MASSACHUSETTS COLLEGE OF LIBERAL ARTS

2017 Summer Research Institute

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Faculty Sponsor: Erin Kiley

Project Title: Mixture Formula Inversion for Creation of Materials with Desired Dielectric Properties

Brief Description of Project (250-300 words):

Permittivity is a property of matter that determines how resistive a material is to the formation of an internal electric field. Air, for example, which has a permittivity approximately equal to that in a vacuum, readily permits electric field formation and therefore heats effectively in microwave ovens, whereas sapphire, which has a permittivity approximately ten times greater than that of air, does not so readily permit electric field formation.

Several formulas can be used to determine the permittivity of a mixture of materials, depending on the permittivities of the component materials and the ratios in which they are mixed. For a mixture of 3 components, the permittivity of the mixture ($\varepsilon_{\mathrm{mix}}$) may be given as one of several relations that take the form

$$\varepsilon_{\mathrm{mix}} = f\,(\varepsilon_1,\, \varepsilon_2,\, \varepsilon_3;\, v_1,\, v_2),$$

where ε_i is the permittivity of the i^{th} component of the mixture, and v_i is the fraction of the total volume that is occupied by the i^{th} component of the mixture. Some models are described in [1].

This summer project is to invert a specific model, the Looyenga model, to determine the optimal volume fractions for a set of more than two materials so that, when the materials are mixed at those volume fractions, the permittivity of the material is equal to a pre-determined value. This project would be useful to polymer engineers, who are interested in designing composites of polymers and ceramics to certain specifications, and would be an extension of the work in [2], which was done for mixtures limited to two component materials. The possibility of testing our algorithm for specific materials exists, and may be pursued at a later time in conjunction with Sebastien Vaucher at the Laboratory for Advanced Materials Processing of the Swiss Federal Laboratories for Materials Science and Engineering.

References:

[1] E. Kiley, V. V. Yakovlev, K. Ishizaki, S. Vaucher, "Applicability Study of Classical and Contemporary Models for Effective Complex Permittivity of Metal Powders", J. Microwave Power E.E., vol. 46, no. 1, pp. 26-38 (2012).

[2] S. Vaucher, V. V. Yakovlev, H. Yeung, "Materials with Required Dielectric Properties: Computational Development and Production of Polymer-Ceramic Composites", Polym. Eng. Sci., DOI 10.1002/pen.24575 (2017).

List of supplies and cost (if any): n/a

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