Estimation of Distributed Parameters in Permittivity Models of Composite Dielectric Materials Using Reflectance

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We investigate the feasibility of quantifying properties of a composite dielectric material through the reflectance, where the permittivity is described by the Lorentz model in which an unknown probability measure is placed on the model parameters. We summarize the computational and theoretical framework (the Prohorov Metric Framework) developed by our group in the past two decades for nonparametric estimation of probability measures using a least-squares method, and point out the limitation of the existing computational algorithms for this particular application. We then discuss improvements of the algorithms, and demonstrate the feasibility of our proposed methods by numerical results obtained for both simulated data and experimental data for inorganic glass when considering the resonance wavenumber as a distributed parameter. Finally, in the case where the distributed parameter is taken as the relaxation time, we show how the addition of derivative measurements improves the accuracy of the method.

This research represents joint efforts with colleagues at NCSU (Jared Catenacci and Dr. Shuhua Hu) and collaborative research efforts of our group with scientists at AFRL (Materials State Awareness and Supportability Branch, Air Force Research Lab, WPAFB 45433, USA) led by Amanda K. Criner and Adam T. Cooney. In these efforts, the goal is to develop a noninvasive technique to characterize the degradation of a complex nonmagnetic dielectric material (e.g., ceramic matrix composites, which are used in a wide range of applications such as high temperature engines) by assessing the small physical and chemical changes in the material using reflectance spectroscopy. This involves determining the components of the permittivity of the composite dielectric medium using the measured spectral responses.

Singular quasilinear elliptic problems on exterior domains

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We introduce the method of sub and supersolutions for quasilinear elliptic problems on exterior domains. We prove general existence theorem using the approximation of the exterior domain by the use of a sequence of expanding bounded domains. We apply the general result to prove the existence (and uniqueness) of solution of singular semipositone (and positone) problem.

Flagellar motility: negotiating sticky elastic bonds and viscoelastic networks

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In the past decade the study of the fluid dynamics of swimming organisms has flourished. With the possibility of using fabricated robotic micro swimmers for drug delivery, the need for a full description of flow properties is evident. In many physiological settings, microorganisms must move through viscous fluids with suspended polymeric networks whose length scales are comparable to that of the organism. Mammalian sperm must penetrate such heterogeneous networks as they make their way through the female reproductive tract. We will discuss a Stokes fluid model that is used to describe the mechanics of these complex systems, where forces due to both the active flagellum and the compliant polymeric structures are coupled to a viscous, incompressible fluid. We will present recent computational investigations of hyperactivated sperm detachment from oviductal epithelium as well as swimming through viscoelastic networks.

Propagating terraces and the dynamics of front-like solutions of parabolic equations on the real line

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In many well studied cases, the behavior of front-like solutions is governed by a traveling front. However, this may not be the case for solutions whose range spans the ranges of several traveling fronts at different levels. For the analysis of the behavior of such solutions, the concept of a propagating terrace, or, a stacked system of traveling fronts, is very useful. In this lecture, we will discuss the structure and global attractivity properties of propagating terraces.