Reversibly Reconfigurable Liquid Metal Antennas Using 3D Printed Microfluidics

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In recent years, antenna designs have been proposed that utilize the displacement of liquid-phase gallium alloys in the radiating aperture to adapt a combination of antenna characteristics – the operating frequency, radiation pattern and polarization. Additive manufacturing enables facile fabrication of complex microfluidic networks for these antennas; however, as these alloys flow through a printed channel, the gallium oxide skin adheres to substrate walls, leaving residues. These residues hinder repeatable actuation of gallium alloys and are typically ignored in the literature as repeatability is not considered. Alternatively, they can be eliminated using corrosive electrolytes that may damage the polymeric substrates and reduce device efficiency. We have previously studied super-hydrophobic coatings for 3D printed substrates as an alternative means to eliminate residues. However, experimental results showed that when these coatings were used in combination with a low-loss pushing fluid to move plugs of liquid metal, metal flakes mix with the pushing fluid and traverse the channels, forming debris inside the channels.

In this work, we discuss challenges associated with 3D printing these multi-layer microfluidic networks and study several techniques to enable repeatable flow of liquid metals within them. Applying these methods, we demonstrate a compound frequency and polarization reconfigurable antenna operating between 4 and 6 GHz with reversible actuation. We characterize the performance of the antenna after several repetitions to illustrate the impact of any residue or debris. A modified low loss pushing fluid enables a high efficiency antenna and produces relatively low debris compared to electrolyte-based designs or prior work on super-hydrophobic coatings. With further study, this approach can be used to create multi-layer reconfigurable microfluidic antennas with high efficiency.