Monolayer MoS_2 Phototransistors using Ferroelectric $Hf_{0.5}Zr_{0.5}O_2$ Dielectrics

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Atomically thin 2D materials such as MoS_2 exhibits interesting optoelectronic properties that have been utilized in applications such as photodetectors, light emitting diodes, and opto-valleytronic devices. Photodetectors are used in various applications such as image sensing, surveillance, and biomedical imaging. Research efforts in photodetectors have been focused towards exploring materials and device structures to improve the incident light absorption and light conversion efficiency. Steep slope transistor device structures that overcome the 60 mV/dec limitation due to the Boltzmann factor kT/q at room temperature holds a promising potential in photodetection applications. In particular, negative capacitance-based field effect transistors (NCFETs) are expected to overcome this constraint[1]. This device structure has a possibility to offer low I_{off} currents allowing for lower dark current suppression resulting in an increase in the light detection sensitivity and enhancement in the detection of weak light signals. In this study, we explore monolayer MoS_2 phototransistors driven by a ferroelectric capacitor consisting of a TiN/$Hf_{0.5}Zr_{0.5}O_2$ (HZO)/TiN/ZrO_2 gate stack as seen in Fig. 1a. The polarization vs. applied electric field in Fig. 1b shows the polarization hysteresis and the Landau-Khalatnikov fitting (orange curve) where the middle segment of the curve displays the region of the negative capacitance effect. A sub-60 mV/dec subthreshold swing was achieved and the dark current was measured in the range of ~10^{-14}A. The photoresponse under green light of the MoS_2 phototransistor can be seen in Fig. 1c. As a result, weak light intensities were detected with strong parallel shifting of the illumination curves, indicating that the dominating photocurrent generation comes from the photogating effect[2]. In addition, we evaluated its photodetection metrics as a potential promising sensitive low-powered photodetector.

Reference: [1] S. Salahuddin, S. Dutta, Nano Lett. 2008, 8, 405-410. [2] R. Nur et al., Commun. Mater. 2020, 103, 1. **Acknowledgement:** This work was partly based on results obtained from a project, JPNP14004, commissioned by the New Energy and Industrial Technology Development Organization (NEDO) and partly supported by JST-Mirai Program Grant Number JPMJMI20A1, and JST, CREST Grant Number JPMJCR2004.

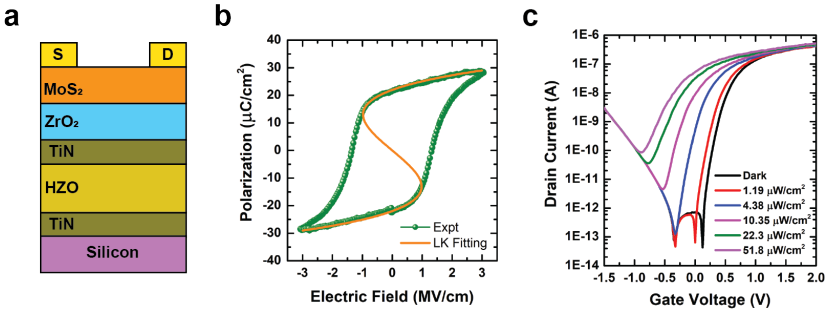

Figure 1 (a) Device structure of monolayer MoS_2 phototransistor. (b) Polarization-Electric Field measurement of a TiN/HZO/TiN capacitor at 1 kHz with annealing of 700°C.(c) Photoresponse under green light illumination.