first material over a substrate and to thereby form a plurality of cross segments; and

employing a second shadow mask provided in a second deposition vacuum vessel to deposit a second material over the substrate and to thereby form a plurality of connecting segments for connecting the plurality of cross segments.

11. A method of forming an electronic device, comprising the steps of:

providing a substrate having at least one electrode formed thereon;

aligning at least one shadow mask with a surface of the substrate; and

forming at least one receptacle structure on the surface of the substrate using the shadow mask.

12. The method of claim 11, wherein the step of forming the receptacle structure on the surface of the substrate further comprises the steps of:

advancing the substrate through a plurality of deposition vacuum vessels, each deposition vacuum vessel having at least one material deposition source and a shadow mask position therein; and

depositing on the surface of the substrate the material from the material deposition source through the shadow mask to form on the surface of the substrate the receptacle structure.

13. The method of claim 11 further comprising the step of providing a light-emissive material within the receptacle structure by inkjet deposition.

14. A method of forming a light-emitting display, comprising the steps of:

providing a substrate having at least one electrode formed thereon;

using a first shadow mask and a second shadow mask to form at least one receptacle on the surface of the substrate; and

inkjet depositing a light-emissive material within the receptacle.

15. The method of claim 14, wherein the step of using the first shadow mask and the second shadow mask further comprises the steps of:

advancing the substrate through first and second deposition vacuum vessels, the first deposition vacuum vessel having a first material deposition source and the first shadow mask positioned therein, and the second deposition vacuum vessel having a second material deposition source and the second shadow mask positioned therein; and

depositing on the surface of the substrate the first material from the first material deposition source through the first shadow mask to form on the surface of the substrate a first pattern of segments of the receptacle.

16. The method of claim 15 further comprising the step of depositing on the surface of the substrate the second material from the second material deposition source through the second shadow mask to form on the surface of the substrate a second pattern of segments of the receptacle.

17. The method of claim 16, wherein the first pattern of segments corresponds to a plurality of cross segments provided on the surface of the substrate, and wherein the second pattern of segments corresponds to a plurality of interconnects for interconnecting the plurality of cross segments.

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