Instrumentation for High-Speed Imaging and Current Detection Studies of Electrohydrodynamic Jet Printing

by

William Carter

A Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the degree of

Master of Science

Major Subject: Mechanical Engineering

Approved:

____

Sandipan Mishra, Thesis Adviser

____

Johnson Samuel, Committee Member

____

Daniel Walczyk, Committee Member

Rensselaer Polytechnic Institute
Troy, New York

July, 2012
(For Graduation August, 2012)

Abstract

Manufacturing is changing. The proliferation of microelectromechanical systems (MEMS) in our everyday lives through new devices like smartphones and tablets and even older ones like cars and video game systems is driving the industry towards processes that can create smaller products quickly and easily while maintaining low costs. At the same time there is a push towards additive manufacturing, the process of building part using layer by layer deposition. Additive manufacturing allows for the creation of more complex structures while reducing the amount of waste. In addition the same machine can be used to create any number of different designs by simply loading a new CAD model without the need for new molds or tooling. Currently additive methods are mainly used for the creation of prototypes, but they are slowly being adopted as a method of manufacturing parts for final products. Jet based additive manufacturing shows the most promise for thinner parts such as electronic circuitry, MEMS devices, and active matrix organic light emitting diode (AMOLED) displays as well as small, high resolution, high aspect-ratio parts. Currently the primary jet based method is inkjet printing. By simply changing the inks being used from brightly colored fluids designed to be absorbed by paper to manufacturing materials such as resins and particles in suspension, a standard inkjet printer can be used as an additive manufacturing device. Another jet based method is electrohydrodynamic jet (e-jet) printing. E-jet uses an electric field to pull small drops of fluid from a nozzle. While inkjet is not capable of printing drops with diameters smaller than around 20μm, e-jet has been shown to be capable of printing drops with sub-micron diameters. This allows for the creation of

smaller, higher resolution objects. In addition to the small size, other advantages of e-jet are that it is faster and holds the potential to be precise and controllable.

This thesis focuses on the creation and demonstration of a third generation e-jet system. This new system included a high speed imaging systems and precise electric current detection system. This allowed for the simultaneous collection of current and high speed imaging data which was used to develop a correlation between the current feedback and specific events in the jetting process. The high speed camera was also used to show the evolution of the deposited drop and the effect of different input waveforms on the printing process. In addition an optical profiler was used to analyze drop properties. This analysis was used to develop a correlation between the input signal and the drop properties as well as the current feedback signal and the drop properties. These correlations will be used to create a system model that will allow for the implementation of a closed-loop control system. The knowledge gained through the development of this system will be applied to other additive manufacturing processes in order to improve their performance.

In addition to system development and integration, several capabilities were demonstrated in both data collection and real-world applications. Current data was collected showing the ability to collect the data necessary to develop a correlation between the current feedback and drop properties as well as the current feedback and the input signal. Printed drops were analyzed with an optical profiler demonstrating the ability to collect the data necessary to develop a correlation between the input signal and drop properties. The high speed imaging system was used to observe the meniscus and show a correlation between the meniscus deformation and the input signal. Finally, both

current data and high speed images were collected simultaneously showing the ability to observe the evolution of the jet and develop a correlation between the current feedback and specific events in the jetting process. In addition to data collection two practical applications were demonstrated including biological sample deposition and layered object printing. Biological sample deposition was demonstrated by printing using an ink containing Escherichia Coli. The cells were deposited and were shown to be able to survive the process. Finally, a small block made up of a UV curing polymer was printed in three layers showing the ability to manufacture three dimensional objects using the new system.