Tip size dependence of passive near-field microscopy

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The wavelength of the THz wave between 10 μm and 50 μm corresponds to the emission peak at room temperature, which contains numerous interesting spectra of matters such as phonon emission, molecular bonding, or bio-motion. To study these spontaneous emission in nanoscale, we have recently developed a scattering-type scanning near-field optical microscope (s-SNOM) equipped with an ultrahighly sensitive THz detector, CSIP (charge-sensitive infrared phototransistor; $\lambda = 14.5 \pm 0.7$ μm), and the spatial resolution of 60 nm is achieved [1]. The diagram of the s-SNOM is shown in Fig. 1(a). A sharp tungsten probe is placed just above the sample surface to scatter thermal evanescent waves without any external illumination (passive microscopy). The scattered photons are collected by a Ge objective lens and are refocused onto the CSIP through Ge relay lenses.

To study interesting objects like biomolecules or nano-particles, much better spatial resolution (< 20 nm), is strongly required. Besides, it is also an unclear issue whether the decay length of passive near-field signals relies on the tip size. In the s-SNOM, the spatial resolution is dependent mainly on the radius of tip apex. With improved AC electrochemical etching procedure, the current through the tungsten probe is monitored in real-time, and the sharper tip can be fabricated when process is stopped at most suitable current. Figure 1(b) shows the lateral profile of the passive near-field signal scanned by the tip with ca. 15 nm apex radius across the boundary between SiO_2 and Au. The spatial resolution has been derived to be ca. 20 nm (λ/725), consisting with the probe tip size. Furthermore, we studied the decay length of the evanescent wave on Au with different tip sizes. The result yielded that the decay length are all ca. 25 nm and independent of the tip size. This is exactly what the theories predict [2].

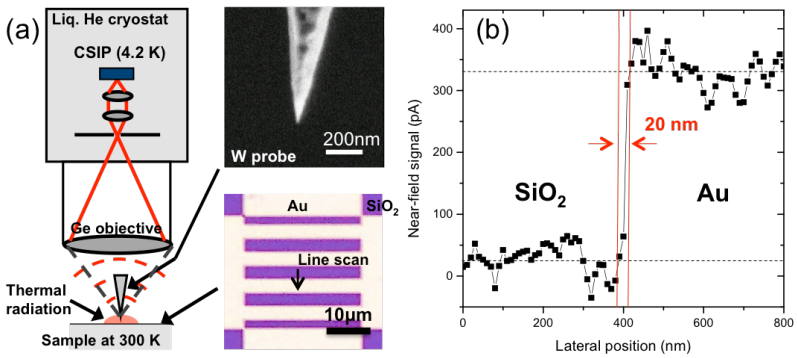

Fig. 1: (a) Schematic diagram of the passive s-SNOM equipped with a sharp tungsten probe (apex radius is ca. 15nm). The sample is Au grating deposited on SiO_2. (b) The spatial resolution ca. 20 nm shown in the step edge between Au and SiO_2.

[1] Y. Kajihara, et al., Opt. Express, **19**, 7695A (2011).
[2] K. Joulain et al., Surface Science Reports, **57,** 59–112 (2005)