グラフェンにおける電流励起熱エバネッセント波のサイズ依存の考察

Size-dependence of current-induced thermal evanescent waves in graphene

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Graphene is a potential material for carbon-based electronic devices, such as optoelectronic and field-effect transistor devices, due to its ultrahigh electrical and thermal conductivity. The study of thermal management in graphene has become an important issue in the examination of device failure and optimization of device design. In the past decade, the local thermal information in graphene devices has been measured by infrared thermal microscopy[1] and Raman scattering microscopy[2]. The spatial resolution of these techniques is, however, diffraction-limited to a scale of several micrometers. Recently, the thermally excited evanescent waves have been detected in Joule-heated bilayer graphene[3] by using a scattering-type scanning near-field optical microscope (s-SNOM)[4]. The graphene device is placed at room temperature. The detection wavelength of the s-SNOM is 14.5 ± 0.5 μm. This approach provides a nanoscale infrared thermal imaging in graphene film via near-field (NF) detection shown in Fig. 1(a).

To further understand the geometric and substrate effects of thermal management in graphene devices, we fabricated graphene narrow constriction devices. The single-layer graphene film was grown by the CVD method and transferred to a SiO_2 substrate. We patterned the graphene into devices of a narrow constriction with a combination of different width (W) and length (L) by using electron beam lithography shown in Fig. (b). Figure 1(c) shows the intensity profiles of NF signals detected on graphene (L: 8 μm, W: 1 μm) with bias current I = 0.4, 0.8, and 1.2 mA. We observed that the NF signal largely increased with increasing current in the constricted region, where the electrons obtained large electrical energy because of the high electric field, and then, released the energy to the lattice that caused Joule heating. With the same current, we found that the NF signal on graphene is sensitive to various widths (W = 1, 3, 8 μm) but insensitive to various lengths (L = 1, 3, 8 μm). These results agree with the simulation results calculated by the finite-element method.

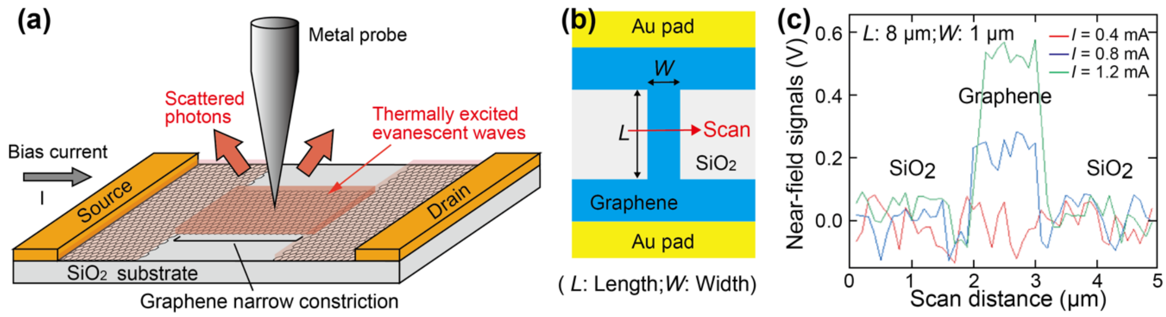

Fig. 1 (a) Schematic view of the NF detection in a current-driven graphene device. (b) Schematic geometry of narrow graphene constriction. (c) One-dimensional profiles of the NF signals across the graphene constriction as indicated in the Fig. (b) with bias current I of 0.4, 0.8, and 1.2 mA.

Reference:

[1] T. E. Beechem *et al.*, *Sci. Rep.*, vol. 6, no. 1, p. 26457, Sep. 2016.

[2] M. Freitag, H.-Y. Chiu, M. Steiner, V. Perebeinos, and P. Avouris, *Nat. Nanotechnol.*, vol. 5, no. 7, pp. 497–501, Jul. 2010.

[3] K. Lin *et al.*, *Appl. Phys. Express*, vol. 13, no. 9, p. 096501, Sep. 2020.

[4] K.-T. Lin, S. Komiyama, S. Kim, K. Kawamura, and Y. Kajihara," *Rev. Sci. Instrum.*, vol. 88, no. 1, p. 013706, Jan. 2017.