Soft-plasma Based Micro-patterning of Metals on Polymers: A Novel Direct Write Technology Enabling Single Step Fabrication of Metal Interconnects

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***Abstract*— Direct-write technologies have evolved from lab scale research to commercial manufacturing. The key advantage of direct writing in contrast to conventional top-down lithography is additive deposition of functional materials with no material waste. However, these direct-write technologies, like ink-jet, aerosol, and screen printing, heavily depend on the stability of the nanoparticles that will be deposited on polymer substrates. Furthermore, high conductivity of printed features is usually achieved by annealing to remove organic surfactants. This poses serious limitations on the choice of substrates. Here, we demonstrate the fabrication of micro-features on the surface of polymer substrates using an atmospheric pressure extracted discharge from a DC Argon microplasma. Comparative studies with a high-vacuum e-beam to understand the possible role of electrons for the reaction mechanism have also been done.**

Polymer substrates were fabricated by solution casting a mixture of poly(acrylic acid) and silver nitrate in water and ethanol on a conducting substrate , either doped Si or Al. An Ar DC microplasma was struck between a stainless steel capillary and stainless steel mesh, separated by a gap of 500 µm. The as-prepared substrates, shadow-masked with laser micro-machined glass slides, were kept under the microplasma at a distance of 5 – 7 mm and biased at a high positive voltage. For electron beam studies, a similar solution was spray coated to produce sub-micron thick films and then exposed to an electron beam.

After exposure, the films were characterized by electron microscopy, energy-dispersive spectroscopy, x-ray photoelectron spectroscopy, and conductivity to assess the properties of the reaction regime. We find that our atmospheric pressure soft-lithographic process produces reduced silver features along the surface of the exposed areas of the film. Similar results were also obtained in the electron beam experiments, with the exception that the reduced areas had conformal reduction of silver as well as carbon from the polymer.