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# Lexmark Inkjet Thickfilm Processes

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## Abstract

Thickfilm is an essential part of inkjet printheads. In the printheads used in Lexmark's 1100 series of printers, a dry film photosensitive laminate material is used to create the ink flow channels and to form an integral unit between the heater chip and the nozzle plate. In the printheads used for Lexmark's 7000 and 5700 series of printers, a liquid spin on photosensitive material is used to passivate the chip surface, planarize the chip surface, and promote adhesion between the nozzle plate and the chip. Both processes will be presented.

## Introduction

The primary parts of a thermal inkjet printhead are the ink reservoir, heater chip, and the nozzle plate. The heater chip is basically a plurality of thin film resistors that are connected to drive circuitry. This circuitry provides a voltage to the appropriate resistor when an ink droplet is required. This causes the resistor surface to become hot. Ink in contact with this surface partially boils and initiates a gaseous bubble which expands to eject a droplet of ink out through the nozzle plate orifice.

How ink is supplied to each resistor (heater) is critical to the resulting print quality of the printhead. In the 1100 series of printers, a photosensitive thickfilm laminate material is used to create chambers around individual heaters and channels on the surface of the heater chip through which ink is conducted from the reservoir into these chambers. The metal nozzle plate is then bonded to the surface of this material. This laminate material must form an ink impervious bond to the heater chip and to the nozzle plate which lasts for the two year design lifetime of the printhead. If it does not do so, ink leaks may result. Also, bond degradation around the individual heaters can lower ink droplet ejection velocities, which degrades print quality.

The dimensions of the ink channel from the ink reservoir to each heater on the chip are critical. How fast ink can traverse from the reservoir to refill a heater chamber after it is fired controls the frequency at which the heater can be fired. If the ink supply is too constricted for a desired firing frequency, the heater may become starved for ink, resulting in small or no droplet ejection. If the supply is insufficiently constricted, droplet reproducibility decreases significantly, which leads to poor print quality. Obviously, the processes used to create these channels must be very reproducible from printhead to printhead to ensure good print quality.

In the 7000 series of printers, a laser ablated polyimide nozzle plate is used in place of the metal nozzle plate used on the 1100 series. The ink channels are ablated directly into the nozzle plate itself, which eliminates the need for the laminate thickfilm material. However, it was found during development of this printhead that a barrier layer on the surface of the heater chip was necessary to passivate and protect the surface metallurgy of the chip during manufacture and in operation. It was also found that the surface of the chip needed to be planarized in order to form an ink tight bond between the nozzle plate and the chip. Without this step, a leak proof seal was virtually impossible to obtain due to the topography of the various thin film layers on the heater chip surface. Finally, this layer would also aid in obtaining durable adhesion of the nozzle plate to the chip over the two year design lifetime of the printhead.

Commercially available photoresist materials did not meet all of the requirements, particularly ability to withstand contact with ink for long periods of time. Because of the small volume of resist material that would be used for this application, the various photoresist suppliers were reluctant to develop new materials. Therefore, a proprietary liquid negative acting photoimageable material was developed at Lexmark that met all of the above requirements. This material, called Lexfilm, offers excellent imaging, ink compatibility, and thickness control. It is patterned to mate to the surface of the laser ablated nozzle plate.

## Manufacturing Processes

The following describes how the thick film material used on the 1100 series printheads is processed. Incoming wafers are washed in a commercial wafer washer with deionized, filtered water. The wafers are spun dry and then baked in a clean oven to ensure dryness of the wafer surface. A hot roll laminator is used to laminate the thickfilm material to the surface of the wafer. This thickfilm material is a commercially available, negative acting, photosensitive material obtained in roll form. It is laminated to the wafer under appropriate heat and pressure to allow the material to conform to all of the topography of the various thin film layers on the chip surface. This step is crucial in obtaining a leak proof seal. The wafer is then allowed to normalize to room conditions.

The negative acting photosensitive material is then exposed with UV light through a photomask on a mask aligner. Where the thickfilm material is exposed to UV light, the material cross links and becomes insoluble in the developer solution. Where the photomask prevents the UV light from striking the surface of the thickfilm material, the material remains soluble in the developer and is washed away. Thus, this step defines the pattern of heater chambers and ink channels in the thickfilm material for each chip on the wafer. Exposure time of the material is critical in obtaining the desired dimensions for the ink channels and heater chambers. If the material is underexposed, the dimensions obtained are much larger than desired. If it is overexposed, the material does not fully develop out of the ink channel areas. Exposure also contributes to the sidewall angle formed between the top and bottom of the thickfilm in the ink channels. With the optimum exposure, the angle can be minimized, which aids in obtaining the desired cross sectional area of the ink channel. In addition, exposure may vary from product to product due to differences in the geometry and materials of the thin layers on the chip surface. Changes in reflectivity of this surface can influence exposure time. Obviously, exposure time and UV lamp intensity are closely monitored for process control.

The exposed wafer is then developed with a solvent mixture on a commercially available spray developer. A rinse is then performed with a second solvent mixture on the same spray developer. The wafer is then spun dry. This development procedure removes all unexposed thickfilm material. Compositions of the developer and rinse materials are monitored to ensure consistent development results.

Measurements are made on a sampling basis of the thickness of the thick film material, the width of the ink flow channels, and the heater chamber dimensions. Measurements of the flow channel width and heater chamber width and length are taken at five places across the surface of the wafer. The results are compared to the specification requirement for that product. A visual inspection of alignment of the thickfilm to the heaters on the chip, and completeness of development is also performed. Thickfilm is not allowed to intrude on the surface of the heater. Even a residual “scum” on the heater surface will be cause for rework. If the measurements are within the specifications, and alignment and development are good, the data are entered into a production database. At that point, the wafer proceeds to the next step in manufacturing. If the measurements are not within specifications, alignment is not good, or there is residual thickfilm on the heater surface, the thickfilm material is stripped from the wafer. The wafer is then sent back to the beginning of this process.

Figure 1 is representative of the heater chambers and ink channels formed in the thickfilm material for a 1100 series product. Note that a nozzle plate has been bonded and then removed on this part, as indicated by the rings around the heater chambers. Also note that you can see the entire surface of the heater.

Nozzle plates are bonded to the patterned thick film material using heat and pressure. The heat and pressure cause the thickfilm to become tacky and adhere to the metal nozzle plate. As stated earlier, an ink tight seal must be obtained during this process that lasts for the design lifetime of the printhead. Otherwise, ink leaks and degraded print quality may result. To test the durability of the chip/nozzle plate assemblies, soaks are carried out in ink at elevated temperature. Parts are taken out from the ink at set intervals. As a measure of the integrity of the assembly, the nozzle plate is pushed off using a probe through the ink via on the chip. It is desirable that the push off force not decrease significantly over the period of the ink soaks. Results of ink soaks of parts made with gold plated nozzle plates did not have the desired life. Degradation of the thickfilm to nozzle plate bond occurred fairly rapidly in the ink. It was found that a thin layer of tantalum deposited on the gold surface of the nozzle plate that adhered to the thickfilm significantly improved ink soak performance. See Figure 2 for a cross sectional view of the chip and nozzle plate assembly. As shown in Figure 3, the pushoff force for tantalum coated nozzle plates decreased initially in the ink but then stayed relatively constant for the life of the test.

Gold plated nozzle plates had essentially failed at 21 days.

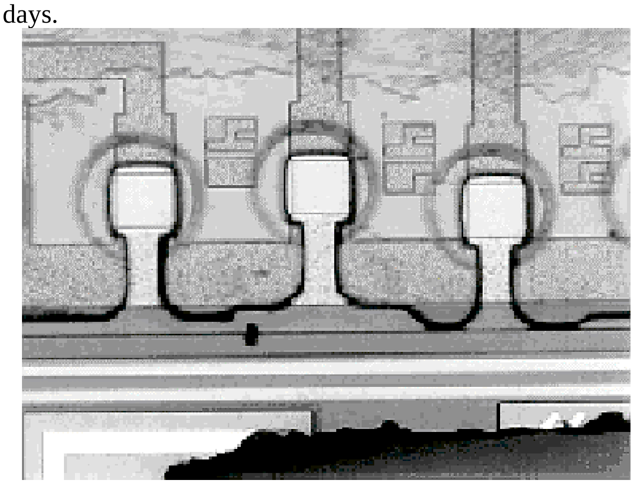

*Figure 1. Representative thickfilm heater chambers and flow features for a 1100 series printhead.*

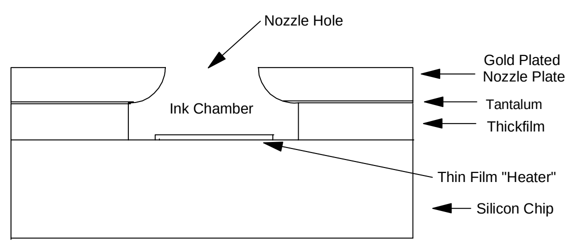


*Figure 2. Cross section of 1100 series chip/nozzle plate assembly*

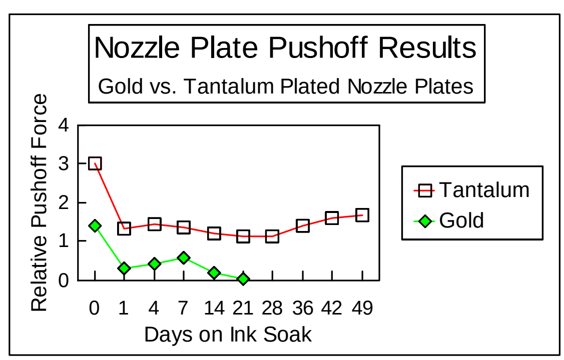


*Figure 3. Ink soak performance of gold vs. tantalum coated nozzle plates.*

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As described earlier, the Lexfilm photosensitive material applied to the surface of a chip used in the printhead of the 7000 series printers is used to protect, passivate, and promote adhesion to the nozzle plate. It is not intended to provide the ink channels and heater chambers. Those features are ablated into the nozzle plate. Therefore, this layer is much thinner, about 2-3 microns nominally vs. approximately 30 microns for the thickfilm material. However, this thickness must still be taken into account when designing the ink flow characteristics of the printhead. It is required that the thickness be uniform and reproducible from wafer to wafer.

The first step in application of this material is to wash and dry the wafer. This is done as described previously. After drying, the wafer is placed on the chuck of a commercial spin coater. An appropriate amount of the liquid photoimageable material is dispensed onto the surface of the wafer. The wafer is then spun for a specified amount of time and spin speed to get the desired thickness. By varying the spin time and spin speed, the thickness can be precisely controlled. The wafer is then baked on a hotplate to remove residual solvent. Note that all of these operations are carried out in a yellow light area with control over room temperature and humidity.

Exposure of the material is performed similarly to the thickfilm laminate. The wafer is aligned to a photomask on a mask aligner, and the wafer is then exposed to a designated amount of UV light. This material is also negative acting, which means that areas not exposed to the UV light are washed away during development. After exposure, the wafer is again heated to promote adhesion of the material to the wafer.

Development is carried out in a commercial spin/spray developer. The same developer and rinse chemicals as used for the dry film laminate material can be used to process this material under similar development conditions. After development, the wafers are baked to remove residual solvents. They are then inspected for flow channel width, alignment accuracy of the features to the wafer, residual photopolymer left on heater surfaces, and thickness. If all of these are acceptable, the wafer proceeds to the next step in manufacturing. As for the thickfilm laminate material, the material can be stripped off from the wafer if any attribute or characteristic is not satisfactory.

Figure 4 shows a representative sample of the features created using the photopolymer. As described previously, the flow channels and heater chambers are ablated into the nozzle plate material. The Lexfilm layer ideally mates up with these features on the nozzle plate.

The polyimide material used to make the nozzle plates comes with an adhesive layer already coated on one side. The ink chambers and nozzle holes are ablated into the adhesive and polyimide layers to form the nozzle plate. The nozzle plate is then accurately aligned to a chip. Heat and pressure are used to soften the adhesive layer and “tack” it to the Lexfilm coated surface of the chip. Finally, the assembly undergoes a bake cycle to complete the cure of the adhesive layer. Figure 5 is a cross sectional view of a completed heater area of a chip/nozzle plate assembly.

As explained earlier, durability of the resulting assembly is paramount. Ink leaks or separation of the nozzle plate from the chip during the design lifetime of the printhead is not acceptable. Similar to the metal nozzle parts, ink soaks at elevated temperatures are performed to test the effects of ink exposure on the chip/polyimide nozzle plate assemblies. Figure 6 shows typical results for assemblies soaked in both the mono or black ink, and a color ink. Little degradation of the pushoff force has occurred for either ink. Obviously, the materials are little affected by the inks.

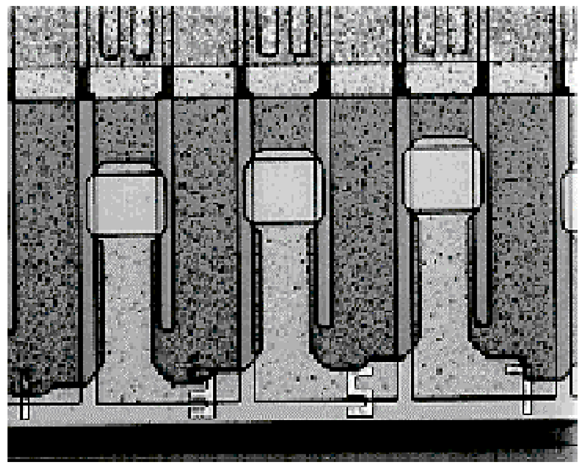

*Figure 4. Representative photopolymer layer on a 7000 series heater chip.*

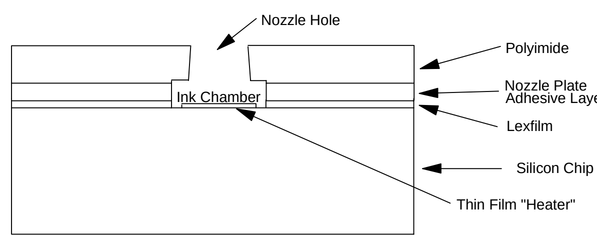


*Figure 5. Cross section of 7000 series chip/nozzle plate assembly*

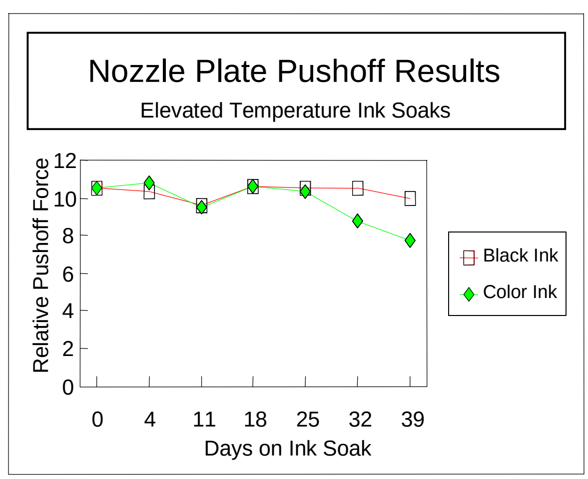


*Figure 6. Ink soak results for polyimide nozzle plate/chip assemblies*

Inspection of the nozzle plate/chip assemblies are also carried out after the bake step to look for alignment and also for voids or bubbles between the Lexfilm coating and the adhesive. If the tack or bake conditions are not correct, bubbling may occur due to entrapped air or outgassing of the adhesive during cure. Minor bubbles are acceptable as long as they do not permit an ingress path for ink underneath the nozzle plate.

## Summary

Thickfilm photopolymers are used at Lexmark on two different series of products. The printheads used in the 1100 series of printers use a dry film laminate photosensitive material to form ink channels and heater chambers on the surface of heater chips. Metal nozzle plates are then bonded to this layer. This process has been used since 1992 and has proven to be very reliable and cost effective.

The second photopolymer material is used as a protective layer on the heater chips used in printheads for the 7000 and 5700 series of printers. It too has proven to be a reliable material for protecting the heater chip, passivating it, and promoting adhesion of the nozzle plate.

## Biography

John F. Sullivan began his career at IBM East Fishkill and worked in development at IBM-Lexington until the formation of Lexmark International from this IBM division. John holds engineering degrees from Rensselear Polytechnic Institute and the University of Wisconsin. He currently works in Inkjet Printhead Manufacturing as a process engineer.

Gary R. Williams received a B.S. in chemistry from the University of Michigan-Flint in 1975. In 1982, he graduated from the University of Kentucky with a Ph.D. in analytical chemistry. He started his career with IBM in Poughkeepsie, NY in Product Assurance, and has worked since 1985 in Lexington, first for IBM and then Lexmark. He currently works in Inkjet Printhead Development.