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Lateral resolution of frequency domain thermal mapping

Limitations of current thermal characterization techniques make complete understanding of thermal transport within composite materials difficult to obtain. Bulk property values may be measured, but do not capture complete information about microscale thermal character of the composite. The constituents may be individually characterized before fabrication, but this will not capture any changes to the thermal properties that result from the fabrication process. If measurements of microscale properties of components within the fully formed composites could be accessed, they could be used as inputs to mesoscale models to inform intelligent design of composite material systems and the fabrication processes used to create them.

As a step towards *in situ* microscale thermal property mapping, a finite element analysis (FEA) model is developed and implemented to predict and analyze data obtained from a pump-probe technique known as Frequency Domain Thermoreflectance (FDTR). The FEA model is used to analyze experimental data to generate *in situ* thermal property maps of multi-material systems and predict resolution limitations of these maps. FDTR is traditionally used to measure thermal properties in radially symmetric samples. A patterned metal transducer layer is typically used to convert incident light from the pump laser into heat, which diffuses into the sample. The magnitude and phase of the reflected probe laser are used to monitor changes in reflectivity of the transducer layer, which is proportional to temperature rise at the transducer layer surface. Thermal properties of the sample are fit using an analytical forward model as an input to an inverse solver. Most commonly, this approach is used to fit for properties of bulk materials, or thin films grown in the same orientation as the transducer layer.

The FEA model presented here extends the data prediction and analysis capability for FDTR from radially symmetric samples to samples with varying character in one lateral (in-plane) direction and the through-plane (cross-plane) direction. Two samples sets were measured to validate the model's predictions. The first sample set contained periodic surface features with pitches varied from 200 nm to 800 nm. The second sample set contains Aluminum wires embedded in an SiO_2 substrate. These samples are measured by a 1-dimensional surface measurement scan in the lateral direction, producing thermal maps of the samples. Measured phase data match closely with simulated phase data from the FEA model. The validated model is used to predict phase measurements of systems with different geometries and feature depth, obtaining a quantitative relationship for how lateral resolution limits vary with feature depth. Additionally, the measured data are used as inputs for inverse fitting for thermal and dimensional properties of samples. Finally, implications for future work on reconstructive imaging are discussed.

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