High-Performance Nanoimprinted Perovskite Nanograting Photodetector

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Recently, the organolead halide perovskite (PS) has emerged as a promising material for next-generation, low-cost, high performance optoelectronic applications. Improving perovskite crystallinity and morphology is crucial to further enhance its optoelectrical properties. Meanwhile, nanoscale photodetectors have attracted tremendous attention for realization of high resolution miniaturized imaging system as they offer high sensitivity, ultra-fast response and capability to detect beyond the diffraction limit. In this work, we report high-performance hybrid organic-inorganic perovskite photodetector with highly crystalline nanograting structure implemented by nanoimprint lithography (NIL). The nanoimprinted perovskite nanograting photodetector (nano-PSPD) shows significantly enhanced responsivity and superior photocurrent to dark current ratio.

The perovskite thin film was spin coated on the Si substrate with 100nm thermally grown Si-oxide. One of the samples was then nanoimprinted using Si nanograting mold while another was not imprinted for reference. Fig. 1 shows SEM images of non-imprinted perovskite thin film (Fig. 1a) and imprinted perovskite nanograting thin film (Fig. 1b). The imprinted film shows much improved morphology and crystallinity with less grain boundaries. Metal-semiconductor-metal photodetectors were fabricated by evaporating 300 nm gold contact pads on both samples. The gap between contact pads is 25 μm in length and 100 μm in width. The inset graphs of Fig. 2 are schematic illustration of as-fabricated non-imprinted thin film perovskite photodetector (tf-PSPD, Fig. 2a, inset) and nanoimprinted perovskite nanograting photodetector (nano-PSPD, Fig. 2b, inset). Both devices were tested under 0.11 mW/cm^2 to 7.27 mW/cm^2 halogen light illumination and the corresponding I-V curves are plotted in Fig 2. The linear curves indicate a good ohmic contact between gold and perovskite. The nano-PSPD shows significantly better performance than tf-PSPD, with over 50 times improvement on illuminated current and nearly 10 times improvement on photocurrent to dark current ratio at 7.27mW/cm^2 illumination with driving voltage of 1V. Both photodetectors were also tested under 466nm blue LED illumination. Fig. 3a shows the relation of photodetector current versus LED forward current. A commercial Si photodiode was used to calibrate the irradiance. The responsivity of nano-PSPD and tf-PSPD were then calculated and plotted against the irradiance, as shown in Fig. 3b. The responsivity of nano-PSPD is about 20 times that of tf-PSPD and > 10 times of commercial Si photodiode in all detection range. The highest responsivity of nano-PSPD is evaluated as 47A/W at lowest irradiance 0.5nW/cm^2,which is >100 times of commercial Si photodiode. Further improvement is discussed in P-I-N diode structures which we are creating.

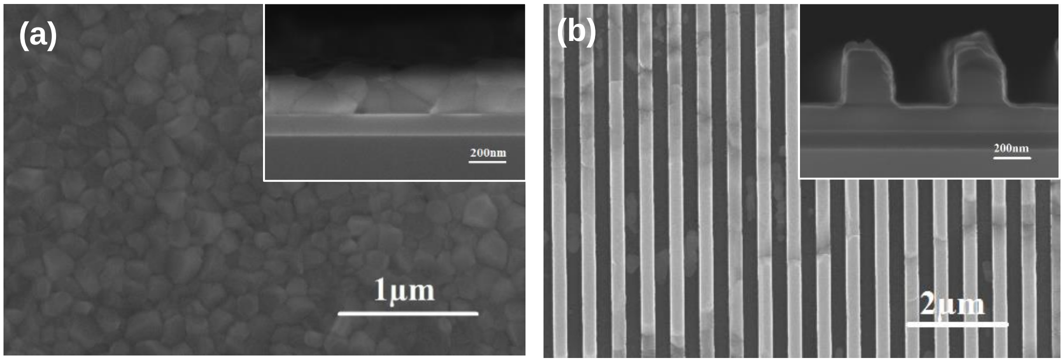

Figure 1: SEM images of (a) non-imprinted perovskite thin film and (b) imprinted perovskite nano-grating thin film. The inset shows the cross-section view.

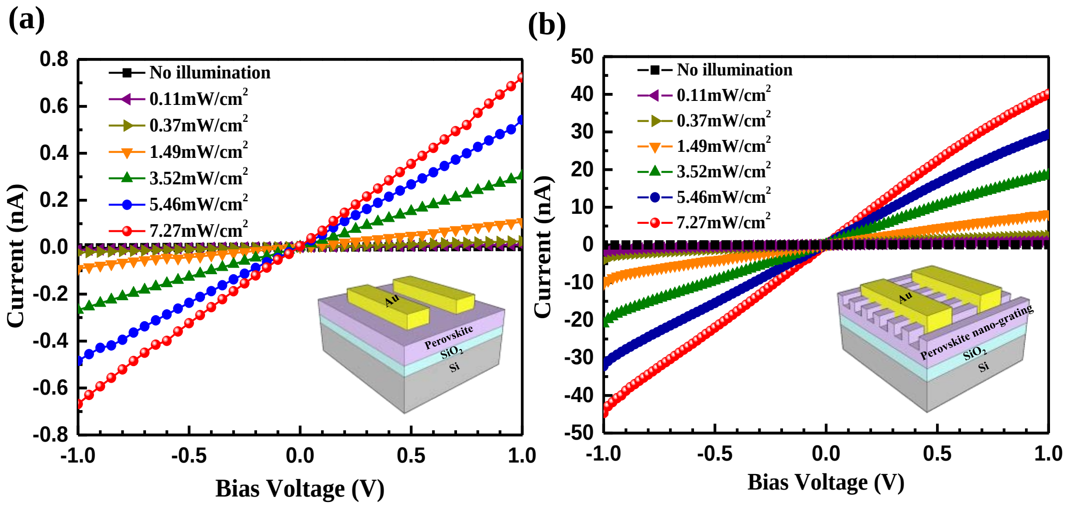

Figure 2: I-V characteristics and schematic view (inset graphs) of (a) non-imprinted perovskite photodetector and (b) nanoimprinted perovskite nano-grating photodetector.

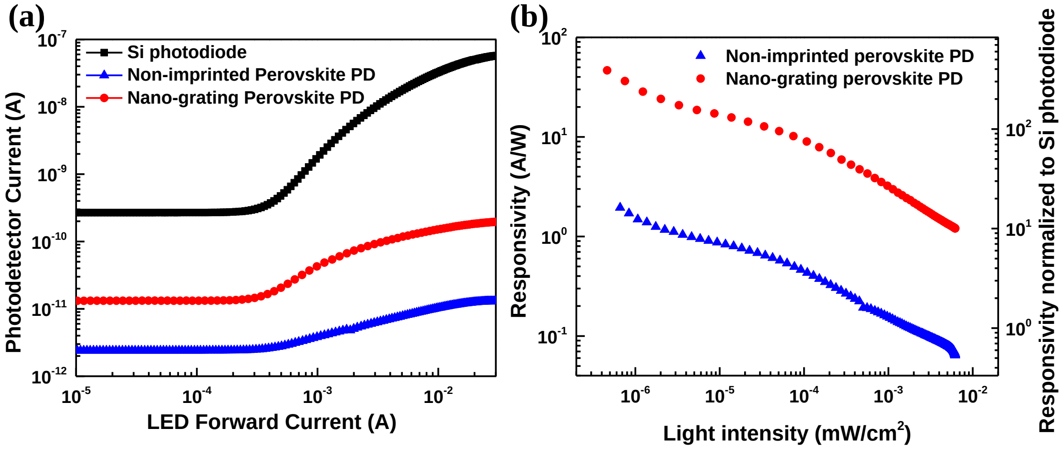

Figure 3: (a) Plot of photodetector current vs LED forward current (b) Light intensity dependent responsivity at 1=466nm with biasing voltage of 1V. Light intensity was calibrated with commercial Si photodiode.