Production of Microchips from Polystyrene Plates

Student paper by Sarah Lindsey Pace

Abstract

Currently manufactured microchips are expensive to make, require specialized equipment, and leave a large environmental footprint. To counter this, an alternative procedure that is cheaper and leaves a smaller environmental footprint should be made. The goal of this research project is to develop a process that creates microchips from polystyrene sheets. This was done by printing with ink on the polystyrene plate to create a mask. Then two methods of plating metal onto the circuit, electroless and electroplating, were tested. Time plated, procedure, and ink level were manipulated to achieve the best results.

None of the samples were conductive. After investigation with a SEM, Scanning Electron Microscope, it was found that when the ink was heated, it shriveled and created cracks, or opens, in the circuit in all trials.

Additional research was done to reduce the cracks in the shrinking process. However, the alternate methods did not reduce cracks. A third round of testing altered the method of measuring resistance, but damaged trials and had to be abandoned. Currently, there is no combination of variables that produced a working circuit, but significant advances have been made.

Microchips created from this procedure would be for small scale applications, such as classrooms or home projects. In future research, microchips that could be used in electronics could reduce electronic waste. They could also lower costs of electronic devices, making them available to lower income markets.

Introduction

Currently manufactured microchips are expensive to make, require specialized equipment, and leave a large environmental footprint. It is estimated that a 32 MB DRAM packed chip that weighs about 30 milligrams uses 1.7 kilograms worth of materials and waste to be produced (Plepys, 2004). If prices to make these chips can be reduced, microchips can be more readily available to the general public and lower the cost of products that use microchips. If alternative methods and materials for low-end microchip production can be researched, a smaller environmental impact can also be made. This research experiment aims to produce a low cost, low impact microchip using polystyrene plates.

Over 2.63 million tons of electronic waste was generated by the United States in 2005 alone (United States Environmental Protection Agency, 2006). Only 12.5 percent of this waste was recycled, with the other 87.5 percent ending up in landfills and incinerators. Using less raw materials to produce more environmentally friendly electronic components could be one way to reduce this waste in our landfills.

This experiment was based on a previous experiment with microfluidic devices created with polystyrene plates done by Anthony Grimes (Grimes et al, 2007). When polystyrene plates were heated, they contracted and became thicker. In doing so, ink printed on the polystyrene from an inkjet printer went from large and flat to small and thick, like a wall. These walls are only several microns tall. In Grimes' experiment, this shrunken polystyrene was used as a negative for a mold to make the microfluidic device. However, in the current experiment, the shrunken polystyrene plate was used as the positive for the microchip.

Currently, microchips are produced through a lengthy process consisting of several steps

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(Stackhouse, 2003). First comes silicon conversion. Next comes wafer fabrication. Then the wafer is etched with photoresist, a type of chemical that is soluble only when it is exposed to light. Then the finished chip is fixed onto a base depending on how it will be used and shipped off to another manufacturing plant.

The solutions for electroless and electroplating were taken from Nickel, Cobalt, and Their Alloys, an informational guidebook to several aspects of the metals (Davis, 2000). To deposit a metal without electricity, an autocatalytic reduction must occur. The chosen group of chemicals can react at room temperature because it has a lower activation energy. Electroplating is the process of causing a reaction to deposit a metal onto a given surface. This process deposits the metals on the conductive parts of the electrode. This is represented in Table 1.

Electroless			
	One Hour	Three Hours	Six Hours
Shrink Then Plate 50% Ink	3	3	3
Shrink Then Plate 100% Ink	3	3	3
Plate Then Shrink 50%	3	3	3
Plate Then Shrink 100%	3	3	3
Electroplating			
	20 Minutes	40 Minutes	60 Minutes
Shrink Then Plate 50% Ink	3	3	3
Shrink Then Plate 100% Ink	3	3	3
Plate Then Shrink 50%	3	3	3
Plate Then Shrink 100%	3	3	3

Methodology

The independent variables were time plated, ink percent, plating method, and procedure order. The times plated for electroless were three, six, and nine hours. The times for electroplating were twenty, forty, and sixty minutes. The ink was printed either at 50% ink or 100% ink. The plating method was either electroless or electroplating. The procedure either was plate then shrink or shrink then plate. The dependent variable in this project was the resistance, a measure of conductivity.

To print the polystyrene sheets, a HP Deskjet 5440 was used to print the template for electroless and electroplating. The sheet was printed on two times to build up the layers of ink on the polystyrene. Then the trials were divided into categories based on time plated, ink percent, plating method, and procedure. To shrink the trials, they were placed in a toaster at 145°C for three to five minutes. Electroless plating was done by mixing 50g Nickel Sulfate, 3g of DMAB (N-dimethylamine borane), and 100g of Sodium pyrophosphate into one liter of water. This solution was stirred overnight. Then it was applied to the trials. The solution was washed off with distilled water. Electroplating was done by mixing 200g of Nickel Sulfate, 5 grams of Nickel Chloride, 25g of Boric Acid, and 3 grams of Saccharin in one liter of water under a laminar flow hood. Electroplating was set up by connecting a variable DC power supply to electrodes at the positive (cathode) and negative (anode). It was run at three volts for the allotted time, and then rinsed with distilled water. To test for conductivity, a multimeter was used to measure resistance on the lines of the trial.

When the solutions were handled, proper safety goggles, gloves and aprons were used to protect direct contact to skin and clothes. While the solutions were being handled, adult supervision was present at all times. The solutions were not stored near heat or flame because of evolving hydrogen gas that is flammable. After use, all waste solutions were properly disposed of in a designated waste solution disposal unit.

Data Analysis

On all trials, the ink lines appeared to be slightly green. This was originally concluded to be the slight presence of nickel. It was also observed that contrary to prior knowledge, the ink acted as a mask on the electroless trials, not as a conductive surface for the nickel to plate on. The raised surface indicated the nickel plating, while the design in ink was bare.

The electroplating samples produced a more uniform plate onto the surface, but were still rough and caused an open (Figure 2). This meant that there was no connection in the circuit. The resistance was infinite because there was so much resistance that the electrons could not pass through. It was seen that the 100% ink worked as a better mask for the electroplating, but was not a complete mask (Figure 3). The red circled area indicated an area that was masked off in ink, but due to the ink not completely covering the surface, was still plated. The black outline showed the actual design on the polystyrene plate.

The results from the multimeter test read that each point of the plate was an open. This showed that all tested combinations of electroless and electroplating did not have a complete circuit. After investigation under the scanning electron microscope, it was determined that there were opens in the circuits, caused by warping of the polystyrene plate when heated. Figure 4 shows one of these cracks on an untreated polystyrene plate.

A second round of testing was conducted, manipulating the shrinking procedure to reduce cracks. Several combinations of uniform heating with a hot plate, heat lamp, and/or weight on the polystyrene plate did not yield a conductive polystyrene plate. A third round of testing manipulated the procedure for measuring resistance. Thin wires were soldered between two points on the polystyrene plate. This allowed for better accuracy as compared to the larger leads on the multimeter. This procedure had to be abandoned because the hot temperature of the solder melted the polystyrene plates.
Currently, this procedure is for small-scale applications. This research is most applicable in an educational setting where a student could print out a microchip at home for a lab. With future research, this procedure could be expanded to large-scale applications. Microchips made with this procedure would cost less due to less specialized equipment needed to produce them. These microchips could lower the production cost of electronic items, making them more available to more diverse markets.

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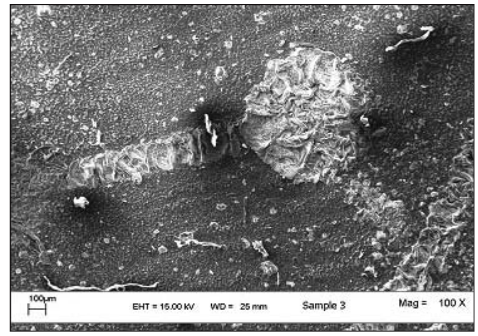

Figure 2. Electroplating, Plate Then Shrink, 20 Minutes, 3 Volts, 100% Ink
(Taken by Dr. Robert Simmons, Georgia State University)

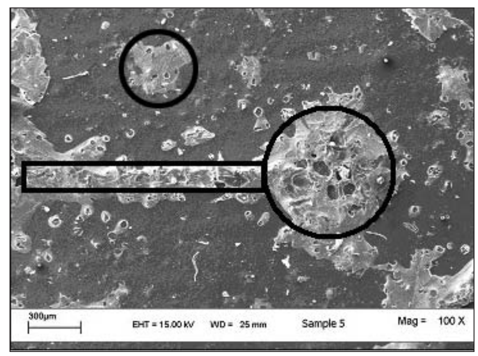

Figure 3. Electroplating, Shrink Then Plate, 60 Minutes, 3 Volts, 100% Ink
(Taken by Dr. Robert Simmons, Georgia State University)

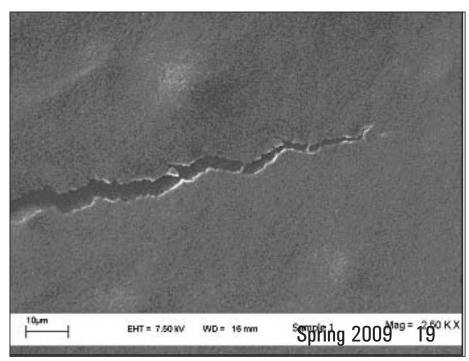

Figure 4. Sample Crack on Polystyrene with No Treatment, Shrunk
(Taken by Dr. Robert Simmons, Georgia State University)