Observation of Photovoltaics and Dynamic Changes on Graphene Nanoflakes by Frequency-Modulated Kelvin Probe Force Microscopy

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The p-n junction is the fundamental building block of semiconductor devices that are essential to modern society, as it exhibits photovoltaic and rectifying effects. For the development of next-generation electronic devices, graphene, a prominent 2D material, is considered indispensable due to its exceptional mobility and electrical conductivity. It is commonly known that when exposed to the air atmosphere, graphene on oxidized silicon substrates exhibits p-type electricity [1]. Our group focuses on graphene nanoflakes (GNFs) of less than 1 μm^2 in size and simultaneously observes their surface electric potentials and topographies, using frequency-modulated Kelvin probe force microscopy (FM-KPFM). Carrier density mapping on the topography reveals not only p-type but also intrinsic and n-type electricity of the GNFs [2]. The p-n junctions observed on the GNFs should provide rectifying properties. However, contact with the electrodes used for conductivity experiments may compromise the spontaneous formation of p-n junctions within the GNFs. In this study, we use FM-KPFM to observe how the surface potential changes before and after irradiating a low-intensity pulsed laser light to confirm the photovoltaic effect. Additionally, FM-KPFM images the structural evolution by repeatedly irradiating the pulsed laser beams on the GNF surface. Based on the results, we create structural models and investigate the mechanism of p-type formation, which has not yet been determined, as well as n-type formation.

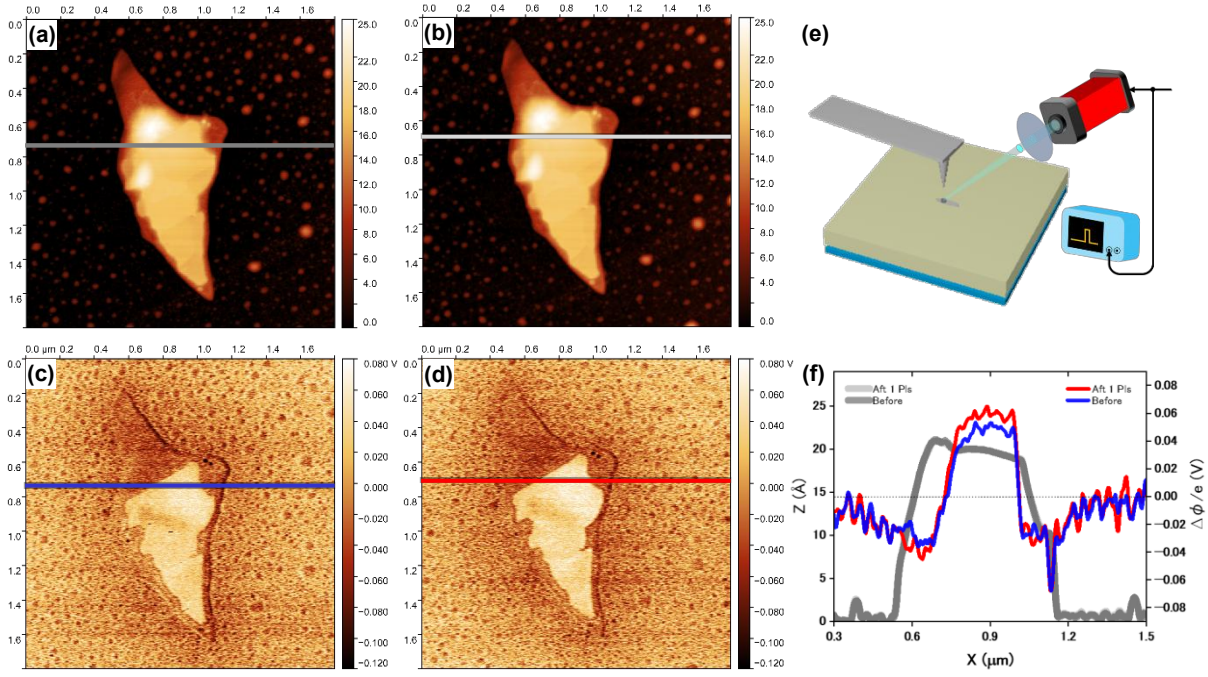

Figure 1. **(a, b)** Topography and **(c, d)** surface potential images of graphene nanoflakes on a SiO_2/Si substrate before and after a pulse-laser-light irradiation. Image sizes: 1.8 μm × 1.8 μm. **(e)** Experimental setup. **(f)** Line profiles of topography (grays) and potential (blue & red).

Reference

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

[2] H. Kaneko, et al., The 10th International Symposium on Surface Science (ISSS-10, 2024).