High Dielectric Constant, Low Loss Additive Manufacturing Materials for RF/Microwave Applications

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Abstract

As part of Rapid Applied Materials and Processes (RAMP) IR&D Materials Thrust, we identified a goal of creating a universal printing material tunable electrical and/or mechanical. We are targeting printing this material on an additive manufacturing tool capable of mixing materials, such as the Connex Objet 260 available in Draper's Rapid Prototyping Lab. This tool is currently capable of printing modulus and color discretized gradients in 3 dimensions with commercial materials, but the materials are limited to only 14 different moduli and the electrical properties are largely unknown. These issues can be traced to both material and tool programming issues. More customizable additive manufacturing tools capable of mixing materials in specific ratios are just making their way to market now (Huang et. Al. 2015). One of these tools, which is yet to be identified for this work, would be capable of a custom mixing custom material that we design and printing them with a 3D gradient in electrical and/or mechanical properties.

The application space we targeted was high dielectric constant, *e*, low loss materials for RF/microwave because this field often struggles with shaping brittle high dielectric constant materials into complex form factors. We have added high *e* ceramic nanoparticles to an epoxy polymer matrix to create a polymer matrix composite (PMC). The approach to the materials design was a pretty classic approach that has been used to make dielectrics high frequency capacitor (Dang, 2012). However, it is only vary recently that high *e* PMCs have be converted into a form that is compatible with additive manufacturing to make functional mm devices (Friederich et. Al, 2015). This approach is extensible to other applications because other types of particles can be added to a similar polymer base to create variability in mechanical and physical properties of materials. Example applications include flame retardant layers added to ballistics or rocket nozzles, windows that can withstand thermal gradients for space applications, or controlled biodegradability for drug release devices (Hussain, 2006).

The ultimate demonstration we targeted was a 3D printed gradient index lens (GRIN) for focusing mm waves because smooth gradients with existing materials are difficult to achieve and the manufacturing processes to create these lenses are expensive and time consuming. GRINs have been created using additive manufacturing tools by adding porosity to a base polymer material (Allen, 2013; Laing 2013) This is not an effective way to make small devices because the *e* for plastics is typically below 5 (Dang, 2012). The ability to print gradients of high dielectric constant ceramics would enable smaller, more covert mm wave lenses. The target delivery date on this demonstration was the end of FY17. We will not be pursuing this effort beyond FY16 Q2, but we will discuss our progress to date in the text below.

This effort was started in Q1 FY16, so we will be reporting on 6 months of progress towards the goals described above. Our major accomplishments include:

· *Electrical Characterization of Additive Manufacturing Materials*: Characterizing dielectric constant and loss tangents of existing additive manufacturing materials available at Draper in both the kHz and GHz ranges.

· *PMC Materials Engineering*: Creating a material with high/tunable dielectric constant and low loss that can be molded into different form factors

· *Device Design and Test*: Creating and testing a dielectric waveguide from both printed and molded materials