Multi-Material Additive Manufacturing as an Enabling Technology for Antennas and Microwave Devices: An Overview

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Additive manufacturing (AM) technologies have matured tremendously in the past three decades and are finally reaching large-scale adoption across a number of industries, from aerospace to healthcare. Printed electronics were among the first application areas to take advantage of the flexibility and additional degrees of design freedom afforded by many of the AM-based approaches, particularly with regard to non-planar and other non-traditional substrates. With some notable exceptions, however, AM applied to RF electronics has focused largely on printing (chemically) simple metallic traces, with great efforts expended to improve achievable conductivity with minimal post-processing in order to integrate printed conductors with every conceivable substrate material.

Much less attention has been paid to printing insulators, particularly those with non-linear electromagnetic responses. It requires little imagination to appreciate the massive expansion of design space that would be afforded by the ability to arbitrarily control the spatial distribution of permittivity, permeability, and conductivity, particularly if these could be tuned during operation in some way. However, this is a classic chicken-or-egg problem, as development of design and analysis techniques capable of handling such boundless possibilities and accompanying fabrication capabilities must be developed in concert for either to have significant value.

Fabrication capabilities based around mature paste techniques with both passive and active enhancements to in-line mixing enable the fabrication of preforms that can be post-processed into solid parts with precisely-controlled and (nearly) arbitrary spatially-varying permittivity and permeability with print (and property) resolution of 10s of microns. This has enabled the creation of a variety of new devices with enhanced performance, such as compact and wideband dielectric resonator antennas, flat reflector and lens antennas, high-Q filters, among others.

The goal of this work is to study the wide range of novel features state-of-the-art multi-material AM can offer the RF industry. First, the nonhomogeneous materials are modeled in commercial electromagnetic CAD software, where we study the modes of operation and electromagnetic behavior of these dielectrics. In the next step, this foundational knowledge is used to design devices with enhanced features from both an electronic/RF aspect, as well as mechanical features. Our initial efforts have focused on the demonstration of graded-permittivity insulators for compact and wideband operation as well as a new generation of flat dielectric reflectarrays.