Flexible Ceramic-Polymer Composite Substrates with Spatially Variable Dielectrics for Miniaturized RF Applications

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Traditionally, RF (Radio Frequency) devices exploit geometry and energy feeds to maximize their performance. New strategies are exploiting 3-dimensional (3D) engineered magneto-dielectric and polymer composites to improve performance such as true conformality/flexibility, high efficiency and size reduction. Their realization is extremely important to the next generation of RF integrated and electronic devices such as miniaturized broadband antennas, smart sensors, high magnetic-energy storage devices. Standard miniaturized low-loss device substrates are commonly restricted to off-the-shelf ceramics with composite forms also made available recently. However, ceramics naturally lack flexibility. Therefore, polymer-ceramic composites have been intensively studied with major work primarily focusing on their dielectric tunability and easy processing capability. In this paper, a new process based on tape casting capable of producing flexible polymer-ceramic magneto-dielectric composites is proposed and analyzed. Specifically, in addition to their known characteristics of deformability and low-temperature processing capability, resulting substrates are analyzed targeting the following features: 1)Full spatial control of material property, and 2)Low dielectric loss and/or loss controllability. Regarding the former, control in 2D is achieved via stacking layers of tape cast films of MCT (Mg-Ca-Ti-O) based LTCC and ferrites. Complete 3D material variation is demonstrated using two methods: 1) Machining pores in tape cast green films to deliver desired effective material properties at desired locations and 2) Mosaic warm binding of square pixels, which are green tapes of multi MCT/ferrite powder systems. Flexibility is a result of the tape casting process used to manufacture thin and flat sheets of MCT/ferrite ceramic based polymers. This technique is optimized to produce flexible, magneto-dielectric substrates with considerable low loss. Dielectric measurements were carried out for three different ceramic samples. Results show that spray dried ceramic powders exhibit a tenfold loss increase when tape cast into green films, but a ten fold loss decrease after these films are sintered at 550C. Hence, suggesting two methods for loss reductions in flexible tape cast films being currently investigated: Use of pre-sintered ceramic particles and particle size reduction of ceramic constituents. Initial investigations prove potential of significant loss reductions via both methods. The combination of powerful engineered designs with the proposed fabrication technique for unique low-loss flexible substrate materials will serve as a general example for a new approach: To produce a 3D arrangement of magneto-dielectric material cells according to a particular engineered design creating novel flexible material systems, useful for many other multi-functional electronic and RF devices.