Lower Power Supply Thermal Bubble Printhead Chip with MEMS Technology Increasing Thermal Energy Effect

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Abstract

This paper describes the low power supply aimed to develop a thermal inkjet(TIJ) printhead by using bulk micro-machining technology (MEMS). This experiment develops new structure designs of chip for inkjet printheads. A thermal inkjet device is designed, several of the dimensions may be adjusted just a few microns to change or optimize the drop generation performance. This energy conversion devices and systems based on Integrated Driver Head with The Performance of High-Frequency And Picoliter Drop Inkjet and structures. The TIJ process is akin to an internal combustion engine driven by an explosive phase change rather than an oxidation. In cooking, boiling is experienced as a process with an unpredictable beginning, following the lighting of the cooking flame. The boiling process is given its essential predictability in TIJ by using very great power densities to superheat the fluid far above its normal boiling temperature. Some of the waste heat can be carried away by silicon substrate. That is, the heater has excellent heat capacity. Deciding it to warm a few degrees by taking up waste heat at a location away from the heater region can significantly assist the heat management problem. For thermal inkjet printhead, the back side etching is used. The technology of microelectro-mechanical system to achieve a better thermal isolation structure and minimize conductive heat losses. Controling energy conversion is important. The fabricated back side etching thermal inkjet (TIJ) printhead is measured by open pool and close pool system. The measured begin voltage is 6.5 V, Life time is 9×10^7.

Introduction

The customer application is the beginning point for selecting the best inkjet printhead technology approach and the most effective. Thermal inkjet printing has several advantages compared with other technology; low cost, high resolution, low noise, ease of color printing, and portability. The inkjet printhead is the key element in the inkjet printer because it determines the print quality, print speed, and maintenance cost. Conventional inkjet printheads are fabricate a inkjet printhead in hybrid form. For low cost, high volume, and high performance it is very important to fabricate a inkjet printhead on the silicon substrate.

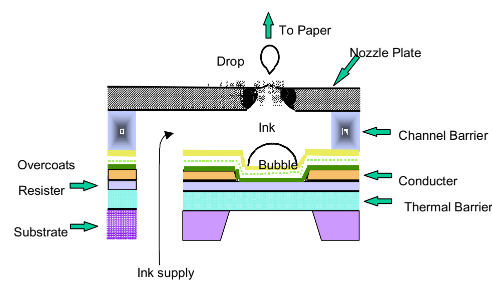

Figure 1. A thermal inkjet (TIJ) printhead

Thermal inkjet technology is now in widespread use for personal and workgroup color printers. The revenues generated by TIJ-based products dwarf those of all other inkjet technology types.[1] The reason for this success is almost entirely due to the favorable size and cost of executing the TIJ transducer. This, in turn, is possible because of the tremendous volume expansion that occurs when a liquid is vaporized. Figure 2 is a final element, Except for the earliest TIJ device, all commercial TIJ heaters substractes are fabricated using silicon wafers. This is done to take advantage of the tremendous material, process, and equipment inventory built up by the microelectronics industry and because silicon is an excellent thermal conductor. The TIJ drop carries away only about 0.03% of the ejection pulse energy as kinetic energy. The rest must be disposed of as heat.

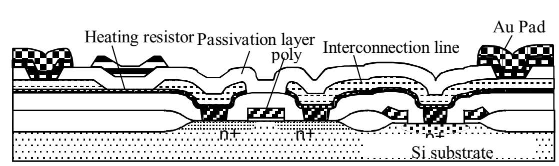

Figure 2. A final printhead element

Fabrication Processes

Figure 3 shows the fabrication process for the thermal inkjet printhead. A microelectronic design for a combination NMOS power transistor (MOSFET) and a TIJ heater that requires only one additional mask level and two ion implants beyond the heater resistor fabrication alone. The integration of TIJ heaters and power transistor on the same silicon substrate is a tremendous new capability for configuring inkjet printheads.[2] A p-type 525 μm thickness silicon substrate was used as a starting material. Thermal oxide (500Å)/silicon nitride (2000Å) films were deposited and patterned. Phosphorus diffusion was down to form a protection region for use during the second electrochemical etching. Local oxidation was performed at 1100°C for 400 min in a team ambient to grow 1.7-μm thermal oxide. continue NMOS standard process. Boron diffusion was done for electrical contact with the metal electrode after SiO_2 Wet etching and then RIE. thick upon which a subsequent layer of tantalum-aluminum (TaAl) resistive material is deposited. The tantalum-aluminum layer is deposited to a thickness of approximately 900 Å . to yield resistivity in the range of 27.Ω. per square to 32. Ω. per square and preferably at a value of 29 Ω. per square.[2] The resistive layer is conventionally deposited using a magnetron sputtering technique and then masked and etched to create discontinuous and electrically independent areas of resistive material. Next, a layer of aluminum-silicon-copper (Al-Si-Cu) alloy conductor is conventionally magnetron sputter deposited to a thickness of approximately 5000. Å . atop the tantalum aluminum layer areas and etched to provide discontinuous and independent electrical conductors and interconnect areas.[3] To provide protection for the heater resistors and the connecting conductors, a composite layer of material is deposited over the upper surface of the conductor layer and resistor layer. A dual layer of passivation materials includes a first layer of silicon nitride in a range of 2350. Å . to 2800. Å . thick which is covered by a second layer of inert silicon carbide (SiC) in a range of 1000. Å . to 1550 Å thick. This extraordinary thin passivation layer provides both good adherence to the underlying materials and good protection against ink corrosion. The passivation layer is reduced in thickness to increase heat flow from the heater resistor to the ink in chamber as opposed to having a significant heat flow into the substrate.[4] An area over the heater resistor and its associated electrical connection is subsequently masked and a cavitation layer of tantalum in a range of 2500. Å . to 3500. Å . thick is conventionally sputter deposited. A gold layer may be selectively added to the cavitation layer in areas where electrical interconnection to the flexible conductive tape is desired. To realize a structure useful for printhead applications, the barrier layer is subsequently photo-lithographically defined into desired shapes and then etched. The barrier layer has a thickness of about 15 um after the printhead is assembled with the orifice plate. The orifice plate is secured to the substrate by the barrier layer.[5] Then the fabricated back side etching thermal inkjet (TIJ) printhead by using bulk micro-machining technology (MEMS).

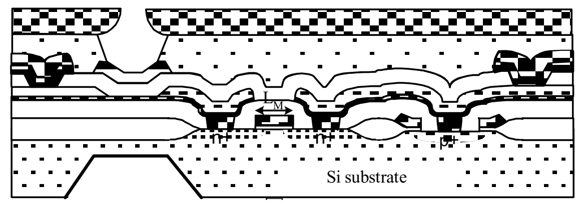

Figure 3. The thermal inkjet printhead by using bulk micromachining technology (MEMS)

Results and Discussion

During printhead reliability testing,[6] TaAl thin film resistors repeatedly failed in a fuse mode at cathode side, from simulation results Figure 4. A heater is located in the floor of an ink channel near the exit nozzle. A short, ~3usec, voltage pulse is applied to the heater resistor, warming the ink in contact with it sufficiently for an ink component to boil. Film boiling begins ~2 μsec after the voltage pulse starts and is complete in ~15usec. This liquid – to – vapor transition results in a very great volume expansion (~50 times) of the heated liquid. Compare before back etching (figure 4(a)) Ink jet printhead chip structure (Si – SiO2 – TaAl), and After Back Etching (Air – SiO2 – TaAl) (figure 4(b)). The same voltage pulse is applied to the heater resistor, There is no bubble at 3 μsec and 10 μsec in before back etching structure. Oppositely, water based TIJ inks are heated to > 290°C in 2-3 μsec in after back etching structure. Figure 5 is shown Observation equipment. Evidently, The high performance fabricated back side etching thermal inkjet (TIJ) printhead is measured by open pool (Figure 6).

In order to verify the bubble generation by heat transfer, a bubble visualization test was performed. The signal from the power source enters the heater and the delay source at the same time. The voltage applied to the heater is for heating the heater and the signal to the delay source determines the exposure time for the CCD camera and the irradiation time for the stroboscope. The stroboscope radiates light and the synchronized CCD camera obtains images.

Figure 7 shows the bubble generating process foe the signal with 6.4V~8.0V at 3.8 usec signal applied. The bubble is not symmetrical and there is a difference in the rate at different pulse. In summary, as the power increases, bubbles are formed symmetrically. The measured begin voltage to pulse width (Figure 8) that is about 6.5V, and the result of Life time is 9 × 10^7 of firing operations. There is a relationship between begin voltage and pulse width as shown in Figure 8, when applied lower voltage for bubble generation, in opposition, pulse width (μsec) will adjust bigger. Figure 9 is shown the measured energy density. In summary, the energy density of with etch type lower than without etch back.

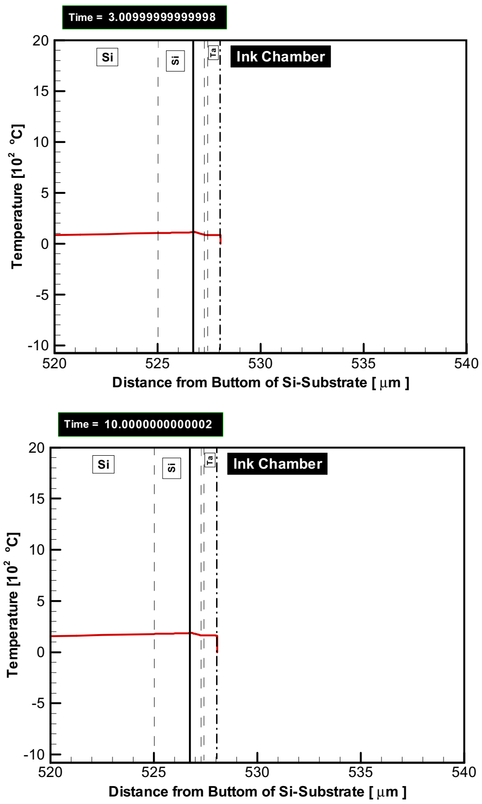

Figure 4(a). Simulation results

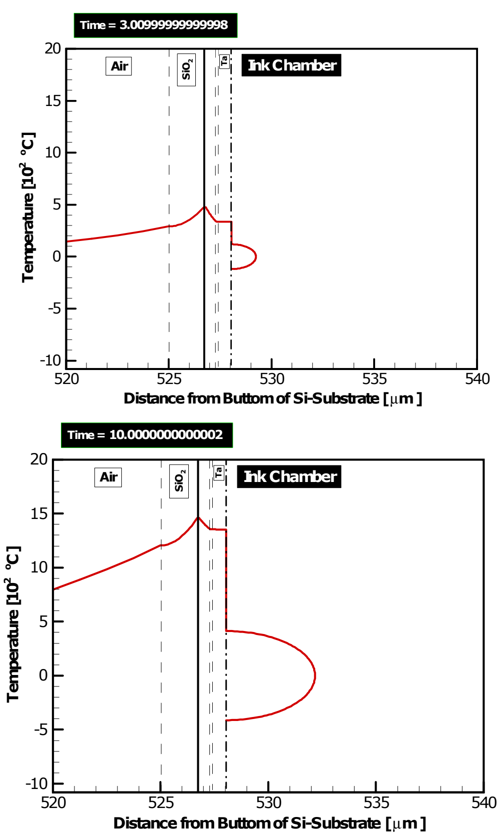

Figure 4(b). Simulation results

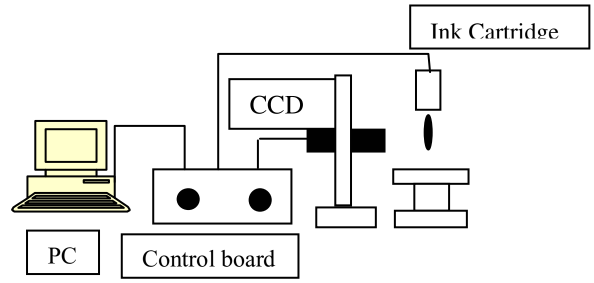

Figure 5. Observation equipment

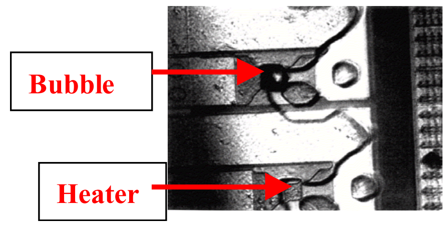

Figure 6. Open Pool on Printhead Chip

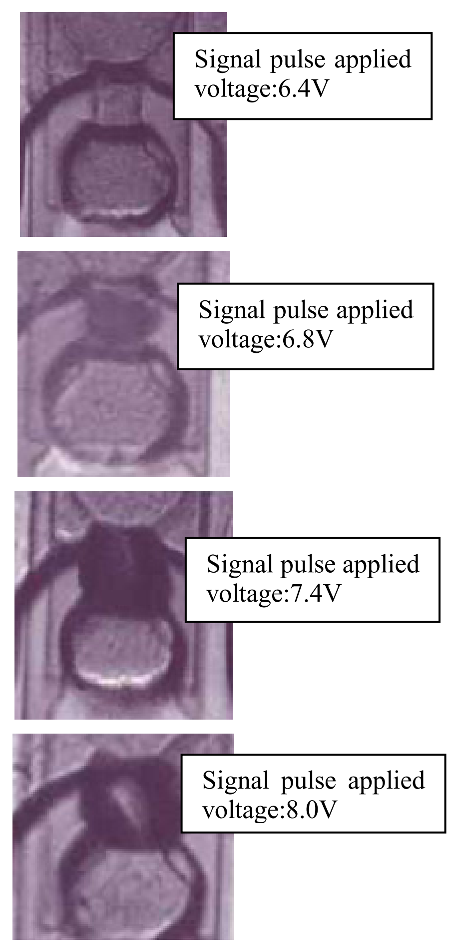

Figure 7. Bubble growth for 3.8usec signal applied.

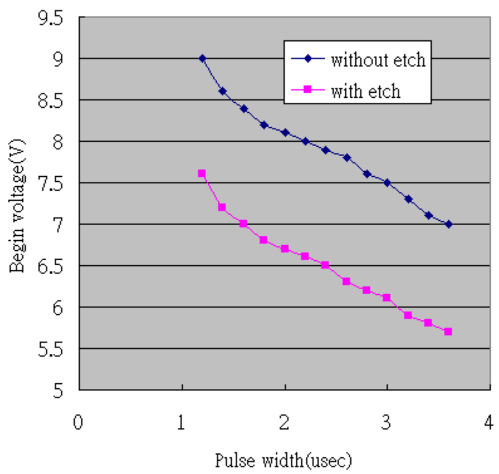

Figure 8. The measured begin voltage

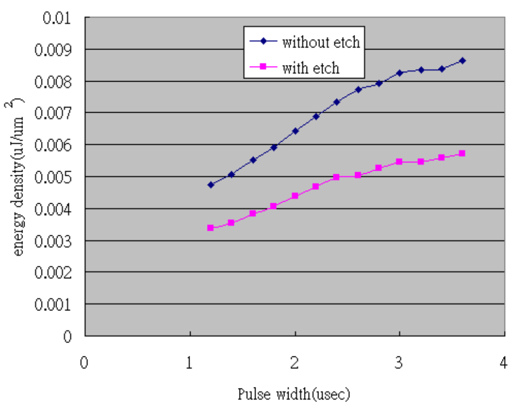

Figure 9. The measured energy density

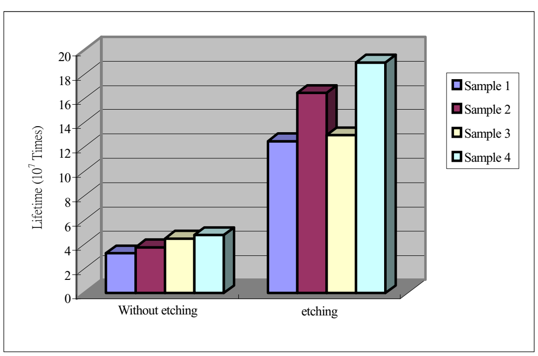

Figure 10. Etch and without etch for life-time Measurement

Compare OES Printhead that without Back Etching and with Back Etching as shown in Figure 10. There are two sample, sample 1、2、3、4 are shown with back etching and without back etching, the same electrical character in different type (the same resister value), and we can observe lower voltage applied with back etching, and long life time, in opposition, high voltage applied without back etching. This result complete fit to simulation droplet result.

Conclusion

For the high efficiency thermal inkjet printhead, the back side etching is used. The technology of microelectro-mechanical system to achieve a better thermal isolation structure and minimize conductive heat losses. Controling energy conversion is important. The fabricated back side etching thermal inkjet (TIJ) printhead is measured by open pool and close pool system.

References

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Biographies

Jian-Chiun Liou joined the Printing technology Development and Manufacturing Section of OES/ITRI in 1999. He received his M.S. degree from Institute of Electronic of National Taiwan Ocean University, Taiwan. He interest lies in the ASIC design, MEMS technology and integration of inkjet printhead processes.

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