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Taff

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(54) **FLUID EJECTION DEVICE WITH MIXING BEADS**

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(51) **Int. Cl.**

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B41J 2/14	(2006.01)
B01F 11/00	(2006.01)
B01F 13/08	(2006.01)

(52) **U.S. Cl.**

CPC ***B41J 2/14*** (2013.01); ***B01F 11/0082*** (2013.01); ***B01F 13/0006*** (2013.01); ***B01F 13/0818*** (2013.01); ***B41J 2/1433*** (2013.01)

(58) **Field of Classification Search**

CPC . B41J 2/1433; B01F 13/0006; B01F 13/0818; B01F 11/0082; B01F 11/0091

See application file for complete search history.

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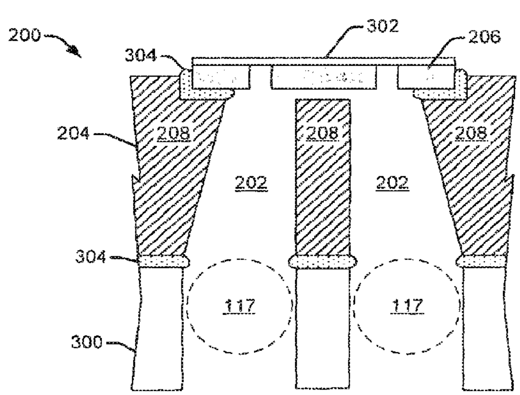
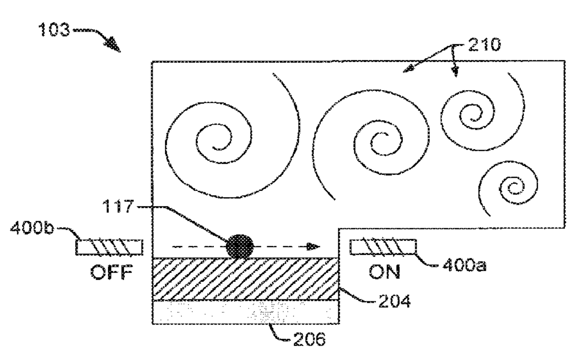
(57) **ABSTRACT**

In an embodiment, a fluid ejection device includes a die substrate with a chiclet adhered by its front side to the die substrate. The fluid ejection device also includes an ink delivery slot formed through the chiclet from its back side to its front side. The fluid ejection device further includes a mixing bead at the back side of the chiclet, adjacent the ink delivery slot.

15 Claims, 6 Drawing Sheets





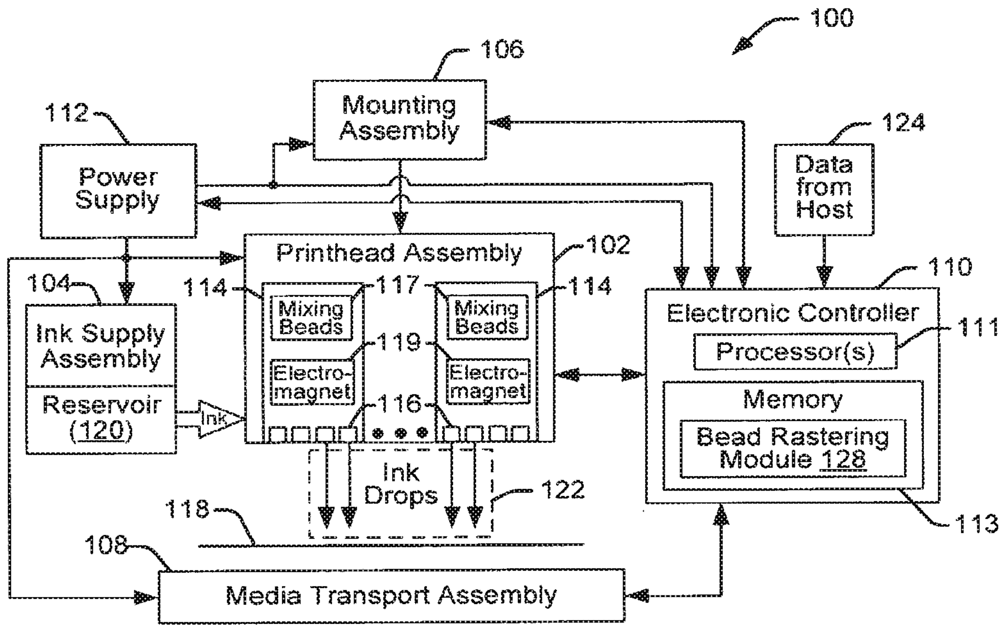

100
106
Mounting Assembly
112
Power Supply
124
Data from Host
Printhead Assembly
102
110
104
114
117
114
Ink Supply Assembly
Mixing Beads
Mixing Beads
Electronic Controller
119
111
Processor(s)
Electro-magnet
Electro-magnet
Reservoir (120)
Ink
116
Memory
Bead Rastering Module 128
Ink Drops
122
118
113
108
Media Transport Assembly

FIG. 1a

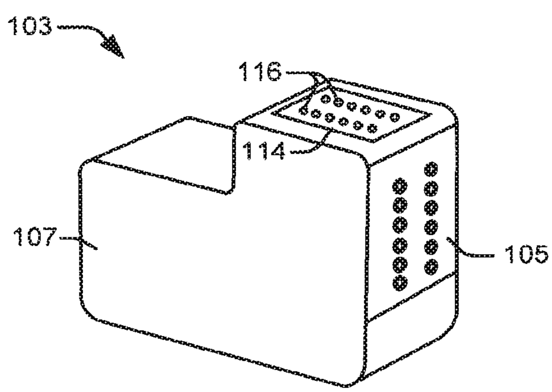

103
116
114
107
105

FIG. 1b

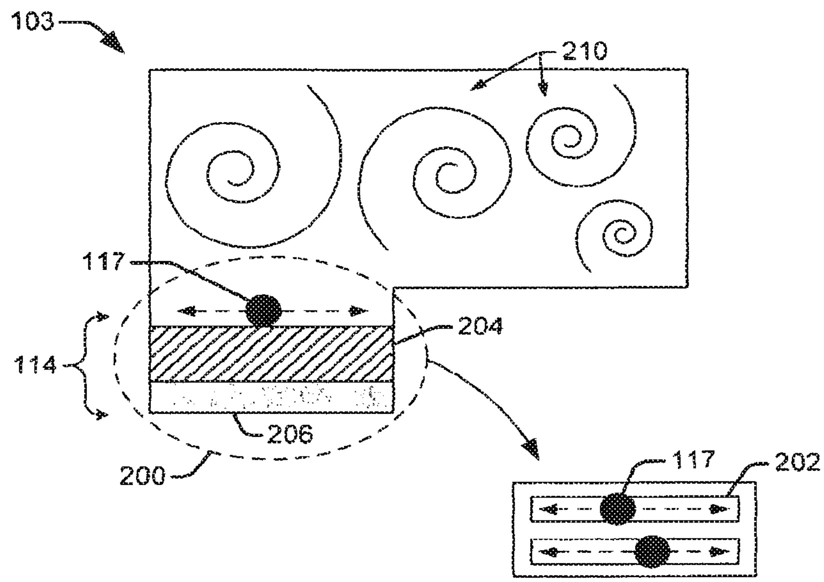

103
210
117
204
114
206
200
117
202

FIG. 2

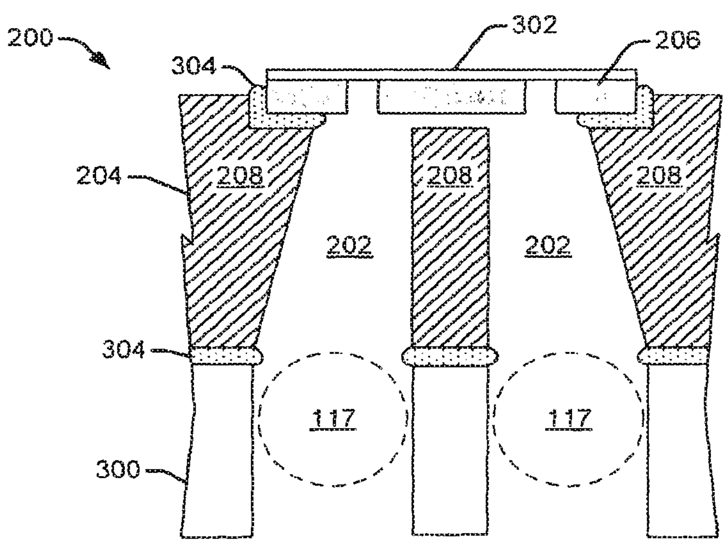

200
302
206
304
204
208
208
208
202
202
304
117
117
300

FIG. 3

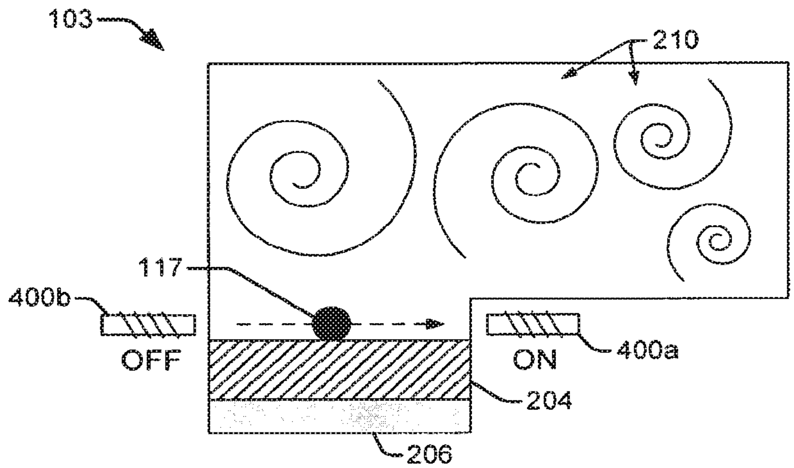

103
210
117
400b
OFF
ON
400a
204
206

FIG. 4

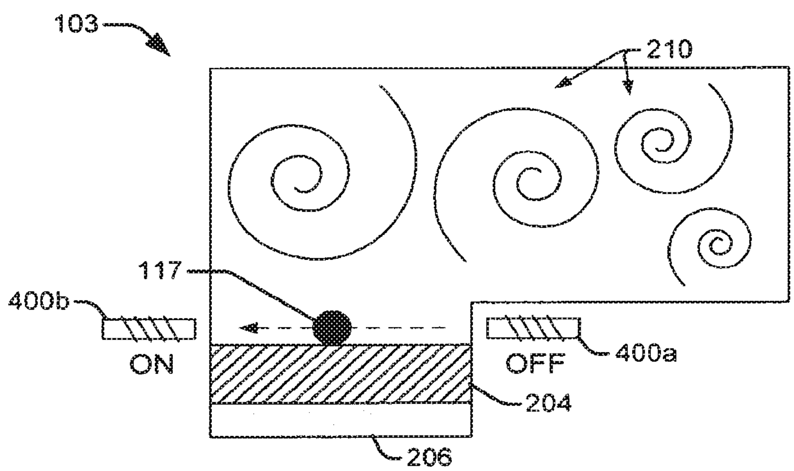

103
210
117
400b
ON
OFF
400a
204
206

FIG. 5

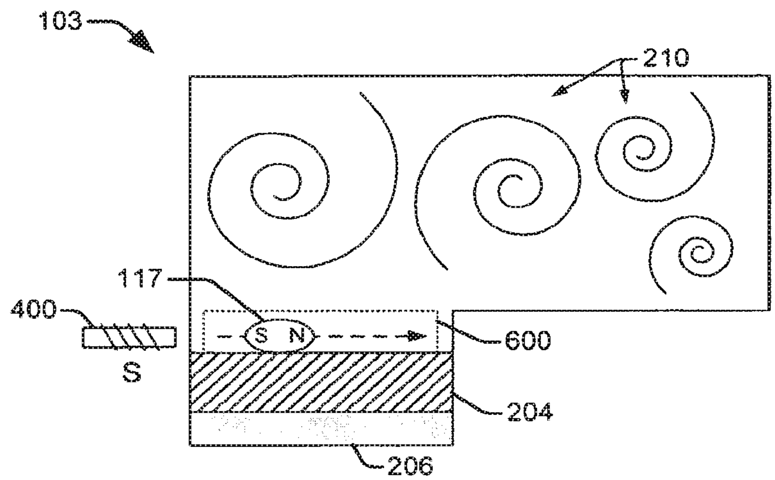


FIG. 6

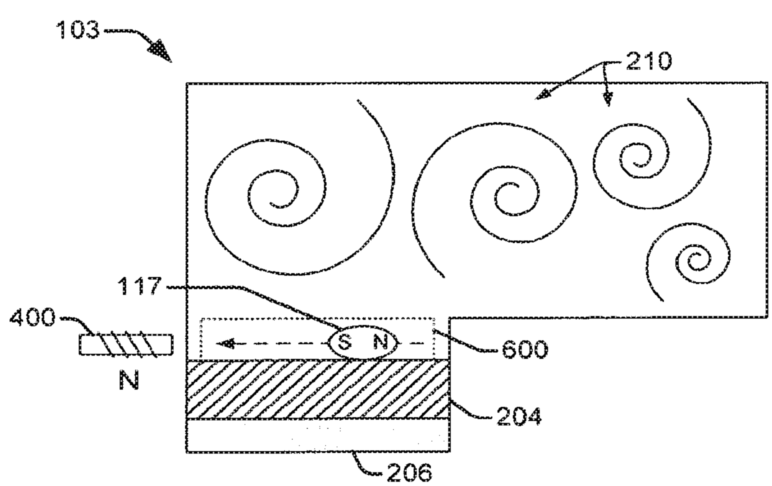


FIG. 7

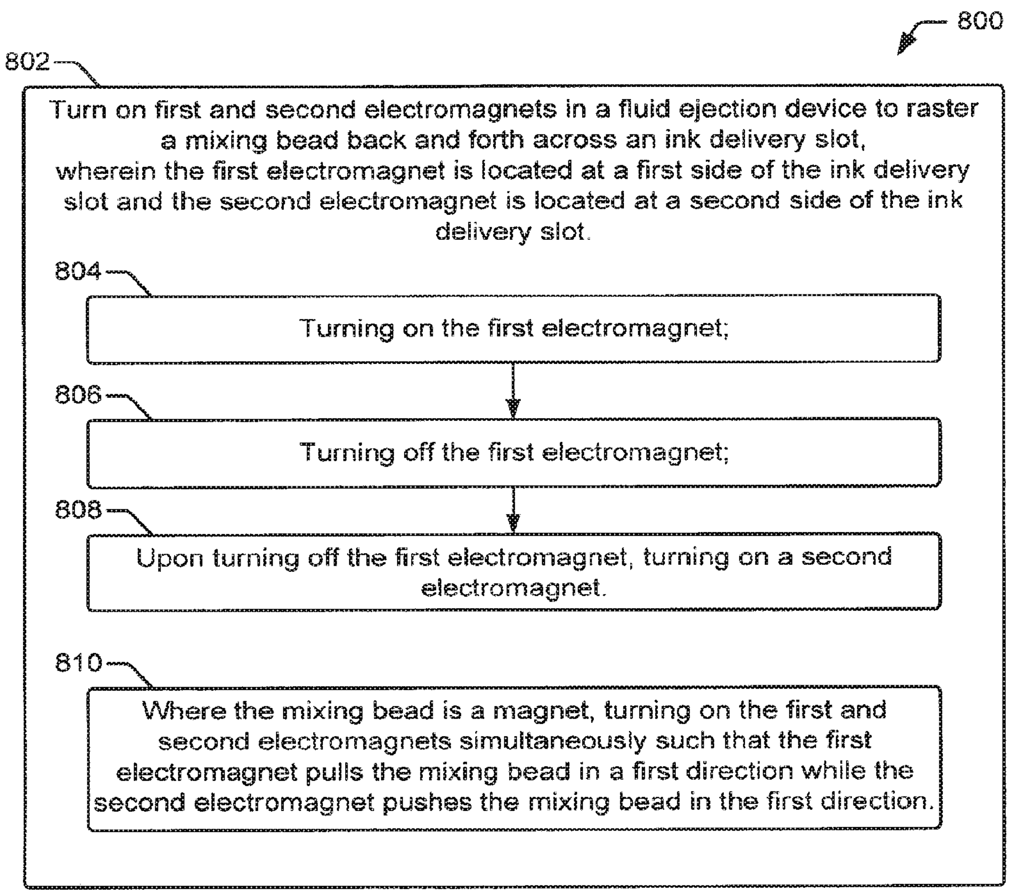

800
802
Turn on first and second electromagnets in a fluid ejection device to raster a mixing bead back and forth across an ink delivery slot, wherein the first electromagnet is located at a first side of the ink delivery slot and the second electromagnet is located at a second side of the ink delivery slot.
804
Turning on the first electromagnet;
806
Turning off the first electromagnet;
808
Upon turning off the first electromagnet, turning on a second electromagnet.
810
Where the mixing bead is a magnet, turning on the first and second electromagnets simultaneously such that the first electromagnet pulls the mixing bead in a first direction while the second electromagnet pushes the mixing bead in the first direction.

Fig. 8

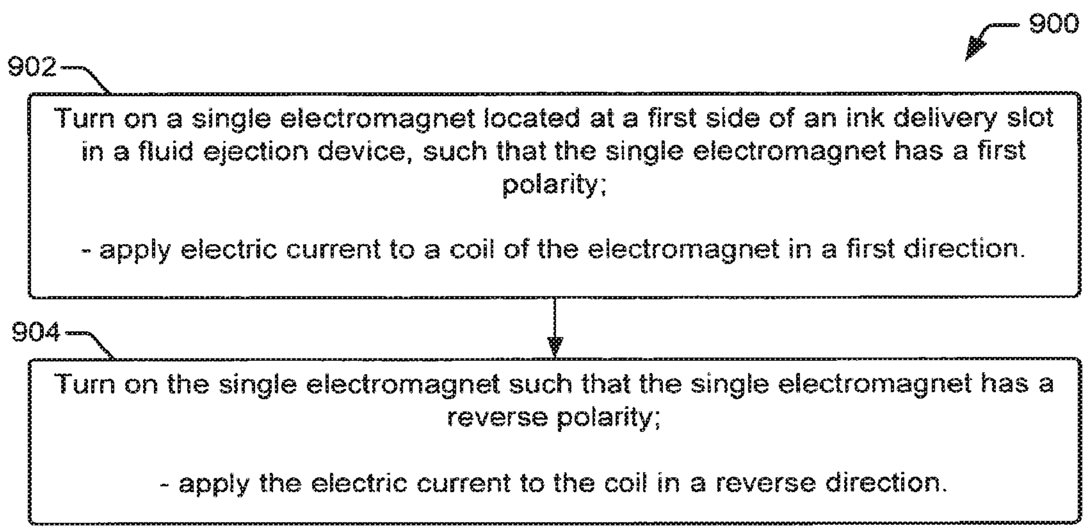

900
902
Turn on a single electromagnet located at a first side of an ink delivery slot in a fluid ejection device, such that the single electromagnet has a first polarity;
- apply electric current to a coil of the electromagnet in a first direction.
904
Turn on the single electromagnet such that the single electromagnet has a reverse polarity;
- apply the electric current to the coil in a reverse direction.

Fig. 9

FLUID EJECTION DEVICE WITH MIXING BEADS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Continuation of copending U.S. patent application Ser. No. 14/765,180, filed on Jul. 31, 2015, and incorporated herein by reference in its entirety, which claims priority to International Application Serial No. PCT/US2013/024018, filed Jan. 31, 2013, and incorporated herein by reference in its entirety.

BACKGROUND

Inkjet printheads are non-contact fluid ejection devices that eject ink from printhead nozzles onto a media substrate (e.g. paper) to form an image. Thermal inkjet printheads eject drops from a nozzle by passing electrical current through a heating element to generate heat and vaporize a small portion of the fluid ink within a firing chamber. Piezoelectric inkjet printheads use a piezoelectric material actuator to generate pressure pulses that force ink drops out of a nozzle. While both dye-based and pigment-based inks are used in inkjet printheads, properties such as color, jettability, drying time, long term storage stability, and decap time (the amount of time a printhead can be left uncapped and idle and can still fire ink droplets properly), influence which type of ink is used in a particular printhead.

Pigment-based inks are increasingly used over dye-based inks because of the various advantages they provide, such as color strength and water fastness. Pigment particles are larger and remain in suspension rather than dissolving in liquid. This provides greater color intensity as the pigment inks remain more on the surface of the paper instead of soaking into the paper. Pigment inks also tend to be more durable and permanent than dye inks. For example, pigment inks smear less than dye inks when they encounter water.

Unfortunately, pigments (colorant particles) suspended in the ink vehicle/carrier tend to settle when a printhead is not used for an extended period of time. Pigment settling can cause printhead nozzles to clog, which reduces the overall print quality.

BRIEF DESCRIPTION OF THE DRAWINGS

The present embodiments will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. **1***a* shows a fluid ejection system implemented as an inkjet printing system, according to an embodiment;

FIG. **1***b* shows a perspective view of an example inkjet cartridge that includes an inkjet printhead assembly and ink supply assembly, according to an embodiment;

FIG. **2** shows a cross-sectional side view of an example inkjet cartridge that includes a printhead with mixing beads, according to an embodiment;

FIG. **3** shows a cross-sectional view of the printhead cutout from FIG. **2**, according to an embodiment;

FIGS. **4** and **5** show cross-sectional side views of example inkjet cartridges where mixing beads are experiencing different bead rastering modes, according to embodiments;

FIGS. **6** and **7** show cross-sectional side views of example inkjet cartridges where magnetic mixing beads are experiencing different bead rastering modes using a single electromagnet, according to embodiments;

FIGS. **8** and **9**, show flowcharts of example methods related to a fluid ejection device with mixing beads and electromagnets that function to disrupt pigment settling within the printhead fluid ejection device, according to embodiments.

DETAILED DESCRIPTION

Overview

As noted above, while the use of pigment-based inks in inkjet printheads provides certain advantages, there are also challenges with their use. When there are extended periods of time when a printhead is inactive, high pigment load and/or settling-prone inks demonstrate a settling dynamic referred to as PIVS (Pigment Ink Vehicle Separation) that can alter the local composition of ink volumes within the printhead nozzles, firing chambers, and in some cases, beyond an inlet pinch toward the shelf/trench (ink slot) interface. In addition to PIVS, an evaporation-driven "thickening" or "hardening" of ink can occur within the bore/nozzle (and in some cases within the chamber as well) due to the depletion of in-ink water molecules and the subsequent elevation in the local ink viscosity. Following periods of nozzle inactivity, the variation in properties of these localized volumes can modify drop ejection dynamics (e.g., drop trajectories, velocities, shapes and colors). When printing resumes after an inactive, non jetting period, there is an inherent delay before the local ink volumes within the nozzle bores are refreshed. This delay, and the associated effects on drop ejection dynamics following a non-jetting period, can be collectively referred to as decap response.

Prior methods of mitigating decap response have focused mostly on ink formulation chemistries, minor architecture adjustments, tuning nozzle firing parameters, and/or servicing algorithms. These approaches have often been directed toward specific printer/platform implementations, however, and have therefore not provided a universally suitable solution.

Efforts to mitigate the decap response through adjustments in ink formulation, for example, often rely on the inclusion of key additives that offer benefits only when paired with specific dispersion chemistries. Architecture focused strategies have typically leveraged shortened shelves (i.e., the length from the center of the firing resistor to the edge of the incoming ink-feed slot), the inclusion or exclusion of counter bores, and modifications to resistor sizes. These techniques, however, usually provide only minimal performance gains. Fire pulse routines have shown some improvements in targeted architectures when exercised as sub-TOE (turn on energy) mixing protocols for stirring ink within the nozzle to combat PIVS forms of the decap dynamic, or by delivering more energetic stimulation of in-chamber ink volumes (delivered at higher voltages or through modified precursor pulse configurations) to compete against viscous plugging forms of the decap response. Again, however, this strategy provides only marginal gains in specific non-universal contexts. Servicing algorithms have functioned as the main systems-based fix. However, servicing algorithms typically generate waste ink and associated waste ink storage issues, in-printer aerosol, and print/wipe protocols that are only feasible for implementation as pre- or post-job exercises.

Another technique for mitigating decap response issues involves "outrunning" the settling and thickening of ink through continued printing. This technique is often a viable choice in high-throughput applications where a printer (e.g., a large format, fixed printbar printing system) is heavily utilized in a consistent and regular way. Unfortunately, it is not always the case that such use modes can be expected, and the penalties associated with settling-prone inks increase significantly as other use modes are employed.

More recent solutions include nozzle-level micro-recirculation strategies, as well as macro-recirculation strategies that focus on stimulating fluid flow behind the back-side of the printhead die. Challenges with micro-recirculation designs include difficulties in homogenizing ink volumes that are upstream of the printhead die, which unfortunately can permit pigment settling in other regions of the printhead that are important for delivering fresh ink. Conversely, challenges with macro-recirculation designs often include pigment settling in smaller regions and regions where the flow follows sharp turns within the printhead. Once settling begins in such areas, it can cascade into other parts of the ink delivery system.

Embodiments of the present disclosure provide significant improvement over prior efforts to mitigate decap response issues, especially with regard to the complex issue of PIVS (Pigment Ink Vehicle Separation) associated with high pigment load and/or settling-prone inks. A printhead fluid ejection device includes bead-like structures such as ball bearings in the ink delivery system (IDS) immediately upstream of the chiclet die carrier. Periodically rastering these mixing beads back and forth along the elongated axis of the chiclet ink delivery slots (one bead per slot) disrupts the settling dynamic and subsequent nozzle fouling complications typically observed with such inks. Entrainment effects of the rastering beads create a mixing dynamic that can re-suspend settled pigments. The beads operate to mix fluid down to regions of the die close to the jetting nozzles, and can also introduce mixing flows that propagate effectively into the larger upstream IDS geometry. The rastering response can be implemented, for example, through the use of small electromagnets positioned within the printhead at opposing ends of the chiclet ink delivery slots. Metal (e.g., ferrous-core) beads can be rastered by actuating the electromagnets at opposing ends of the chiclet, 180 degrees out of phase. The coupling between the beads and the magnetic field can be amplified (made stronger) by using a magnet as the bead. In this case, the electromagnets at each end of the chiclet slot can work in combination, and simultaneously, with an electromagnet at one end of the slot pushing the bead magnet away while the electromagnet at the other end of the slot draws the bead magnet near. In a further implementation, a single electromagnet on one end of the chiclet can perform the rastering of a bead magnet by shifting its polarity through current reversal through the coil. Such a configuration enables this technology to more easily fit into varying printhead form factors.

In an example embodiment, a fluid ejection device includes a die substrate. A chiclet is adhered to the die substrate at its front side. An ink delivery slot is formed through the chiclet from its back side to its front side. A mixing bead is installed at the back side of the chiclet, adjacent the ink delivery slot. In other embodiments, the fluid ejection device includes an electromagnet to raster the bead back and forth across the ink delivery slot.

In another example embodiment, a processor-readable medium stores code representing instructions that when executed by a processor cause the processor to turn on first and second electromagnets in a fluid ejection device to raster a mixing bead back and forth across an ink delivery slot, wherein the first electromagnet is located at a first side of the ink delivery slot and the second electromagnet is located at a second side of the ink delivery slot.

In another example embodiment, a processor-readable medium stores code representing instructions that when executed by a processor cause the processor to turn on a single electromagnet located at a first side of an ink delivery slot in a fluid ejection device, such that the single electromagnet has a first polarity, and turn on the single electromagnet such that the single electromagnet has a reverse polarity.

Illustrative Embodiments

FIG. 1*a* illustrates a fluid ejection system implemented as an inkjet printing system **100**, according to an embodiment of the disclosure. Inkjet printing system **100** generally includes an inkjet printhead assembly **102**, an ink supply assembly **104**, a mounting assembly **106**, a media transport assembly **108**, an electronic controller **110**, and at least one power supply **112** that provides power to the various electrical components of inkjet printing system **100**. In this embodiment, fluid ejection devices **114** are implemented as fluid drop jetting printheads **114**. Inkjet printhead assembly **102** includes at least one fluid drop jetting printhead **114** that ejects drops of ink through a plurality of orifices or nozzles **116** toward print media **118** so as to print onto the print media **118**. Nozzles **116** are typically arranged in one or more columns or arrays such that properly sequenced ejection of ink from nozzles **116** causes characters, symbols, and/or other graphics or images to be printed on print media **118** as inkjet printhead assembly **102** and print media **118** are moved relative to each other. Print media **118** can be any type of suitable sheet or roll material, such as paper, card stock, transparencies. Mylar, and the like. As further discussed below, each printhead **114** comprises one or more mixing beads **117** and electromagnets **119** that function in varying implementations to effect a disruption of a PIVS settling dynamic that maintains and/or restores local ink volumes within the printhead fluid ejection device according to their natural suspended compositions.

Ink supply assembly **104** supplies fluid ink to printhead assembly **102** and includes a reservoir **120** for storing ink. Ink flows from reservoir **120** to inkjet printhead assembly **102**. Ink supply assembly **104** and inkjet printhead assembly **102** can form either a one-way ink delivery system or a macro-recirculating ink delivery system. In a one-way ink delivery system, substantially all of the ink supplied to inkjet printhead assembly **102** is consumed during printing. In a macro-recirculating ink delivery system, however, only a portion of the ink supplied to printhead assembly **102** is consumed during printing. Ink not consumed during printing is returned to ink supply assembly **104**.

In some implementations, as shown in FIG. 1*b*, inkjet printhead assembly **102** and ink supply assembly **104** (including reservoir **120**) are housed together in a replaceable device such as an integrated inkjet printhead cartridge or pen **103**. FIG. 1*b* shows a perspective view of an example inkjet cartridge **103** that includes inkjet printhead assembly **102** and ink supply assembly **104**, according to an embodiment of the disclosure. In addition to one or more printhead dies **114**, inkjet cartridge **103** includes electrical contacts **105** and an ink (or other fluid) supply chamber **107**. Electrical contacts **105** carry electrical signals to and from controller **110**, for example, to cause the ejection of ink drops through nozzles **116**. Cartridge **103** can have a single supply chamber **107** that stores one color of ink, or a number of chambers **107** that each store a different color of ink. In some implementations, a larger reservoir may also be located separately from the cartridge **103** to refill the local chamber **107** through an interface connection, such as a supply tube. In various implementations, cartridge **103** and/or reservoir **120** of ink supply assembly **104** may be removed, replaced, and/or refilled.

Mounting assembly **106** positions inkjet printhead assembly **102** relative to media transport assembly **108**, and media transport assembly **108** positions print media **118** relative to inkjet printhead assembly **102**. Thus, a print zone **122** is defined adjacent to nozzles **116** in an area between inkjet printhead assembly **102** and print media **118**. In one implementation, inkjet printhead assembly **102** is a scanning type printhead assembly. As such, mounting assembly **106** includes a carriage for moving inkjet printhead assembly **102** relative to media transport assembly **108** to scan print media **118**. In another implementation, inkjet printhead assembly **102** is a non-scanning type printhead assembly. As such, mounting assembly **106** fixes inkjet printhead assembly **102** at a prescribed position relative to media transport assembly **108**. Thus, media transport assembly **108** positions print media **118** relative to inkjet printhead assembly **102**.

In one implementation, inkjet printhead assembly **102** includes one printhead **114**. In another implementation, inkjet printhead assembly **102** is a wide-array assembly with multiple printheads **114**. In wide-array assemblies, an inkjet printhead assembly **102** typically includes a carrier that carries printheads **114**, provides electrical communication between the printheads **114** and electronic controller **110**, and provides fluidic communication between the printheads **114** and ink supply assembly **104**.

In one implementation, inkjet printing system **100** is a drop-on-demand thermal bubble inkjet printing system where the printhead(s) **114** is a thermal inkjet (TIJ) printhead. The TIJ printhead employs a thermal resistor ejection element in an ink chamber to vaporize ink and create bubbles that force ink or other fluid drops out of a nozzle **116**. In another implementation, inkjet printing system **100** is a drop-on-demand piezoelectric inkjet printing system where the printhead(s) **114** is a piezoelectric inkjet (PIJ) printhead that implements a piezoelectric material actuator as an ejection element to generate pressure pulses that force ink drops out of a nozzle.

Electronic controller **110** typically includes one or more processors **111**, firmware, software, one or more computer/processor-readable memory components **113** including volatile and non-volatile memory components (i.e., non-transitory tangible media), and other printer electronics for communicating with and controlling inkjet printhead assembly **102**, mounting assembly **106**, and media transport assembly **108**. Electronic controller **110** receives data **124** from a host system, such as a computer, and temporarily stores data **124** in a memory **113**. Typically, data **124** is sent to inkjet printing system **100** along an electronic, infrared, optical, or other information transfer path. Data **124** represents, for example, a document and/or file to be printed. As such, data **124** forms a print job for inkjet printing system **100** and includes one or more print job commands and/or command parameters.

In one implementation, electronic printer controller **110** controls inkjet printhead assembly **102** to eject ink drops from nozzles **116**. Thus, electronic controller **110** defines a pattern of ejected ink drops that form characters, symbols, and/or other graphics or images on print media **118**. The pattern of ejected ink drops is determined, for example, by the print job commands and/or command parameters from data **124**.

In one implementation, electronic controller **110** includes a bead rastering module **128** stored in a memory **113** of controller **110**. Bead rastering module **128** includes coded instructions executable by one or more processors **111** of controller **110** to cause the processor(s) **111** to implement various rastering routines to control electromagnets within a printhead **114** to effect the rastering back and forth of mixing beads **117** along the elongated axis of chiclet ink delivery slots within the printhead **114**, as discussed more fully below.

FIG. **2** shows a cross-sectional side view of an example inkjet cartridge **103** that includes a printhead **114** with mixing beads **117**, according to an embodiment of the disclosure. FIG. **3** shows a cross-sectional view of the printhead **114** cutout **200** from FIG. **2**. Referring to FIGS. **2** and **3**, the mixing beads **117** are located in printhead **114** adjacent to ink delivery slots **202** (one bead per slot) on the back side of chiclet **204**. In general, the beads are sized large enough that they cannot slip down into ink delivery slots **202** of the chiclet **204**. As can be seen more clearly in FIG. **3**, chiclet **204** is the printhead die substrate **206** carrier, and it includes carrier ribs **208** which define the chiclet ink delivery slots **202** (i.e., the fluid passageways within the chiclet). The chiclet **204** is a fluid distribution manifold such as a plastic fluidic interposer whose ink delivery slots **202** provide fluid passageways between the plastic housing **300** of cartridge **103** and the printhead die substrate **206**. While only two slots **202** are illustrated and discussed, it should be apparent that the concepts disclosed herein apply equally to printhead configurations in which a chiclet has varying numbers of slots **202**. The printhead substrate **206** is typically fabricated from a silicon or glass wafer through standard micro-fabrication processes such as electroforming, laser ablation, etching, sputtering, dry etching, photolithography, casting, molding, stamping, machining, and so on. The printhead substrate **206** is also further developed to include a fluidics and nozzle layer **302** on a top side of the substrate **206**. Adhesive bonds **304** generally adhere substrate **206** to the carrier ribs **208** at the front side of chiclet **204**, and adhere the back side of chiclet **204** to the plastic housing **300** of cartridge **103**.

As beads **117** raster back and forth along the elongated axis of chiclet **204** ink delivery slots **202** within the printhead **114**, they create a fluid mixing dynamic **210** that re-suspends pigments that have settled out of the fluid ink vehicle. The beads **117** operate to mix fluid down to regions of the substrate **206** close to the jetting nozzles **116** of nozzle layer **302**, and can also introduce mixing flows that propagate effectively into the larger upstream IDS geometry within the plastic housing **300** of cartridge **103**.

While moving the cartridge **103** back and forth (e.g., by shaking it manually) can effectively raster the beads **117** back and forth within the printhead **114** to achieve fluidic mixing, automated processes of rastering of the beads **117** are also possible. FIGS. **4** and **5** show a cross-sectional side view of an example inkjet cartridge **103** where the mixing beads **117** are experiencing different bead rastering modes, according to embodiments of the disclosure. In the implementations of FIGS. **4** and **5**, the mixing beads **117** are metal beads, formed of a ferromagnetic material, such as ferrous-core beads. The beads **117** in FIGS. **4** and **5** can also be formed of other ferromagnetic materials such as nickel and cobalt. In addition, beads **117** may be coated with a protective layer that protects them from the corrosive effects of ink, such as a polymer layer.

Because beads **117** are formed of a ferromagnetic material, they are responsive to the forces of magnetic fields, which can attract and repel such materials. Accordingly, printhead **114** can be equipped with one or more electromagnets **400** positioned within the printhead **114** at opposing ends of the chiclet ink delivery slots **202**. Electromagnets **400** generally comprise a coil of wire wrapped around a core of ferromagnetic material such as steel. An electromagnet **400** acts as a magnet when an electric current passes through the coil, and ceases acting as a magnet when the current stops. The ferromagnetic core around which the coil is wrapped enhances the magnetic field produced by the coil.

Electric current (e.g., from a power supply **112**) passing through the coils of electromagnets **400** is controllable by a processor **111** executing instructions from a bead rastering module **128** stored in a memory **113**. Thus, the processor **111** controls when the electromagnets **400** turn ON, and when they turn OFF, to control when and how the beads **117** are rastered back and forth across the ink delivery slots **202** of chiclet **204** within the printhead **114**. For example, as shown in FIGS. **4** and **5**, the processor **111** can raster the beads **117** back and forth by actuating the electromagnets **400** (**400***a* and **400***b*) at opposing ends of the chiclet **204**, 180 degrees out of phase with one another. In FIG. **4**, an electromagnet **400***a* at one end of the chiclet **204** (i.e., on the right side) is turned ON by processor **111**, which pulls the bead to the right, toward the electromagnet **400***a*. At this time, the electromagnet **400***b* (i.e., on the left side) is OFF. This raster mode allows the bead(s) **117** to move to the right and traverse the length of the slot **202**. Thereafter, as shown in FIG. **5**, the electromagnet **400***b* at the other end of the chiclet **204** (i.e., on the left side) is turned ON by processor **111**, while the electromagnet **400***a* is turned OFF. This raster mode pulls the bead(s) **117** back across the slot **202** to the left, toward the electromagnet **400***b*.

In another implementation of the printhead **114** configuration shown in FIGS. **4** and **5**, the beads **117** can be magnets. That is, the beads **117** are formed of material that is magnetized and creates its own persistent magnetic field. When beads **117** are magnets, the magnetic coupling between the beads **117** and electromagnets **400** is amplified. By the processor **111** alternately shifting the polarity of the electromagnets **400** through reversing the direction of current through the coils, the electromagnets **400** at each end of the slot **202** can work simultaneously and in combination to move the beads **117** back and forth across the slots **202**. That is, for example, while electromagnet **400***a* is ON in one polarity (e.g., a positive polarity), electromagnet **400***b* is ON in the reverse polarity (e.g., a negative polarity). In this mode, electromagnet **400***a* will pull magnetic bead **117** to the right, while electromagnet **400***b* pushes magnetic bead **117** to the right. After the magnetic bead **117** reaches the right side of the slot **202**, processor **111** can control a reversal of the direction the current flows through the coils of electromagnets **400***a* and **400***b*, thereby reversing their polarities. In this mode, electromagnet **400***a* will push magnetic bead **117** to the left, while electromagnet **400***b* pulls magnetic bead **117** to the left.

FIGS. **6** and **7** show a cross-sectional side view of an example inkjet cartridge **103** where magnetic mixing beads **117** are experiencing different bead rastering modes using a single electromagnet, according to embodiments of the disclosure. In the implementations of FIGS. **6** and **7**, the mixing beads **117** are formed of magnetized material, such that they create their own magnetic fields. Materials that can be magnetized include, for example, various ferromagnetic materials such as iron, nickel, cobalt, some metal alloys, and some naturally occurring minerals such as lodestone.

The bead rastering modes illustrated in FIGS. **6** and **7** are achieved with the use of a single electromagnet **400** on one end of the chiclet **204** ink delivery slots **202**. The polarity of the single electromagnet **400** is alternately shifted through current reversal through the coil. As shown in FIG. **6**, a barrier **600** in the printhead **114** maintains the orientation of the polarized magnetic bead **117**. In the raster mode show in FIG. **6**, the processor **111** controls current flow through the coil of electromagnet **400** so that it generates a south (S) polarized magnetic field. The magnetic bead **117** is oriented such that its south (S) pole is toward the electromagnet **400**, which causes the electromagnet **400** to repel the magnetic bead **117**, moving it toward the right side of the slot **202**. In the raster mode show in FIG. **7**, the processor **111** reverses the direction of current flow through the coil of electromagnet **400** so that it generates a north (N) polarized magnetic field. Because the magnetic bead **117** is oriented such that its south (S) pole is toward the electromagnet **400**, the electromagnet **400** pulls on the magnetic bead **117**, moving it toward the left side of the slot **202**. The use of a single electromagnet **400** to raster the magnetic beads **117** back and forth across the chiclet slots **202** improves the likelihood that such technology can be fit into additional printhead form factors that have tighter space restrictions.

FIGS. **8** and **9**, show flowcharts of example methods **800** and **900**, related to a fluid ejection device (e.g., a printhead) with mixing beads and electromagnets that function to disrupt pigment settling within the printhead fluid ejection device, according to embodiments of the disclosure. Methods **800** and **900** are associated with the embodiments discussed above with regard to FIGS. **1**-**7**, and details of the steps shown in methods **800** and **900** can be found in the related discussion of such embodiments. The steps of methods **800** and **900** may be embodied as programming instructions stored on a computer/processor-readable medium, such as memory **113** of FIG. **1**. In an embodiment, the implementation of the steps of methods **800** and **900** are achieved by the reading and execution of such programming instructions by a processor, such as processor **111** of FIG. **1**. Methods **800** and **900** may include more than one implementation, and different implementations of the methods **800** and **900** may not employ every step presented in their respective flowcharts. Therefore, while steps of methods **800** and **900** are presented in a particular order within the flowcharts, the order of their presentation is not intended to be a limitation as to the order in which the steps may actually be implemented, or as to whether all of the steps may be implemented. For example, one implementation of method **800** might be achieved through the performance of a number of initial steps, without performing one or more subsequent steps, while another implementation of method **800** might be achieved through the performance of all of the steps.

Method **800** of FIG. **8**, begins at block **802**, where the first step shown is to turn on first and second electromagnets in a fluid ejection device to raster a mixing bead back and forth across an ink delivery slot. In this step, the first electromagnet is located at a first side of the ink delivery slot and the second electromagnet is located at a second side of the ink delivery slot. As shown at blocks **804**, **806**, and **808**, respectively, turning on the first and second electromagnets can include turning on the first electromagnet, turning off the first electromagnet, and, upon turning off the first electromagnet, turning on a second electromagnet. As shown at block **810**, where the mixing bead is a magnet, turning on the first and second electromagnets can include turning on the first and second electromagnets simultaneously such that the first electromagnet pulls the mixing bead in a first direction while the second electromagnet pushes the mixing bead in the first direction.

Method **900** of FIG. **9**, begins at block **902** where the first step shown is to turn on a single electromagnet such that the single electromagnet has a first polarity. The single electromagnet is located at a first side of an ink delivery slot in a fluid ejection device. Turning on the single electromagnet includes applying electric current to a coil of the electromagnet in a first direction. The next step in method **900**, as shown at block **904**, is to turn on the single electromagnet such that the single electromagnet has a reverse polarity (i.e., an opposite polarity from the first polarity). Turning on the single electromagnet such that the single electromagnet has a reverse polarity includes applying the electric current to the coil in a reverse direction.

What is claimed is:

1. A fluid ejection device comprising:

a die substrate;

a chiclet adhered by a front side thereof to the die substrate;

an ink delivery slot formed through the chiclet from a back side thereof to the front side thereof;

a mixing bead at the back side of the chiclet, adjacent the ink delivery slot; and

at least one electromagnet on at least one side of the ink delivery slot to raster the mixing bead back and forth across the ink delivery slot away from and toward the at least one side.

2. A fluid ejection device as in claim **1**, wherein the at least one electromagnet comprises two electromagnets, one on each side of the ink delivery slot to raster the mixing bead back and forth across the ink delivery slot through alternating activation of the two electromagnets.

3. A fluid ejection device as in claim **1**, wherein the mixing bead comprises a magnet, wherein the at least one electromagnet comprises two electromagnets, one on each side of the ink delivery slot to raster the mixing bead back and forth across the ink delivery slot through simultaneous activation of the two electromagnets.

4. A fluid ejection device as in claim **1**, wherein the at least one electromagnet comprises a single electromagnet on one side of the ink delivery slot to raster the mixing bead back and forth across the ink delivery slot through reversing a direction of current flow through a coil of the electromagnet.

5. A fluid ejection device as in claim **3**, wherein simultaneous activation of the two electromagnets comprises alternating the polarities of the two electromagnets with each activation.

6. A fluid ejection device as in claim **1**, wherein the mixing bead comprises a metal bead.

7. A fluid ejection device as in claim **6**, wherein the metal bead is formed of a ferromagnetic material selected from the group consisting of iron, nickel, cobalt, and metal alloy.

8. A fluid ejection device as in claim **1**, wherein the mixing bead comprises a magnet.

9. A fluid ejection device as in claim **1**, wherein the mixing bead is sized such that the mixing bead cannot enter the ink delivery slot.

10. A fluid ejection device as in claim **1**, further comprising a polymer layer coating the mixing bead.

11. A processor-readable medium, storing code representing instructions that when executed by a processor cause the processor to:

turn on first and second electromagnets in a fluid ejection device to raster a mixing bead back and forth across an ink delivery slot away from and toward the first and second electromagnets;

wherein the first electromagnet is located at a first side of the ink delivery slot and the second electromagnet is located at a second side of the ink delivery slot.

12. A processor-readable medium as in claim **11**, wherein turning on the electromagnets comprises:

turning on the first electromagnet;

turning off the first electromagnet; and

upon turning off the first electromagnet, turning on the second electromagnet.

13. A processor-readable medium as in claim **11**, wherein the mixing bead is a magnet, and turning on the electromagnets comprises turning on the first and second electromagnets simultaneously such that the first electromagnet pulls the mixing bead in a first direction toward the first electromagnet while the second electromagnet pushes the mixing bead in the first direction away from the second electromagnet.

14. A processor-readable medium storing code representing instructions that when executed by a processor cause the processor to:

turn on a single electromagnet located at a first side of an ink delivery slot in a fluid ejection device, such that the single electromagnet has a first polarity; and

turn on the single electromagnet such that the single electromagnet has a reverse polarity,

wherein turning on the single electromagnet to have the first polarity and turning on the single electromagnet to have the reverse polarity is to raster a mixing bead back and forth across the ink delivery slot away from and toward the single electromagnet.

15. A processor-readable medium as in claim **14**, wherein:

turning on the single electromagnet to have the first polarity comprises applying electric current to a coil of the electromagnet in a first direction; and

turning on the single electromagnet to have the reverse polarity comprises applying the electric current to the coil in a reverse direction.

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