

PRINTER HAVING A PRINT WIRE WITH ALTERNATING HYDROPHILIC AND HYDROPHOBIC AREAS TO FORM DROPLETS FOR PRINTING INKS

BACKGROUND

5 Two conventional printing techniques include ink jet printing and screen printing. Ink jet printers work by depositing small droplets of ink in various colors, typically cyan, magenta, yellow and black, on a print medium or substrate to form a color image. Conventional thermal ink jet printing heads include several nozzles and thermal elements. Ink is expelled from the nozzles in a jet by bubble pressure created by heating the ink
10 using the thermal elements while the nozzles and thermal elements are in close proximity. Ink jet print heads use relatively small orifices, valves, and nozzles for depositing the desired quantity and color of ink on the print medium. Therefore, very fine grade inks are required in which particle sizes of the pigments within the inks are kept to a minimum to help keep the orifices, valves, and nozzles of the ink system from becoming clogged.

15 In screen printing, ink is forced through a design-bearing screen onto the substrate being printed. The screen is made of a piece of porous, finely woven fabric stretched over a wood or aluminum frame. Areas of the screen are blocked off with a non-permeable material, a stencil, which is a negative of the image to be printed. The screen is placed on top of a piece of print substrate, often paper or fabric. Ink is placed on top of the screen,
20 and scraper blade is used to push the ink evenly into the screen openings and onto the substrate. The ink passes through the open spaces in the screen onto the print substrate; then the screen is lifted away. The screen can be re-used for multiple copies of the image, and cleaned for later use. If more than one color is being printed on the same surface, the ink is allowed to dry and then the process is repeated with another screen and different
25 color of ink. Screen printing requires use of inks having a relatively high viscosity to prevent all the ink from simply passing through the screen onto the print substrate.

Accordingly, a need exists for an improved apparatus and method for printing inks.

SUMMARY

30 A method, consistent with the present invention, can be used to form a pattern on a substrate. The method includes coating at least a portion of an exterior surface of a cable with alternating hydrophilic and hydrophobic areas, coating at least a portion of the

exterior surface of the cable with an ink, directing an air stream at the portion of the cable coated with the ink, and electronically controlling advancement and position of the cable through the air stream such that a metered amount of the ink is removed from the exterior surface of the cable and is deposited onto the substrate to form a pattern on the substrate.

5 An apparatus, consistent with the present invention, can deposit an ink on a substrate. The apparatus includes an electronically controllable drive mechanism and a structure associated with the drive mechanism and movable thereby. At least a portion of an exterior surface of the structure has alternating hydrophilic and hydrophobic areas. An ink supply is in communication with the structure for depositing ink on at least a portion
10 of the structure. At least one fluid nozzle having at least one nozzle orifice is positioned and oriented for directing at least one jet of fluid toward at least a portion of the structure to remove an amount of the ink from the structure and direct the amount toward a substrate. The movement of the structure relative to the at least one fluid nozzle substantially controls the amount of the ink removed from the structure, and the amount of
15 the ink directed to the substrate form a pattern on the substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are incorporated in and constitute a part of this specification and, together with the description, explain the advantages and principles of
20 the invention. In the drawings,

FIG. 1 is a perspective view of one embodiment of a fluid delivery system or printer;

FIG. 2 is a side view of the fluid delivery system of FIG. 1;

FIG. 3 is a diagram of a system to use the printer to print materials onto a
25 substrate;

FIG. 4 is a diagram illustrating a first type of ink flow when a print wire is not moving;

FIG. 5 is a diagram illustrating a second type of ink flow when a print wire is not
moving;

FIG. 6 is a diagram illustrating a print wire having alternating hydrophilic and
30 hydrophobic areas; and

FIG. 7 is a diagram illustrating the alternating hydrophilic and hydrophobic areas forming droplets on the print wire.

DETAILED DESCRIPTION

5 **Printing System**

FIG. 1 is a perspective view of one embodiment of the fluid delivery system or printer, generally indicated at 10. FIG. 2 is a side view of the fluid delivery system or printer of FIG. 1. A pulley 13 having a circumscribing groove 38 defined therein is secured to a shaft 15 of a motor 14. An elongate frame member 32 is secured to frame or plate 12 and extends into a reservoir of ink 24. A rotatable or stationary guide 34 is attached to a distal end 37 of elongate frame member 32. Guide 34 is illustrated as a cylindrical, non-rotatable member having a groove 40 circumscribing guide 34 in which a wire cable 36 can slide during rotation of wheel 13. Alternatively, guide 34 can be implemented with a rotatable member. As used herein, the term "cable" or "wire" or "wire cable" or "elongate segment" is meant to include the use of a wire, a cable formed of multiple wires, a rod, a saw tooth wheel, or variations thereof. Wire cable 36 is disposed in groove 38 circumscribing the wheel 13 and in groove 40 circumscribing guide 34.

An elongate reservoir retaining member 16 is attached to plate 12 and includes a flange 18 defining a notch 20 between the flange 18 and elongate reservoir retaining member 16. Notch 20 is configured to receive a top lip 22 of ink reservoir 24. A bottom plate 26 is secured to a distal end 28 of elongate reservoir retaining member 16 with a threaded nut 31 that is threaded onto a threaded shaft 33. Threaded shaft 33 is secured to distal end 28 of elongate reservoir retaining member 16. Bottom plate 26 abuts against the bottom 30 of ink reservoir 24 and holds it between flange 18 and bottom plate 26.

25 An air supply hose 42 is secured to a nozzle body 44 and supplies air through a nozzle orifice 46 that is aimed at a portion of cable 36. A cable guide 48 defining a longitudinal slot 50 is positioned proximate nozzle orifice 46. Cable 36 rides within slot 50 and is thus held in relative position to nozzle orifice 46 so that air passing therethrough does not substantially move cable 36 from in front of nozzle orifice 46 or cause cable 36 to substantially vibrate. Slot 50 can alternatively include a small rotatable guide.

30 Rotation of shaft 15 may be controlled by a controller, generally indicated at 57. Any type of controller may be used. In one embodiment, the controller includes circuitry

54 in a module 56 that receives signals from a signal generating device 52, such as a microprocessor or other devices that can supply discrete signals to instruct selective rotation of the shaft 15 of the motor. Circuitry 54 receives a signal(s) from generating device 52 and rotates shaft 15 of the motor according to the signal(s).

5 In operation, ink contained in reservoir 24 is picked up by wire cable 36 and advanced by rotation of wheel 13, indicated by the arrow, in front of nozzle orifice 46. Fluid that is blown through nozzle orifice 46 disperses or pulls the ink from cable 36 toward the print medium. Depending on the viscosity of the ink in the reservoir, the cross-sectional diameter of cable 36, and the diameter of wheel 13, a relatively precise amount
10 of ink can be dispensed. The ink is dispersed onto a substrate 58, as illustrated in FIG. 2.

 The print head in system 10 can include alternative implementations, as shown in FIG. 1A in U.S. Patent No. 5,944,893 and described in the corresponding text. For example, the print head can include a discontinuous wire, guide 34 can be rotatable, a spring tensioning mechanism can be used, and an air solenoid can be used to turn the air
15 supply on and off.

 The fluid delivery system or printer of the present invention is based on printer technology that is described in U.S. Patent Nos. 5,944,893; 5,972,111; 6,089,160; 6,090,445; 6,190,454; 6,319,555; 6,398,869; and 6,786,971, all of which are incorporated herein by reference.

20 As used herein, the term "ink" is meant to include any pigmented material, including, but not limited to, inks, dyes, paints, particle loaded suspensions, or other similarly pigmented liquids.

 As used herein, the term "print medium" or "substrate" are meant to include any print medium known in the art, including but not limited to paper, plastic, polymer,
25 synthetic paper, non-woven materials, cloth, metal foil, vinyl, films, glass, wood, cement, and combinations or variations thereof. The print medium or substrate can be a rigid material or a flexible material.

 FIG. 3 is a diagram of a system 130 to use the printer to print ink onto a substrate. System 130 includes a print head 148 mounted on a track 142 supported by vertical posts
30 144 and 146, a wall, or other support. Print head 148 corresponds with printing system 10. A drive unit 134, using a motor, controls movement of print head 148 along track 142 in an x-direction as indicated by arrows 140. A substrate support 150 is located on a track

136, which would be supported by a vertical post, wall, or other support. A drive unit 132, using a motor, controls movement of substrate support 150 along track 136 in a y-direction as indicated by arrows 138. A substrate can be mounted or otherwise affixed to substrate support 150, and a line or pattern can be printed upon the substrate by print head 148. The configuration of the line or pattern is determined by the coordinated movement of print head 148 along track 142 and the substrate on substrate support 150 along track 136.

A computer 100, corresponding with controller 57 and used to implement controller 57, electronically controls print head 148 and drive units 132 and 134 for moving substrate support 150 and print head 148, respectively. Computer 100 can include, for example, the following components: a memory 112 storing one or more applications 114; a secondary storage 120 for providing non-volatile storage of information; an input device 116 for entering information or commands into computer 100; a processor 122 for executing applications stored in memory 112 or secondary storage 120, or as received from another source; an output device 118 for outputting information, such as information provided in hard copy or audio form; and a display device 124 for displaying information in visual or audiovisual form. Computer 100 can optionally include a connection to a network such as the Internet, an intranet, or other type of network.

Computer 100 can be programmed to control movement of print head 148 along track 142 and substrate support 150 along track 136. In particular, computer 100 can be programmed to electronically control movement of print head 148, via drive unit 134, in x-direction 140 laterally across a substrate on substrate support 150, and computer 100 can be programmed to electronically control movement of the substrate on substrate support 150, via drive unit 132, in y-direction 138 vertically with respect to print head 148. Computer 100 also controls print head 148, as described above, for movement of the wire and delivery of the ink from the wire to the substrate. Computer 100 can also be programmed to control an air solenoid in system 10. The use of tracks 136 and 142 for coordinated movement of substrate support 150 and print head 148, respectively, thus effectively functions as an X-Y stage for using the printer to print a wide variety of shapes and configurations of patterns, lines, or other elements. As an alternative, lines or patterns can be printed using one of the following techniques: coordinated movement of print head

148 in the y-direction and substrate support 150 in the x-direction; movement of print head 148 in both the x-direction and y-direction; or movement of substrate support 150 in both the x-direction and y-direction.

Computer 100 can also be programmed to control the printer for radial printing. In particular, a first orifice can direct an air jet at the wheel or wire to remove paint in a purely radial direction, while other orifices supplying air can be angled above the air jet created by the first orifice to help eliminate conical divergence of the paint as it is pulled from the surfaces of the wheel or wire.

Use of Hydrophilic and Hydrophobic Areas on the Print Wire

As described above, the printer uses a wire to carry ink from the ink reservoir to the air jet, which blows the ink off the wire and onto the surface being coated. The quantity and quality of ink applied to the surface depends on the wire feed rate, rheologic properties of the ink, air flow, orifice geometry, and distance from the print head to the surface, among other things. The mechanism for this ink transport is shown in FIGS. 1 and 2. FIG. 3 illustrates an exemplary system for printing a line or pattern on a substrate using the printer.

The printing system tends to provide overspray of the ink, which can be undesirable for certain uses of the system in that the overspray may provide ink where it is not required. When a pixel is meant to be printed, the wire is forwarded to pull the ink out of the doctor blades and in front of the orifice. When the system is to stop printing, the wire is stopped. The air flows out of the orifice at all times during the printing process, the main effect of which produces most of the overspray on a printed line by ink moving on the wire. Simply stopping the wire does not stop the ink from moving in front of the orifice. This effect is due to either the ink trickling back down from the wire above the orifice due to gravity, or the ink getting pulled out of the doctor blades back up the wire due to the venturi effect and cohesion of the ink.

These effects are shown in FIGS. 4 and 5. As shown in FIG. 4, an orifice 162 provides an air spray 164 across a wire 160. When wire 160 stops moving, ink flow 166 and 168 occurs down the wire and into air spray 164 due to gravity. As shown in FIG. 5, an orifice 172 provides an air spray 174 across a wire 170, and doctor blades 180 and 182

are positioned adjacent wire 170. When wire 170 stops moving, ink flow 176 and 178 occurs upward from doctor blades 180 and 182 into air spray 174 due to the venturi effect.

One method to eliminate this potentially undesirable effect involves using alternate stripes of hydrophilic areas 192 and hydrophobic areas 194 on a wire 190, as shown in FIG. 6. The ink 196 sticks only to the hydrophilic part of the wire, creating droplets, as shown in FIG. 7. The droplets can then be blown from the wire with the air jet, creating a discrete volume pixel. The hydrophobic areas 194 also act to block the flow of ink up and down the wire 190 when it is not moving. This feature can improve print quality by reducing overspray and quantizing the ink on the wire. Depending upon the type of ink used, it may adhere to either the hydrophilic or hydrophobic areas of the wire. For example, a water-based ink will adhere to the hydrophilic areas, and a solvent-based ink will adhere to the hydrophobic areas.

The wire can be coated or otherwise treated in order to create the hydrophilic and hydrophobic areas. Examples of such coatings include the following: diamond-like glass (DLG); diamond-like carbon (DLC); fluoropolymers; polymers; and silanes. Example of such treatments include the following: etching; a plasma treatment; and a corona treatment. The hydrophilic areas on the wire can alternatively comprise bare sections of the wire without any coating. Examples of materials used to create hydrophobic and hydrophilic regions on the surface of an article are described in U.S. Patent No. 6,352,758, which is incorporated herein by reference. Examples of plasma treatment and corona treatment are described in, respectively, U.S. Patent Nos. 5,888,594 and 5,939,182, both of which are incorporated herein by reference.

DLG is an amorphous carbon system including a substantial quantity of silicon and oxygen that exhibits diamond-like properties. In these films, on a hydrogen-free basis, there is at least 30% carbon, a substantial amount of silicon (typically at least 25%) and no more than 45% oxygen. DLC is an amorphous film or coating comprising approximately 50 to 90 atomic percent carbon and approximately 10 to 50 atomic percent hydrogen, with a gram atom density of between approximately 0.20 and approximately 0.28 gram atoms per cubic centimeter, and composed of approximately 50% to approximately 90% tetrahedral bonds.

The use of DLC, or alternatively DLG, is desirable to create a durable surface energy differential. It is desirable to create a very durable surface on the membrane of a

wire jet print head. This durable surface would allow the print head to be cleaned occasionally by wiping the head across a squeegee-type element to remove surface materials. It is possible to deposit a thin uniform layer of DLC on a polymer substrate. If the polymer substrate is part of the print head, the outside surface of the nozzle membrane would have the DLC on it at the end of manufacturing. DLC is a very low surface energy material, making it extremely difficult for a fluid to wet out and remain on that surface. This feature would make it difficult for an wire jet ink to cause adverse or undesirable effects in the print head. In addition, DLC is a very durable surface, allowing a user to wipe the surface clean from time to time. The long term stability and usability of the print heads would be improved by this coating.

DLG and DLC are described in U.S. Patent Application Serial No. 11/185078, filed July 20, 2005, which is incorporated herein by reference.

EXAMPLE

The print head used to print ink for the example refers to a print head consistent with the print head in the printer described above. The term "standoff" used in the example describes the distance between the wire on the print head and the print medium. The term "air pressure" refers to the regulated air pressure applied to the orifice block. The term "shim thickness" refers to the size of the shim placed between the two halves of the doctor blade. The shim determines the gap between the edges of the doctor blade and the wire. The terms "paint velocity", "paint acceleration", and "paint deceleration" refer to the velocity, acceleration, and deceleration parameters of the program controlling the motor. The orifice design OP-001 refers to a three-hole orifice in a substantially equilateral triangular configuration in which a center hole at the top point of the triangular shape has a diameter of 0.023 inches and the lower holes at the bottom two points of the triangular shape each have a diameter of 0.02 inches.

Alternating hydrophilic and hydrophobic areas were formed on a print wire in the printer. The hydrophobic areas consisted of TSS 888I acrylic screen print ink (available from 3M Company, St. Paul, Minnesota) applied to the wire. The ink was diluted in methyl ethyl ketone, then applied to the wire in regular intervals with a cotton swab. The hydrophobic areas were approximately 0.5 centimeter (cm) long, with approximately 1cm

gaps between areas. The hydrophilic areas comprised the bare wire, the 1cm gaps, without any coating.

Water with green food coloring was applied to the wire and was observed adhering only to the hydrophilic part of the wire, creating droplets. The droplets were then blown from the wire onto a paper substrate with the air jet, creating a discrete volume pixel. Discrete spots of the green water droplets from the wire were observed on the paper substrate. Table 1 provides the coating parameters for this example.

Table 1 - Coating Parameters	
Coating Parameter	Data
Work type	Functionalized wire
Paint formulation	Green food coloring and water
Viscosity	Unknown
Substrate	Paper
Air pressure	10 psi
Standoff (can to substrate)	0.25 inches
Wire diameter	0.008 inches
Shim thickness	0.010 inches
Orifice design	OP-001
Paint velocity	6.28 inches/second (in/s)
Paint acceleration	62.8 in/s ²
Paint deceleration	62.8 in/s ²
Wire multiple	Wire feed = 3.14 in/s
Number of passes	1

CLAIMS

1. A method of forming a pattern on a substrate, comprising:
creating on at least a portion of an exterior surface of a cable alternating
5 hydrophilic and hydrophobic areas;
coating at least a portion of the hydrophilic and hydrophobic areas on the exterior
surface of the cable with an ink;
directing an air stream at the at least a portion of the cable coated with the ink; and
electronically controlling advancement of the cable through the air stream such
10 that a metered amount of the ink is removed from the exterior surface of the cable and is
deposited onto the substrate to form a pattern on the substrate.
2. The method of claim 1, wherein the creating step includes coating portions of the
exterior surface of the cable with one of the following: diamond-like glass; diamond-like
15 carbon; a fluoropolymer; a polymer; or a silane.
3. The method of claim 1, wherein the creating step includes treating portions of the
exterior surface of the cable using one of the following: etching; a plasma treatment; or a
corona treatment.
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4. A method of digital printing to form a pattern on a substrate, comprising:
providing at least one paint injector, the at least one paint injector having a wheel
rotatable by a shaft of a motor, an idler at least partially disposed in ink contained in a
reservoir, and a wire-like member disposed at least partially around the wheel and the
25 idler, wherein the wire-like member has alternating hydrophilic and hydrophobic areas on
a least a portion of an exterior surface of the wire-like member;
advancing the wire-like member with the motor to apply a coating of the ink to the
wire-like member;
electronically controlling the position of the at least one paint injector relative to
30 the surface and electronically controlling advancement of the wire-like member through
the fluid stream; and
directing the fluid stream at the coated portion of the wire-like member, while

controlling the position of the paint injector and the advancement of the wire-like member, thereby removing at least a portion of the ink from an exterior of the wire-like member and depositing it onto a substrate to form a pattern on the substrate.

- 5 5. The method of claim 4, wherein the providing step includes coating portions of the exterior surface of the wire-like member with one of the following: diamond-like glass; diamond-like carbon; a fluoropolymer; a polymer; or a silane.
- 10 6. The method of claim 4, wherein the providing step includes treating portions of the exterior surface of the wire-like member using one of the following: etching; a plasma treatment; or a corona treatment.
- 15 7. An apparatus for digitally printing a pattern on a substrate, comprising:
a support structure;
a carriage associated with and movable in at least one direction relative to the support structure;
an ink injector secured to the carriage, the ink injector comprising:
a motor having a rotatable shaft;
a wheel rotatable by the shaft of the motor;
20 an idler; and
an elongate segment disposed around at least a portion of the wheel and a portion of the idler and advanceable by the wheel, the elongate segment having alternating hydrophilic and hydrophobic areas on at least a portion of an exterior surface of the elongate segment and has a quantity of ink coated onto at least a
25 portion of the elongate segment;
at least one fluid nozzle positioned and oriented for directing a jet of fluid toward the at least a portion of the elongate segment to remove an amount of the ink from the elongate segment and direct the amount toward a surface of a substrate to form a pattern on the substrate; and
30 a controller electronically connected to the motor for controlling rotation of the wheel and for controlling the position of the carriage relative to the support structure.

8. The apparatus of claim 7, wherein portions of the exterior surface of the elongate segment are coated with one of the following: diamond-like glass; diamond-like carbon; a fluoropolymer; a polymer; or a silane.

5 9. The apparatus of claim 7, wherein portions of the exterior surface of the elongate segment are treated using one of the following: etching; a plasma treatment; or a corona treatment.

10. An apparatus for forming a pattern on a substrate, comprising:

10 an electronically controllable drive mechanism;

a structure associated with the drive mechanism and movable thereby, wherein at least a portion of an exterior surface of the structure has alternating hydrophilic and hydrophobic areas;

15 an ink supply in communication with the structure for depositing ink on at least a portion of the structure; and

at least one fluid nozzle having at least one nozzle orifice positioned and oriented for directing at least one jet of fluid toward at least a portion of the structure to remove an amount of the ink from the structure and direct the amount toward a substrate,

20 wherein movement of the structure relative to the at least one fluid nozzle substantially controls the amount of the ink removed from the structure, and wherein the amount of the ink directed to the substrate forms a pattern on the substrate.

11. The apparatus of claim 10, wherein the structure comprises a wire.

25 12. The apparatus of claim 11, further including a biasing device associated with the wire to maintain tension in the wire.

13. The apparatus of claim 11, further including a mechanical metering device in contact with the wire for removing an amount of the ink from the wire before the wire
30 passes in front of the at least one orifice.

14. The apparatus of claim 10, wherein portions of the exterior surface of the structure are coated with one of the following: diamond-like glass; diamond-like carbon; a fluoropolymer; a polymer; or a silane.
- 5 15. The apparatus of claim 10, wherein portions of the exterior surface of the structure are treated using one of the following: etching; a plasma treatment; or a corona treatment.