Development of Nanoscale Temperature Measurement Method by Polarized Near-field Light under High Vacuum

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The temperature measurement at the nanoscale is important for the thermal design of the highly integrated electric devices. However, the spatial resolution of the conventional optical methods is limited by the diffraction of light, which is approximately half of the wavelength. Therefore, we have developed a novel nanoscale temperature measurement method using the polarized near-field light, namely Polarized Near-field Optics Thermal Nanoscopy (P-NOTN). Our method can achieve nanoscale spatial resolution beyond the diffraction limit of light, because the size of the near-field light doesn’t depend on the wavelength but on the aperture diameter of the near-field fiber probe. The polarization was employed into the measurement principle in order to measure the temperature with high sensitivity. The polarized near-field light has high sensitivity for the refractive index, which has temperature dependence. Therefore, the temperature can be measured at nanoscale by detecting the polarization change in near-field. We have developed a high-vacuum near-field optical system for the highly sensitive temperature measurement. This system consists of a high-vacuum chamber, a sputter ion pump and five-axis probe-sample positioning stages. The sputter ion pump enables vibration-free pumping during the measurement and the high vacuum ($10^{-4}$ Pa) can be achieved. Under high vacuum, the highly sensitive measurement is possible in a wide range of the sample temperature, because the heat conduction from the sample is negligibly small, compared to that in the atmosphere. Moreover, the probe-sample distance can be controlled more precisely in high vacuum, because the quality factor of a quartz crystal tuning fork that is a sensor for the probe-sample distance is higher than that in the atmosphere. In this paper, the polarization change in near-field is detected under high vacuum, and we assess the feasibility of the nanoscale temperature measurement and estimate the temperature resolution of P-NOTN.