Small Dot Printing with Ion Head

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Abstract

A novel solution is proposed and tested for the blooming problem present when generating latent images on a dielectric with an Ion head. Blooming refers to the increase in the latent image diameter as charges accumulate on the dielectric imaging substrate typically used for Ionography. The proposed solution consists on operating the Ion Head at pressures higher than atmospheric to enable large extraction fields without arcing. A pressurized chamber is built to demonstrate that higher pressure operation (2-3 atm) indeed allows extraction fields up to 12 V/µm. These large extraction fields (9-12 V/µm) allow to maintain the charge beam focused, enabling small dot (~40 um) latent images. A liquid toner based development process is implemented combined with a 6.35 µm Mylar dielectric to generate small dot images and contrast them with those obtained when the extraction field is limited by arcing at atmospheric pressure.

Ion head Background

Ionography is a direct imaging printing process employing direct charge deposition on a dielectric imaging substrate to create a latent image which may be then developed with toner. Several different Ion sources have been employed for Ionography, with the DBD (Dielectric barrier Discharge) based Ion Print-Head being the most successful one and still being used by Delphax Systems[6]. The reader is referred to [1] for a comprehensive summary of the history of the Ion Print-Head (afterwards renamed electron beam imaging, a name more representative to the true operation of the device as s discussed on [3]). Figure 1 shows an image of a typical Ion Print-Head from a Delphax patent.

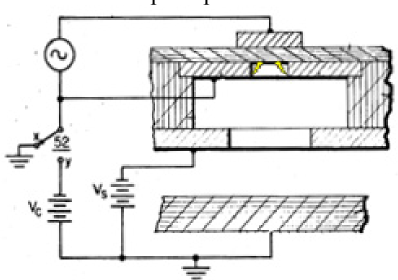

***Figure 1**. Ion Print Head drawing from US Patent 4,160,257 granted on 1979*

The Ion Print-Head consist of an AC driven electrode pair with a dielectric layer in between forming a DBD. One electrode (discharge) has an opening (nozzle) where the plasma is generated while the other is fully enclosed (embedded electrode) to prevent discharges on its surface as depicted in figure 3. A second dielectric and a third electrode(screen) are placed on top of the generator, this one serves the purpose of gating current being extracted from the plasma. A key metric for an Ion head is the amount of charge extracted per nozzle per AC cycle, this charge which is of the order of ~1-2 pC will be denoted as Charge Factor. Typical AC excitations are on the order of 3000 Vpk-pk at 2.5 MHz.

Key challenges for an Ion Print-Head based print engine are:

- Resolution requirements [2] limited both by the Print-head charge beam size and blooming on the dielectric imaging surface,
- Current requirements for high speed operation [3]
- Lifetime.

Additionally there several manufacturing challenges related to an Ion Print-head including coating of the dielectric layer serving as barrier for the DBD which needs to sustain AC potentials of 3000 Vpk-pk while at the same time provide uniform discharge across the width of a print head, alignment of several nozzle layers and elimination of parasitic discharges due to unfilled air gaps within the structure.

HP small dot Ion head

Design and operating details for the HP small dot Ion head are presented in [8]. As shown in figure 2 the typical nozzle cross section is similar to that from figure 1 except that it boasts an optimized discharge electrode as described in [8].

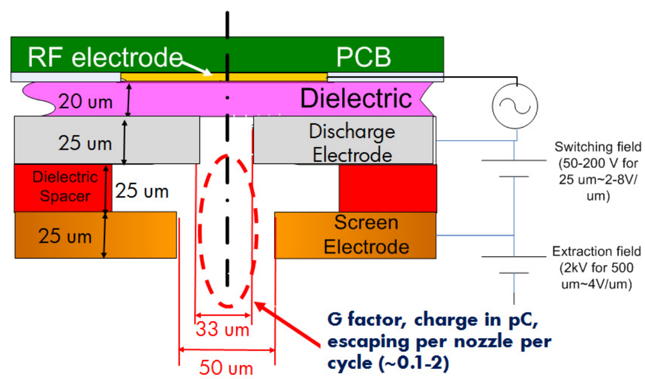

***Figure 2**. HP Ion Print Head nozzle cross section*

***Figure 3**. HP Ion Print Head prototype*

Typical AC excitation is 3 kV pk-pk at 2.5 MHz. The extraction field is about 4 V/µm and mostly limited by breakdown to the imaging substrate. A prototype of an Ion head built as shown in figure 2 is featured in figure 3. This prototype head has 4x RF lines that maybe addressed and 100 nozzles per lines (non-addressable). The overall size of the prototype is a 1"x1" PCB mounted on an aluminum heat sink base.

Blooming effects in Ionography

To quantify the blooming effect on a latent image printed with this HP small dot Ion head a numerical model using FEM (COMSOL) was built. The model does not attempt to recreate the discharge physics in the discharge electrode, but rather focuses on modeling the electrostatic field and the drift/diffusion motion of charges as they leave the discharge electrode. The cold plasma is replaced with a boundary condition pertaining to charges being injected at the dielectric layer at the center of the nozzle. A typical 2-D field plot is shown in figure 4. Electrical field lines and charge density (electron density) are shown in figure 4. The image shows a snapshot after some charge has been deposited in the 18 µm thick (relative permittivity 3) dielectric so the field lines are shown to distort and bloom as they get close to the dielectric imaging substrate, increasing the size of the latent image as compared to the original beam prior to charging. Figure 4 also shows how we define the latent image dot size, basically as the half amplitude full width (diameter).

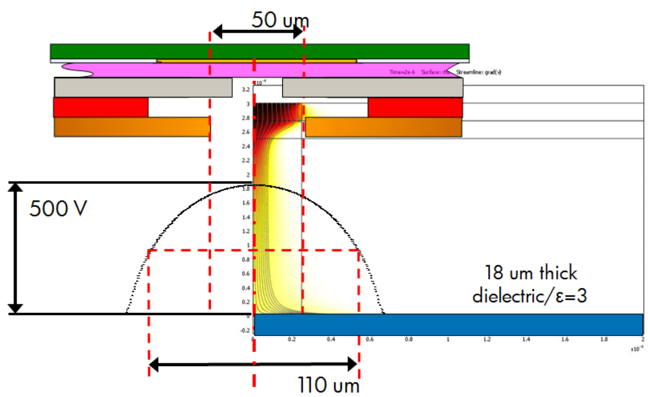

***Figure 4**. FEM model of blooming*

Depending on the process used for development of the latent image the choice of dielectric thickness and required image charge (and thus voltage) would vary. Figure 5 shows the attained latent image dot size for different image peak potential at different extraction fields (DC field applied to the screen electrode). The screen electrode to imaging substrate gap is fixed at 500 µm and the dielectric is kept as shown above for these results. As expected the extraction field has a focusing effect and helps keep the dot size closer to the pre-blooming beam size as it is increased. However this is a purely theoretical experiment as the breakdown field in air will be in the vicinity of a few V/µm (about 4-6 V/µm) for a gap of about 500 µm between the screen and the imaging substrate. Yet the capability to run at a 12-16 V/µm extraction field would enable making 40-60 µm latent images fit for 600 dpi resolution printing.

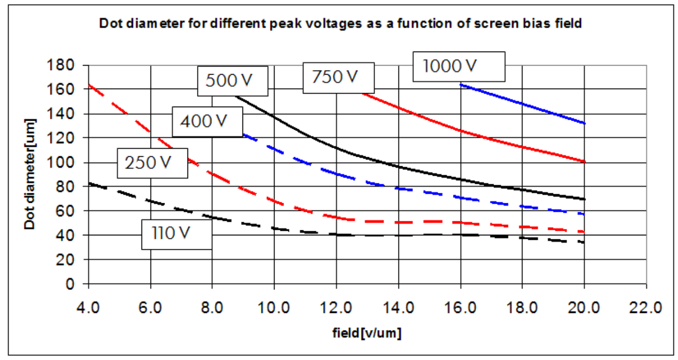

***Figure 5**. Effect of Bias field on latent image dot size for different image peak potential levels*

Pressurized Operation of an Ion Head

The Paschen discharge curve[7] provides a guideline to the onset of breakdown between parallel surfaces so it is the right place to look for answers to the question posed above, how to enable larger extraction fields?. Even though it is typically plotted as a function of the gap distance at atmospheric pressure, the breakdown potential is actually a function of the combined pressure and gap multiplied by each other. In other words increasing the pressure has a similar effect to that of increasing the gap at constant pressure. The insight is then that an Ion head could be run at an elevated pressure in order to increase the extraction field. In order to verify this claim we built the pressurized testbed shown in figure 6. This setup allows running an HP Ion head at several times atmospheric pressure while measuring the extracted current from the head and visualizing the glow discharge through the use of an ITO collector electrode and a clear window in the chamber. The chamber also allows different gases to be used in lieu of air.

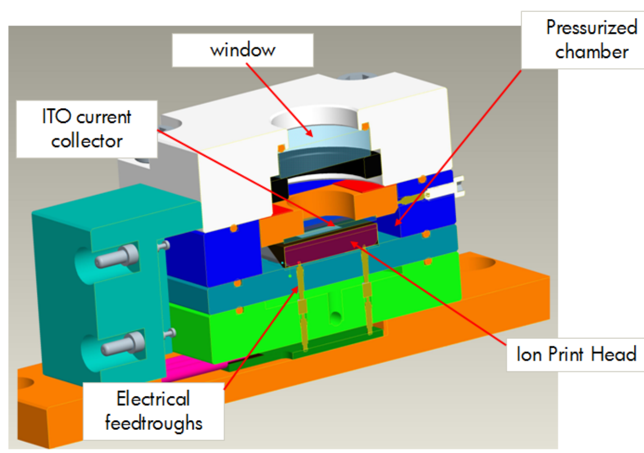

***Figure 6**. Pressurized chamber for testing*

Typical results for tests run on this chamber are shown in figure 7. The Ion Head screen electrode was spaced 250 µm (0.010") away from the collector electrode. Tests were performed both with the RF excitation on. The breakdown field reported is the average field computed as the ratio of the extraction potential to the screen electrode-collector gap. Tests were run also for both compressed dry air and nitrogen as environments for the printhead. As predicted by the Paschen discharge curve, increasing the pressure in the chamber increased the attainable extraction field before arcing occurs. Arching/breakdown threshold is defined by the presence of large transient and random current spikes superimposed on the measured current at the collector current. These results provide initial feasibility to the idea of pressurizing an Ion Head in order to reduce the blooming effect.

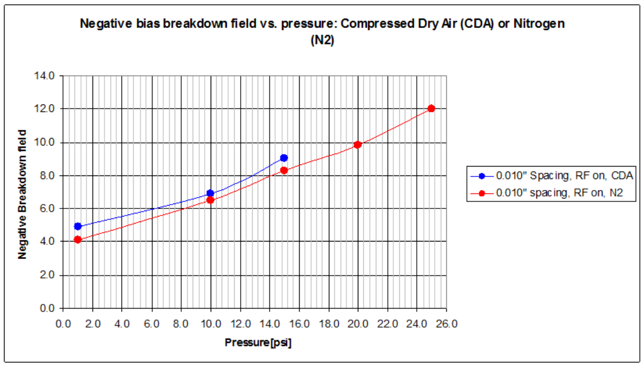

***Figure 7**. Effect of pressure on Ion head current and breakdown bias*

Small dot imaging with Pressurized Ion head

In order to fully test how a pressurized Ion Head would behave in a printing process a Rotary rig testbed was developed. It consists of a motorized 12" diameter drum covered with a 6.35 µm thick aluminized mylar blanket to provide as the imaging substrate. A positive magenta liquid toner was used for development. The liquid toner is positively charged and has a pigment loading of 4% NVS. Image areas are charged to -300 V whereas background areas are kept at ground potential.

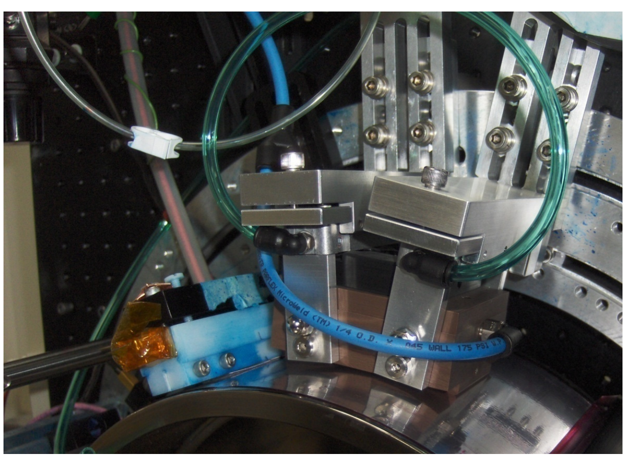

***Figure 8**. Rotary Rig testbed with pressurized head unit*

A conductive reverse roller biased at -150 V and spaced 100 µm from the drum was used to develop the liquid toner onto the image. A pressurized base is designed and built for the Ion head which allows for pressurized operation while the drum rotates. The base features a sliding bearing (solid lubricated polymer) portion and a small gap (125 µm) between the base and the drum on the imaging areas to prevent contact. The resulting developed dots are shown in figure 9. At atmospheric pressure the extraction field is limited to about 6 V/µm yielding about 71-100 µm dots. With the pressure inside the Ion head chamber increased to 2 Atmospheres the extraction field may be increased to 9 V/µm without arcing which allows keeping the beam focused and yields 45 µm dots. Tape transfer is used to remove the dots from the imaging substrate onto a separate carrier so that microscope imaging is possible.

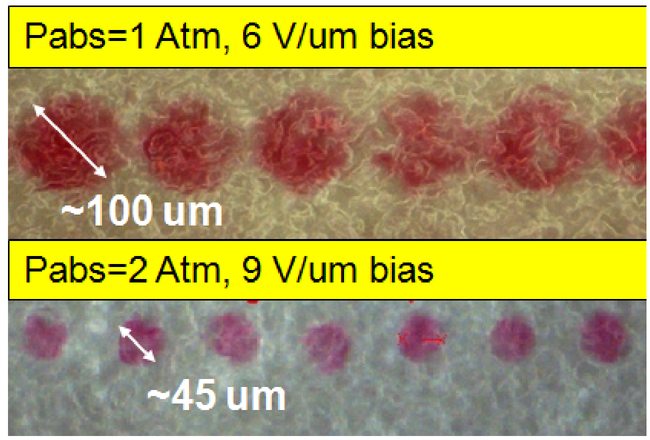

***Figure 9**. Small dots printed with liquid toner*

Conclusions

A novel approach is presented to allow printing of small dots from an Ion head while preventing the blooming phenomena present when writing charge directly onto a dielectric. Pressurized operation of an Ion Head is proposed and validated as a viable alternative to develop ~40 µm dots onto a dielectric and the process is illustrated with the use of a positively charged liquid toner for development, a pressurized base which allows pressurizing the Ion Printhead while mounted to a rotating drum and a 6.35 µm Mylar sheet as the dielectric imaging substrate. The results show a viable method to remove one of the key challenges for high IQ printing with direct charging technologies such as the Ion Printhead.

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Author Biography

Napoleon Leoni is a Mechanical Engineer in the Commercial Print Engine Lab of Hewlett Packard Laboratories. He received his B.Sc. in Mechanical Eng. from Universidad Simon Bolivar in 1994 and his Ph.D. from Carnegie Mellon University in 1999. Prior to joining HP he worked on nano-positioning systems for Disk Drive head testers. He joined HP in 2003 and has worked on novel charging systems for digital presses.

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Richard Fotland is a consultant with over 50 years experience in product and process development. His professional achievements have been recognized thru many awards including the Society for Information Display Johann Gutenberg Award and the IS&T Kosar Memorial Award for the development of Ion Printing. He holds a B.S. Physics(1954), and a M.S. E.E(1958) from Case Western Reserve.