“3D Printing of Liquid Metal-Based Soft Electronics”

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Abstract

Present metal additive manufacturing methods for electronic materials tend to be expensive and energy-intensive requiring high sintering temperatures and vacuum, making them difficult to integrate with different polymeric, organic, soft and biological materials. Here, we present a simple approach to print low melting point gallium-based alloys at room temperature. Due to the instantaneous formation of a thin (~3 nm), passivating surface oxide skin, we can direct-write planar as well as out-of-plane, mechanically stable conductive microstructures down to a resolution of ~10 microns as shown in **Figure 1a**, on-demand, using a customized lab-built 3-axis pneumatic dispensing robot.

Using this direct-writing process, we can pattern 3D multilayered microchannels with vasculature where the printed liquid metals act as a sacrificial template as shown in **Figure 1b** and can be employed in various lab-on-a-chip (LoC) sensing devices to enable inexpensive fabrication of personalized healthcare sensors. In addition, we have demonstrated rapid prototyping of functional electronics such as flexible and stretchable radio-frequency (RF) antennas for communication as shown in **Figure 1c** and wearable thermoelectric generators (TEGs) for energy-harvesting applications. Finally, we have developed electronic inks consisting of gallium-based liquid metals doped with other bulk metals such as copper and silver for additive patterning of solid metals at ambient temperatures and environments compatible with polymers as well as the creation of micro- and nano-structured metallic surfaces that may be useful for optics, non-wetting surfaces, or electrowetting as shown in **Figure 1d**.

Figure 1. (a) 3D printing liquid metal droplets on a Si wafer using a 10 μm glass capillary. (b) 3D multi-layered spiral-shaped microchannels and (c) flexible & stretchable RF antennas printed with liquid metals and embedded in a soft silicone elastomer. (d) Replica of the front side of a penny made using a gallium-copper imprint.

Bio:

Dishit P. Parekh received his BS in Chemical Engineering from the Institute of Chemical Technology (formerly known as UDCT), India in 2013. He graduated with a PhD in Chemical Engineering at North Carolina State University in 2018 working under the supervision of Professor Michael D. Dickey where he developed a novel cleanroom-free, additive platform for fabrication of “smart” microfluidics with vasculature (https://goo.gl/yZFALa) using printing of gallium-based liquid metal alloys as a sacrificial template for advancement of lab-on-a-chip

(LoC) applications to help the progress of Internet-of-Things (IoT) in healthcare. In addition, his research interests include 3D printing of flexible and stretchable electronic devices (https://goo.gl/WNjcrv) using direct-write patterning and nano-imprinting of liquid metal alloys near room temperature.

Currently, Dishit is a Materials R&D Engineer in the Heterogenous Integration Process Technology Research group at the IBM Research's AI Hardware Center in Albany, NY where he is developing advanced semiconductor packaging elements that will be used in IBM's strategic core of cognitive and artificial intelligence hardware solutions and systems.