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**Harwell et al.**

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(54) **SCREEN PRINTER HAVING PLATEN INCLUDING CAVITY HOLDING RELEASE FLUID AND FLUID CONTROL SYSTEM**

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*B41F 15/38* (2006.01)

(52) **U.S. Cl.**
CPC .................................. *B41F 15/38* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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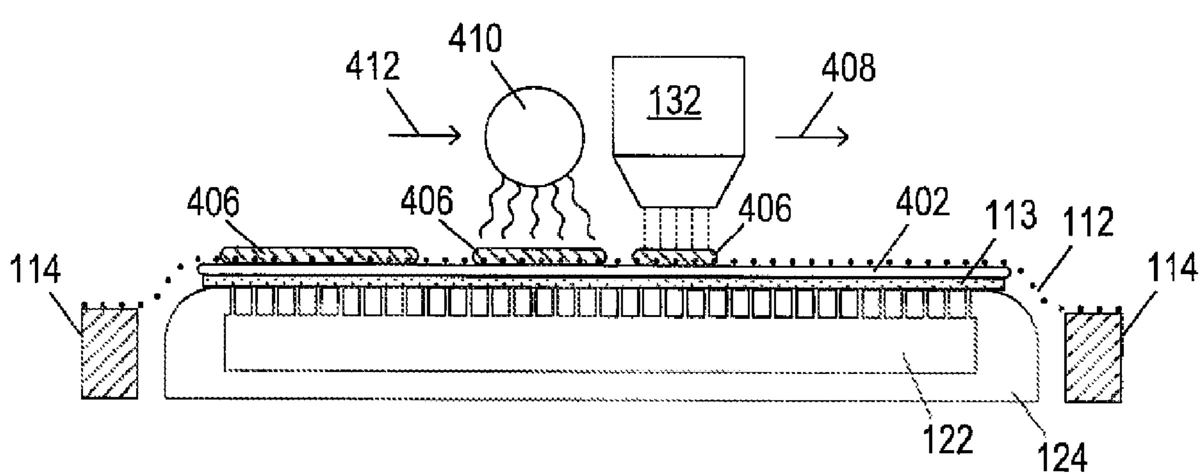
(74) *Attorney, Agent, or Firm* — Workman Nydegger

(57) **ABSTRACT**

A direct to mesh (DtM) screen printer for creating a screen stencil is provided. The DtM screen printer includes a fixture to hold a frame, which holds a pre-stretched mesh in place during application of a jettable emulsion, a platen having a cavity and an array of holes in a top surface of the platen, a non-woven fabric placed on the top surface of the platen and saturated with a release fluid located against one side of the pre-stretched mesh, and a printer carriage supporting a print head for printing the jettable emulsion on a side of the pre-stretched mesh opposite the non-woven fabric.

**19 Claims, 10 Drawing Sheets**



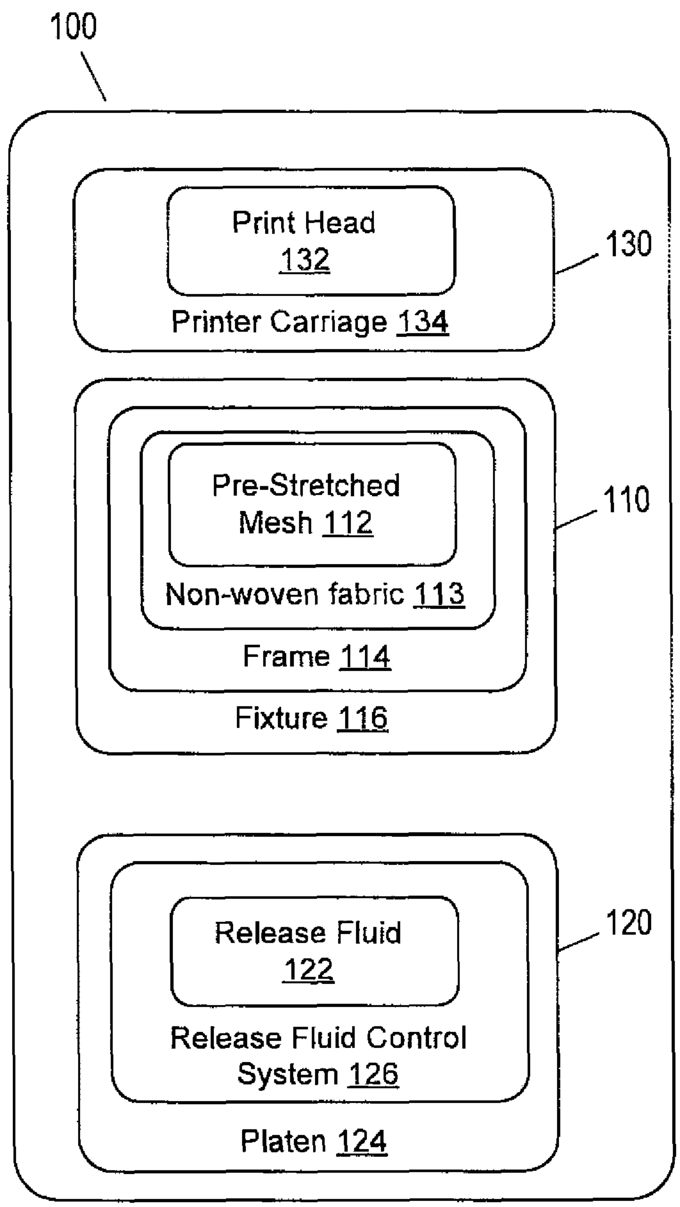

100
Print Head
132
Printer Carriage 134
130
Pre-Stretched
Mesh 112
Non-woven fabric 113
Frame 114
Fixture 116
110
Release Fluid
122
Release Fluid Control
System 126
Platen 124
120

FIG. 1

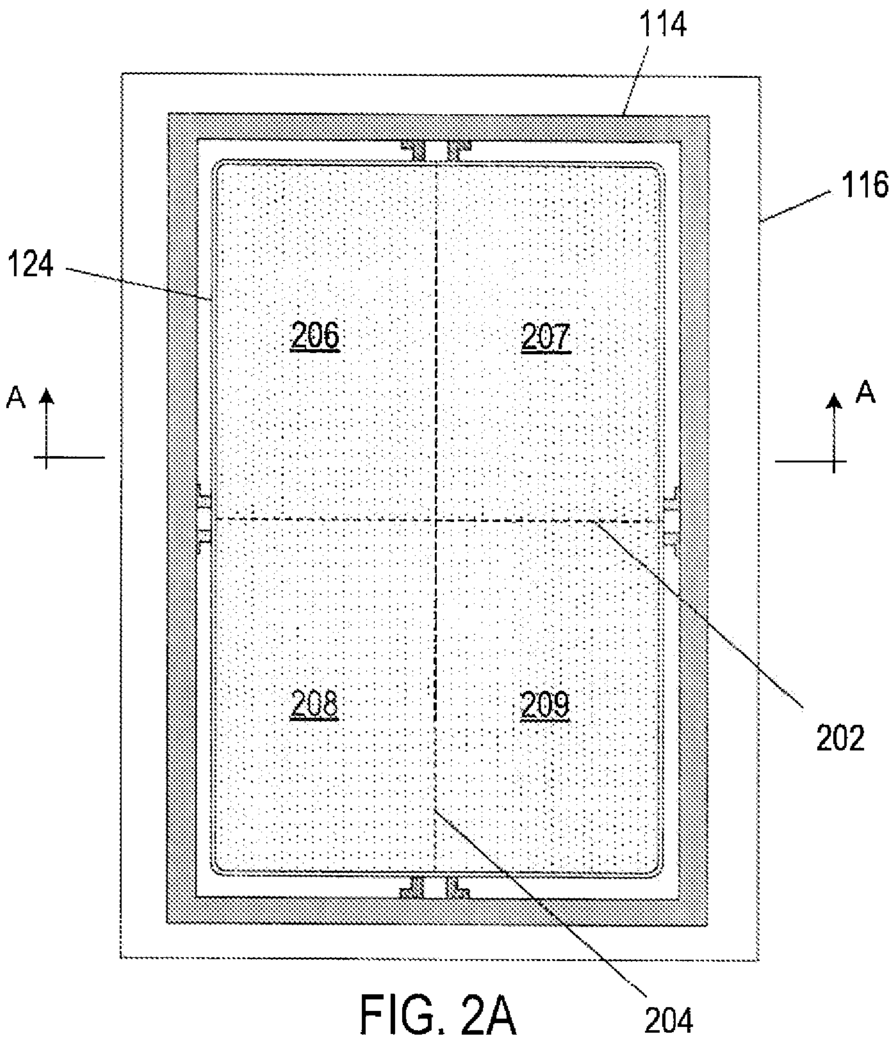



FIG. 2A

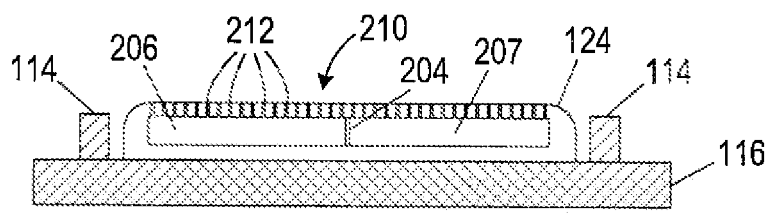



FIG. 2B

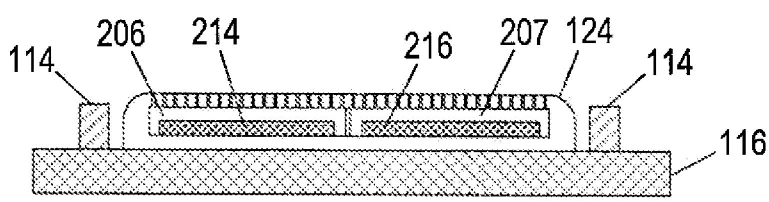
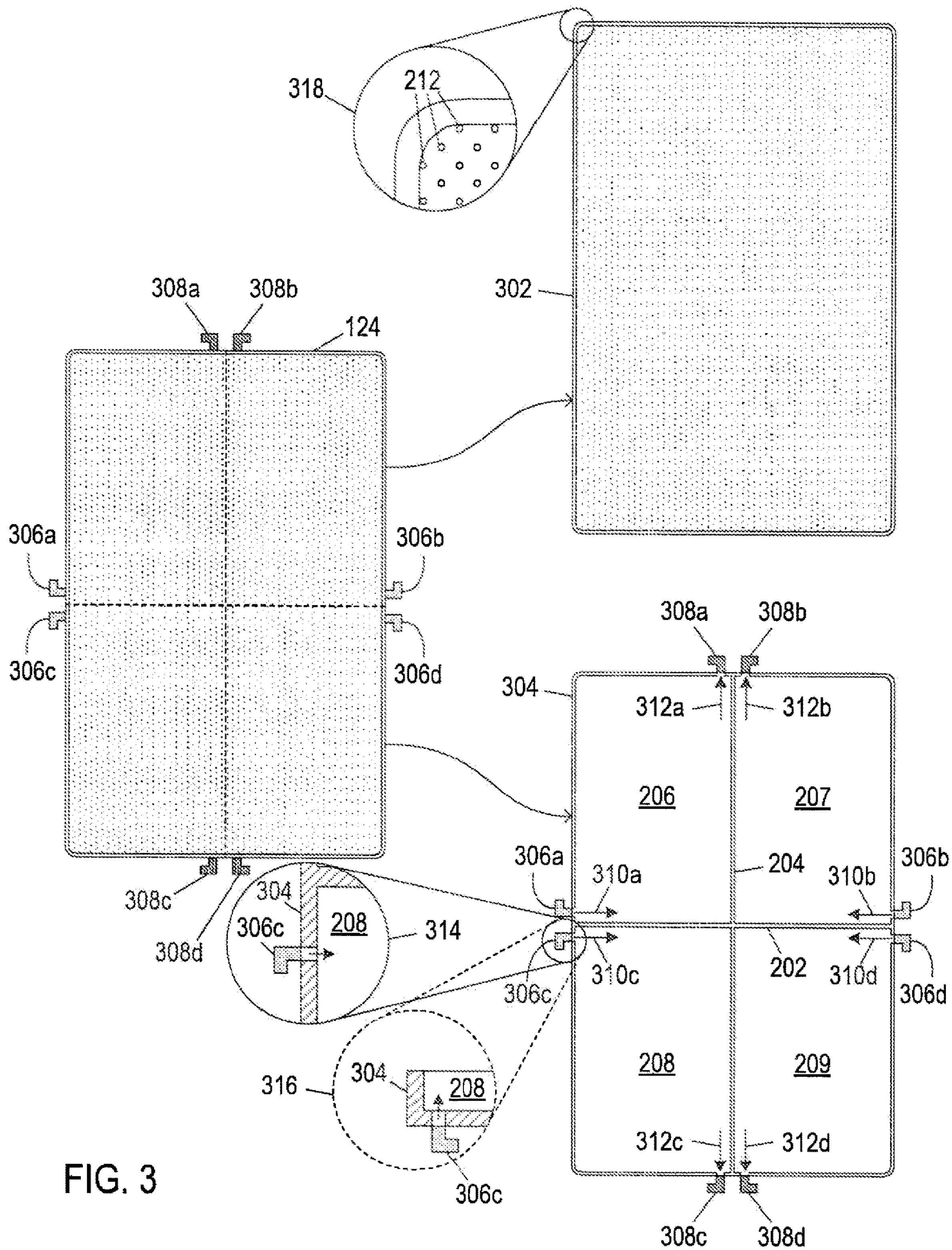



FIG. 2C



318
212
302
308a
308b
124
306a
306b
306c
306d
308c
308d
304
312a
312b
206
207
204
310a
310b
310c
310d
202
208
209
314
316
312c
312d


FIG. 3

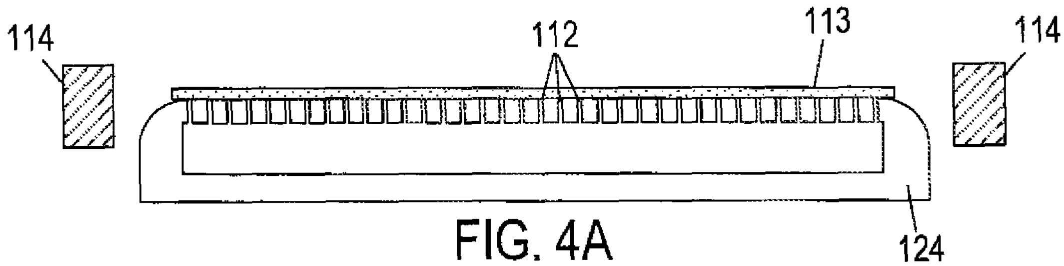



FIG. 4A

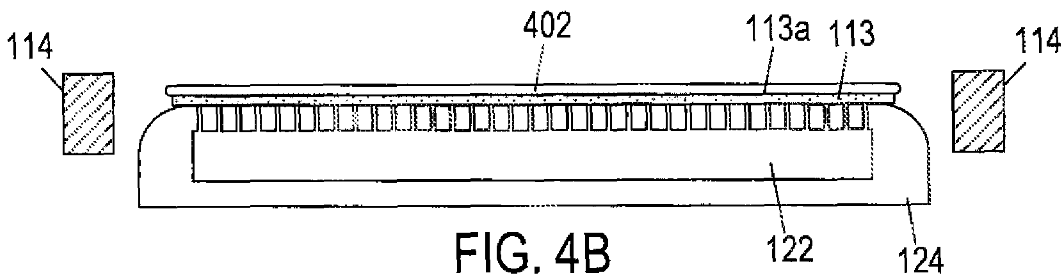



FIG. 4B

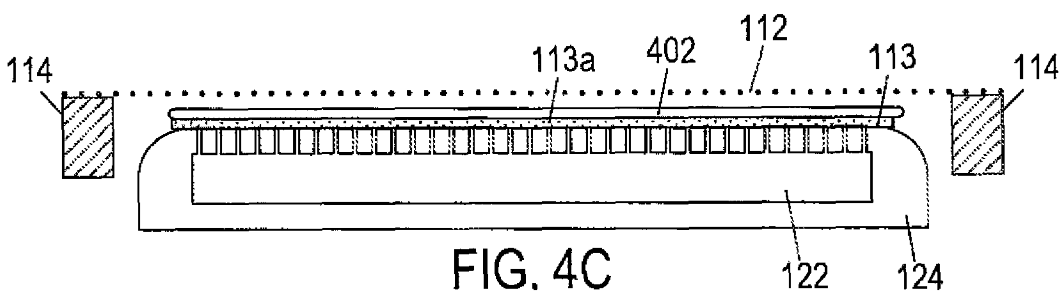



FIG. 4C

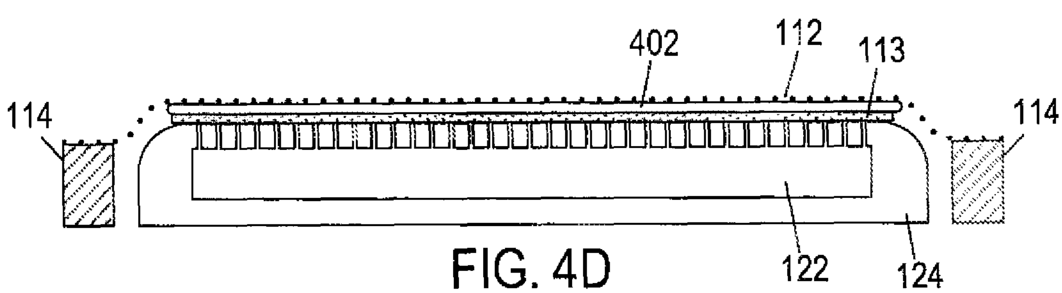



FIG. 4D

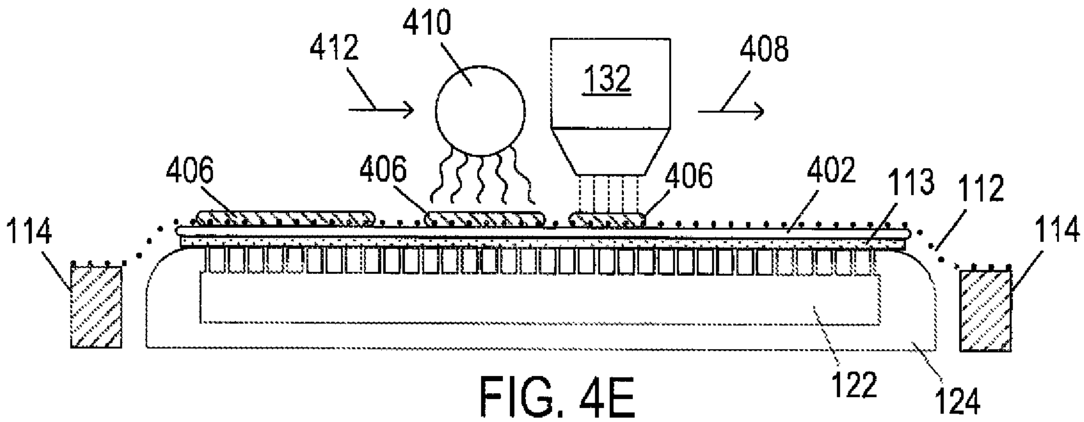

410
412
132
408
406
406
406
402
113
112
114
114
122
124

FIG. 4E

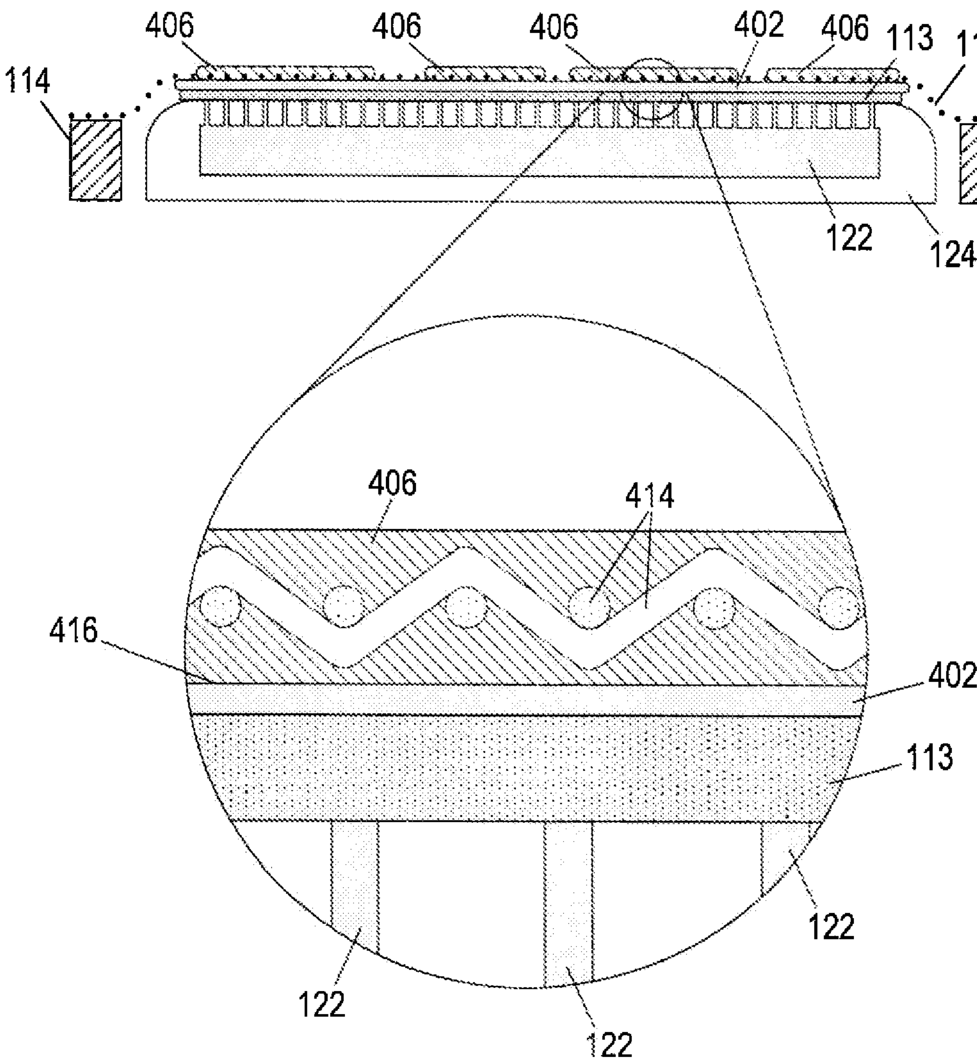

406
406
406
402
406
113
112
114
114
122
124
406
414
416
402
113
122
122
122

FIG. 4F

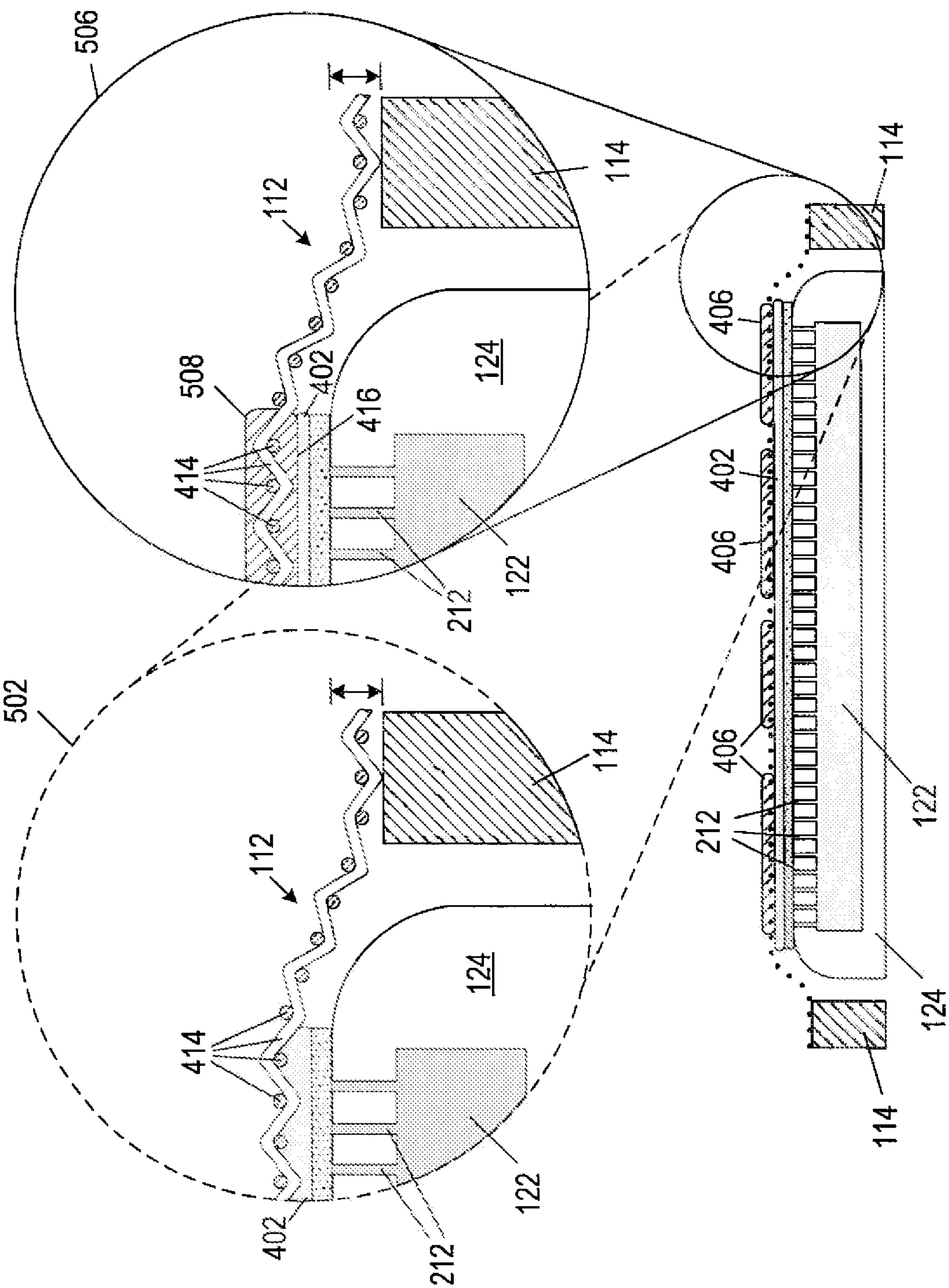

506
114
112
124
508
402
416
414
212
122
502
114
112
124
414
402
212
122
114
406
402
406
406
212
122
124
114

FIG. 5

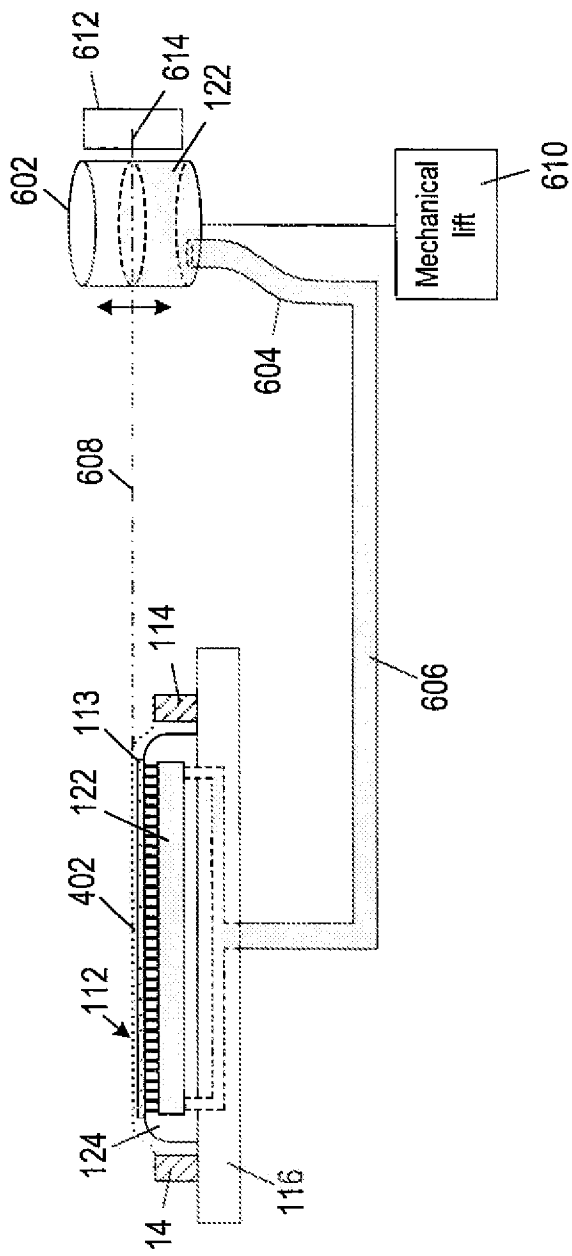

612
614
122
602
Mechanical lift
610
604
608
606
114
113
122
402
112
124
116
114

FIG. 6

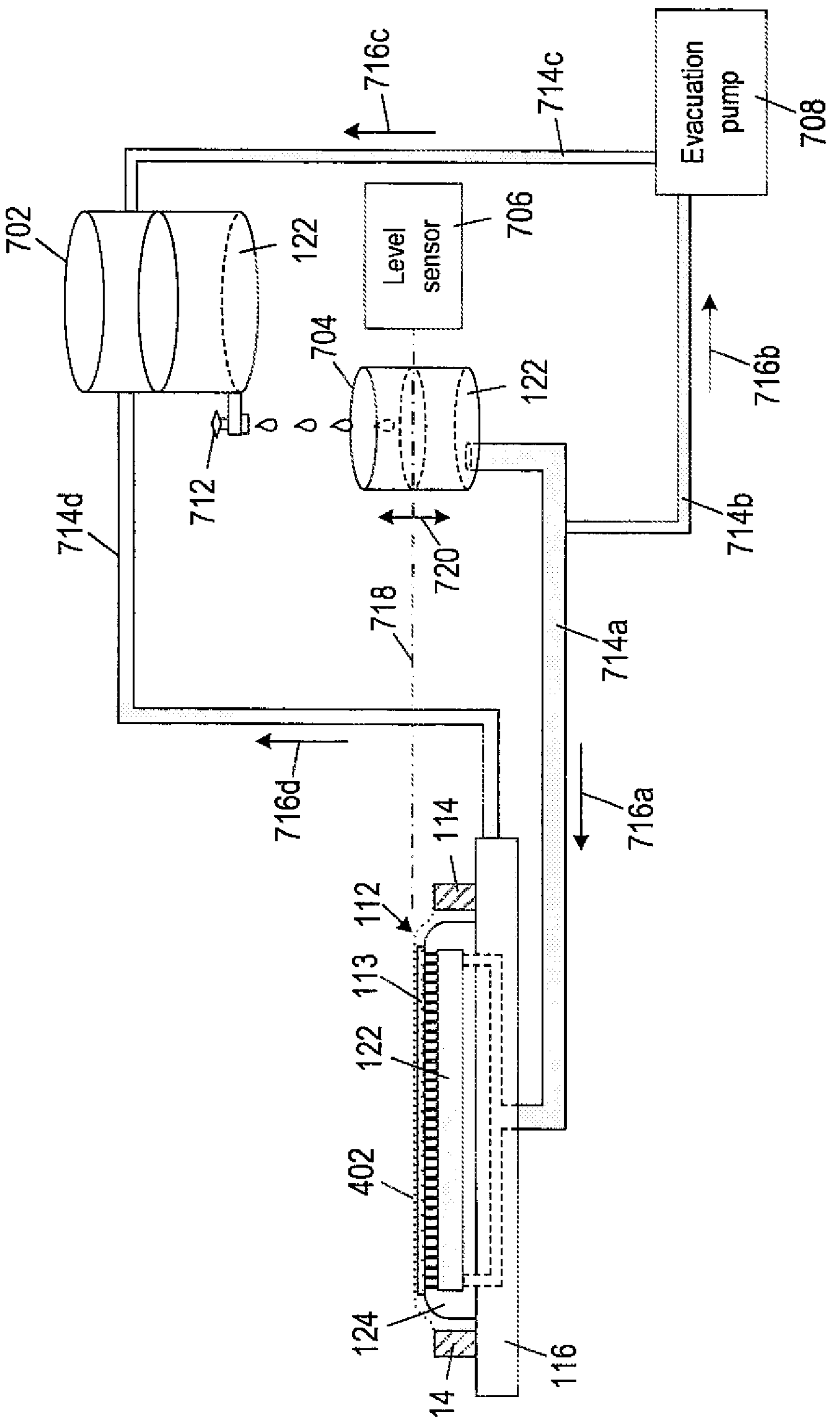

Evacuation pump
708
716c
714c
702
122
Level sensor
706
704
122
716b
712
714b
714d
720
718
714a
716d
716a
114
112
113
122
402
124
114
116

FIG. 7

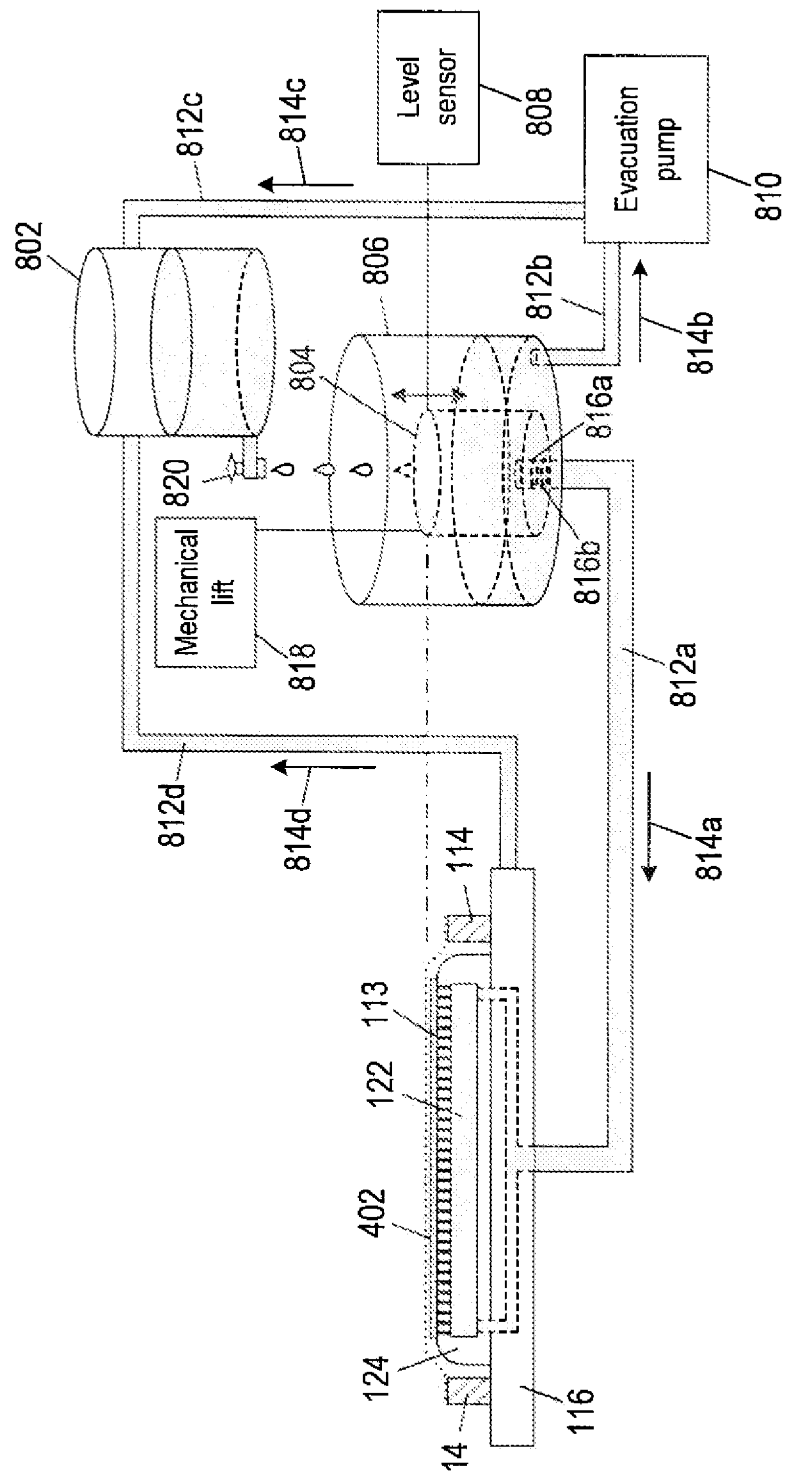

Level sensor
808
Evacuation pump
810
812c
814c
802
806
812b
814b
804
816a
820
Mechanical lift
818
816b
812a
812d
814d
814a
114
113
122
402
124
116
114

FIG. 8

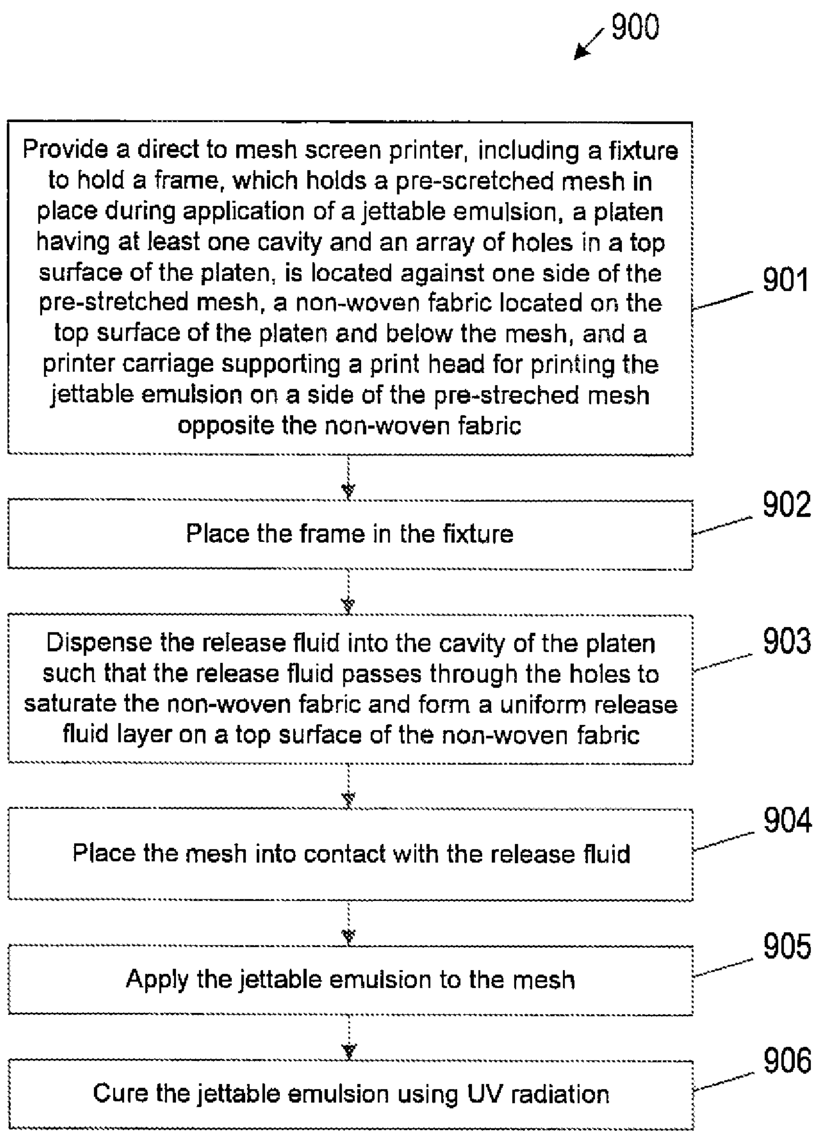

900
Provide a direct to mesh screen printer, including a fixture to hold a frame, which holds a pre-scretched mesh in place during application of a jettable emulsion, a platen having at least one cavity and an array of holes in a top surface of the platen, is located against one side of the pre-stretched mesh, a non-woven fabric located on the top surface of the platen and below the mesh, and a printer carriage supporting a print head for printing the jettable emulsion on a side of the pre-streched mesh opposite the non-woven fabric
901
Place the frame in the fixture
902
Dispense the release fluid into the cavity of the platen such that the release fluid passes through the holes to saturate the non-woven fabric and form a uniform release fluid layer on a top surface of the non-woven fabric
903
Place the mesh into contact with the release fluid
904
Apply the jettable emulsion to the mesh
905
Cure the jettable emulsion using UV radiation
906

FIG. 9

# SCREEN PRINTER HAVING PLATEN INCLUDING CAVITY HOLDING RELEASE FLUID AND FLUID CONTROL SYSTEM

## CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to PCT Application No. PCT/EP2020/072899, filed Aug. 14, 2020.

## BACKGROUND

Screen printing is a printing technique whereby a mesh is used to transfer ink onto a substrate, except in areas made impermeable to the ink by a screen printing stencil, also called a blocking stencil. A blade or squeegee is moved across the screen to fill the open mesh apertures with ink, and a reverse stroke then causes the screen to touch the substrate momentarily along a line of contact. This causes the ink to wet the substrate and be pulled out of the mesh apertures as the screen springs back after the blade has passed.

The creation of a screen printing stencil is a tedious, labor-intensive job. It is one that requires a number of process steps, chemical products, lots of water, and is largely manual. It is the least automated part of the current screen printing business.

## BRIEF DESCRIPTION OF THE DRAWINGS

Features of examples of the present disclosure will become apparent by reference to the following detailed description and drawings, in which like reference numerals correspond to similar, though perhaps not identical, components. For the sake of brevity, reference numerals or features having a previously described function may or may not be described in connection with other drawings in which they appear.

FIG. **1** illustrates a direct to mesh screen printer, according to an example of the present disclosure.

FIG. **2**A illustrates top plan view of a platen, a frame, and a fixture.

FIGS. **2**B-**2**C illustrate cross-sectional views of the platen, frame, and fixture shown in FIG. **2**A.

FIG. **3** shows a top plan view of platen and top and bottom plates of the platen.

FIGS. **4**A-**4**F depict, in cross-sectional view, elements of a process in screen printing, using a direct to mesh screen printer, according to an example of the present disclosure.

FIG. **5** shows a cross-sectional view of capillary behavior of a release fluid to aid with encapsulation of strands (or threads) of a mesh by the emulsion.

FIG. **6** shows a release fluid control system, according to an example of the present disclosure.

FIG. **7** shows a release fluid control system, according to an example of the present disclosure.

FIG. **8** shows a release fluid control system, according to an example of the present disclosure

FIG. **9** is a flow chart illustrating a method of screen printing, according to an example of the present disclosure.

## DETAILED DESCRIPTION

There are several examples of previous solutions for directly coating a mesh to form a stencil for screen printing. These are now described.



### Mesh Preparation and Coating

Direct application of emulsion: this is done either with a machine or by hand. Both sides of the screen must be coated with the emulsion to ensure proper coverage. The machine or automated version is strictly a machine replacing a human. The machine is much more accurate at applying precise amounts of the emulsion and getting even coverage. The machine generally has less waste.

Capillary films: These are films that are pre-coated with an emulsion. The mesh is oversaturated with water and the film (emulsion side down) is placed against the supersaturated mesh. The capillary action draws the emulsion into the mesh. This gives a more precise coating of the emulsion, both in thickness and in cover. Once the emulsion has diffused into the mesh, the film is peeled off.

Once the screen mesh is emulsified it must be dried. Once dry, it is ready for the image transfer or making of the stencil. As the emulsion dries, it contracts and conforms to the mesh causing a rough, uneven surface. (This rough surface causes an accelerated aging of the squeegee during the printing process.)

Most emulsions today are activated by ultra-violet (UV) radiation (i.e., UV-activated) but may also be visible-light activated. Once coated, the stencils must be protected from any exposure to light (even normal visible light has enough UV to start the curing process). Hereinafter, it is assumed that the emulsion is UV-activated/cured.

Film Positive Ink: A totally black, UV absorbent layer is printed onto a clear sheet of plastic. The printing is done normally by laser or inkjet printers with special film positive inks (film positive ink means a high opacity black ink that completely blocks al visible and UV light). The film is then attached to the pre-coated mesh and exposed to UV light. The attachment is usually by a removable tape (such as masking tape). Once exposed, the film is removed and the uncured emulsion is washed off.

However, this approach is very labor intensive at all stages, and it is not possible to automate many steps. In addition, it is prone to error, such as during mounting the film, using the correct film, adjusting the final stencil before print. Lots of chemicals and washing, as well as lots of consumables (inks, films), are required.

Thermal Screen: In this method, the mesh is pre-coated with a thermally-activated emulsion. Typically, the mesh (without a frame) is put into a thermal printer, where the emulsion is directly cured/activated. Once completed, the un-exposed emulsion is washed off, the stencil is mounted on a frame, and printed.

However, this approach suffers from limited mesh counts. Also, the emulsions are typically not as robust. The pre-treated mesh is expensive. The stencil alignment is more intensive. Finally, the stencil can be damaged while it is being mounted.

### Computer to Screen (CtS)

CtS—Printed: In this method, the coated mesh is directly printed onto the emulsified screen with a high-opacity black ink. This is similar to Film Positive Inks without the film. All of the processes are the same.

However, these machines require a high-opacity ink, which is more expensive than regular inkjet inks.

CtS—Wax: This method is a close relative of CtS—Printed, but uses wax to block the UV light. All else is the same.

However, due to the use of melted wax, these machines can be temperamental. Further, they require that the wax be heated to apply it to the mesh.

CtS—Direct Exposure: This technology directly exposes the emulsion using a UV laser.

However, the machines used in this technology are typically very expensive. Further, the process does not work as well on coarse grade mesh. Finally, UV lasers are still very expensive when they need replacing.

Each of the above methods require some post-processing/follow-up. Except for Thermal Activated and CtS Direct Exposure, all stencils must be exposed after the image blocking is applied (either films or CtS Printed and Wax). This process takes, for example, at least about 1 to 2 minutes per screen with an intense developer.

All screens must have the excess emulsion washed off. Care must be taken so that the emulsion does not get into the drainage system. Screens must be thoroughly dried after washing.

For the Film and Thermal Activated methods, the finished stencil must be fine adjusted when placed on the carousel to ensure proper registration.

## Current Disclosure

It is clear from the foregoing description of the current technology that a simpler approach that uses fewer chemicals and less water would be desirable.

A Direct to Mesh (DtM) approach is used to form a stencil by directly applying and activating/exposing an emulsion onto a screen using inkjet technology. In particular, and in accordance with the teachings herein, a DtM screen printer includes:

- a frame to hold a pre-stretched mesh in place during application of a jettable emulsion onto the pre-stretched mesh;
- a fixture to hold the frame;
- a platen having a cavity and a top surface perforated with an array of holes, the cavity to hold a release fluid to be dispensed through the holes;
- a non-woven fabric placed on the perforated top surface and positioned to receive the released fluid dispensed through the holes and form an evenly distributed release fluid layer against one side of the pre-stretched mesh;
- a release fluid control system for dispensing the release fluid into the cavity of the platen and form the release fluid layer; and
- a printer carriage supporting a print head for printing the jettable emulsion on a side of the pre-stretched mesh opposite the platen.

As disclosed and claimed herein and in accordance with the teachings herein, the non-woven fabric is a flat, porous sheet or web-structured material created from bonding of entangled fibers or perforation of films using chemical, mechanical, or thermal processes. The platen includes a perforated top surface and is used to introduce and maintain the level of the release fluid absorbed by the non-woven fabric. The non-woven fabric rapidly absorbs and becomes saturated with the release fluid diffused through the perforated top surface. The non-woven fabric maintains an even distribution of the release fluid against the pre-stretched mesh. A release fluid control system controls saturation of the non-woven fabric with the release fluid, thereby maintaining an essentially constant evenly distributed release fluid moisture level of the mesh throughout printing of the emulsion onto the mesh.

FIG. **1** depicts a block diagram of the direct to mesh (DtM) printer **100**. The DtM printer **100** includes a mesh support system **110** that includes a pre-stretched mesh **112** and a non-woven fabric **113**. The pre-stretched mesh is held in place by the frame **114**. The non-woven fabric **113** is placed on the platen **124**. The frame **114** is in turn held by the fixture **116**. The fixture **116** securely and firmly holds the frame **114** with the pre-stretched mesh **112** in place during the application of the jettable emulsion. In other configurations, the frame **114** firmly holds the pre-stretched mesh **112** and the non-woven fabric **113**.

As used herein, the mesh **112** is made of connected strands of textiles, fiber, metal, or other flexible/ductile materials, here, woven in a crisscross pattern. The material comprising the mesh may be any of a number of textiles including silks; polyesters; metals, such as stainless steel; plastics. such as polypropylene, polyethylene, nylon, polyvinyl chloride (PVC) or polytetrafluoroethylene (PTFE); or fiberglass. The diameter of the strands may be any diameter common in screen printing, and the mesh size may also be any size common in screen printing. Coarser mesh is typically woven with larger diameter (gauge) strands, which requires a thicker application of the emulsion.

The non-woven fabric **113** is a flat material with a substantially uniform thick and is made from fibers bonded together by chemical, mechanical, heat or solvent treatment. The non-woven fabric **113** may be manufactured by placing small fibers together in the form of a sheet or web, followed by binding the fibers mechanically, thermally, or by melting a binder onto the web by increasing the temperature. The fibers are hydrophilic and may be made from cotton, cellulose, carbonate-based materials, or any of many different hydrophilic materials. The non-woven fabric **113** has holes or openings between fibers that retain the release fluid **122**.

The DtM printer **100** further includes a platen support system **120**, including a release fluid **122** held against the underside of the pre-stretched mesh **112** by a platen **124**. The platen **124** provides a smooth flat surface for holding the non-woven fabric **113** saturated with the release fluid **122** firmly against the bottom of the pre-stretched mesh **112**. The platen **124** includes a surface that is perforated with holes, is smooth, and is resistant to dents and cracks. The platen **124** includes a cavity for storing the release fluid that is forced through the holes to saturate the non-woven fabric **113** against the pre-stretched mesh **112**. The platen **124** may also act to dissipate energy from a UV curing source **410** (not shown in FIG. **1** but shown in FIG. **4**E).

The release fluid **122** may be applied to the non-woven fabric **113** once the non-woven fabric **113** is placed against the perforated surface of the platen **124** prior to placement of the mesh **112**. For example, a release fluid control system **126** controls the amount of the release fluid **122** released from the cavity of the platen **124** and into the non-woven fabric **113**. In particular, the release fluid control system **126** controls the amount of the release fluid released through perforated top surface of the platen **124** thereby saturating the non-woven fabric **113** such that a meniscus of the release fluid and the capillary action of the release fluid enable the emulsion to wrap around the threads in the mesh.

The release fluid **122** inhibits dot-gain, which is the effect of a printed fluid spreading into a print medium, by not reacting with the curing emulsion. Dot-gain need only be inhibited for a short period, as the curing occurs very quickly after the emulsion fluid is jetted.

Finally, the DtM printer **100** includes an inkjet printer **130** that includes a print head **132** mounted on a printer carriage **134**. The print head **132** prints the jettable emulsion on the side of the pre-stretched mesh **112** opposite the non-woven fabric **113**. The printer carriage **134** is a high-precision printer carriage, accurate in both the X and Y Cartesian directions to support accurate droplet placement over one or more passes while building up the jettable emulsion. Indeed, the emulsion can be "built up" to accommodate a wide range of mesh gauges, from very fine to super coarse. The layering can be used to maintain high resolution as it builds up the emulsion.

The print head **132** may be an inkjet print head, such as thermal inkjet, piezoelectric inkjet, drop-on-demand inkjet, or other suitable jetting printhead capable of jetting fluids, including the jettable emulsion disclosed herein.

The screen mesh **112**, which may be of any type, is stretched onto the frame **114**. The frame **114** is put into the inkjet printer **130** with the release fluid **122** which has been dispensed through the perforated surface of the platen **124** to saturate the non-woven fabric **113** such that the non-woven fabric **113** supports an evenly distributed layer of release fluid below the mesh **112**. The jettable emulsion is then applied by the inkjet printer **130** to the masking areas and substantially simultaneously exposed with high intensity UV lamps or other suitable UV source, such as UV-light emitting diodes (LEDs). The wavelength of the UV lamp (or LED) may be tuned to the reaction range of the jettable emulsion for optimal performance. For the jettable emulsion disclosed herein, the emulsion reacts at a wavelength of 395 nanometers (nm). Other jettable emulsions may have other reaction wavelengths, including lower than 395 nm. For coarse mesh, the application may be a multi-pass operation in order to build up the necessary emulsion thickness. By "coarse mesh" is meant mesh having a loose weave, and thus having larger gaps between the strands than a fine mesh screen. Mesh counts are given as either tpi (threads per inch) or T (threads per centimeter). For example, 335 tpi (130 T) mesh count is considered to be fine mesh, while 110 tpi (43 T) mesh count is considered to be a coarse mesh, where mesh count is the number of thread crossings per square inch. 110 tpi (43 T) is most commonly used for general textile printing.

The Direct to Mesh process disclosed herein is made possible with the recent development of low viscosity jettable emulsions. By "low viscosity" is meant a range from about 4 centipoises (cP) to about 15 cP (about 4 millipascal second to about 15 millipascal second). These jettable emulsions are used to create an embossing effect with UV printers onto a wide variety of materials. These new jettable emulsions are also more elastic, so they can be used more readily as a replacement for previous emulsions. Any color can be used for the jettable emulsion, including transparent or clear, although light cyan or light magenta may be used to provide a slight contrast in order to verify the stencil.

An example of a jettable emulsion that may be suitably employed in the process disclosed herein is a UV-activated acrylate monomer with elastomeric qualities after curing. The jettable emulsions are specialty embossing "varnish" polymers that quickly cure into both highly durable/resistant layers that quickly build up on the substrate. The cured polymer is also durable and flexible/elastic (if it were rigid, it would crack easily under use and render the stencil useless). VersaUV (Roland DG) technology is an example of a material that may be useful in the practice of the teachings herein.

The release fluid **122** provides a smooth, non-reactive printing surface under the mesh **112**. It also serves to limit dot gain of the printed emulsion. Dot gain occurs when a jetted droplet (or dot) expands or spreads out before exposure to the UV light source (i.e., UV curing). This is particularly important when a half tone is employed, i.e., less than the entire space in the mesh is filled with emulsion. However, the dot-gain need only be Inhibited for a short period as the UV curing occurs very quickly after the emulsion is jetted.

The release fluid **122** is a fluid that manages the dot gain and is non-reactive with the curing emulsion so that the release fluid **122** does not lift, dissolve, or separate the emulsion from the mesh **112**. The fluid for the release fluid **122** may be modified or tailored for the jettable emulsion by changing certain characteristics of the release fluid **122**, including, but are not limited to, the addition of surfactants or wetting agents that change, the surface tension, ionic mix, polar or non-polar components, or whether the fluid is aqueous or non-aqueous.

The release fluid **122** may be water-based (e.g., distilled water), either water alone or with at least one emulsifier in a sufficient amount to prevent evaporation of the release fluid. Examples of emulsifiers, along with a class of emulsifiers known as surfactants. include, but are not limited to, polysorbates, glycerins, and glycols, such as butyl cellosolve. In some embodiments, the emulsifier(s) may be present in an amount of at least 3 vol % to 5 vol % to prevent evaporation of the release fluid **122**. Further examples of the release fluid **122** include water-based varnishes, such as butyl acetate, xylene, xylol, dimethyl benzene, and combinations thereof.

In most preparations in the current art, the emulsion can be quite rough; this is often caused by conformance of the emulsion to the mesh during the drying process. This rough emulsion surface can wear away at the squeegee, requiring resurfacing or replacing of the squeegee blade. In the Direct to Mesh process, however, when the jettable emulsion is built up in the mesh, the release fluid **122** ensures encapsulation of the mesh strands see, for example, FIG. **5** and its associated discussion. Saturation of the non-woven fabric **113** with the release fluid **122** ensures that the emulsion forms a flat surface between the mesh **112** and the non-woven fabric **113**.

Since the emulsion applied to the mesh **112** is only in a blocking area, there is essentially little risk of over-shoot or over-exposure from reflection of the UV light into masked areas. This provides a much smoother, cleaner image. (These over-shoot and over-exposure areas can create spots or drops inside the image; especially around the edges. These are the "inverse" of pin holes.)

Examples of platens with perforated surfaces are depicted in FIGS. **2A-3**.

In FIG. **2**A, a platen **124** is disposed on a fixture **116** and is surrounded by a frame **114**. The fixture **114** may include clamps (not shown) that hold the frame **114** and the platen **124** in place during printing. Dashed lines **202** and **204** identify internal walls that separate four internal cavities **206-209** of the platen **124**. In general, the walls. such as walls **202** and **204**, are for controlling the flow of the release fluid inside of the platen **124**. FIG. **2**B shows a cross-sectional view of the platen **124**, fixture **116**, and frame **114** in the direction indicated by line A-A. The cross-sectional view reveals the cavities **206** and **207** separated by a wall **204**. The cross-sectional view also shows that the top surface **210** of the platen **124** is perforated with holes **212** that lead to the cavities **206** and **207**. Inserts may be added to the cavities to reduce the volumes of the cavities and aid in even distribution of the release fluid within each cavity. FIG. **2**C shows a cross-sectional view of the platen **124**, fixture **116**, and frame **114** in the direction indicated by line A-A with inserts **214** and **216** located within the internal cavities **206** and **207**, respectively. The inserts **214** and **216** may be made of foam, plastic, or wood. The inserts **214** and **216** reduce the release fluid volume.

Each cavity of the platen **124** has an input port and may have an output port. In certain implementations, the platen **124** may have only input ports and no outputs. Output ports may be included to control the flow of the release fluid and drain the release fluid when the platen **124** is no longer in use. When output ports are not included, the input ports are bi-directional in order to quickly lower the release fluid level. The platen **124** also comprises a top plate and a bottom plate.

In FIG. **3**, the platen **124** is separated into a top plate **302** and a bottom plate **304**. FIG. **3** shows the input ports **306***a*-**306***d* located along the long sides of the bottom plate **304** and the output ports **308***a*-**308***d* located along the short sides of the bottom plate **304**. Directional arrows **310***a*-**310***d* represent the inflow of the release fluid into the cavities **206**-**209** through the input ports **306***a*-**306***d*. Directional arrows **312***a*-**312***d* shows the outflow of the release fluid from the cavities **206**-**209** through the output ports **308***a*-**308***d*. Magnified view **314** shows the input port **306***c* located in the long side of the bottom plate **304**. In other implementations. the output ports may be located along the long sides of the bottom plate **304** and the input ports may be located along the short sides of the bottom plate **304**. In still other implementations, the input ports **306***a*-**306***d* and/or the output ports **308***a*-**308***d* may be located in the underside of the bottom plate **304**. Magnified view **316** shows an example of the input port **306***c* located underneath the cavity **208** of the bottom plate **304**.

Input and output ports may be barbed fittings made of metal or plastic. For example, a straight, barbed fittings may be used for the input and output ports located along the long and short sides, or edges, of the bottom plate **304**. Alternatively, barbed L-shaped fittings may be use for underside mounts.

It should be noted that the bottom plate **304** is not limited to four cavities. In other implementations, the bottom plate **304** may be includes a single cavity with multiple input and output ports (e.g., the walls **202** and **204** may be omitted). In other implementations, the bottom plate **304** may have two cavities, each cavity having at least one input port and at least one output port. In still other implementations, the bottom plate **204** may have six or more cavities, each cavity having at least one input port and at least one output port.

In FIG. **3**, the top plate **302** is perforated with an array of holes that extend the thickness of the top plate. Magnified view **318** shows the top surface of the top plate **302**. Holes **212** located in the top plate **302** allow for passage of the release fluid. The top plate **302** of the platen **124** provides a smooth, hard flat surface. When release fluid is dispensed into the cavities **206**-**209** and emerges through the array of holes **212**, the distribution of holes **212** in the top plate **302** allows the release fluid to evenly coat the top surface of platen **124** and gently pushes mesh **112** taut to ensure an even, flat surface upon which to apply the emulsion. By "smooth" is meant that the surface of the plate **302** is a polished/glossy or frosted/matte as long as the surface is regular.

Example steps of the Direct to Mesh (DtM) process using the non-woven fabric **113** placed on the perforated surface of the platen **124** are depicted in FIGS. **4A**-**4F**, which are cross-sectional views of the DtM apparatus with the non-woven fabric **113** placed on the perforated top surface of the platen **124**.

In FIG. **4**A, the frame **114** surrounds the platen **124**. The non-woven fabric **113** is placed on the perforated top surface of the platen **124**. The fixture **116** for supporting the frame **114** is omitted in this figure and in FIGS. **4**B-**4**F. The frame fixture **116** is similar to what is currently used in the art.

In FIG. **4**B, the release fluid **122** fills the cavities of the platen **124**, emerges through the holes **212**, and is absorbed by the non-woven fabric **113**. The non-woven fabric **113** is saturated by the release fluid and forms an evenly distributed release fluid layer **402** on a top surface **113***a* of the non-woven fabric **113**. Examples of release fluid control systems for dispensing the release fluid into the cavities of the platen **124** and into the non-woven fabric **113** are described below with reference to FIGS. **6** and **7**.

In FIG. **4**C, mesh **112** is placed over the top of the frame **114**. The platen **124** and non-woven fabric **113** are located below the mesh **112** with a thin, evenly distributed release fluid layer **402** of the release fluid **122** supported on the surface **113***a* of the non-woven fabric **113**. In some embodiments, the thickness of the release fluid **122** is about 20 micrometers (μm), but in any event less than the gauge of the mesh and is within ±0.5 μm planarity. The release fluid **122** backs up the mesh **112** to provide good coverage of the jettable emulsion, as it is applied. The release fluid **122** is formulated to avoid adherence of the jettable emulsion to the non-woven fabric **113**. The formulation of the release fluid **122** prevents the emulsion from bonding, reacting, or otherwise sticking to the non-woven fabric **113**. In some cases, the emulsion may react with the release fluid **122**, but that interaction/reaction typically may not allow any adhesion to the non-woven fabric **113**. If the adhesion to the non-woven fabric **113** is greater than the adhesion to the mesh **112**, then the emulsion may de-bond/delaminate from the mesh. This may cause pin holes or bare patches. In the worst case, it could cause the mesh to be damaged or to tear.

In FIG. **4**D, the platen **124** and non-woven fabric **113** with the release fluid layer **402** are moved up to the mesh **112**, tightening the mesh **112** and pressing the underside of the mesh **112** into the evenly distributed release fluid layer **402**, which provides a smooth, tensioned, level surface to print the emulsion on. Alternatively, frame **114** with the mesh **112** attached may be moved downward with the underside of the mesh **112** pressed into the release fluid layer **402**. The mesh **112** may be pressed against non-woven fabric **113**, preventing the non-woven fabric **113** from moving.

In FIG. **4**E, the print head **132**, which is translatable by the printer carriage **134** (not shown in FIG. **4**E, but shown in FIG. **1**) prints (i.e., deposits the emulsion) the blocking image, or stencil, **406** (seen in FIG. **4**F) directly onto the mesh **112**, where the blocking image is the reverse, or negative, of the actual image that is to be printed, or screened, onto a suitable print medium. The print head **132** moves laterally in the direction indicated by arrow **408** to form a screen stencil **406** on the mesh **112**. The "ink" emitted from the print head is the UV-cured jettable emulsion, described above, which, in this example, is UV-cured essentially as it is applied by means of UV source **410**. In an example, the UV source **410** moves laterally in the direction indicated by arrow **412**. FIG. **4**D depicts the print head **132** and UV source **410** moving across the mesh **112**. However, the mesh support system, including the mesh **112** and frame **114** (and fixture **116**), could be translated relative to the print head **132** and UV source **410**. The UV source **410** can be fitted to both sides of the print head **132** to facilitate bi-directional printing of the mesh **112**.

In FIG. **4**F, the resulting stencil **406** is shown. FIG. **4**F includes a magnified view of the emulsion covering strands

414 of the mesh 212. The evenly distributed release fluid layer 402 enables the emulsion to encapsulate the strands 414 of the mesh 112 and form a flat bottom surface 416 for the emulsion. With DtM, because the mesh 112 has been supported by the smooth platen 124 and the flat non-woven fabric 113 distributed release fluid layer 402 is evenly distributed below the mesh 112 and the underside 416 of the stencil 406 is nearly planar or flat. The stencil 406 can typically be removed from the printer and used immediately without any further preparation or treatment. With thicker emulsion coverage (e.g. greater than 20% emulsion over mesh) post process curing may be used to complete curing of the stencil.

In some embodiments, a top surface of the top plate of the platen may be coated with a UV reflective material, such as a mirror, clear glass, or white polyethylene or another material to create reflection of the UV light upward to the emulsion coating the underside of mesh 112.

The process is called Direct to Mesh (DtM) to distinguish it from CtS (computer to screen), which requires additional processing both before (i.e., application of the emulsion) and after (washing off the unexposed emulsion and ink). In the DtM process, typically no additional processing is performed before and after application of the jettable emulsion, thus simplifying creation of the stencil 406.

FIG. 5 shows a cross-sectional view of capillary behavior of the release fluid layer 402 to aid with encapsulation of the strands (or threads) of the mesh 112 by the emulsion. The release fluid 122 fills the cavities of the platen 124 and emerges through the holes 212 to saturate the non-woven fabric 113 and form an evenly distributed release fluid layer 402 on a top surface 113*a* of the non-woven fabric 113. Magnified view 502 shows an enlarged cross-sectional view of strands 414 of the mesh 112 and the release fluid layer 402 shown in FIG. 4D. The release fluid has a meniscus and exhibits capillary action that causes the release fluid to fill in spaces between and around strands of the mesh 112. The combination of meniscus and capillary action of the release fluid enables the release fluid to facilitate encapsulation of the strands 414 of the mesh 112 by the emulsion 508 during printing described above with reference to FIG. 4E. Magnified view 506 shows the strands 414 of the mesh 112 encapsulated by the emulsion 508 to form the stencil 406 shown in FIG. 4F. Note also that the release fluid layer 402 created by saturation of the non-woven fabric 113 in turn creates a flat emulsion surface against the release fluid layer 402.

Examples of release fluid control systems 126 are depicted in FIGS. 6, 7, and 8. The release fluid control systems are used to maintain the amount and level of the release fluid in the release fluid layer 402.

In FIG. 6, an example release fluid control system is connected to platen 124 and fixture 116. In this example, the release fluid control system includes a fluid level tank 602 and a fluid distribution system formed from a flexible hose 604 connected at one end to the base of the fluid level tank 602 and at the other end to a pipe or hose 606 that is in turn connected to the cavity 122 of the platen 124 (e.g., through the side or bottom of the platen 124 as described above with reference to FIG. 3). The fluid level tank 602, fluid distribution system, and cavity of the platen 124 contain the release fluid. The vertical position of the fluid level inlet tank 604 may be maintained and controlled with a mechanical lift 610. The mechanical lift 610 may be, for example, a ratchet jack or a screw jack. The level of the release fluid in the fluid level inlet tank 604 may be monitored with a measuring device 612, such as a linear encoder, that includes a mark 614 corresponding to a desired level of the release fluid layer 402 formed on the non-woven fabric 113 as represented by dot-dashed line 608. The mechanical lift 610 may be used to raise or lower the fluid level inlet tank 604. Atmospheric pressure and gravity are relied on to ensure that the amount of release fluid dispensed to form the release fluid layer 402 corresponds to the level, or height, of the release fluid in the fluid level inlet tank 602. The amount of release fluid in the release fluid layer 402 is controlled by raising or lowering the fluid level inlet tank 602. When the level of the release fluid in the fluid level inlet tank 604 is raised above the mark 614, such as by raising the fluid level inlet tank 604 using the mechanical lift 610, atmospheric pressure and gravity force additional release fluid into the release fluid layer 402. Alternatively, when the level of the release fluid in the fluid level inlet tank 604 is lowered below the mark 614, such as by lowering the fluid level inlet tank 604 using the mechanical lift 610, atmospheric pressure and gravity force the release fluid back through the fluid distribution system to raise the level of the release fluid in the fluid level inlet tank 604, which decreases the amount of release fluid in the release fluid layer 402 or causes the release fluid layer 402 to disappear. Release fluid control system shown in FIG. 6 provides a position accuracy of less than about 1 mm, such as 0.8 mm.

In FIG. 7, an example release fluid control system is connected to platen 124 and fixture 116. In this example, the release fluid control system includes a release fluid reservoir 702, a fluid level inlet tank 704, a level sensor 706, and an evacuation pump 708. The release fluid reservoir 702 contains a volume of release fluid 122. The rate at which the release fluid fills the fluid level inlet tank 704 is controlled with a control valve 712. The release fluid control system also includes a fluid distribution system comprising a network of fluid connectors 714*a*-714*d*. The fluid connectors may be a combination of pumps, pipes and/or hoses. Directional arrows 716*a*-716*d* represent the directions the release fluid may flow within the network of fluid connectors. Connector 714*a* transmits release fluid from the fluid level tank 704 to cavities of the platen 124 (e.g., through the bottom or side of platen 124 as described above with reference to FIG. 3). Connector 714*b* carries release fluid from connector 714*a* to evacuation pump 708. Connector 714*c* carries release fluid from the evacuation pump 708 back to the release fluid reservoir 702. Connector 714*d* may be included to carry excess release fluid from the platen 124 back to the release fluid reservoir 702. Alternatively, the connector 714*d* may be omitted and the release fluid is allowed to drain away.

The fluid level inlet tank 704 is stationary. The level sensor 706 measures the level of the release fluid in the fluid level inlet tank 704 to ensure the level corresponds to a desired amount of release fluid in the release fluid layer 402. The level sensor 706 may be an ultrasonic sensor or an ultrasonic distance measuring sensor. The level sensor 706 may be accurate to within about 0.1 mm. The fluid volume metering at control valve 712 and evacuation pump 708 are used in combination to rapidly control changes to the level of the release fluid in the fluid level inlet tank 704 and corresponding changes in the amount of release fluid in the release fluid layer 402 formed on the non-woven fabric 113. Atmospheric pressure and gravity ensure that the amount of release fluid dispensed onto the top surface of platen 124 to form the release fluid layer 402 corresponds to the level of the release fluid in the fluid level inlet tank 704 as represented by dot-dashed line 718. For example, if the level of the release fluid in the fluid level inlet tank 704 is raised above the top surface of the platen **124** by, for example, adding more release fluid into the fluid level inlet tank **704**, atmospheric pressure and gravity will force additional release fluid into the release fluid layer **402**. Alternatively, if the level of the release fluid in the fluid level inlet tank **704** is lowered below the top surface of the platen **124** by, for example, using the evacuation pump **708**, atmospheric pressure and gravity will force release fluid back through the connector **714***a* to raise the level of the release fluid in the fluid level inlet tank **704**, which decreases the amount of release fluid in the release fluid layer **402** or causes the release fluid layer **402** to disappear.

In FIG. **8**, an example release fluid control system is connected to a platen **124** and fixture **116** and is similar to the release fluid control system in FIG. **7**. In this example, the release fluid control system includes a release fluid reservoir **802**, a fluid level inlet tank **804** located within an overflow tank **806** (i.e., catch basin), a level sensor **808**, and an evacuation pump **810**. The release fluid control system also includes a fluid distribution system comprising a network of fluid connectors **812***a*-**812***d*. The fluid connectors may be a combination of pumps, pipes and/or hoses. Directional arrows **814***a*-**814***d* represent the directions the release fluid may flow within the network of fluid connectors. End of fluid connector **812***a* passes through an opening in the base of the overflow tank **806** and an opening in the base of the fluid level inlet tank **804**. A sealing ring **816***a* is located between the opening in the fluid level inlet tank **804** and the connector **812***a* to prevent release fluid **122** from leaking into the overflow tank **806**. A sealing ring **816***b* is located between the connector **812***a* and the opening in the overflow tank **806** to prevent the release fluid **122** from leaking out of the overflow tank **806**. The end of connector **812***a* located within the fluid level inlet tank **804** may include openings or may be perforated to allow the free flow of release fluid. The fluid level inlet tank **804** may be raised or lowered using a mechanical lift **818**, such as a linear encoder or a screw jack. The evacuation pump **810** is used to ensure that the level of the release fluid **122** in the overflow tank **806** is lower than the level of the release fluid **122** in the fluid level inlet tank **804** by pumping release fluid back to the release fluid reservoir **802**. Release fluid **122** is added to the fluid level inlet tank **804** via control valve **820**. Alternatively, the connector **812***d* may be omitted and the release fluid is allowed to drain away.

The level sensor **808** measures the position of the fluid level inlet tank **804** to ensure the level corresponds to a desired amount of release fluid in the release fluid layer **402**. Unlike the release fluid control system in FIG. **7**, the amount of release fluid in the release fluid layer **402** formed on the non-woven fabric **113** is controlled by raising or lowering the fluid level inlet tank **804** such that any excess fluid overflows the sides of the fluid level inlet tank **804** in the overflow tank **806**. When the fluid level inlet tank **804** is raised so that the level of the release fluid is above the level of the top surface of the platen **124**, atmospheric pressure and gravity force release fluid into the release fluid layer **402**. Alternatively, when the fluid level inlet tank **804** is lowered so that the level of the release fluid in the fluid level inlet tank **804** is below the level of the top surface of the platen **124**, atmospheric pressure and gravity force the release fluid back through fluid distribution system to raise the level of the release fluid in the fluid level inlet tank **804**, which decreases the amount of release fluid in the release fluid layer **402** or causes the release fluid layer **402** to disappear.

The level sensor **808** and the mechanical lift **818** may be connected to a computer system (not shown) that receives a feedback signal from level sensor **808** regarding the level of the fluid level inlet tank **804**. The computer system may electronically control the mechanical lift **818** to raise or lower the fluid level inlet tank **804**.

Note that the release fluid control system shown in FIG. **7** relies on high precision and accuracy in controlling the level of the release fluid in the fluid level inlet tank **804** to maintain the level of the release fluid layer **402**. By contrast, the release fluid control system shown in FIG. **8** relies on high precision and accuracy in positioning the fluid level inlet tank **804** to maintain the level of the release fluid layer **402**.

FIG. **9** is a flow chart of an example DtM process **900**, in accordance with the disclosure herein, for preparing a stencil for screen printing. In the DtM process **900**, the direct to mesh printer **100** is provided **901**. As noted above, the DtM printer **100** includes the fixture **116** to hold the frame **114**, the frame holds the pre-stretched mesh **112** in place during application of the jettable emulsion. The platen **124** of the DtM printer **100** has at least one cavity to hold the release fluid **122**. The non-woven fabric **113** is placed on the perforated top surface of the platen **124**. Finally, the DtM printer **100** includes the printer carriage **134** supporting the print head **132** for printing the jettable emulsion on the side of the pre-stretched mesh **112** opposite the platen **124**.

The DtM process **900** continues with placing **902** the frame **114** in the fixture **116**. The fixture **116** is part of the DtM printer **100** and is adapted to receive a wide variety of frame **114** sizes. The fixture **116** accurately holds the frame **114** in place, so that the printer carriage **134** is accurately registered to the mesh **112**.

The DtM process **900** continues with dispensing **903** the release fluid **122** into the cavity of the platen **124** such that the release fluid is dispensed through an array of holes in the perforated top surface of the platen **124** to saturate the non-woven fabric **113** and form the release fluid layer **402**. The non-woven fabric **113** evenly distributes the release fluid layer **402**. This may be important for very large stencils or very high dot density, such as 5,000 DPI, where the release fluid **122** might be consumed in the printing process or have time to evaporate even with a good emulsifier.

The DTM process **900** continues with placing **904** the mesh **112** into contact with the release fluid **122** in order to apply to the release fluid to the underside of the mesh **112**. The top surface of the platen **124** is positioned even with or above the top surface of the frame. For example, the top surface of the platen **124** may exert little to no pressure on the mesh.

The DtM process **900** continues with applying **905** the jettable emulsion to the mesh **112** opposite the platen **124**. As noted above, the jettable emulsion is applied relative to the mesh **112** by means of the inkjet printer **130**, in which the inkjet print head **132** is to jet the jettable emulsion.

The DtM process **900** concludes with curing **906** the jettable emulsion using UV radiation. A UV light source may be used to cure the jettable emulsion, such as an LED or a halogen lamp.

At the conclusion of the DtM process **900**, the stencil is formed and cured and is ready to be used to screen print colors onto an appropriate print surface, such as clothing, for example. In particular, the jettable emulsion after curing forms the screen stencil, in which openings in the screen stencil are to be used to print an image on the print surface.

It is appreciated that the previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present disclosure. Various modifications to the embodiments will be apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the disclosure. Thus, the present disclosure is not intended to be limited strictly to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

What is claimed is:

**1**. A direct to mesh screen printer for creating a screen stencil, including:

a frame to hold a pre-stretched mesh in place during application of a jettable emulsion onto the pre-stretched mesh;

a fixture to hold the frame;

a platen having a cavity and a top surface perforated with an array of holes, the cavity to hold a release fluid to be dispensed through the holes;

a non-woven fabric placed on the perforated top surface and positioned to receive the released fluid dispensed through the holes and form an evenly distributed release fluid layer agamst one side of the pre-stretched mesh;

a release fluid control system for dispensing the release fluid into the cavity of the platen and form the release fluid layer; and

a printer carriage supporting a print head for printing the jettable emulsion on a side of the pre-stretched mesh opposite the platen.

**2**. The direct to mesh screen printer of claim **1**, wherein the fixture securely and firmly holds the frame with the pre-stretched mesh in place during application of the jettable emulsion.

**3**. The direct to mesh screen printer of claim **1**, wherein the platen has at least one input port to receive the release fluid and at least one output port to dispense with release fluid into the at least one cavity.

**4**. The direct to mesh screen printer of claim **1**, wherein the holes in the perforated surface of the platen extend to the at least one cavity.

**5**. The directed to mesh screen printer of claim **1**, wherein the non-woven fabric and top surface of the platen are flat, thereby forming the evenly distributed release fluid layer and a flat bottom surface of a stencil formed from the jettable emulsion.

**6**. The direct to mesh screen printer of claim **1**, wherein the non-woven fabric is saturated with the release fluid forced through the holes and forms the evenly distributed layer on the non-woven fabric.

**7**. The direct to mesh screen printer of claim **1**, wherein the non-woven fabric comprises a hydrophilic material.

**8**. The direct to mesh screen printer of claim **1**, wherein the release fluid inhibits dot-gain while providing a smooth, non-reactive surface for the jettable emulsion after curing.

**9**. The direct to mesh screen printer of claim **8**, wherein the jettable emulsion is a UV-activated acrylate monomer with elastomeric qualities after curing.

**10**. The direct to mesh screen printer of claim **1**, wherein the release fluid comprises water and at least one emulsifier in a sufficient amount to prevent evaporation of the release fluid.

**11**. The direct to mesh screen printer of claim **1**, wherein the jettable emulsion has a low viscosity of about 4 cP to about 15 cP and is both durable and flexible/elastic.

**12**. The direct to mesh screen printer of claim **1**, further including a UV source for curing the jettable emulsion and forming a stencil for screen printing.

**13**. A process, including:

a direct to mesh screen printer, including a fixture to hold a frame, which holds a pre-stretched mesh in place during application of a jettable emulsion, a platen having a cavity and an array of holes in a top surface of the platen, a flat non-woven fabric located on the top surface and is located against one side of the pre-stretched mesh, and a printer carriage supporting a print head for printing the jettable emulsion on a side of the pre-stretched mesh opposite the platen;

placing the frame in the fixture:

dispensing the release fluid into the cavity of the platen such that the release fluid passes through the holes and saturates the non-woven fabric to form an evenly distributed release fluid layer on top of the non-woven fabric;

bringing the platen and the mesh together such that the release fluid in the release fluid layer wets the underside of the mesh;

printing the jettable emulsion on the mesh; and

curing the jettable emulsion using UV radiation.

**14**. The process of claim **13**, wherein the jettable emulsion after curing forms a screen stencil, in which openings in the screen stencil are to be used to form an image on a surface.

**15**. The process of claim **13**, wherein the release fluid inhibits dot-gain while not adhering to the jettable emulsion following its curing.

**16**. The process of claim **13**, wherein the release fluid comprises water and at least one emulsifier in a sufficient amount to prevent evaporation of the release fluid.

**17**. The process of claim **13**, wherein the jettable emulsion is a UV-activated acrylate monomer with elastomeric qualities after curing.

**18**. The process of claim **13**, wherein printing the jettable emulsion on the mesh comprises the evenly distributed release fluid layer and flat non-woven fabric forming a flat bottom surface of a stencil formed from the jettable emulsion.

**19**. The process of claim **13**, wherein the non-woven fabric comprises a hydrophilic material.

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