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A gate-free MoS_2 phototransistor assisted by ferroelectrics

Shuaiqin Wu[1, 2], Guangjian Wu[1], Xudong Wang[1], Yan Chen[1], Tie Lin[1, 2], Hong Shen[1, 2], Weida Hu[1, 2, †], Xiangjian Meng[1, 2], Jianlu Wang[1, 2, †], and Junhao Chu[1, 2]

[1]State Key Laboratory of Infrared Physics, Shanghai Institute of Technical Physics, Chinese Academy of Sciences, Shanghai 200083, China

[2]University of Chinese Academy of Sciences, Beijing 100049, China

Abstract: During the past decades, transition metal dichalcogenides (TMDs) have received special focus for their unique properties in photoelectric detection. As one important member of TMDs, MoS_2 has been made into photodetector purely or combined with other materials, such as graphene, ionic liquid, and ferroelectric materials. Here, we report a gate-free MoS_2 phototransistor combined with organic ferroelectric material poly(vinylidene fluoride-trifluoroethylene) (P(VDF-TrFE)). In this device, the remnant polarization field in P(VDF-TrFE) is obtained from the piezoelectric force microscope (PFM) probe with a positive or negative bias, which can turn the dipoles from disorder to be the same direction. Then, the MoS_2 channel can be maintained at an accumulated state with downward polarization field modulation and a depleted state with upward polarization field modulation. Moreover, the P(VDF-TrFE) segregates MoS_2 from oxygen and water molecules around surroundings, which enables a cleaner surface state. As a photodetector, an ultra-low dark current of 10^{-11} A, on/off ration of more than 10^4 and a fast photoresponse time of 120 μs are achieved. This work provides a new method to make high-performance phototransistors assisted by the ferroelectric domain which can operate without a gate electrode and demonstrates great potential for ultra-low power consumption applications.

Key words: TMDs; MoS_2 phototransistor; P(VDF-TrFE); PFM; ultra-low power consumption

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Supplementary information

The transfer curves of MoS_2 transistor show large hysteresis whenever in fresh state or in P_{up} state. It has been reported that trapping states between semiconductor and substrate is the prior factor causing the observed hysteresis in MoS_2 transistor. Besides, the hysteresis would increase because of the photosensitivity of MoS_2 transistor when which is exposed to white illumination[1, 2].

References

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Correspondence to: W D Hu, wdhu@mail.sitp.ac.cn; J L Wang, jlwang@mail.sitp.ac.cn

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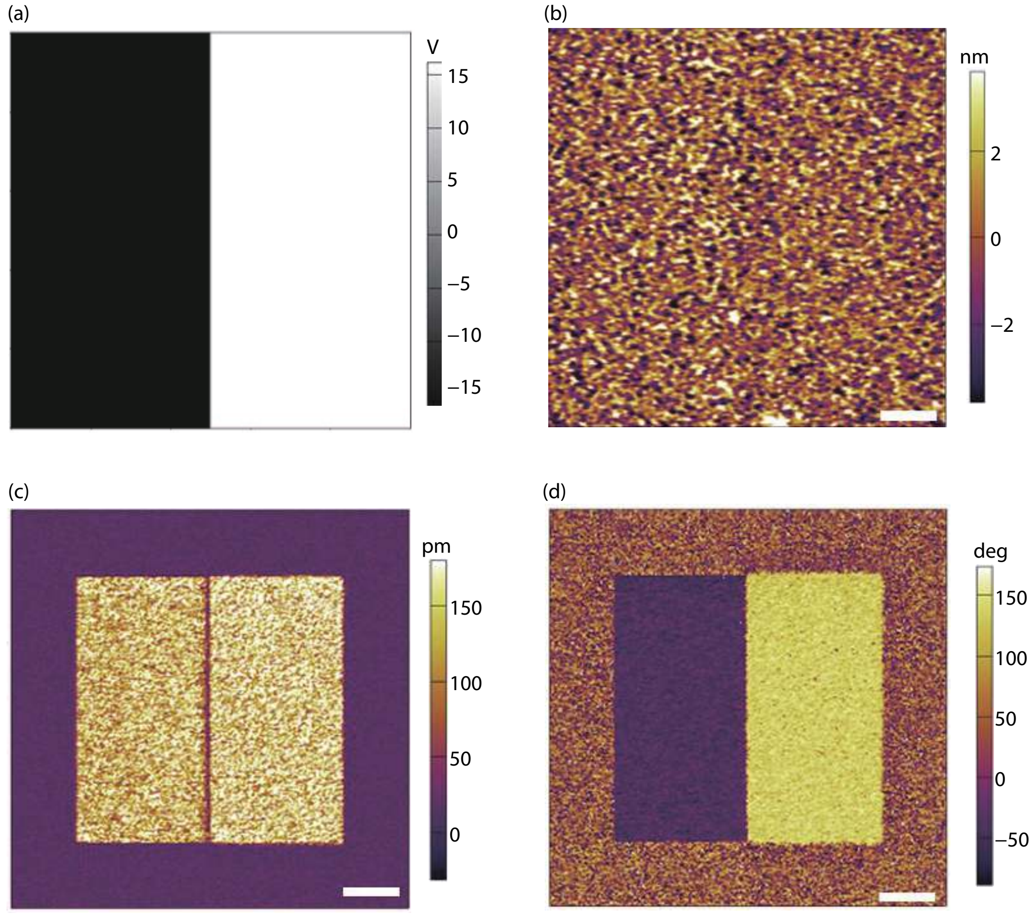

Fig. S1. (Color online) Polarizing the 50 nm-thick P(VDF-TrFE) film by PFM. (a) Voltage map. DC voltage was applied on P(VDF-TrFE) in a 10 × 10 μm^2 square shape in which a half part was applied −15 V and the other half part was applied +15 V. (b) Topography image, (c) amplitude image and (d) phase image were scanned in a 15 × 15 μm^2 square including the previous 10 × 10 μm^2 pattern in the middle place after polarization, scale bar is 2 μm.

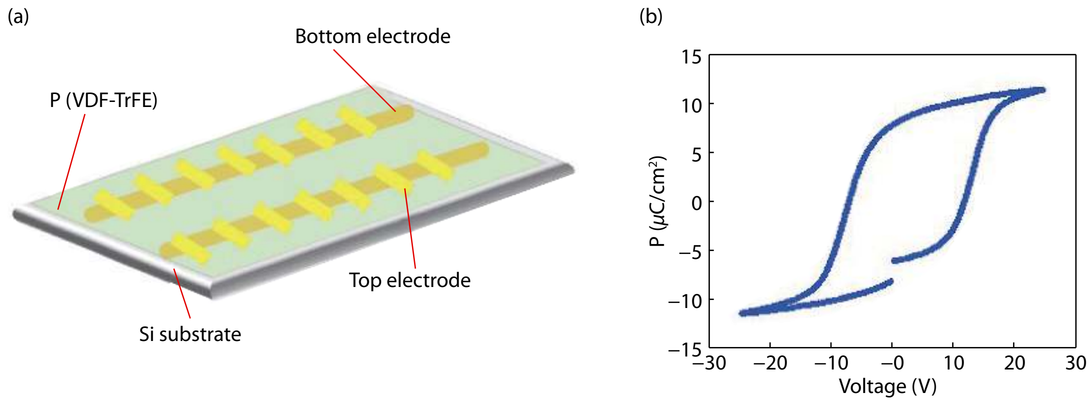

Fig. S2. (Color online) Ferroelectric hysteresis loop of a 50 nm-thick P(VDF-TrFE) capacitor. (a) The structure schemtic of the P(VDF-TrFE) capacitor sample. The top electrode is aluminum (Al, 20 nm) and the bottom electrode is Cr/Au (3/7 nm). (b) Ferroelectric hysteresis loop of P(VDF-TrFE) and the remnant polarization is about 10 μC/cm^2.

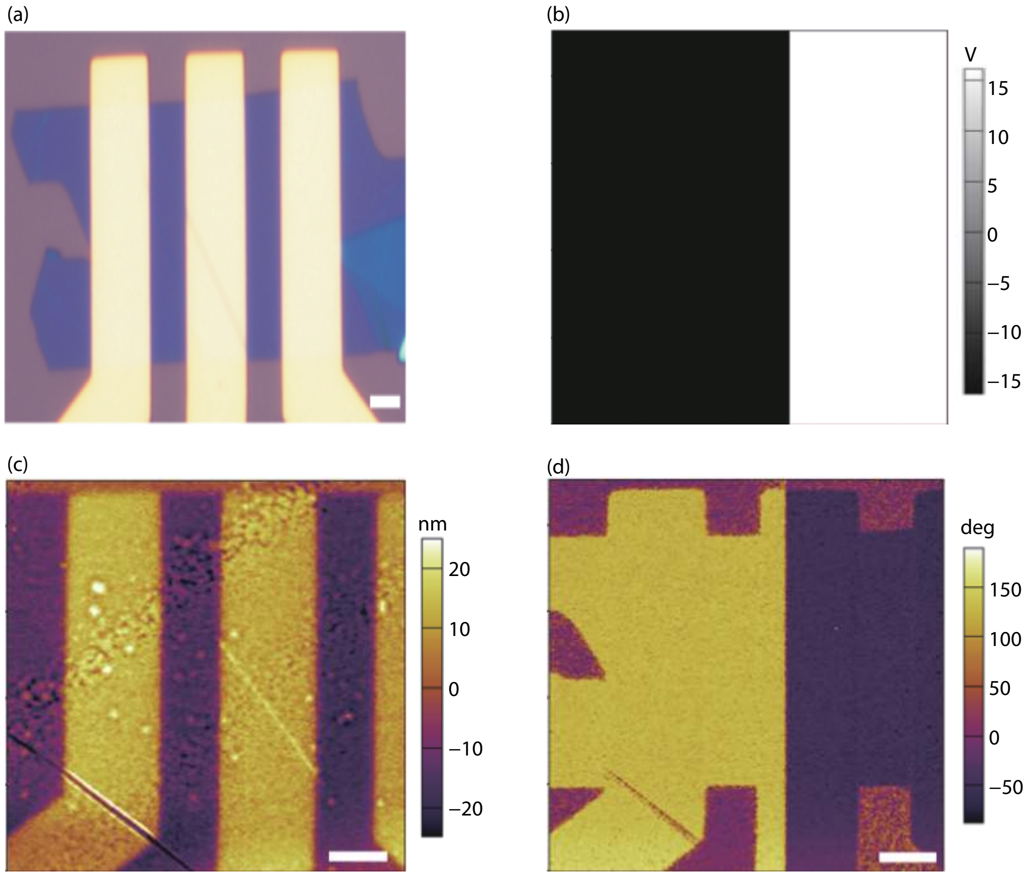

Fig. S3. (Color online) Polarizing the P(VDF-TrFE) film covering the MoS_2. (a) Optical image of an MoS_2 device covered by 50 nm-thick P(VDF-TrFE) film. (b) Pattern of the DC voltage applied on P(VDF-TrFE) film by PFM tip. (c) Topography image of the device. (d) 180° phase difference between two regions with upward and downward polarization, scale bar is 2.5 μm.

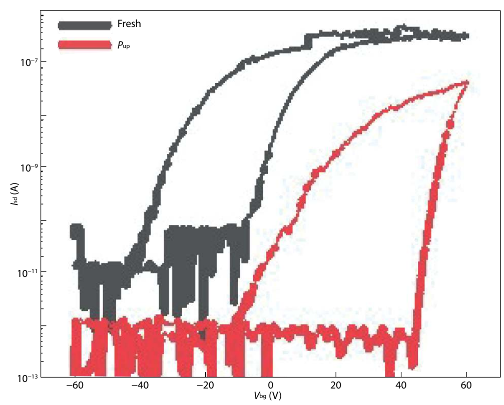

Fig. S4. (Color online) Transfer curves of MoS_2 transistor gated by SiO_2 backgate with before and after polarized P(VDF-TrFE) modulation.