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Measurement of Thermal Conductivity at a Nanoscale Using Bayesian Inversion

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Thermal management is a key issue for the miniaturization of electronic devices due to overheating and local hot spots. To anticipate these failures, manufacturers require knowledge of the thermal properties of the used materials at the nanoscale (defined as the length range from 1 nm to 100 nm), which is a challenging issue because thermal properties of materials at nanoscale can be completely different from those of the bulk materials (materials having their size above 100 nm in all dimensions).
The proposed approach aims at establishing a calibration curve (as part of a calibration protocol) to provide metrologically traceable estimations of the thermal conductivity at nanoscale and its associated uncertainty (x-axis), using SThM (Scanning Thermal Microscopy, having a high spatial resolution of tens of nm) measurements and their associated uncertainty (y-axis).
This contribution focuses on the development of a Bayesian approach to simultaneously estimate the calibration curve with uncertainty on both axes and to predict the thermal conductivity of unknown materials and their associated uncertainty.
The approach is applied to 12 samples of bulk materials with traceable thermal conductivities with 5% relative expanded uncertainty in the range 1-100 $Wm^{-1}K^{-1}$. For these materials, uncertainty on the y-axis ranges between 0.4% and 2% relative expanded uncertainty.
With this methodology, a thermal conductivity of 0.2 $Wm^{-1}K^{-1}$ is estimated with less that 4 % relative uncertainty.
The effect of uncertainty sources (in particular on the y-axis) on the range of sensitivity of the SThM technique for quantitative thermal conductivity measurements is investigated.

Keywords

Nanomaterials, Bayesian analysis, uncertainty evaluation

Classification

Both methodology and application

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