082

NANOSCALE THERMOPOWER PROFILING TECHNIQUE USING A DIAMOND THERMOCOUPLE PROBE

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SUMMARY: A scanning Seebeck microscopy method is developed to map out the thermopower of a semiconductor with nanometer resolution. This technique profiles the thermopower by simultaneously conducting local heating, temperature sensing and thermoelectric voltage measurement at the tip of a diamond thermocouple probe. The core advantage of this technique is that it enables quantitative measurement of thermopower by monitoring the tip-sample contact temperature from the thermocouple junction located at the end of the diamond tip. The diamond thermocouple probe, the key component of the proposed scheme, is fabricated by integrating nano-thermocouple at the diamond tip. The probe should withstand the contact stress higher than 10 GPa, which is necessary for establishing stable electric contact to the silicon surface. The tip and the cantilever of the probe are made of boron-doped diamond by means of the silicon lost mold technique, which guarantees a sharper tip apex than that of a diamond coated probe. Then, the gold-chromium thermocouple junction is integrated at the tip apex for simultaneous heating and sensing. The size of the thermocouple is about 500 nm and the radius of the tip apex is less than 50 nm. The measurement technique is demonstrated by measuring the thermopower distribution across a silicon p-n junction. By heating the tip with an AC current and simultaneously measuring the temperature and the thermoelectric voltage between the tip and the sample, the thermopower distribution is measured quantitatively. The profiled thermopower follows faithfully the sharp variation over the depletion region of 50 nm width in comparison with the theoretical value obtained from Poisson’s equation. Evaluating from the abrupt change of the phase signal across the junction, the spatial resolution of the method is estimated to be about 5 nm.