Supplementary Information for: Reversible Electromechanical Manipulation of Domain Wall in Trilayer Graphene via Ferroelectric Sliding

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Methods

Sample preparation. The graphene layers were prepared by the mechanical exfoliation of natural graphite and transferred onto a 285 nm SiO_2/Si substrate. An optical microscope was used to locate the flakes, while the layer number was further identified by an atomic force microscope (AFM).

Atomic Force Microscopy experiments. The main part of the experiments were carried out with a commercial AFM equipment (Bruker, Dimension Icon) in ambient environment (room temperature 25^{o}C and 45% relative humidity). A DC bias voltage $V_{\rm DC}$ was applied on the tip with the values of 0 V, $\pm$1 V and $\pm$2 V. The adhesion force was measured via the force spectroscopy under the electric field. Additionally, the piezoresponse force microscope (PFM) assembled with AFM system was used to distinguish the stacking sequence of the trilayer graphene and measure the ferroelectric hysteresis loop, with the contact resonance frequency $\omega_{\rm cont}$ of the probe is $\sim$32 kHz. The friction force $F_{\rm F}$ as well as the topography were also measured in PFM with a soft and conductive probe (Bruker, SCM-PIC, spring constant $k \approx 0.2$ N/m, resonance frequency $\omega_0 \approx 13$ kHz, tip radius $r < 20$ nm), due to the contact measurements under PFM. For force calibration, we use the formulas from the book "B. Bhushan, Nanotribology and Nanomechanics, 2008" [1]. The normal force F_{N} and lateral force F_{L} are calibrated as below:

$$F_{\mathrm{N}} = \frac{Ewt^3}{4l^3} \cdot S \cdot V_{\mathrm{N}}, \tag{S1}$$

$$F_{\mathrm{L}} = \frac{Gwt^3}{2hl^2} \cdot S \cdot V_{\mathrm{L}}. \tag{S2}$$

where E and G are elastic and shear modulus of the cantilever, here we use the values of silicon for $E = 1.69 \times 10^{11}$ N/m^2 and $G = 0.5 \times 10^{11}$ N/m^2, respectively [1]; l, w and t are the length, width and thickness of the cantilever, here we use the values of l = 450 μm, w = 50 μm, t = 2 μm, respective; h is the tip height setting as 12.5 μm; V_{N} and V_{L} are the normal and lateral deflection recorded by the quadrant photodetector. Then, the friction force F_{F} can be calculated as the half of F_{L} (trace) minus F_L (retrace), *i.e.* the area enclosed by the hysteresis loop of the lateral force is equal to the work done by friction force. The frictional hysteresis loops we obtained in PFM seem no big difference from the static contact mode of AFM. The graphene samples were scanned at a speed of at different normal forces F_N, ranging from -10∼60 nN. Kelvin probe force microscope (KPFM) was performed in non-contact frequency modulation to measure the surface potential of the sample surface. Scan rate of 1 Hz for PFM/FFM and 0.5 Hz for KPFM, respectively, and pixel resolution 512×512 in length and width.

References

[1] Bhushan, B.: Nanotribology and Nanomechanics: an Introduction. Springer, Berlin (2008)

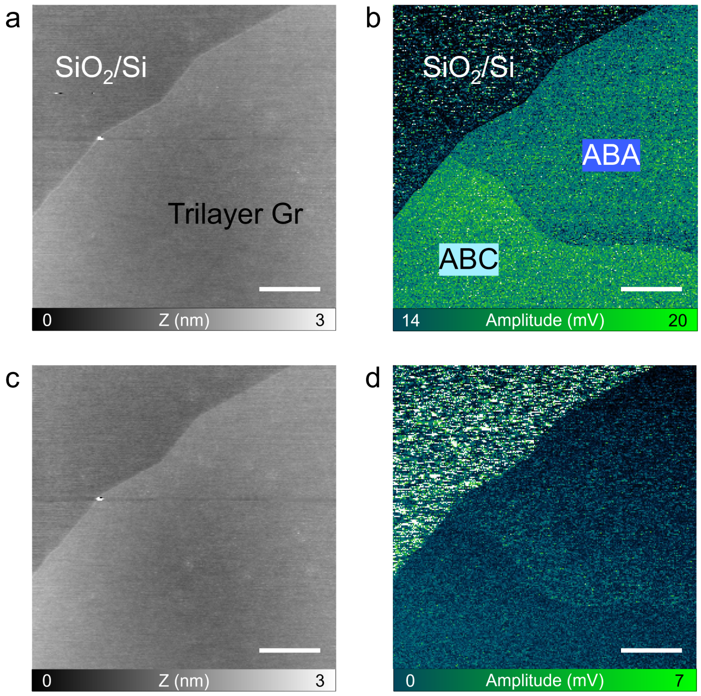

Fig. 1 Characterization of ABC and ABA-stacked domains in trilayer graphene on SiO_2/Si substrate scanned by PFM: (**a**) and (**b**) Topography and amplitude with AC on (V_{AC} = 2 V). (**c**) and (**d**) Topography and amplitude with AC off (V_{AC} = 0 V). Scale bars: 3 μm.

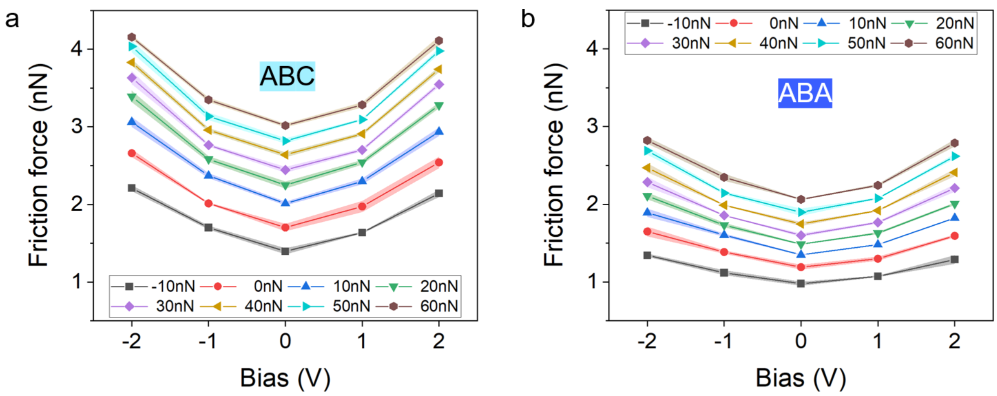

Fig. 2 Friction-bias curves under the applied normal force: (**a**) ABC domain. (**b**) ABA domain.

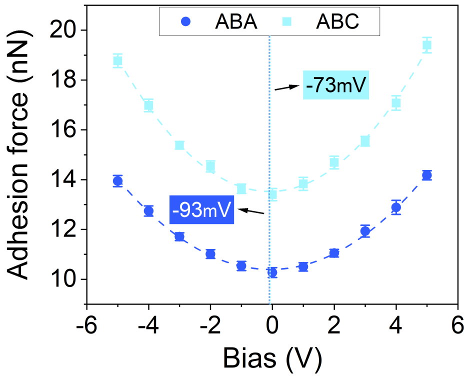

Fig. 3 Adhesion force of ABC and ABA-stacked domains under the electric field.

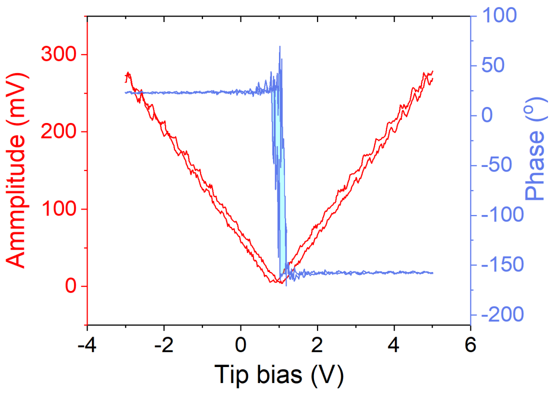

Fig. 4 Full data of amplitude and phase for ABC domain measured at $V_{\mathrm{AC}} = 4$ V.