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USE OF CAPILLARY FLOW TO CREATE FLEXIBLE AND EMBEDDED ELECTRONICS

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Continuous printing processes are attractive for manufacturing electronic devices on flexible substrates and embedding electronically functional materials into polymers. In this presentation, a new method to create flexible electronics based on embedded conductive networks is presented. The route involves creating the electronic architecture in a curable polymer layer on a flexible substrate and then using capillary flow to create the conductive network. In this presentation, the method will be discussed with an emphasis on the role of processing. A key process step is liquid ink flow in channels. Liquid flow in open capillary channels depends on the channel geometry and ink properties, including the drying behavior. The length of travel of a reactive silver ink down an open capillary was measured for a variety of rectangular capillary geometries with widths of ~1 – 100 µm and depths from ~3 – 20 µm[1]. For a capillary channel of fixed depth, the length of travel of the ink initially increased with the channel width due to a lessening of the flow resistance and then decreased due to a decrease in the capillary pressure driving force and the increased importance of drying, which raises the viscosity and eventually halts flow. To gain a better understanding of these phenomena, scaled up channels with dimensions in the 50 – 250 µm range were created and a long working distance microscope was used to track the velocity of the liquid flowing in the capillary. For non-evaporating liquids (e.g., glycerol), channels with height-to-width ratios close to 1 gave the highest rates of liquid flow. Using polyvinyl alcohol – water solution as a model system[2], experiments are underway to determine the influence of concurrent drying on liquid front velocity and extent of travel. The goal of this study is to not only explore the relative importance of drying compared to capillarity, but also to uncover key parameters for ink and capillary design so that the extent of ink travel can be engineered.

[1]A. Mahajan, W. J. Hyun, S.B. Walker, J. A. Lewis, L. F. Francis and C. D. Frisbie. "High-Resolution, High-Aspect Ratio Conductive Wires Embedded in Plastic Substrates," *ACS Applied Materials & Interfaces*, **7,** 1841-7 (2015).

[2] R. K. Lade Jr., J.-O. Song, A. D. Musliner, B. A. Williams, S. Kumar, C. W. Macosko, and L. F. Francis,"Sag in Drying Coatings: Prediction and Real Time Measurement with Particle Tracking," *Progress in Organic Coatings* (2015) in press.