Evaluation of Binary Mixture Models for 3D Printed Biosensors

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Abstract

3D printing as applied to the area of electronics manufacture covers a broad range of traditional printing technologies [1]. The attraction in 3D printing lies in its potential to disrupt the traditional photolithographic/subtractive manufacturing line with simpler additive processes. Additive electronics manufacturing which utilises 3D printing techniques allow for fewer production steps and significant reduction in material wastage. In particular the so called Direct Digital (DD) processes such as Inkjet Printing, Aerosol and Multijet Printing allow for the potential manufactured of the Printed Circuit Board straight from the digital file in a single processing step.

Despite its tremendous potential a significant challenge faced by Direct Digital 3D printed electronics are its materials. 3D printed materials as created for DD processes such as Inkjet printing are often liquid or paste formulations of conductive, dielectric or insulator particles which are jetted or extruded to build the desired shape and then reconstituted using post processes such as baking, laser sintering and UV curing. The reconstituted materials often possess differing properties to their constituents, particularly in the area of electrical properties (e.g., conductance, permittivity, and permeability) [2]. It is therefore essential that the properties of 3D-printed materials be factored into future designs leveraging this technology.

One method is the modelling of the materials based on the known properties of their constituent materials and the geometric distribution pattern of these materials within the body of the substrate [3]. Such models of these composite mixtures are known as mixture models. This work evaluates the use of existing binary mixture models to model 3D printed structures. The specific 3D printed structure which was examined was an interdigital biosensor. Using COMSOL Multiphysics®, the AC/DC Module was utilised to create a 3D model of an interdigital biosensor. The COMSOL modelling environment was then used to create a series of models where the selected binary mixture models were applied to represent the material properties of the structures. In all instances the capacitance of the interdigital structure was measured for each binary model and contrasted with the other scenarios to stablish a sense of the model variation. The results generated illustrate the range of variations in the measured capacitance for the various applied binary material mixture models. The results further demonstrate the challenges in assessing the electromagnetic performance of systems using 3D printed materials, and the utility of using simulation tools such as COMSOL for this system.

Reference

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3. Tuncer, E., et. al. "Dielectric mixtures--electrical properties and modeling." arXiv preprint cond-mat/0111254 (2001).

Figures used in the abstract

Figure 1

Figure 2

Figure 3

Figure 4