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Advancements in Ink Jet Technology for Materials Deposition and Manufacturing

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Abstract

Ink jet technology continues to advance, providing greater opportunities for research, prototyping, and manufacturing. 3D printing continues to evolve, enabling advancements in market segments from medical devices to industrial components. This presentation will provide an overview of the capabilities today's ink jet technologies provide, as well as where this technology is headed. We will target multi-head systems and their uses for research, prototyping, and manufacturing. We will look at some of the current uses of printhead technology for development, research, and manufacturing.

Print Technology

Today's printhead technology provides a robust, precise, fast method of ejecting fluids and materials. Advancements in speed, print area, and durability are ongoing, to the point where referring to these tools as printheads is severely understating their capabilities and usefulness. With these advancements, printheads are finding their way into a multitude of uses and functions.

Thermal Ink Jet (TIJ)

There are a number of ink jet technologies in the marketplace. For example, thermal ink jet provides a low-cost ink jet technology. However, because thermal ink jet heats the fluid rapidly (and to a very high temperature) to expel materials, it is limited in the fluids and materials it can jet.

***Figure 1**: HP thermal ink jet printhead. [1]*

Piezoelectric Ink Jet

Piezoelectric printheads fire the material when a voltage is applied to the piezo element. The material chamber can be heated, to aid in the jettability, but it is not a prerequisite for firing the material. Piezo-based ink jet printheads offer precise performance, ideal for countless opportunities of research, development, and manufacturing applications.

Figure 2: Dimatix piezo-based printhead/jetting device. [2]

The evolution of ink jet printheads make it possible to jet a wide variety of fluids, including aqueous and solvent-based fluids, solutions and particle suspensions. Typical fluid characteristics are viscosities in the 2-30 centipoise range. Ink jet printhead components have advanced to where there is little or no impact or "contamination" to the jetted material, ensuring pure performance from the deposited fluid. In fact, today's ink jet printhead technologies are compatible with most organic solvents and acrylate materials.

Another key feature and important characteristic, particularly when scaling up from research to manufacturing, is consistency. Printheads provide drop size repeatability within ranges of 3.5%, and can be adjusted to provide in the area of 0.5% repeatability. Drop size and drop spacing are also widely ranging. For example, there are printheads commercially available that can print a one (1) pl drop. And drops are getting smaller (and larger, if necessary) with advanced technology developments.

Material Deposition Systems

Developmental systems typically feature a single printhead. These systems provide a method for developing jettable materials, as well as prototyping.

Figure 3: *Dimatix materials printer DMP-2831. [2]*

Multi-Printhead Depositing Systems

Multi-head ink jet systems provide tri-dimensional printhead positioning for accurate drop placement and materials deposition. Multi-head systems are ideally suited for configurable 3D materials deposition, as well as for printed electronics, biology, and other applications requiring a high degree of placement accuracy. These systems feature multiple camera installations, to ensure precise printhead alignment and saber angle adjustment.

These systems can utilize multiple fluids and materials, allowing the build-up and mixing of unique fluids. With extremely precise process repeatability, jetting accuracy, and a broad range of materials compatibility, multi-head systems serve as excellent tools for product development, and can also be scaled up for small-scale manufacturing, and beyond. Applications such as optical device manufacturing and biologic dosing are being achieved utilizing ink jet technology.

Figure 4: *ImTech four printhead I-Jet 4100. [3]*

Another benefit of these multi-head systems is that they enable blending, as well as multiple-material layering. Curing stations add to the functionality. Some applications require an ultra-clean environment, and need features such as glove boxes.

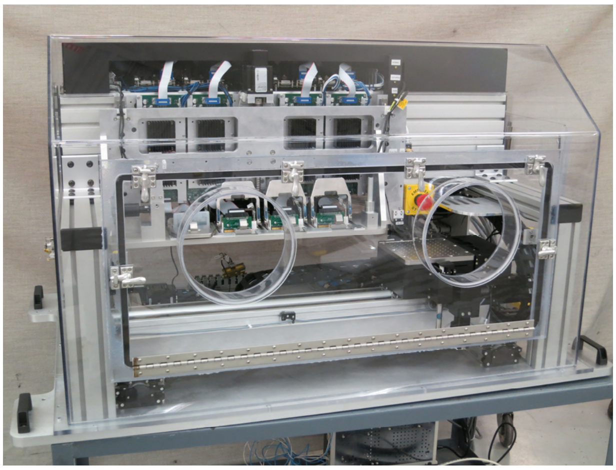

Figure 5: *ImTech I-Jet 4100 with glove box. [3]*

Beyond these systems, integrating print technology into a production environment involves scaling up the process to meet demand. It would be remiss to omit a few key points, some of which may present significant hurdles to overcome. These include conveyance and transport, bulk material delivery, and the general scale required to produce the desired results. Understanding the process at the prototyping stage will help prepare for the scale-up. Applications where the printheads are stationary require extra detail regarding the conveyance, staging, and other variables that could negatively impact the deposition process. The speed at which the printed object is moving is another concern, as air flow could impact drop placement accuracy. It is critical that the material handling system is designed with as much care as the jettable fluids and printhead deposition system.

Printhead Deposition Applications

Real-world applications are evolving from specialty applications, such as printing images on cakes, to full-on industrial production featuring digital decoration. And those applications are evolving as well. Pringles utilized ink jet technology to print trivia questions and images on potato crisps.

Figure 6: *Printed Pringles. [4]*

Admittedly, applications like Pringles are merely an extension of traditional printing, with non-traditional inks. Food is now being produced with ink jet technology, at least in the lab, using 3D printing techniques. To take the concept a bit further, add a little flavor to the mix, literally. Using ink jet technology to deposit flavor in-line offers manufacturers more options for meeting demand, and allows companies the ability to provide on-the-fly custom offerings. The flavors could be deposited as an image, or simply added to the product to enhance or change the flavor profile. Sensation, such as cooling or heat, could also be jetted onto food products.

The manufacturing of electronic components using printing processes has been forecasted to grow exponentially in the coming years. These new processes are intended for sectors as diverse as energy, aerospace, defense, transportation and health and require large volumes of production.

The advantages of printed electronics over traditional methods are numerous: lower investments, mass customization, performance, and integration of components on substrates of any size and complexity.

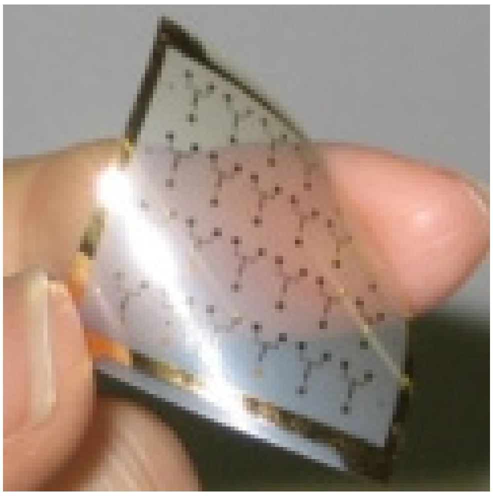

Figure 7: *Ink jet printed single-walled carbon nanotube (SWCNT) flexible thin-film transistor (TFT). [5]*

Because ink jet technology provides consistent, repeatable fluid deposition, it can be installed inline as part of the production process. Both the hardware and fluid technologies are advancing. Other areas where advancements are happening include the fluid deposition of scratch-resistant coatings, adhesives and conductive and non-conductive patterning, to liquid silver used in the fabrication of flexible electronic circuits, to organic materials found in pharma and bioscience applications.

Another exciting arena for the application of printhead deposition technology is in the field of gradient-index (GRIN) optics, which have been shown to possess tremendous optical performance due to their ability to eliminate monochromatic aberrations. Challenges to manufacture GRIN materials have limited their applications.

By using two materials, or inks, of high- and low-refractive index, they can be jetted to "produce a continuum of refractive index values while maintaining excellent transmission through the optic." [6] The deposition system is designed to provide control over drop volume, firing parameters, ink temperature, resolution, cure and back-pressure of each print cartridge. The built-in diagnostic tools enable the monitoring of the droplets to ensure they are firing properly and precisely. The system prints the 2D pattern of each layer. The droplets interact on the substrate to form optical devices. [6]

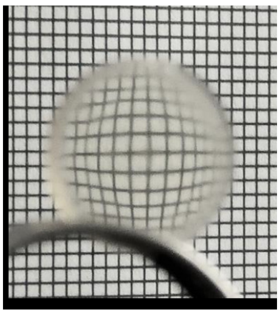

Figure 8: *Ink jet printed 12 mm diameter GRIN lens. [6]*

Fluids and Materials

While the print technology continues to improve, the jettable materials are also evolving. When it comes to scaling from lab to production, the jettable materials are incredibly critical to ensure the consistency and reliability necessary to produce acceptable performance. This is where devices that aid in the development of these materials are important. A dropwatcher is just that.

By pairing a high speed strobe light with a zooming camera and synchronizing them with the printhead firing, a dropwatcher is able to capture clear images of single drops in flight. Software then analyzes the images, and provides data to ascertain how well the fluid performs. Issues with drop formation, variations in drop size, and a host of other parameters can then be tweaked until the jettable material is refined to perform as desired.

Figure 9: *ImageXpert JetXpert drop-in-flight analysis tool. [7]*

These systems also provide tools for drop observation, so materials can be fine-tuned to optimize printhead performance and ensure consistent performance. With this droplet ejection analysis, these systems provide a qualitative measure of trajectory and velocity, enabling the refinement of the performance of inks and jettable materials.

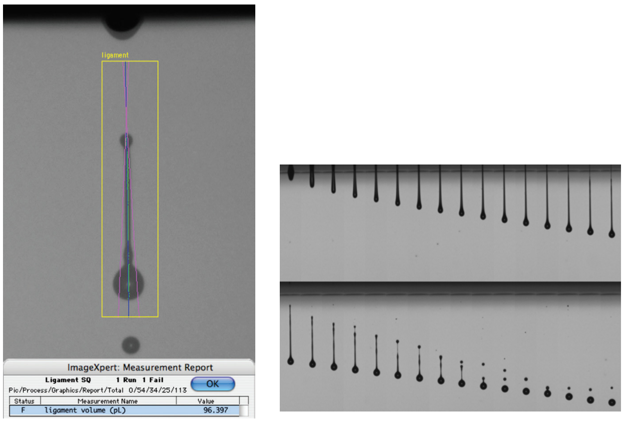

Figure 10: *ImageXpert JetXpert drop-in-flight analysis tool. [7]*

Conclusion

Applications are appearing in a variety of areas. Ink jet technology is being used for high-level research in the field of micro-fabrication of electrochemical systems (sensors, batteries, fuel cells), and can pave the way for 3D printing of intelligent multi-function components. These systems are also used for fabricating electrochemical systems for energy conversion and storage. The technology is successful because printheads can jet multiple materials, including metals and ceramics, predictably and consistently. Ink jet is used for manufacturing thin film transistors, the formulation of electronic inks, and the printing of electronic components over large areas. Other applications feature optical device manufacturing, using layering and curing to build up the material – 3D printing, for instance – that can ultimately be scaled to production levels.

Ink jet technology is proving an ideal development tool for materials deposition, jetting analysis, and any project where a high degree of analytical analysis and jetting accuracy is required. The hardware continues to improve, with increased speed capability, materials compatibility, and other features that make it an ideal tool, from development to production. Materials continue to develop as well, offering a range of ways to address the needs and requirements of research, prototyping, and production. Smaller, scalable print technologies are around the corner, offering a wider range of fluid capabilities.

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