Strong piezoelectricity in single-layer graphene deposited on SiO_2 grating substrates

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Piezoelectricity is an ability of certain materials to produce mechanical strain under applied electric field or charge under mechanical stress. It is widely used in various devices such as sensors, actuators and transducers.

Piezoelectricity in 2D materials such as graphene opens up new opportunities for functional devices based on the direct and converse piezoelectric effects. Being 2D monoatomic material with many unique properties, graphene is one of the favorable candidates for these applications. However, its centrosymmetric structure does not allow for any piezoelectricity. In this work, we discovered strong piezoelectric effect in a single-layer graphene deposited on SiO2 calibration grating (left panel of Figure 1). Vertical displacement induced by applied voltage was measured by Piezoresponse Force Microscopy (PFM) in a contact mode (right panel to Figure 1). The calculated vertical piezocoefficient is about 1400 pmV-1, that is, much higher than that of the conventional piezoelectric materials such as lead zirconate titanate (PZT) and comparable to that of relaxor single crystals (PMN-PT).

The observed piezoresponse was associated with polar surface states induced by the chemical interaction of graphene's carbon atoms with the oxygen from the underlying SiO2. Piezoelectric activity was mainly observed on the supported graphene regions where van der Waals and/or chemical interaction between the SiO2 surface and graphene layer can induce an anisotropic strain and detectable PFM signal. The correlation of mechanical in-plane strains in a graphene layer with the substrate morphology was established via Raman mapping.

The results provide a basis for future applications of graphene layers for sensing, actuating and energy harvesting. The displacement level can be even increased by fabricating thin SiO2 membranes or bridge/cantil-ever structures.

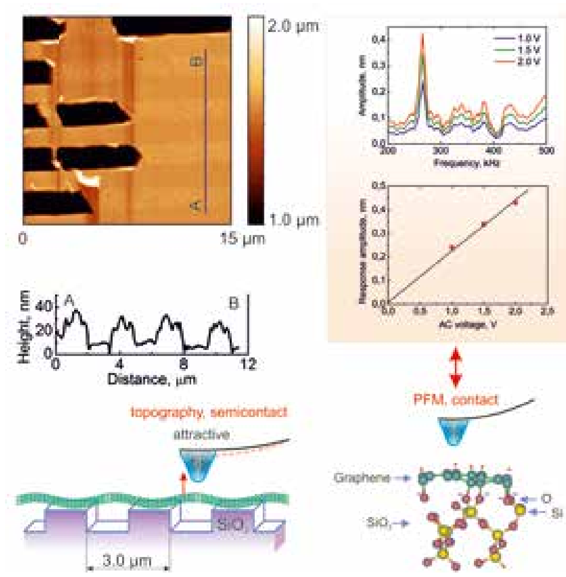

FIGURE 1
Left panel: Topography of the graphene membrane deposited on the SiO2 grating with the pitch 3 µm. Right panel: piezoresponse as a function of frequency and ac voltage and schematic of the C-O bonds formation leading to strong piezoelectric effect.