Development of a Thermal Properties Sensing Technique with 100 nm Spatial Resolution Using Near-field Optics

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Nanoscale thermophysical properties are absolutely imperative in the field of semiconductor devices and new nanomaterials. In addition, accurate prediction of nanoscale temperature distributions is quite important for the elaborate thermal design of LSI. Because of this, we have developed a nanoscale thermophysical properties (thermal conductivity and thermal diffusivity) and temperature distribution measurement technique using near-field optics.

In conventional optical measurement techniques, the spatial resolution is limited by the diffraction limit of light, which is approximately half of the wavelength of the optical beam. Therefore, we have adopted near-field light for the heating of the sample and the detection of the temperature change. The sample is periodically heated by a near-field light, and the reflectivity of the sample changes, due to the alteration of the sample temperature. The temperature change of the sample is detected as a change of the reflectivity by a probing near-field light. The phase difference between the heating and the temperature change contains information about thermal properties. Therefore, by analyzing the phase difference, thermal conductivity and thermal diffusivity values are obtained. We call this technique Near-field Optics Thermal Nanoscopy (NOTN). NOTN enables noncontact and in situ measurements of the thermal conductivities and thermal diffusivities of nanoscale devices and materials.

In this paper, a detailed description of the measurement principle is given. As a recent report, we have measured the thermal properties of Al with 500 nm spatial resolution. However, higher resolution is desired. The aim is 100 nm spatial resolution, which cannot be achieved by conventional optical methods. For this purpose, a highly-sensitive detection system is developed by adapting a sensitive detector and a low noise amplifier. The validity of measuring thermal properties with 100 nm spatial resolution is discussed through preliminary measurements. Furthermore, a new experimental method to evaluate the spatial resolution of NOTN is attempted.