ND*nano* Undergraduate Research Fellowship (NURF)
2015 Project Summary

1. Student name: Maxwell Kennard

2. Faculty mentor name: Dr. David Hoelzle

3. Project title: Micro-maker system for custom printed electronics

4. Acquired Skills:

Before my research began I had no knowledge of printed electronics. After a group field trip to the University of Western Michigan and their Center for Advancement of Printed Electronics program, I had a much better idea of what I would be working with. I came to be familiar with the printing process utilized by an inkjet printer and the properties of various conductive inks. Throughout my research I worked on designing circuits in AutoCad and then evaluating them visually, through the use of an inverted microscope, and electrically, through the use of an Arduino.

5. Practical Application of Research:

Currently there are two main ways of prototyping a circuit, breadboards and printed circuit boards (PCB). A breadboard allows for a cheap way to easily connect wires and different components, but projects must be built around its standard layout. A PCB can be designed to suit the exact needs for a particular project, but the manufacturing costs and use of potent chemicals is its downfall for hobbyists. The ability to print electronics on demand combines the best qualities of a breadboard and PCB. They are cheap to print, easy to add parts to, and can be revised very quickly. Printing electronics is becoming to the electronics industry what 3D printing has become to the mechanical industry.

Project Summary:

The goal of my project was to develop a widely accessible printing platform for the printing of functional materials. To accomplish this I needed to modify a commercial inkjet printer to print using conductive ink. It was also imperative that I be able to convey my work to other researches and hobbyists around the world. The idea was to help make printed electronics a more easily accessible thing in the "maker movement". I blogged about my research throughout the summer and wrote in depth tutorials so others could easily try it for themselves.

The ink that was chosen for this task was self-sintering, silver-nanoparticle ink. The self-sintering property of the ink removed the need for the printed circuit to be heated after printing. This allowed for a quicker method of prototyping. After some initial testing, I realized that paper was not a viable substrate for printing circuits. The fibers in the paper ended up absorbing the ink instead of letting it collect on the surface and form a conductive trace. When the ink has formed a conductive trace it turns a gold color. If the ink remains silver in color than it is resistive to the flow of current (Fig 1).

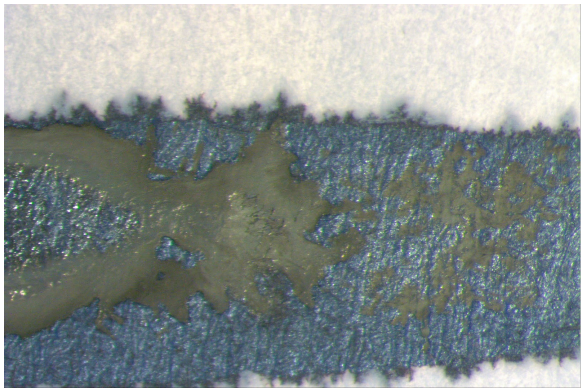
Figure 1 Conductive Gold versus Non-Conductive Silver

I then settled on cellulose acetate, transparencies, to use as my substrate. The lack of fibers provided a much better surface for which the ink could be properly sintered on. A circuit was then designed to test the capabilities of my printed traces. I utilized an ATtiny85 AVR microcontroller, programmed via Arduino as an ISP, to be control the blinking of a red LED. The components were attached to the substrate with the use of copper tape. The circuit was then tested with 5 V from a regulated power source and operated as expected.

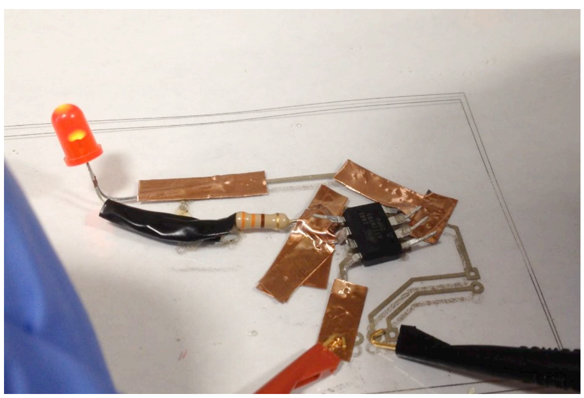
Figure 2 Printed Circuit with Components

After a circuit was able to be printed and proven functional. It was then my task to be able to print a sensor. I designed a capacitive touch and distance sensor. The sensor has a total of nine interlocking legs that are 3.175 mm wide. The gap distance between them is 1.5875 mm at their shortest length and 0.79375 mm on their longest side. The measured capacitance of these printed capacitors was 400 pF on average. The printed capacitor was then connected to an Arduino in series with a resistor. Depending on the resistor value being either 1 MΩ or 10 MΩ, the capacitor could act like a touch or distance sensor respectively. The sensor works by sending a signal on the microcontroller and then measuring how long it takes to be received by the other port. This time measurement is then used to calculate the time constant of the capacitor. As the human body interacts with the capacitor it changes the dielectric constant. This in turn will create a new time constant for the capacitor and it is able to figure out the position of your finger in relation to the sensor. The capacitor is shown being utilized as a button in Figure 3.

Figure 3 Operational Printed Capacitor

Publications (papers/posters/presentations):
I maintained a blog that was updated periodically throughout the course of my research. The blog includes descriptions of my project, problems I was faced with, and tutorials on how to print your own circuits. The blog can be found at http://inkjetcircuits.blogspot.com/

Sources:
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[2] Y. Kawahara, S. Hodges, B. S. Cook, C. Zhang, and G. D. Abowd, “Instant inkjet circuits: lab-based inkjet printing to support rapid prototyping of UbiComp devices,” 2013, p. 363.

[3] P. H. King, J. Scanlan, and A. Sobester, “From Radiosonde To Papersonde: The Use of Conductive Inkjet Printing in the Massive Atmospheric Volume Instrumentation System (MAVIS) Project,” 2015.

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[6] Y. Kawahara, S. Hodges, N.-W. Gong, S. Olberding, and J. Steimle, “Building Functional Prototypes Using Conductive Inkjet Printing,” *IEEE Pervasive Comput.*, vol. 13, no. 3, pp. 30–38, Jul. 2014.