Microplasma Sputtering for 3D Printing of Metallic Microstructures

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Abstract

Additive manufacturing technologies promise to transform the development and production of agile microsystems, but are limited by the ability to print microelectronics-quality interconnects. State of the art 3D printing techniques for conductors cannot yet deliver the feature resolution and electrical conductivity required for high performance microcircuits, and have materials and substrate constraints, as well as post-processing requirements. We are developing a novel microplasma sputtering system that has the potential to provide direct-write capability of quality metal interconnects on non-standard substrates for integrated circuits –with future extensibility to dielectrics and semiconductors. The microplasma is generated at atmospheric pressure, obviating the need for a vacuum. By manipulating the metal at the atomic level, we retain the resistivity of bulk metal, and by sputtering the metal, we eliminate the need for post-processing or lithographic patterning.

We have modeled, designed, and constructed a first-generation atmospheric-plasma system that incorporates continuous material feed and focusing with electrostatic fields. The microplasma head has a central target wire surrounded by two pairs of electrodes, an anode pair that provides a bias to form the plasma, and a focus pair that shapes electrostatic fields to guide the ionized fraction of the working gas towards a localized spot on the substrate. The directed ions collide with sputtered metal atoms from the target dragging the metal atoms towards the substrate. This indirect electrostatic focusing mitigates the inherent spread of the sputtered material caused by collisions at atmospheric pressure, and enables fine feature definition with imprints significantly narrower than the target wire diameter. Multi-physics COMSOL simulations predict that features orders of magnitude narrower than the target-wire cross section can be printed with appropriate electric fields. We present findings from COMSOL simulations which indicate that focusing is most effective when the net normal force on the substrate is near zero, and we demonstrate printing of gold lines narrower than the target wire diameter on planar substrates.

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