Supplementary Information

Designable Dirac Point Voltage of Graphene by Mechanical Bending Ferroelectric gate of Graphene Field Effect Transistor and Its Multifunctional Application

Guangliang Hu[ab], Jingying Wu[b], Chunrui Ma[*a], Zhongshuai Liang[b], Weihua Liu[b], Ming Liu[b], Judy Z. Wu[c], Chun-Lin Jia [bd]

[a] State Key Laboratory for Mechanical Behavior of Materials, Xi'an Jiaotong University, Xi'an, 710049, China

[b] School of Electronic and Information Engineering, Xi'an Jiaotong University, Xi'an, 710049, China

[c] Department of Physics and Astronomy, University of Kansas, Lawrence, Kansas, 66045, USA

[d] Ernst Ruska Centre for Microscopy and Spectroscopy with Electrons, Forschungszentrum Jülich

[*] Address correspondence to: chunrui.ma@mail.xjtu.edu.cn

Mechanical model for strain gradient in the PLZT film.

The strain gradient formed in the PLZT film can be estimated using a mechanical model as below: A sample (films with substrate) with L for length, W for width and h for thickness was considered. Along the thickness direction, we assumed that the length at $h/2$ is not change when the sample was bent at a certain radius (r_0). For the upward bending state, as shown in the Figure. S4 (a), the angle (θ) corresponding to the sample can be expressed as

$$\theta = \frac{180}{\pi} \cdot \frac{L}{r_0 + \frac{h}{2}}. \tag{1}$$

Therefore, the length (L') of the sample at r can be expressed as

$$L' = \frac{\theta \cdot \pi}{180} \cdot r = L \cdot \frac{r}{r_0 + \frac{h}{2}}. \tag{2}$$

The strain (u) at r can be expressed as

$$u = \frac{L' - L}{L} = \frac{r}{r_0 + \frac{h}{2}} - 1. \tag{3}$$

So, the strain gradient ($\frac{\partial u}{\partial r}$) can be written as

$$\frac{\partial u}{\partial r} = \frac{1}{r_0 + \frac{h}{2}}. \tag{4}$$

For downward bending state, as shown in the Figure. S4 (b), the strain gradient can be estimated as $\frac{\partial u}{\partial r} = \frac{1}{r_0 - \frac{h}{2}}$ using a similar mechanical model.

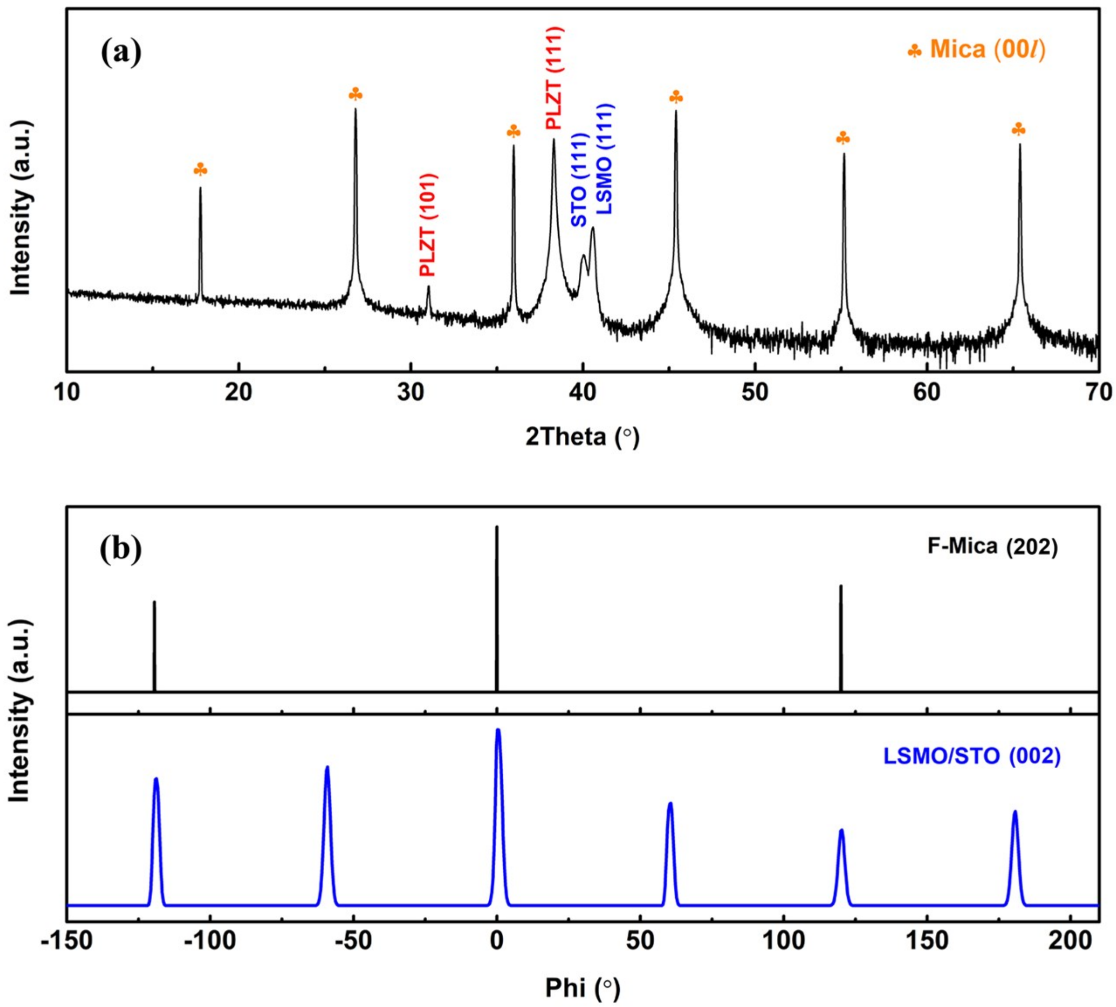

Figure S1. (a) A typical XRD θ-2θ scans for the PLZT/LSMO/STO multilayer on F-Mica. (b) φ scans taken around the (202) reflections of the F-Mica substrate (top), (002) reflections of the LSMO/STO layer (bottom).

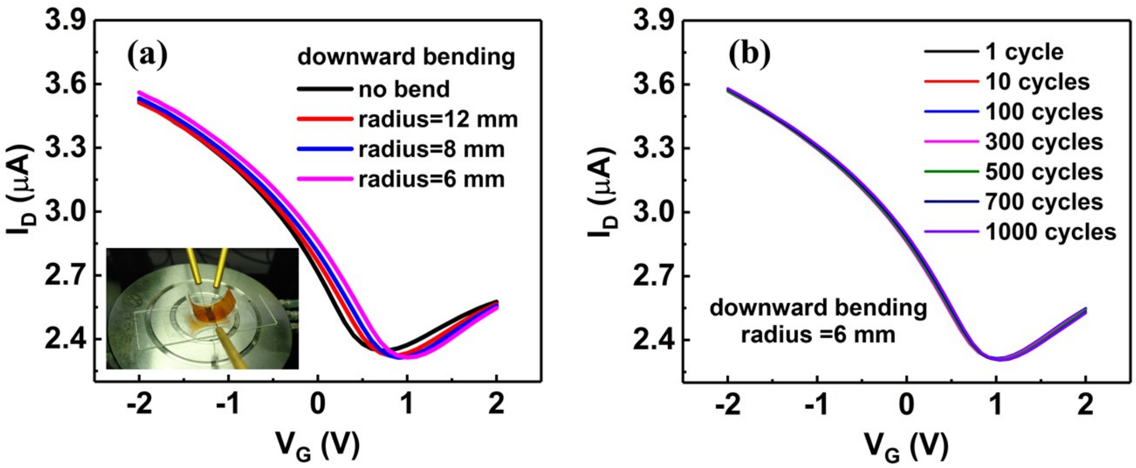

Figure S2. (a) I_D-V_G curves at different downward bending radius. (b) I_D-V_G curves at different bending cycles under 6 mm downward bending radius.

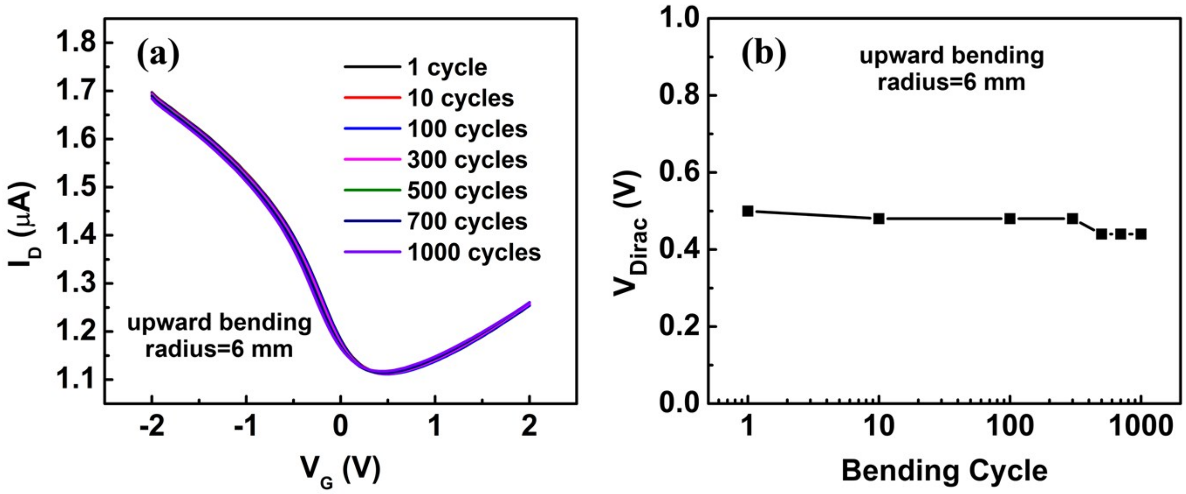

Figure S3. (a) I_D-V_G curves at different bending cycles under 6 mm upward bending radius (V_D=10 mV). (b) V_{Dirac} of curves in (a) at different bending cycles under 6 mm upward bending radius

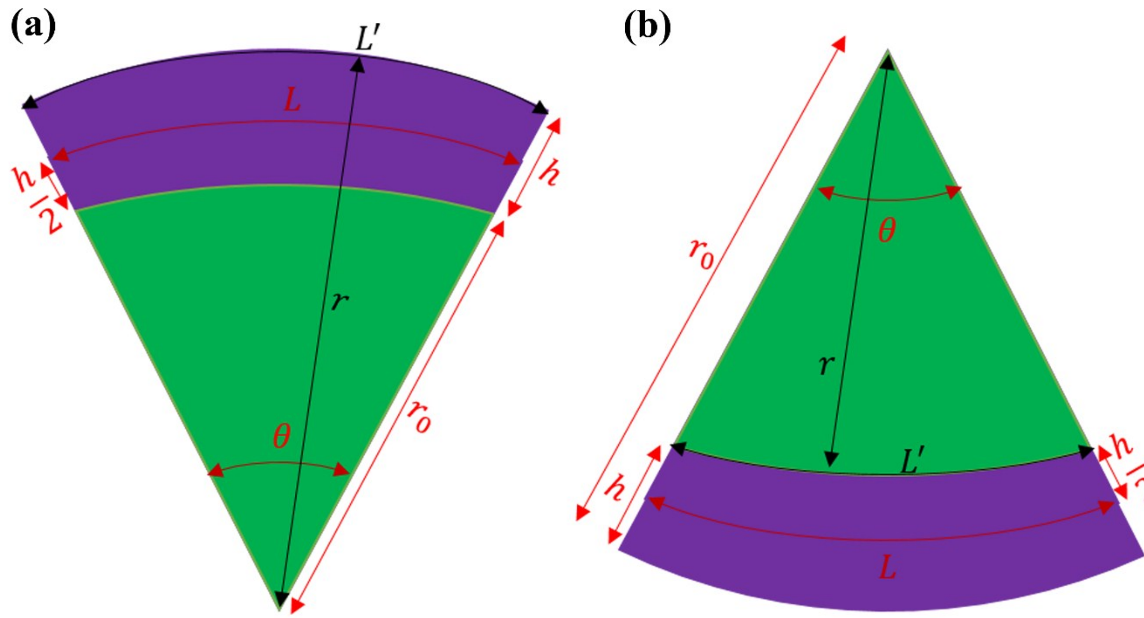

Figure S4. Mechanical model for upward bending state (a) and downward bending state (b).

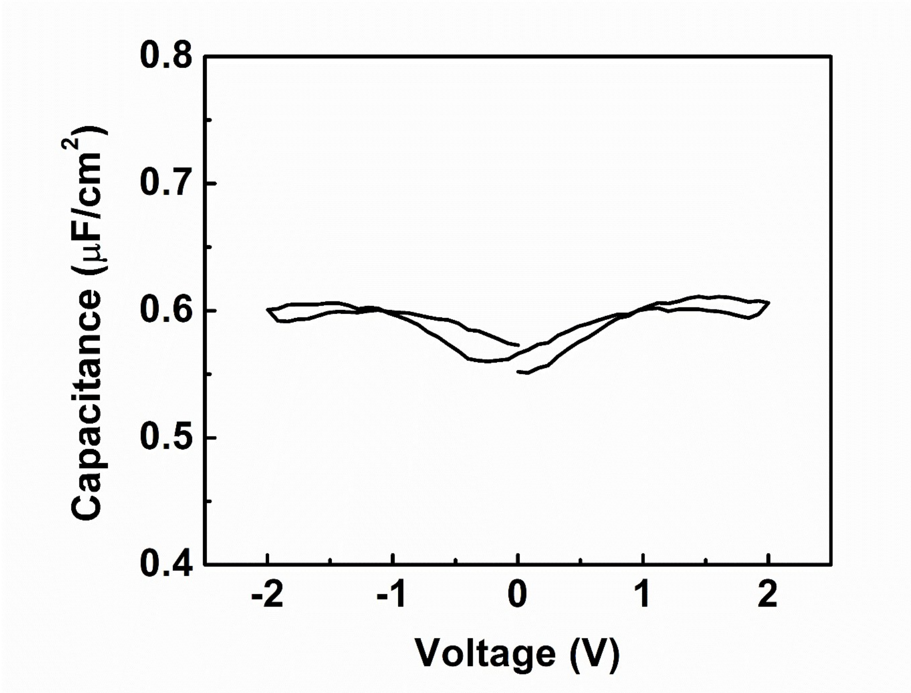

Figure S5. The capacitance of the PLZT under the voltage of 2 V.

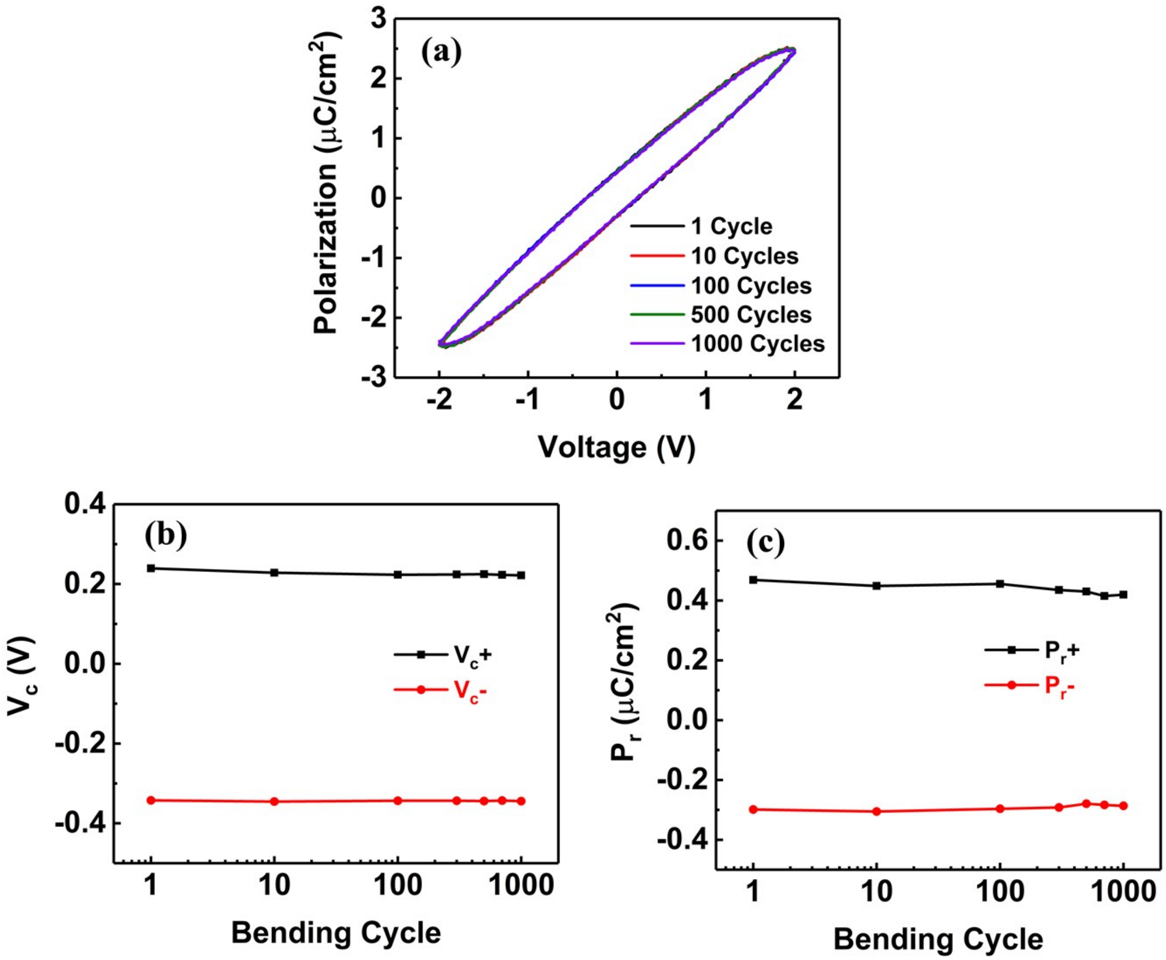

Figure S6. (a) *P-E* loops at different bending cycles and at the voltage of 2 V after different downward bending cycles (6 mm bending radius). (b) and (c) are V_c and P_r after different bending cycles in (a), respectively.