# Color Flat Panel Manufacturing Using Ink Jet Technology

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**Abstract**

*A new manufacturing technology is coming to the flat panel industry. Ink jet technology is already used in the manufacture of wafer-scale and board-level electronic devices. Recently developed spherical, micron-size color display phosphors and light-emitting polymers have been ink jet printed to the resolutions being used in today's flat panels demonstrating that ink jet printing offers a practical and economic manufacturing process for the display industry.*

## Introduction

Development of ink jet technology into a manufacturing tool for the electronics industry has reached the level of commercial products. From its origin as a non-contact ink printing invention, in which it became a success in the 1980's, ink jet technology with its precision dispensing capability has become sufficiently robust to handle the difficult fluids and meltable solids that are used in the manufacture of a variety of electronic devices, including flat panel displays.

Hansel [1] in the 1950's noted that drops could be produced by the action of electromechanically induced pressure waves. In a piezoelectric drop-on-demand ink jet system, the pressure waves are produced through a volumetric change in the fluid that is caused by a voltage applied to a piezoelectric material to which it is coupled. Volumetric changes cause pressure and velocity transits in the fluid which, by the ink jet print head's design, produce a drop from the orifice. Because drops only issue when voltage is applied, systems incorporating print heads of this type are known as drop-on-demand (DOD). Figure 1 shows the generation of 50 µm drops by a DOD print head at 2 kHz. Practical drop diameters for DOD print heads range from 25 to 125µm.

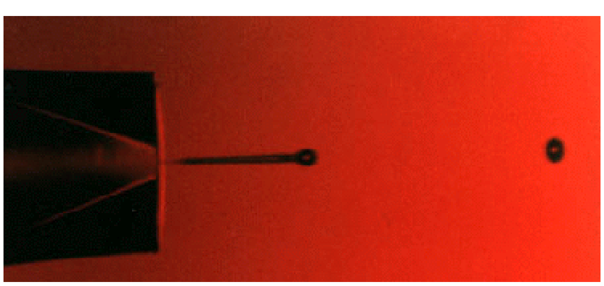

*Figure 1: Generation of 50 mm drops by a DOD print head at 2 kHz.*

DOD ink jet technology is now printing eutectic solder bumps on wafer and chip pads. MPM/Speedline Technologies is selling a platform using MicroFab's high temperature print head for these applications. Figure 2 pictures the commercial platform complete with wafer handling robot, and Figure 3 is a view of the print head and targeting microscope above an 8" wafer.

The solder printing process is completely data driven in that pad locations can be variable. Solder bump heights are precise as the printer has active control of the drop's volume. This solder printing system offers unprecedented process flexibility and requires no expensive mask or screen inventory with their associated clean-up expense and environmental impact. SolderJet deposition can be used for BGAs (ball grid arrays), PCBs (printed circuit boards), and CSPs (chip-scale packaging) as well as flip-chip bumping.

MicroFab has used experience gained in the SolderJet development program to operate analogous polymer printing ink jet devices at temperatures up to $220^{O}$ C. Both thermoplastic and thermosetting polymer systems have been printed at ele-

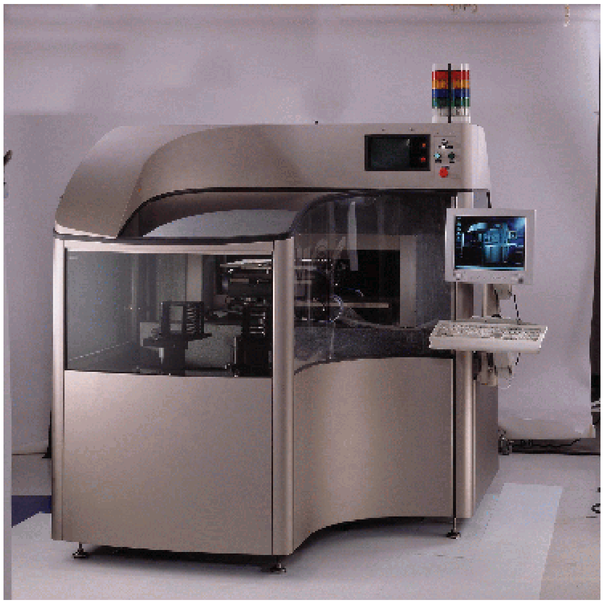

*Figure 2: Commercial platform complete with wafer handling robot.*

vated temperature with an majority of the micro-lenses being printed with UV-cure thermosets due to their durability. Figure 4 [2] pictures an array of 40µm diameter micro-lenses printed on 50µm centers.

Polymer systems containing dispersed solids have also been jetted at elevated temperatures, and thick film polymer resistors on PCBs have been printed. Continued development of polymer jetting for electronics purposes led to the printing of polymer solutions that are applicable to flat panel display manufacture.

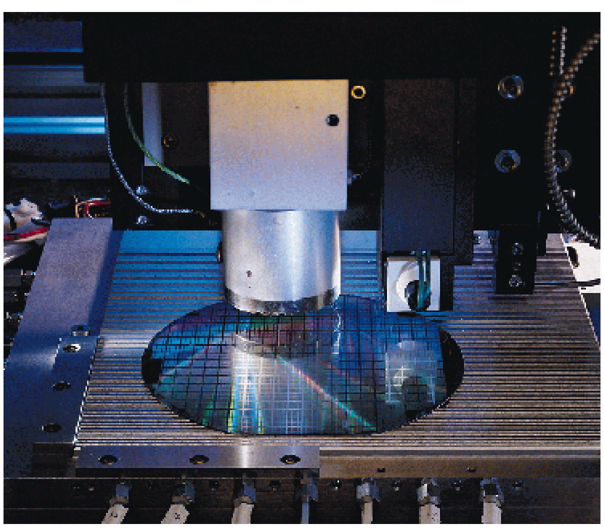

*Figure 3: View of the print head and targeting micro-scope above an 8" wafer.*

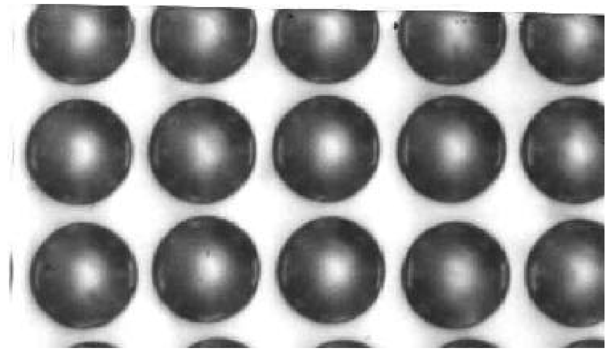

*Figure 4: Pictures an array of 40mm diameter micro-lenses printed on 50mm centers.*

**Objectives**

Our objectives are to show that the ink jet printing of phosphor powders is a feasible alternative to the usual methods of their deposition and that new phosphors are especially compatible with this technique. Panels that could benefit include both low and high voltage FEDs, plasma displays, VFDs, and thick film EL devices [3] – [6]. CRT anodes, aperture grill or shadow mask, may also benefit from ink jet printing. Ink jet fabrication is especially valuable when combined with newly available spherical, micron-size phosphors that are being produced by Superior MicroPowders (SMP).

The advantages of printing SMP's spherical, micron-size powders compared to conventional irregular morphology phosphors include

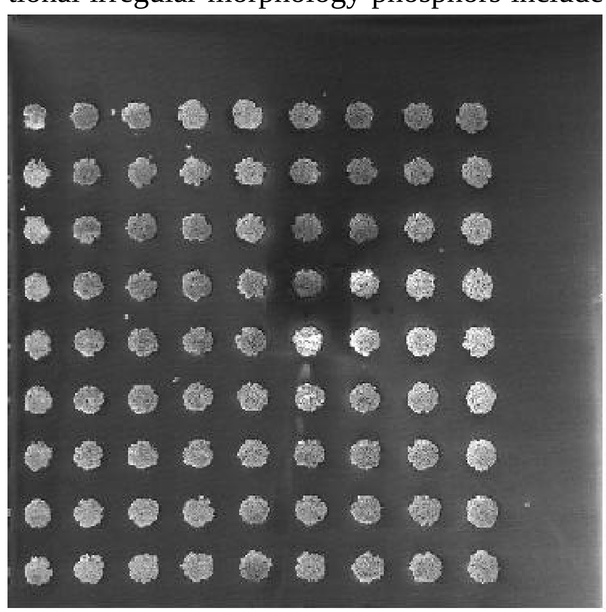

*Figure 5: SEM of ink-jet printed $Zn_2SiO_4$:Mn phosphor powder dots with 90µm diameters.*

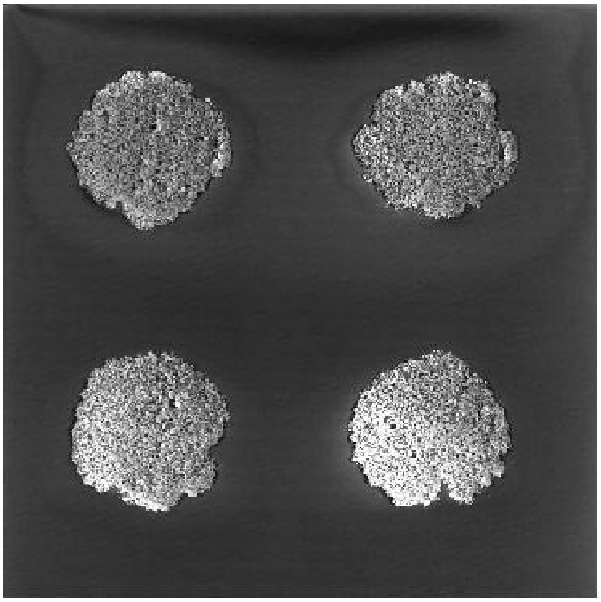

*Figure 6: Higher magnification view SEM of ink jet printed $Zn_2SiO_4$:Mn phosphor powder dots with 90 micron diameters.*

the ability to print smaller features, a higher packing density, higher resolution, and improved luminescence characteristics.

Another objective is to show that ink jet printing technology is applicable to the printing of the polymers used in manufacture of polymer LED displays. Since it is possible for MicroFab's ink jet systems to print a variety of non-aqueous solutions, they can print conducting polymer solutions and light-emitting polymer solutions in exact pixel locations, or in area coverage, to provide a cost effective approach for manufacturing full color displays with polymer technology.

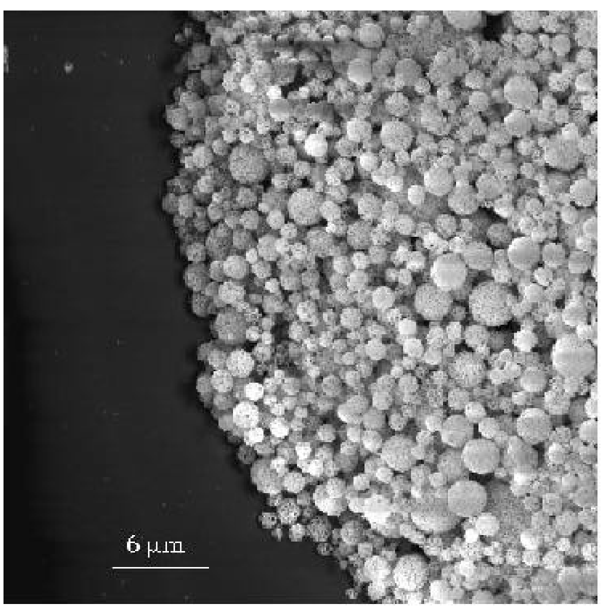


*Figure 7: Higher magnification view SEM of ink jet printed $Zn_2SiO_4$:Mn phosphor powder dots with 90 micron diameters.*

**Results**

Dispersions and suspensions of phosphor powders were prepared at MicroFab for ink jet printing using either a ceramic media mill or a high intensity ultrasonic processor. The latter dispersed SMP's powders without difficulty. A low molecular weight acrylic polymer was used as a binder for SMP's phosphor powders, and a mixture of organic solvents modified the dispersions' rheology for ink jet printing that was done with a simplified version of the print head shown in Figure 3.

Superior Micropowders has produced a variety of red, green, and blue spherical morphology, micron-size, narrow distribution, phosphor powders optimized for various cathodoluminescent and photoluminescent applications. The MicroFab printed dispersions of SMP's micron-sized, spherical powders are shown in Figures 5 –9.

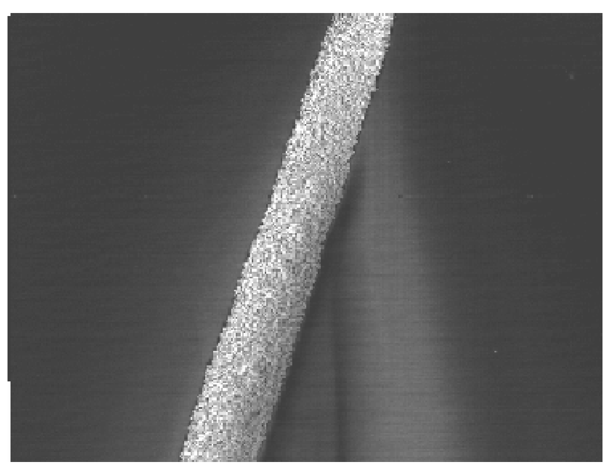

*Figure 8: SEM of ink jet printed $Zn_2SiO_4$:Mn phosphor powder 90µm line.*

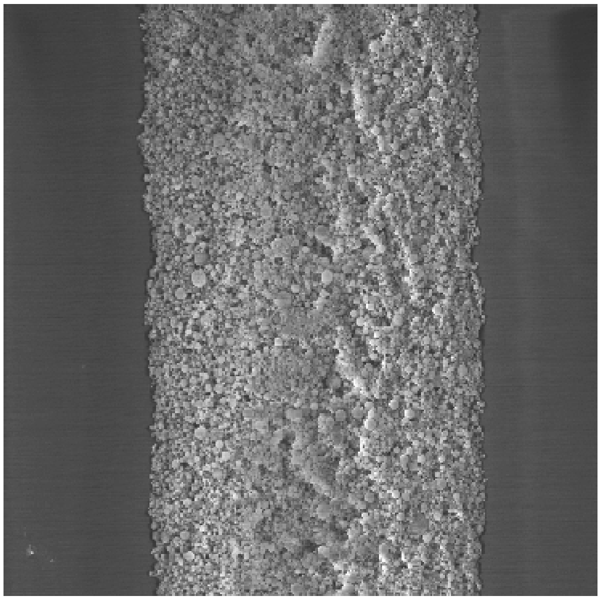

***Figure 9: Higher Magnification SEM of ink jet printed $Zn_2SiO_4$:Mn phosphor powder 90 micron line.***

## Conclusion

With the growth of the flat panel display market, manufacturing efforts are underway on a variety of display types that are relatively new to the industry. Ink jet printing offers an economy in the manufacture of phosphor screens that conventional slurry photolithography or screen printing techniques can not match even with recovery.

Where phosphor screens use SMP's spherical, micron-size phosphor powders for their performance advantages, where expensive materials must be used, or where pixellated patterns can not easily or economically otherwise be produced, as in color polymer LED panels, there ink jet fabrication has an unique advantage. Additionally, digital control over site-specific deposition of high-resolution features is also an important advantage. Color display panel fabrication where all three colors can be deposited in the same operation offer a unique opportunity for a manufacturer. The capability of computerized data driven platforms matched with compact array ink jet print heads in a high-speed printing system for deposition of phosphors or polymers is a new way to manufacture color display screens with both cost savings and lower environmental impact.

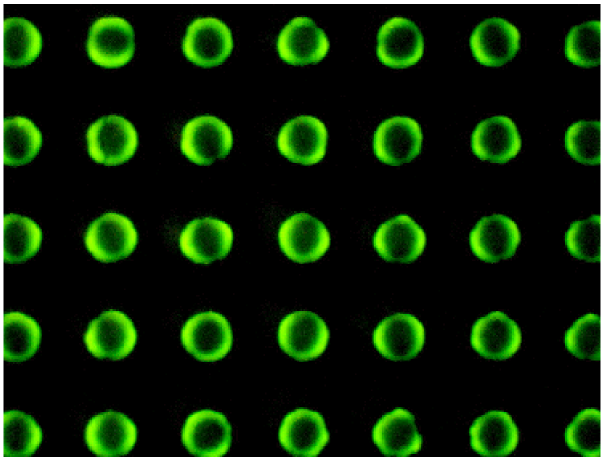

***Figure 10: Array of printed LEPs in UV illumination.***

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