Carrier Density Mapping on Graphene Nanoflakes to Explore Their Internal p-n Junctions

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Graphene is widely known to have p-type electricity on oxidized silicon (SiO_2/Si) substrates in air [1]. In contrast, n-type electricity has been achieved using field-effects, other materials to be adsorbed on the surface or doped during chemical vapor deposition, and so on, resulting in planar and vertical homogeneous p-n junctions. However, those require large-scale equipment, and stability and performance issues have also been identified [2]. In our study, we focus on graphene nanoflakes (GNFs) of less than 1 μm^2 in size to test our hypothesis that they might not always have p-type electricity. We have simultaneously observed their surface electric potentials and topographies, using frequency-modulated Kelvin probe force microscopy (FM-KPFM). The distribution images of the carrier density, derived from the relationship to the surface potentials [3], represent not only p-type regions but also intrinsic and n-type regions in the GNFs. We quantitatively evaluate the "depletion region widths" and "work function differences" by applying the Poisson equation to the "depletion regions," highlighted in yellow in Figs. 1(g) and 1(h). We also simulate the surface potentials based on the formation model for each region and interface, including the intrinsic region.

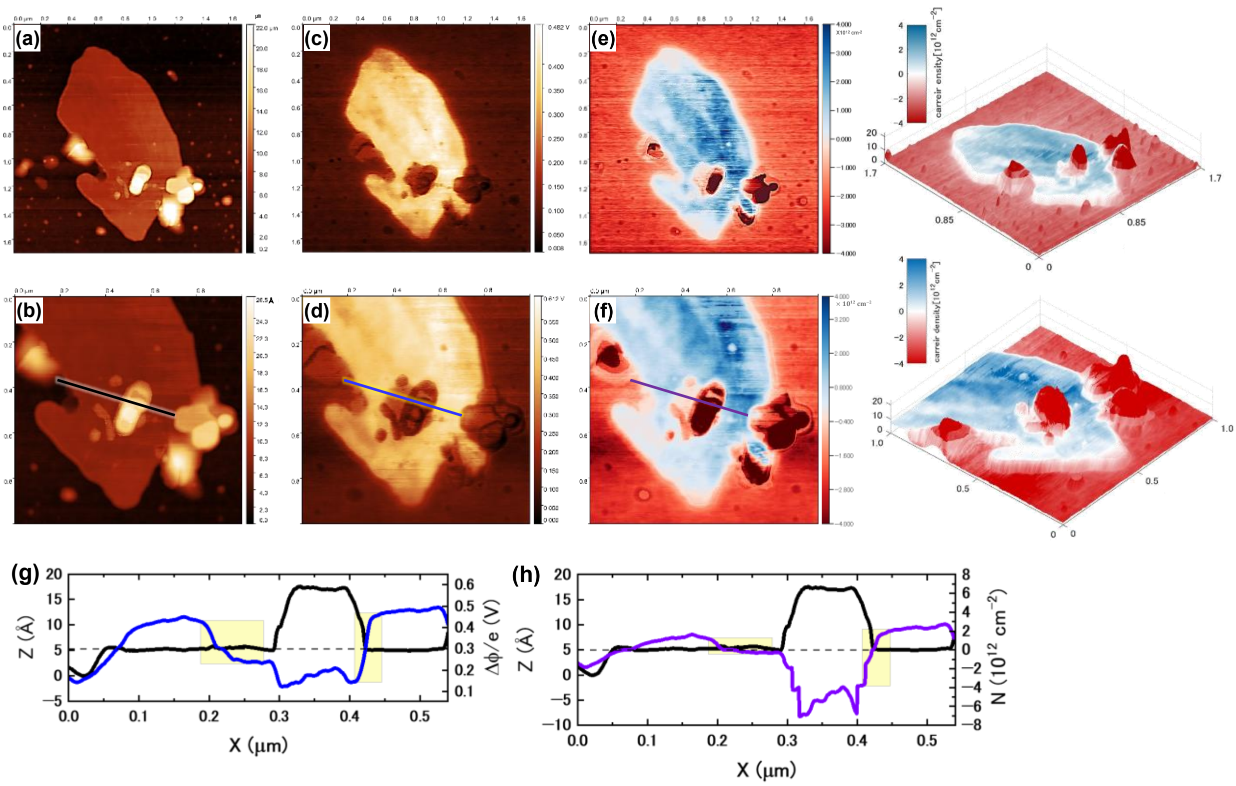

Figure 1. (a, b) Topography, **(c, d)** surface potential, and **(e, f)** carrier density images of graphene nanoflakes on a SiO_2/Si substrate. Image sizes: 1.7 μm × 1.7 μm (upper) and 1.0 μm × 1.0 μm (lower). **(g)** Potential (blue) and **(h)** carrier density (purple) profiles along the lines with those of topography. The right sides display 3D views.

Reference

[1] K. S. Novoselov et al., Science **306**, 666-669 (2004).

[2] P. Tian, et al., Adv. Mater. Technol. **4**(7), 1900007 (2019).

[3] Y.-J. Yu et al., Nano Lett. **9**, 3430–3434 (2009).