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(54) **ADA-COMPLIANT BRAILLE SIGNAGE PRINTER AND METHOD OF PRINTING UV LED CURABLE INK USING A FLAT BED INK JET PRINTER**

(71) Applicant: **DIRECT COLOR SYSTEMS LLC**, Rocky Hill, CT (US)

(72) Inventors: **Blair Allen**, Cromwell, CT (US); **Bill Allen**, Kensington, CT (US);
(Continued)

(73) Assignee: **Direct Color LLC**, Rocky Hill, CT (US)

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B41J 11/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***B41J 11/002*** (2013.01); ***B41J 2/01*** (2013.01); ***B41M 7/0081*** (2013.01)

(58) **Field of Classification Search**
CPC B41J 11/001; B41J 11/0015; B41J 2/01; B41J 29/377; B41J 11/008; B41J 13/103; B41J 2/04515; B41J 2/07
See application file for complete search history.

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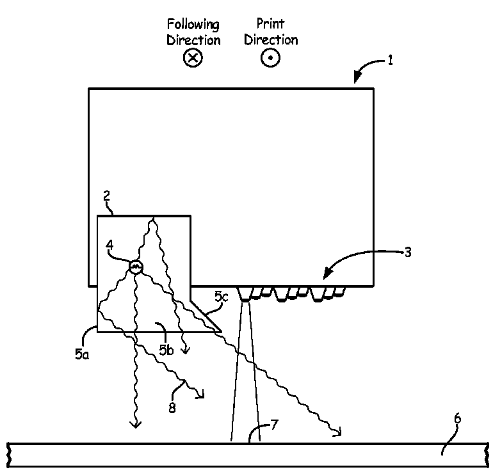
Primary Examiner — Lamson Nguyen
(74) *Attorney, Agent, or Firm* — Kinney & Lange, P.A.

(57) **ABSTRACT**

A printer includes a substrate and a print head. The print head is movable in a print direction. The print head includes an ink jet dispenser configured to jet ink toward the substrate. The print head further includes a UV source coupled to the ink jet dispenser in a following direction. The UV source is configured to emit UV irradiance. The plurality of mirrors are coupled to the UV source and configured to deflect UV irradiance from the UV source in a direction perpendicular to the print direction.

27 Claims, 6 Drawing Sheets



(72) Inventors: **Steve Chamberland**, Berlin, CT (US); **Lawrence Erikson**, Glastonbury, CT (US); **Matthew Sands**, Rocky Hill, CT (US)

(51) **Int. Cl.**

B41M 7/00	(2006.01)
B41J 2/01	(2006.01)

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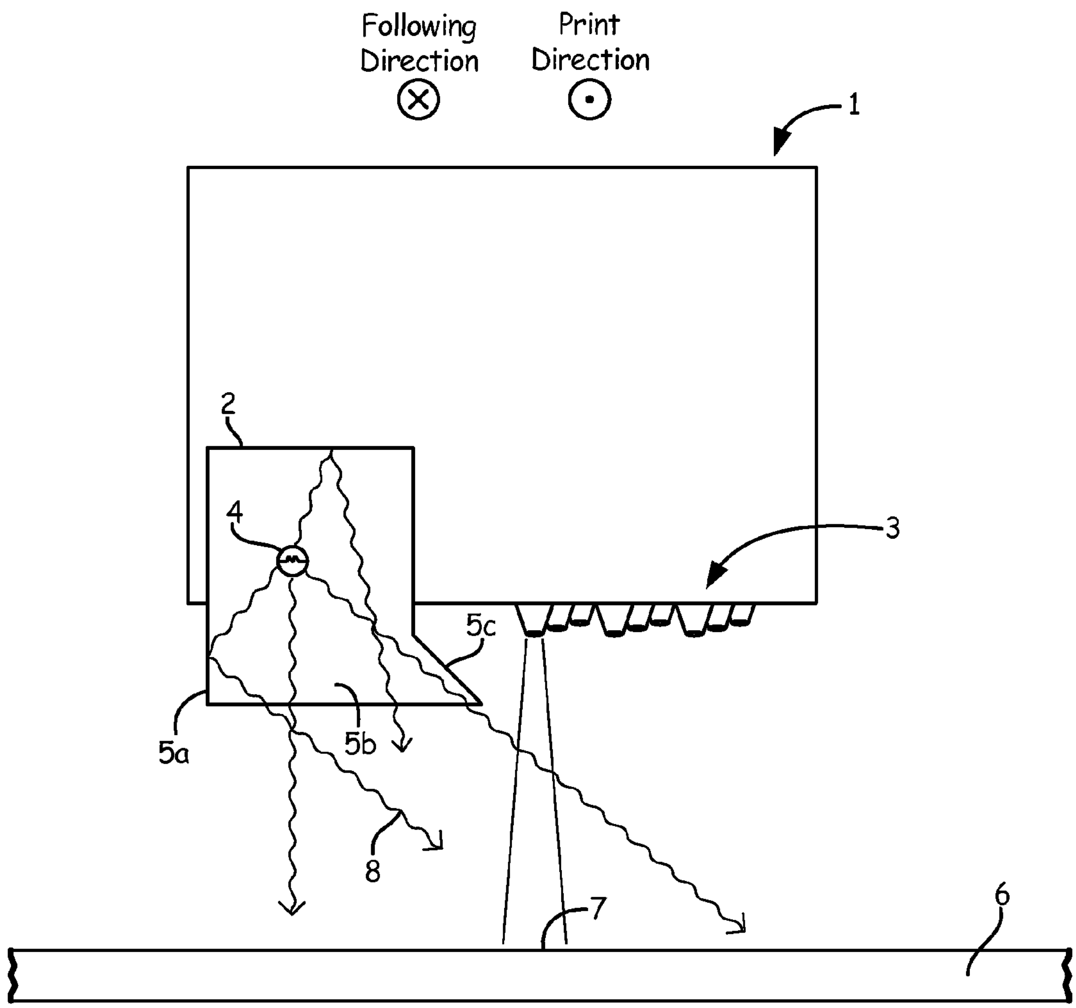

Fig. 1

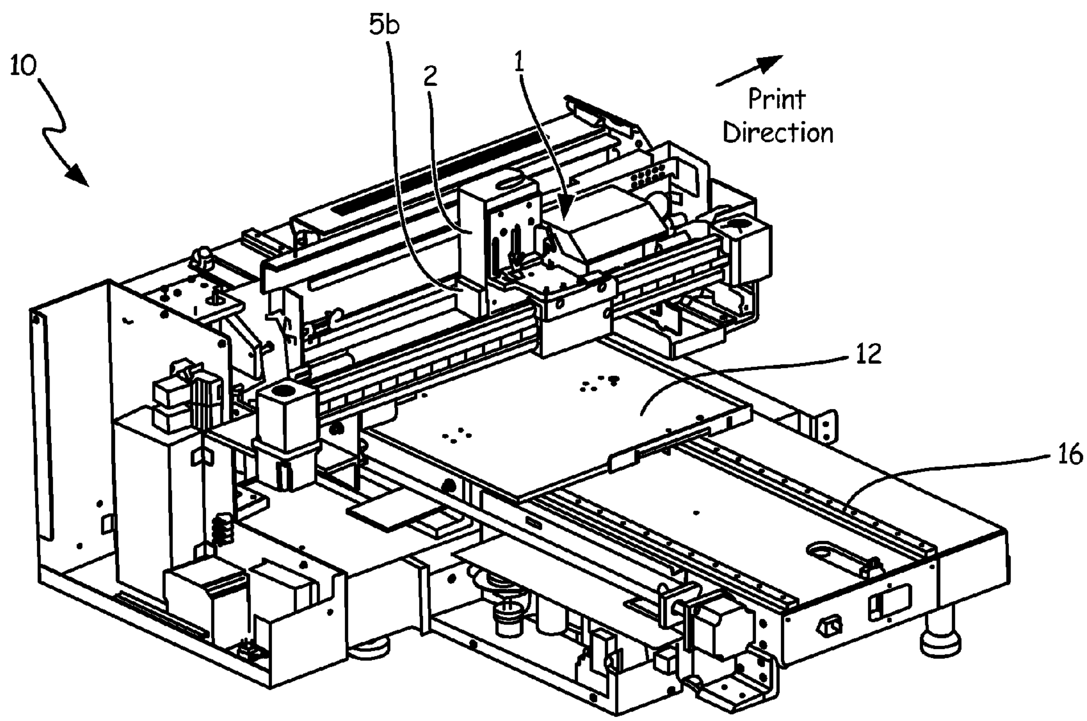

Fig. 2

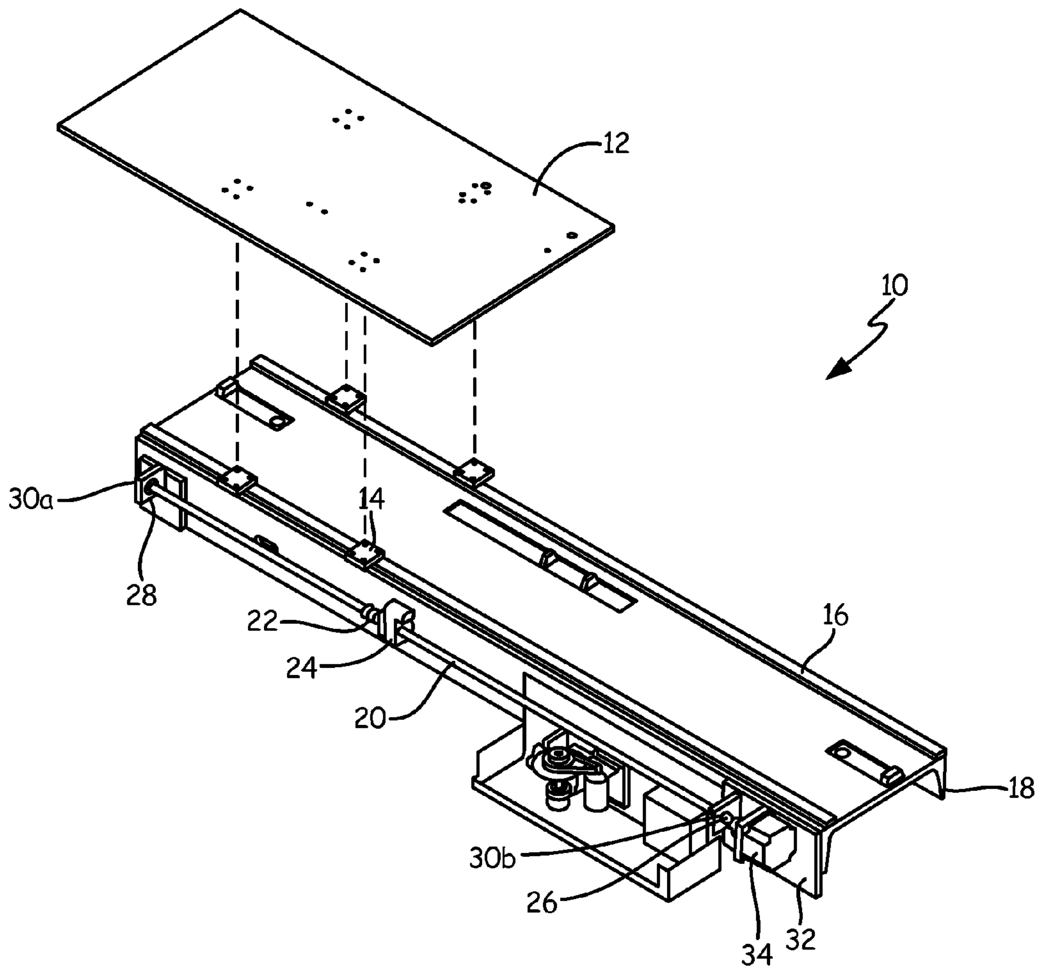

Fig. 3

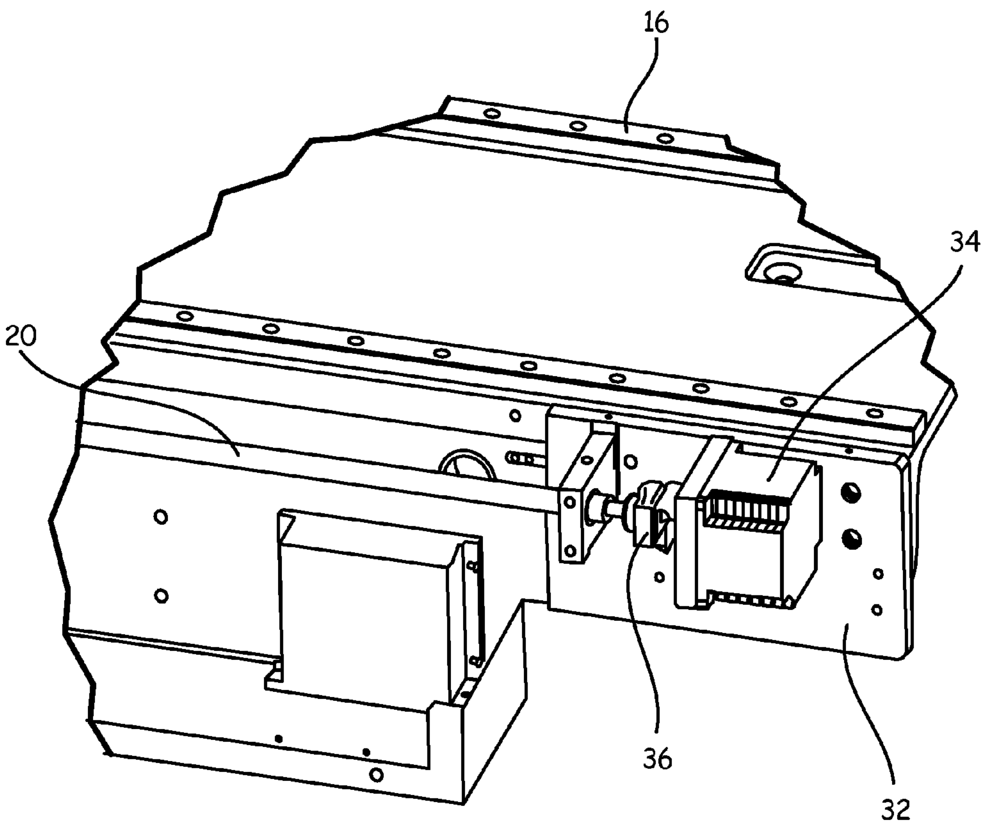

Fig. 4

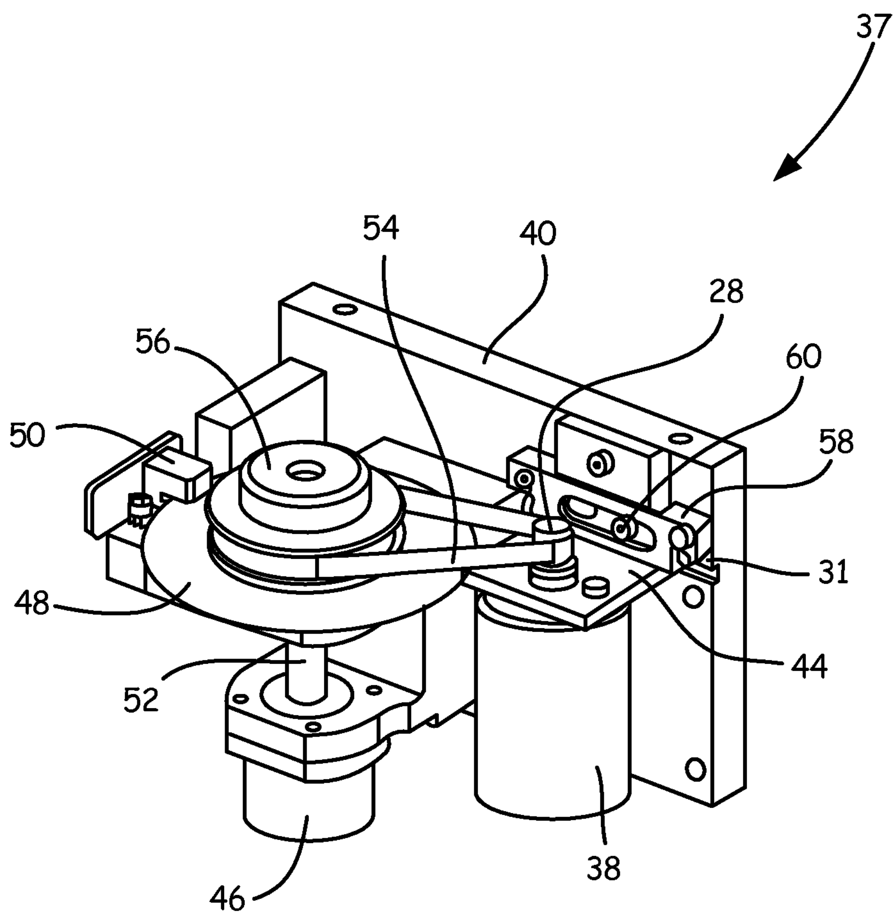

Fig. 5

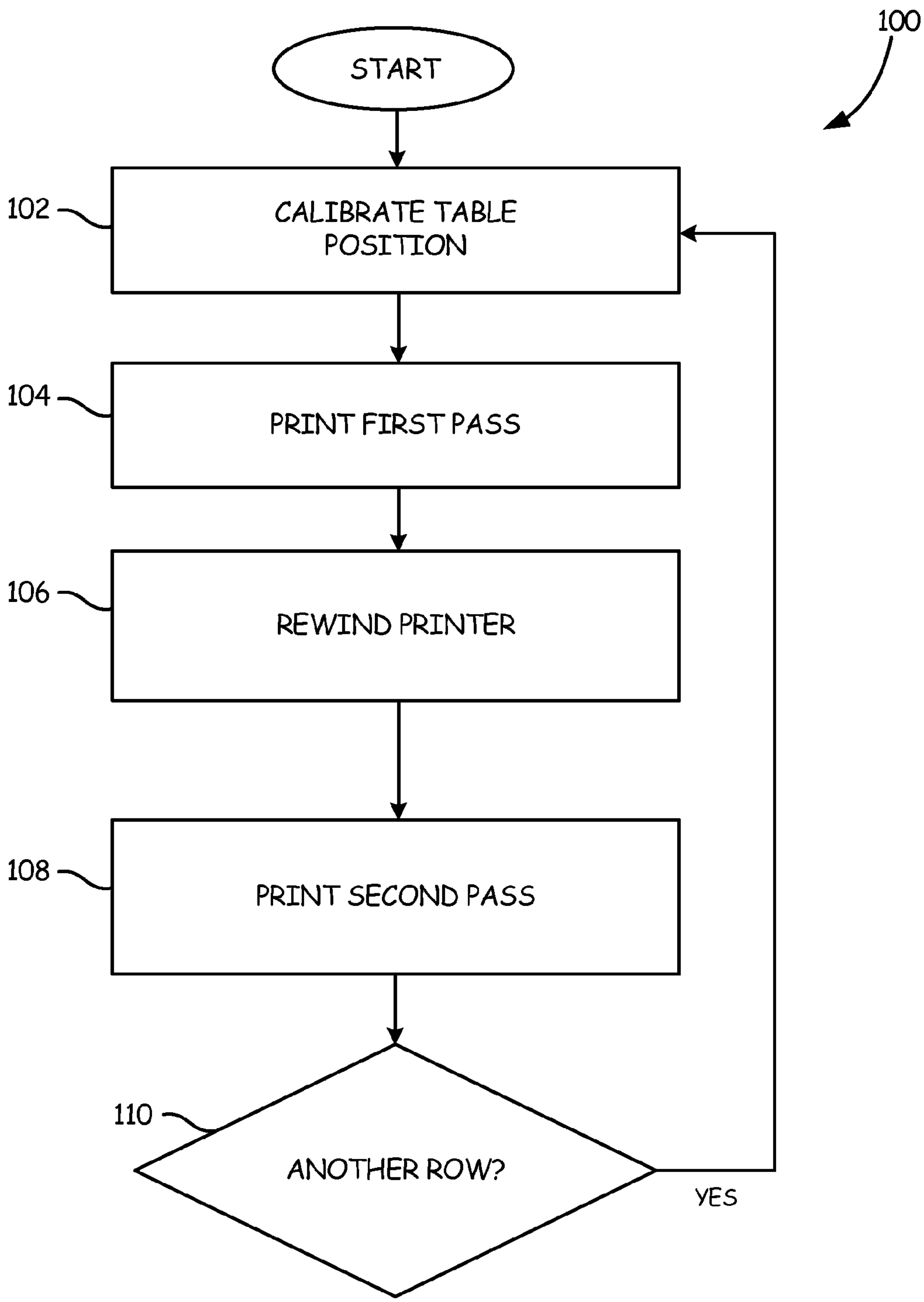
100
START
102
CALIBRATE TABLE POSITION
104
PRINT FIRST PASS
106
REWIND PRINTER
108
PRINT SECOND PASS
110
ANOTHER ROW?
YES

Fig. 6

ADA-COMPLIANT BRAILLE SIGNAGE PRINTER AND METHOD OF PRINTING UV LED CURABLE INK USING A FLAT BED INK JET PRINTER

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. provisional application Ser. No. 61/805,263, entitled "MANUFACTURING OF SIGNAGE WITH UV LED CURABLE INK JETTED USING A FLAT BED INK JET PRINTER," filed Mar. 26, 2013, the content of which is incorporated by reference.

BACKGROUND

The present invention relates to the technical field of sign manufacturing, and in particular manufacture of signs that are ADA compliant, such as Braille signs that conform to ADA rules on dot spacing, height, and finish. Previously known technologies in the art include use of photopolymer, engraving/routing, and similar techniques and technologies.

In general, greater printing height and dot placement accuracy are desirable. Printing height is generally limited by the type of ink used, as low-viscosity inks may wet out across the printing substrate. Likewise, dot placement accuracy may be negatively affected by wetting of the printed ink. Known technologies utilize UV curable ink, which may be dispensed easily and cured on the substrate.

SUMMARY

A printer includes a substrate and a print head. The print head is movable in a print direction. The print head includes an ink jet dispenser configured to jet ink toward the substrate. The printer further includes a UV source coupled to the ink jet dispenser in a following direction. The UV source is configured to emit UV irradiance. The plurality of mirrors are coupled to the UV source and configured to deflect UV irradiance from the UV source in a direction perpendicular to the print direction for increased print speeds.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic cross-sectional view of an inkjet printer.

FIG. **2** is a perspective view of an inkjet printer, showing the UV LED lamp and print head.

FIG. **3** is an exploded perspective view of an inkjet printer table drive mechanism.

FIG. **4** is a cutaway perspective view of the drive mechanism for a printer table.

FIG. **5** is a partial perspective view of a printer following subassembly.

FIG. **6** is a flowchart of a method for using a UV printer.

DETAILED DESCRIPTION

An improved printer is described herein that reduces or eliminates several inefficiencies of previously known Braille printers. For example, printers incorporating the invention can produce ADA-compliant signage using fewer passes, resulting in faster printing. Furthermore, by reducing the number of passes of the print head, accuracy of dot placement of Braille or other ADA-compliant signage is greatly increased.

FIG. **1** is a schematic cross-sectional view of print head **1**, including UV curing system **2** and print nozzles **3**. UV system **2** includes UV bulb **4**, following direction mirror **5*a***, side mirrors **5*b***, and print direction mirror **5*c***. Print head **1** is arranged above substrate **6**, such that UV system **2** and nozzles **3** are configured to print on a target area **7** associated with each of the nozzles **3**.

Print head **1** can be used to generate printed materials such as ADA-compliant and/or Braille signage. Dot spacing, height, and finish of printed material are dependent on the capabilities of print head **1**. Print head **1** is capable of producing signage with accurate dot spacing, using few passes to create a desired height.

UV system **2** is a curing system used to cure a UV ink (not shown) dispensed from print nozzles **3**. For clarity, only some of print nozzles **3** are shown in FIG. **1**. Print nozzles **3** may extend across substantially the entire width of print head **1**. In all, print head **1** may include several thousand print nozzles **3**. Print nozzles **3** are arranged in the print direction relative to UV system **2**.

Print nozzles **3** can be, for example, piezo dispensers, or more particularly micro piezo dispensers. Micro piezo technology is based on the phenomenon of piezoelectricity where materials like crystals and ceramics (known as "piezoelectric materials") react physically by bending, vibrating or expanding when an electrical charge is applied to them. Micro piezo print heads feature microscopic piezoelectric actuators that are built behind the print nozzles. When an electrical charge is applied to them, the piezoelectric elements bend backward, drawing precise amounts of ink from the ink chamber into the firing chamber. When the electrical pulse is reversed, the piezoelectric elements bend the opposite way very rapidly, propelling the ink out of the nozzles at high speed. Micro piezo technology is able to precisely eject ink droplets of up to five different sizes by controlling minute variations in the charge applied to the piezoelectric actuators of the print heads.

UV system **2** includes a UV source. In the embodiment shown in FIG. **1**, the UV source is UV bulb **4**, which can generate UV radiation. UV bulb **4** is a UV LED lamp. UV bulb **4** is partially surrounded by mirrors, including side mirror **5*a***, following mirror **5*b***, and angled mirror **5*c***, which cooperate to direct the UV irradiation from UV bulb **4**. As shown in FIG. **1**, radiation is able to pass undeflected directly towards substrate **6**. Side mirror **5*a*** redirects that portion of the UV irradiation from UV bulb **4** that would be incident on a portion of substrate **6** that is perpendicular to the print direction and the following direction along the surface of substrate **6**. Likewise, following mirror **5*b*** redirects that portion of UV irradiation **8** from UV bulb **4** that would be incident on a portion of substrate **6** that is beyond a certain distance in the following direction from print head **1**. Likewise, a print direction mirror (not shown) can be employed to redirect that portion of UV irradiation **8** from UV bulb **4** that would be incident upon a portion of substrate **6** that is beyond a certain distance in the print direction from print head **1**.

In alternative embodiments, UV system **2** may include more than one UV source. For example, UV system may comprise two UV LED lamps, positioned in the following direction from associated print nozzles.

The effect of side mirror **5*a***, following mirror **5*b***, and/or a print direction mirror (not shown) is to intensify the dosage of UV irradiation **8** that is incident upon recently printed UV-curable ink from print nozzles **3**. By preventing the diffusion of UV irradiance **8** from UV bulb **4**, more curing is possible on each pass of print head **1**. In the embodiment shown in FIG. **1**, print nozzles **3** are capable of dispensing a range of quantities of ink from 1.5-21 pL.

UV bulb **4** is not as wide as print head **1**. In order to ensure that all of the UV ink dispensed by print nozzles **3** is at least "pinned," or cured sufficiently to prevent undesirable running or bleeding, angled mirror **5***c* is employed to extend the area cured by UV bulb **4**. Angled mirror **5***c* is angled compared to side mirror **5***a* and following mirror **5***b*. In particular, angled mirror **5***c* extends at an angle that does not deflect as much UV irradiation **8** as is deflected by side mirror **5***a* or following mirror **5***b*. Thus, UV irradiation **8** is predominantly redirected towards those targets **7** over which UV bulb **4** would not otherwise pass during one printing pass.

Target **7** is the location where UV ink from ink nozzles **3** falls upon substrate **6**. Each nozzle **3** is associated with a separate target **7**, though only one target **7** is pointed out particularly in FIG. **1**. As shown in FIG. **1**, angled mirror **5***c* is angled to redirect a portion of UV irradiance from UV bulb **4** to the target **7** associated with each of nozzles **3**. In this way, UV curable inks that fall on each target **7** is polymerized during the same pass. Thus, the viscosity and/or other rheological properties of a UV ink at target **7** are modified before the ink has the ability to wet out across substrate **6**.

In operation, print head **1** moves along the print direction. During the movement of print head **1**, UV system **2** emits UV irradiation that is focused and directed by the mirrors **5***a*-**5***c*. UV curable ink dispensed from nozzles **3** is exposed to irradiance from UV bulb **4** immediately after contact with substrate **6** at target **7**. Side mirror **5***a* and following mirror **5***b* cooperate to intensify the dosage of UV irradiance **8** that is incident upon the UV curable ink that is dispensed onto targets **7** that UV bulb **4** passes directly over. Furthermore, angled mirror **5***c* directs a portion of UV irradiance **8** towards those targets **7** that UV bulb **4** does not pass directly over. In this way, all of the UV ink is at least pinned. Immediate irradiance provides for greater dot height on each pass of print head **1**, as well as greater accuracy of dot placement.

Because UV irradiation **8** is intensified by side mirror **5***a* and following mirror **5***b*, print nozzles **3** can dispense large quantities of UV curable ink onto targets **7**. Print head **1** can be configured, for example, to print "inline" Inline printing may consist of first printing out a white base from those print nozzles **3** that are arranged furthest in the print direction. The white base may be a textured layer, such as the base of a Braille sign. A second set of print nozzles **3** that are arranged closer to the following direction can then print colored UV curable ink on the textured layer. All of the dispensed ink can then be cured as UV system **2** passes over the targets **7** that were just printed to. This process can be completed in a single pass. A second pass of print head **1** may be used to add height or additional color or features.

In alternative embodiments, the nozzles **3** may be configured in the opposite way; that is, those print nozzles **3** arranged furthest in the print direction may dispense colored ink (e.g., black ink or a multitude of colors) in order to set up the base, textured portion, and the print nozzles **3** that are arranged furthest in the following direction may be used to print white ink over that. In either case, because of the intensity-increasing effect of mirrors **5***a*-**5***b*, and the extension of range of angled mirror **5***c*, cure or pin all of the dispensed UV curable ink. Additional inline printing methods are described in more detail with respect to FIG. **6**.

Thus, the orientation of side mirror **5***a*, following mirror **5***b*, and angled mirror **5***c* facilitate printing Braille signage with very few passes. For example, print head **1** may be used to produce a sign having pictograms and/or text that are a minimum of 0.079375 cm. (0.03125 in.) in height and Braille that is between 0.0635-0.09398 cm (0.025-0.037 in.) in height, using only two passes of print head **1** over substrate **6**.

FIG. **2** is a perspective view of inkjet printer **10**. FIG. **2** shows the implementation of print head **1** within an inkjet printer **10**. In addition to the components previously described with respect to FIG. **1**, inkjet printer **10** includes table **12** positioned on rails **16**.

Print head **1** is movable relative to the rest of inkjet printer **10** both away from table **12** and across table **12** (i.e., perpendicular to rails **16**). Because both table **12** and print head **1** are movable relative to the rest of inkjet printer **10**, inkjet printer **10** can be controlled to modify the position of table **12** and height of print head **1** from table **12**. Print head **1** may be set to a standard height above substrate **6**. In the embodiment shown in FIGS. **1**-**2**, print head **1** is maintained at a distance of 0.1016 cm. (0.040 in.) above the most recently printed layer (or substrate **6**, if no layer has yet been printed). This allows successive print layers to be printed on top of each other while retaining the necessary 0.1016 cm. (0.040 in.) clearance between print nozzles **3** and target **7**. UV system **2** is arranged on the following direction of print head **1**, as previously described.

A UV LED ink curing process and various other control features necessary for multi-layer printing operation, including the control of registration repeatability, can be controlled. For example, the print engine sub-system may consist of a standard photo quality printer control system and components capable of resolutions ranging from 360 DPI up to 5760 DPI. Inkjet printer **10** may dispense a single layer or multiple layers of ink onto print media.

Inkjet printer **10** of FIG. **2** may be calibrated by the following method. First, the print table position is registered, which may be achieved while the printer is in Local Mode by an operator pressing the Print Home Key on the printer's keypad (not shown). The print engine interface board firmware algorithm receives this key command and then drives the table motor system while monitoring data related to print table position (e.g., the datum described with respect to FIG. **2**). This data may be used to put the printer into a Print Home position, within a desired accuracy (e.g., ±0.00254 cm. (0.001 in.)). After the print engine interface board places the print table into Print Home position then the Print Engine Interface board firmware algorithm automatically switches over to Print Engine Mode where the firmware algorithm then allows the Print Engine access to the printer's table motor and encoder resources. At this time the operator would initialize the elevator to start position by pressing the Down Arrow key on the printer's keypad to which commands the print engine interface boards to drive the elevator motor to initial level where the print head is 0.1016 cm. (0.040 in.) above the media. To do this the print engine interface system uses a set of calibrated photo-electric thru-beam sensors to sense the position of the top of the print Media. This creates the necessary initial print head height registration point for the first layer pass height above the printer table. Now the printer system is ready to start a print. At this time the operator can send a print job from the operator's computer. After the multi-layered print job is sent to the printer the print engine interface system(s) firmware continually monitors the printer's position and after completion of each printed layer the firmware automatically switches back into Local Mode operation, which then brings the print table position back into the Print Home position, while also automatically readjusting the print head height so the print head is again 0.1016 cm. (0.040 in.) above the newly printed layer. This auto adjusting head height control scheme allows successive print layers to be printed on top of each other while retaining the necessary 0.1016 cm. (0.040 in.) clearance between the print head and table **12** and printed media.

A second method of using inkjet printer **10** of FIG. **2** varies from the first in that when the print engine interface board firmware algorithms receive the Print Home key command the firmware algorithms return to the Print Home position by first driving table **12** past the Right Limit (RL), Print Home (PH), Paper Edge (PE), then into the Left Limit (LL) sensor, then reverses the motor and drives it at a slower rate back into the PE sensor, then clears the table back out of the PE sensor and stops. Now the printer is in the Media Home position. The PE sensor has an accuracy of +/−0.00254 cm. (0.001 in.). Use of the encoder positioning feedback and quadrature detection with the print engine interface system allows table repeatability accuracy of 0.00254 cm. (0.001 in.) and monitoring of the table position to within 0.00022 cm (0.0000868 in.).

After calibration, inkjet printer **10** can print using print head **1**, which contains a UV lamp and is precision controlled by the print engine interface as previously described. Print head **1** is positioned so that the UV lamp of print head **1** polymerizes UV curable ink dispensed therefrom during the printing process, as described in more detail with respect to FIG. **6**.

In alternative embodiments, print head **1** may be kept stationary and table **12** may be moved instead. In fact, movement of one, the other, or both of print head **1** and table **12** are possible, so long as there is relative movement of print head **1** to table **12** that permits for dispensing and curing UV ink in a satisfactorily precise manner.

FIG. **3** is a perspective view of inkjet printer **10**. Inkjet printer **10** is a printer capable of generating printed ADA-compliant signs, such as Braille signs. Although ADA rules are subject to change, generally these rules require minimum standards regarding such signs, including materials and sizes of signs. For Braille signs, other standards may include dot height or dot spacing. Inkjet printer **10** is capable of printing with high accuracy, to exceed all the minimum standards in place as of Feb. 4, 2014, and to do so using a low number of printing passes. By reducing printing passes, the accuracy of inkjet printer **10** is increased at the same time that printing speed of signage is reduced.

Inkjet printer **10** includes table **12**, linear cars **14**, rails **16**, base beam **18**, lead screw **20**, anti-backlash screw threaded nut **22**, screw mount block **24**, lead screw drive end **26**, roller ball bearing **28**, support blocks **30***a* and, drive sub plate **32**, and motor **34**.

Table **12** is shown in exploded view, removed from the other components that make up inkjet printer **10**. In the embodiment shown, table **12** is a precise aluminum cast jig plate with a complete surface flatness less than 0.025 cm (0.010 in) and a dimensional square tolerance less than 0.005 cm (0.002 in). This allows printed media to be positioned flat and square to a print head (e.g., print head **1** of FIG. **1**). Linear cars **14** are configured to be secured to table **12**, and each of linear cars **14** is free to move parallel to one of rails **16** to which it is attached. In the example shown in FIG. **2**, there are four linear cars **14**.

In operation, linear cars **14** generally do not have any head space under the four points of contact with table **12**, as shown in FIG. **2**. Linear cars **14** may be adjusted along rails **16** to define a datum corresponding to the position of table **12** relative to rails **16**.

Base beam **18**, which may be made of a relatively inflexible material such as Aluminum, is aligned with rails **16** and is mounted to be substantially flat, and aligned to each other within the desired tolerance in all directions.

Table **12** is driven via lead screw **20** and anti-backlash lead screw threaded nut **22**. Anti-backlash lead screw nut **22** is a three prong spring loaded split nut to accomplish anti backlash by eliminating thread space engagement. Anti-backlash lead screw threaded nut **22** may be adjusted so that it is centered with lead screw **20** throughout its length of travel. Lead screw **20** is parallel to rails **16**, and rails **16** are parallel to one another, within dimensional tolerances determined by the desired finished printed product.

Anti-backlash lead screw threaded nut **22** is positioned in screw mount block **24**, which has a dimensional square tolerance less than the desired printing tolerance previously described with respect to FIG. **1** (e.g., 0.005 cm. (0.002 in)). Screw mount block **24** is attached to the bottom surface of table **12**.

Lead screw drive end **26** is configured to be driven by motor **34**. On the opposite end of lead screw **20** from drive end **26**, lead screw **20** is arranged on roller ball bearing **28**, allowing free rotation of lead screw **20**.

Support blocks **30***a* and **30***b* hold lead screw **20** and include roller ball bearings pressed into common bearing supports. Support blocks **30***a* and **30***b* are attached to drive sub plate **32** and on the idler end of inkjet printer **10**. Dimensional tolerances are set as appropriate so that tolerance stackups do not affect the alignment of the parallelism of lead screw **20** with rails **16**.

Drive sub plate **32** is coupled to rails **16** via base beam **18**. Furthermore, drive sub plate **32** provides support for motor **34**.

When motor **34** is driven, lead screw **20** is caused to rotate. Table **12** is coupled to lead screw **20** via screw mount block **24**. Thus, when lead screw **20** is driven, table **12** will move along rails **16**.

In alternative embodiments, additional rails **16** may be used and adjusted so that no more than 20% variance of measured drag is experienced throughout the travel distance of aligned table **12** mounted to four linear cars **14** which are in turn mounted onto rails **16**. One of rails **16** may be mounted to determine the positional datum first, then a second rail **16** may be mounted such that the measurement from the datum to be aligned is within a desired tolerance. For ADA-compliant signage, for example, a tolerance of 0.013 cm (0.005 in.) may be used to ensure necessary accuracy of signage printed by inkjet printer **10**.

Inkjet printer **10** provides a highly accurate work surface (table **12**) that may be translated along one axis while providing a datum representative of the position of the work surface.

FIG. **4** is a cutaway perspective view of the drive mechanism for table **12** (FIG. **3**), including motor **34**. In the embodiment shown, motor **34** is a stepper motor, and is mounted to drive sub plate **32**. Motor **34** may be a relatively high torque motor, using Bipolar holding torque, capable of imparting 125 ounce inches-200 ounce inches. Motor **34** connects to lead screw drive end **26** (FIG. **3**) via flexible coupling **36**. Motor **34** is controlled by a stepper driver control unit, which is signaled by printer following subassembly described in more detail with respect to FIG. **5** to accurately drive lead screw **20** and, by extension, table **12** of inkjet printer **10**.

FIG. **5** is a detailed partial perspective view of printer following subassembly **37**. Printer following subassembly **37** includes mechanical sub plate frame **40**, print engine DC motor **38**, adjustable mount **44**, brake **46**, encoder disc **48**, encoder sensor **50**, shaft **52**, timing belt **54**, timing pulley **56**, locking plate **58**, and screws **60**.

Mechanical sub plate frame **40** is a stable mounting platform for the other components of printer following subassembly **37**. Print engine DC motor **38** is mechanically coupled to mechanical sub plate frame **40** via adjustable mount **44**.

Brake **46** is a magnetic brake. While brake **46** as shown in FIG. **5** is magnetic, in other embodiments alternative brake mechanisms known to those of skill in the art may be used.

Encoder disc **48** is a rotatable disc that passes through a sensing region of encoder sensor **50**. Encoder disc **48** is mounted to encoder shaft **52**, which is supported by two ball bearings (not shown). In the embodiment shown in FIG. **5**, shaft **52** runs true with a tight tolerance run-out of less than 0.0005". In alternative embodiments, shaft **52** may have other tolerances sufficient to ensure a desired level of accuracy. Brake **46** is capable of adding a specific drag to stop encoder shaft **52**.

Encoder shaft **52** is driven by timing belt **54**. Timing pulley **56** is mounted on encoder shaft **52**, adjacent to encoder disc **48**. Timing pulley **56** is connected to motor **38** via timing belt **54**. Adjustable mount **44** may be adjusted to modify the tension of timing belt **54**. The angle and position of adjustable mount **44** is adjusted with screws **60**. Screws **60** may be adjusted to move overlapping lock plate **58**. Overlapping lock plate **58** can be adjusted to move adjustable mount **44** when screws **60** are loose, resulting in a change in both position and angle of DC motor **38**, as desired.

FIG. **6** is a flowchart of a method for printing with a UV curable ink. At step **100**, the print procedure is developed. Design software and raster image processing software communicate with the printer that prints the ADA compliant sign.

The process begins with the design of the sign. According to one embodiment, the process uses an ADA design module, where the user can create ADA compliant Text and Braille. In alternative embodiments, various design modules may be used that correspond to other printing specifications. There are options for; raised text, visual text, visual with raised text and Braille only. Once the text and Braille components are complete the pictogram can be imported, or designed by the user. After the design is complete a priming function is used to distinguish between the variations in height of the pictogram, text and Braille. These different components have different height requirements. The default settings will produce a sign with a Pictogram and Text that are a minimum of 0.079375 cm (0.03125 in.) in height and Braille that is between 0.0635-0.09398 cm (0.025-0.037 in.) in height.

After the design of the sign is complete, the setup menu allows the user to control the trapping and bleeding of the different layers of the image. This insures that there is no color but the one that is printed in the final layer showing on the sign. The trap and bleed values can easily be changed to achieve different widths.

The file is then sent to the RIP (Raster Image Processing) software. The file is received as a .PS (postscript) file. Postscript files have the ability to handle line-art which makes the processing time from the design software to the RIP almost instantaneous, cutting down on overall workflow time. The RIP uses a Queue based system which categorizes the different file qualifications. There are separate Queues for ADA printing. These Queues have a very specific set of parameters; while the user has the ability to manipulate the job further, none are necessary.

The ADA queue is set up to print two layers or passes (e.g., with printer **10** as previously described), with an automatic rewind of the flat-bed table between the passes. Vertical offsets, which change the y-axis start points, are used to account for the variations between a standard 2880×1440 print (first pass) and an inline 1440×1440 print (second pass). The layer profile feature keeps the process simple, multiple printer settings can be chosen on different layers and therefore the software only requires one image to be sent. The layer profile will do the layer breakdown interpretation from that point forward. If additional graphics are desired the user can perform other passes to do so.

At step **102**, table position is calibrated. As previously described with respect to FIGS. **1-4**, this can be accomplished using an encoder sensor and a series of calibration procedures.

At step **104**, a first layer of ink is applied. The ink dispensed in this first pass may, for example, be strictly intended for building height. Variable dot profiling can be turned off, allowing for the maximum amount of ink to jet from the piezo-electric ink jet dispensers. Through the use of separation curves, the amount of ink volume is precisely controlled and can be easily adjusted to produce a variation in height. This layer can print in both a uni-directional (left to right) mode or a bi-directional mode. Often, the first pass comprises inline printing; that is, those nozzles positioned furthest upstream on the print head dispense sufficient ink to form the desired printed texture, for example including raised dots or platforms. Nozzles that are positioned further downstream dispense a top coating over the printed texture, such as a white priming layer.

At step **106**, the printer is reset for a second pass, as previously described with respect to step **100**.

At step **108**, a second pass is used to print additional UV curable ink. The overall height of the ink applied in the second pass may vary. For example, a second layer can be printed at a resolution of 1440×1440 Bi-Directional and covers all areas with the desired color. Bi-Directional printing greatly increases throughput time. Also, Bi-Directional printing with a higher head height allows for the CMYK to cover both sides of the high first layer. Only a small amount of clear ink is used in the second pass to help with surface cure but keep the gloss level down at the same time. During the second pass, a smaller quantity of UV curable ink can be dispensed from each of the print nozzles. In this way, a rough approximation of the finished product can be generated in the first pass (i.e., step **104**) and more detailed work can be done during the second pass (i.e., step **108**). This allows printing at the resolution needed for fine detail and/or accurate color rendering.

As previously described with respect to step **104**, the first pass can utilize inline printing to form a desired printed texture, which is covered by a background color ink. In that case, the second pass may be used to further increase the height of textured areas, and/or to add a desired color selectively. For example, textured areas that correspond to raised text on a sign may have a color added to them, or Braille dots that were created in the first pass may have an ink with a desired texture printed on top.

At step **110**, the next row is printed, if required. This generally requires moving the print head relative to the table in the direction perpendicular to what has heretofore been referred to as the print direction. In this way, additional rows of raised printed material may be created. Some overlap of the rows may be present, for example to ensure any pinned UV ink is fully cured. Upon moving to the new row, the table position and print head position are re-calibrated at step **102** and the process continues until the desired sign is complete.

While the invention has been described with reference to an exemplary embodiment(s), it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

The invention claimed is:

1. A printer comprising:
- a table configured to hold a substrate;
- a print head movable in a print direction, the print head comprising:
  - an ink jet dispenser configured to jet ink toward the substrate;
  - a UV source coupled to the ink jet dispenser in a following direction, the UV source configured to emit UV irradiance; and
  - a plurality of mirrors coupled to the UV source and configured to deflect UV irradiance from the UV source in a direction perpendicular to the print direction; and
  - an encoder sensor coupled to the substrate.

2. The printer of claim **1**, wherein the ink jet dispenser is a piezo-electric dispenser.

3. The printer of claim **1**, wherein the ink jet dispenser is configured to dispense a UV curable ink.

4. The printer of claim **1**, wherein the plurality of mirrors includes:
- a following mirror that extends towards the substrate;
- a side mirror that extends towards the substrate; and
- an angled mirror that extends both towards the substrate and also extends in a direction perpendicular to the print direction.

5. The printer of claim **4**, wherein the ink jet dispensers are configured to dispense the UV curable ink onto a plurality of targets, and the angled mirror is configured to permit UV irradiance to at least partially cure UV ink present at the targets.

6. The printer of claim **4**, wherein the angled mirror is angled by 45° relative to the side mirror.

7. The printer of claim **4**, wherein the angled mirror is configured to deflect less UV irradiance than the side mirror.

8. The printer of claim **1**, and further comprising a stepper motor configured to move the substrate along a rail.

9. The printer of claim **8**, wherein the stepper motor is coupled to a lead screw, and the lead screw is coupled to the substrate.

10. The printer of claim **1**, wherein the encoder sensor is configured to generate a datum corresponding to the position of the substrate.

11. A method of printing, the method comprising:
- formulating a print design procedure;
- calibrating a position of a substrate relative to a print head, the print head including an ink jet dispenser and a UV source, the UV source arranged in a following direction from the ink jet dispenser;
- dispensing a first pass of UV curable ink from the ink jet dispenser while moving the print head in a print direction;
- emitting UV irradiance from the UV source, wherein the UV irradiance is deflected by a plurality of mirrors; the plurality of mirrors comprising:
  - a following mirror that extends towards the substrate;
  - a side mirror that extends towards the substrate; and
  - an angled mirror that extends both towards the substrate and also extends in a direction perpendicular to the print direction;
- dispensing a second pass of UV curable ink from the ink jet dispenser while moving the print head in a print direction; and
- emitting UV irradiance from the UV source.

12. The method of claim **11**, wherein the ink jet dispenser is a piezo-electric dispenser.

13. The method of claim **11**, wherein the angled mirror is angled 45° relative to the following mirror and the side mirror.

14. The method of claim **11**, wherein the ink jet dispensers are configured to dispense the UV curable ink onto a plurality of targets, and the angled mirror is configured to permit UV irradiance to at least partially cure UV ink present at the targets.

15. The method of claim **11**, wherein moving the print head opposite the following direction comprises operating a stepper motor.

16. The method of claim **15**, wherein the stepper motor is coupled to a lead screw, and the lead screw is coupled to the substrate.

17. The method of claim **11**, and further comprising an encoder sensor coupled to the substrate.

18. The method of claim **17**, wherein the encoder sensor is configured to generate a datum corresponding to the position of the substrate.

19. A method of manufacturing a sign, the method comprising:
- dispensing and curing a first pass of UV curable ink from a print head on a substrate;
- resetting the print head; and
- dispensing and curing a second pass of UV curable ink from the print head onto the first pass of UV curable ink, such that after the second pass the substrate, the dispensed ink of the first pass, and the dispensed ink of the second pass form a printed row having a plurality of printed features having heights between 0.0635 cm and 0.09398 cm, with a precision of 0.00254 cm.

20. The method of claim **19**, wherein:
- the first pass includes inline printing, comprising:
  - dispensing a textured base of UV curable ink from a first plurality of print nozzles arranged furthermost in a print direction; and
  - dispensing a coat of white UV curable ink from a second plurality of print nozzles arranged furthermost in a following direction.

21. The method of claim **19**, wherein:
- the second pass includes inline printing, comprising:
  - dispensing a base coat of white UV curable ink from a first plurality of print nozzles arranged furthermost in a print direction; and
  - dispensing a top coat of colored UV curable ink from a second plurality of print nozzles arranged furthermost in a following direction.

22. The method of claim 19, wherein curing the first pass of UV curable ink and curing the second pass of UV curable ink comprises directing UV irradiance from a UV source towards the substrate.

23. The method of claim 22, wherein the UV source is a UV LED lamp.

24. The method of claim 22, wherein directing UV irradiance from the UV source towards the substrate comprises positioning a side mirror, a following mirror, and an angled mirror adjacent to the UV source.

25. The method of claim 24, wherein:

the following mirror extends towards the substrate;

the side mirror extends towards the substrate; and

the angled mirror extends both towards the substrate and also extends in a direction perpendicular to a print direction.

26. The method of claim 19, and further comprising:

resetting the print head;

moving the substrate relative to the print head; and

printing an adjacent printed row.

27. The method of claim 19, wherein resetting the print head comprises:

positioning the print head such that an encoder sensor that is mechanically coupled to the print head measures a position datum associated with a start position.

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