Thermal Diffusivity Measurement for High Thermal Diffusivity Materials by Applying Undersampling to the Lock-in Thermography

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The rapid performance enhancement in semiconductor devices coupled with the miniaturization of electronic modules have resulted in increased heat generation density, posing significant challenges for thermal management. As a solution, highly thermal conductive materials are implemented to increase heat-dissipation from the electronic circuit boards. Evaluating the thermophysical properties of these materials at the full scale is crucial for designing optimal thermal management solutions.

In this study, we present a lock-in thermography-based periodic heating method for accurate and rapid high thermal diffusivity measurements. Utilizing a laser for sample periodic heating and lock-in thermography for temperature detection, this method enables non-contact measurements of the thermal diffusivity with high sensitivity and reliability. The thermal diffusivity is obtained by fitting the frequency dependence of the phase delay to the theoretical solution. As the sample becomes thinner or the thermal diffusivity increases, the frequency dependence of the phase delay obtained becomes smaller, requiring measurements at higher frequencies. The measurable frequency range of conventional lock-in thermography is limited by the instrument frame rate constraints and Nyquist's sampling theorem, restricting the measurable thermal diffusivity range. To overcome this limitation, we implement undersampling to the lock-in thermography-based periodic heating method, enabling measurements at higher frequencies and thus expanding the measurable thermal diffusivity range. We validate the proposed measurement method and demonstrate its ability to extend the measurable thermal diffusivity range beyond that of the conventional method. This method enables rapid, accurate high thermal diffusivity measurements across a wide range of materials, offering a significant potential for optimizing thermal management systems including electronics, energy, and aerospace.