Nanoscale Temperature Mapping of Current-heated Narrow Metal Wires

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Thermometry techniques with high spatial resolution on sub-micron scales have attracted great interest in recent years, being motivated by applications in a variety of areas such as microelectronic devices[1], dissipative quantum systems[2], and even living cells[3]. However, realization of nanoscale temperature mapping is not an easy task: Development of high performance nanothermometric technique with negligible influence on the measured temperature is highly demanded.

Here, we report a novel radiative-type thermometer which can overcome the diffraction-limit and achieve nanoscale spatial resolution. It is a home-made thermal near-field optical microscope[4], which is so sensitive to detect thermally induced fluctuating electromagnetic evanescent waves[5]. The detected thermal near-field signal is then directly related to the electromagnetic energy density of thermal near-field radiation, which is temperature dependent. Fig. 1(a) shows the diagram of radiative local temperature detection: a nanoscale metal tip is placed close (~ 10 nm) to the sample surface to locally scatter the thermally induced evanescent waves, which is generated on a Nichrome (NiCr) wire (Fig. 1(b)) heated by the current. Fig. 1(c) shows the experimentally derived temperature distribution of the heated NiCr, which is consistent with temperature simulations by considering the Joule heating. The observed hot-spot is due to the current-crowding induced local energy dissipation, which can be directly imaged by our experimental technique.

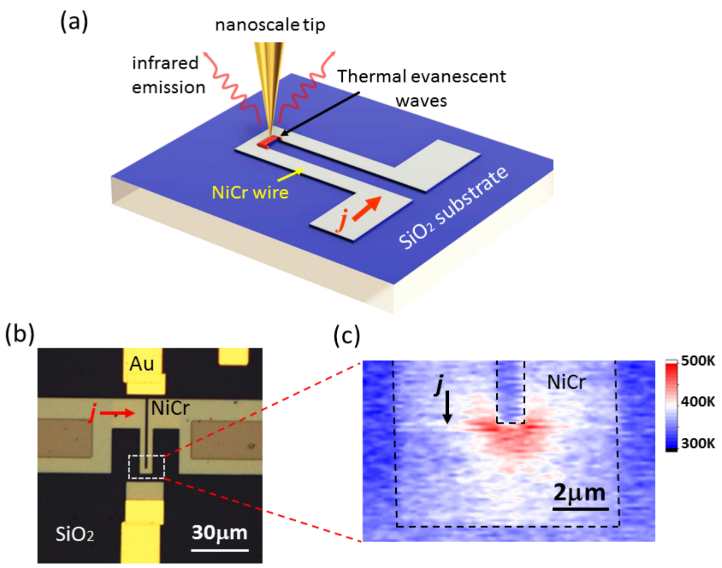

Fig. 1. (a) Diagram of the local temperature detection with a thermal near-field optical technique. (b) Optical image of the NiCr device under study. The width of the narrowest part is 3.3 μm, and the thickness is 50 nm. (c) Thermal near-field image of the NiCr device with an input current of 4.3 mA. The NiCr wire is heated due to the applied current, and a localized hot-spot is imaged due to current-crowding effect. The temperatures are estimated from the detected near-field signal as shown in the color bar.

Reference:

[1] M. Mecklenburg, *et al*. *Science* **347**, 627-632 (2015).

[2] D. Halbertal, *et al*. *Nature* **539**, 407-410 (2016).

[3] G. Kucsko, *et al*. *Nature* **500**, 54-58 (2013).

[4] Y. Kajihara, *et al*. *Rev. Sci. Instrum*. **81**, 033706 (2010).

[5] S. Komiyama, *et al*. Preprint at https://arxiv.org/abs/1601.00368.