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Electronic Supplementary Information

High-Performance Stretchable Photodetector based on $CH_3NH_3PbI_3$ Microwires and Graphene

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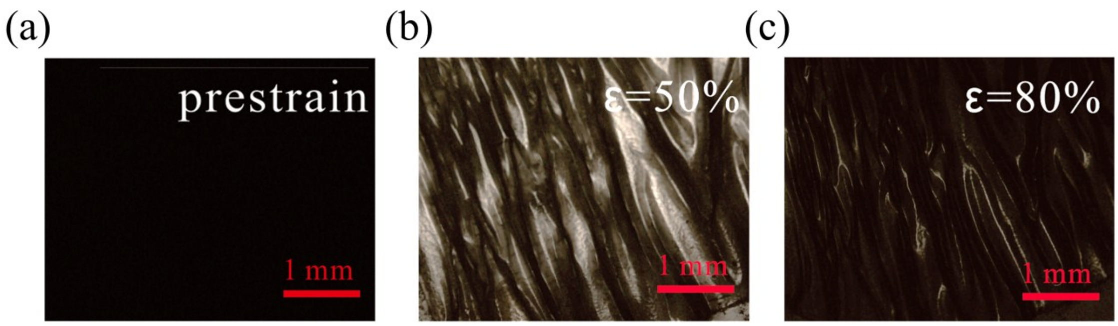

Fig. S1. a) Photo of device before releasing (i.e., under 100% strain). b) After releasing and then stretching to 50% strain. c) After stretching to 80% strain.

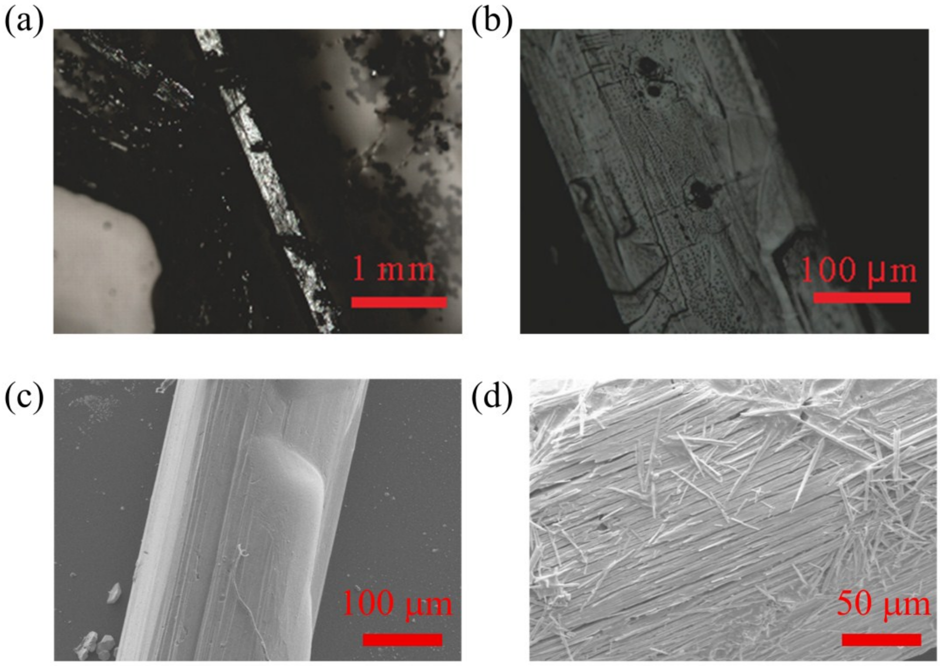

Fig. S2. (a-b) Optical photographs of the $CH_3NH_3PbI_3$ mirowires. (c-d) SEM photographs of the $CH_3NH_3PbI_3$ microwires.

Fig. S3 demonstrates the PL spectra of samples under different temperature during the conversion from monohydrate perovskite to pure perovskite. In Fig. S3(a)-(g), the samples were excited by 510 nm laser. The peaks at 575 nm, 638nm, 703 nm can be assigned to monohydrate perovskite. However, the intensity of the peaks decreased when the temperature increased to 29 °C, indicating a change from yellow acicular hydrate to black $CH_3NH_3PbI_3$ perovskite. When changed the excitation wavelength from 360 nm to 510 nm, it showed a peak at 740 nm which was attributed to $CH_3NH_3PbI_3$ perovskite (Fig. S3(h)). It also reveals the turning from $CH_3NH_3PbI_3 \cdot H_2O$ to CH_3NH_3PbI.

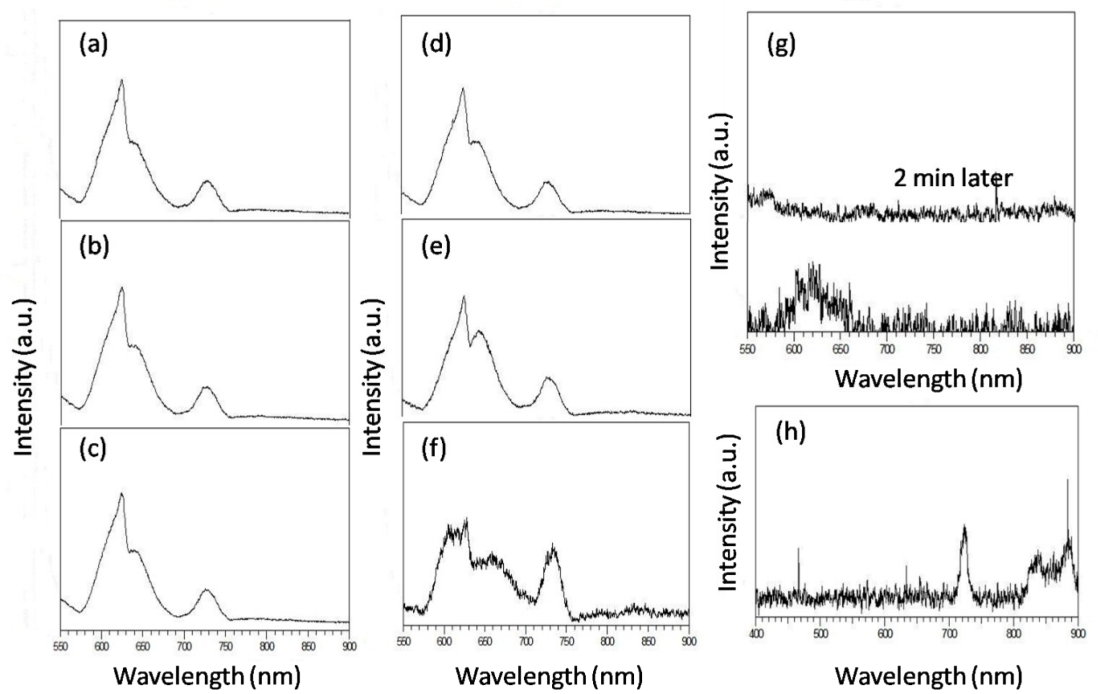

Fig. S3. PL spectra of the sample under (a) 23 °C, (b) 24 °C, (c) 25 °C, (d) 26 °C, (e) 27 °C, (f) 28 °C, the excitation wavelength is 510 nm. (g) PL spectra under 29 °C and 2 minutes later, the excitation wavelength is 510 nm. (h) PL spectrum under 29 °C under the excitation wavelength of 360 nm.

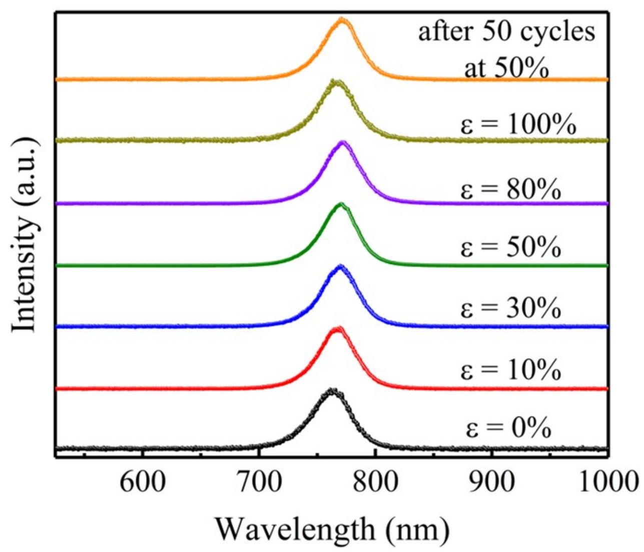

Fig. S4. PL spectra of the device at varying stretching strains and after repetitive stretching to 50% stretching strain for 50 cycles.

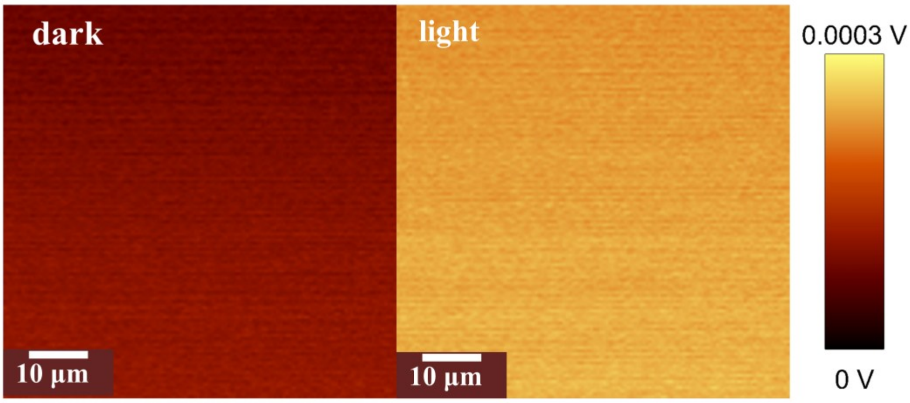

Fig.S5. Mapping voltage of device under dark and light.

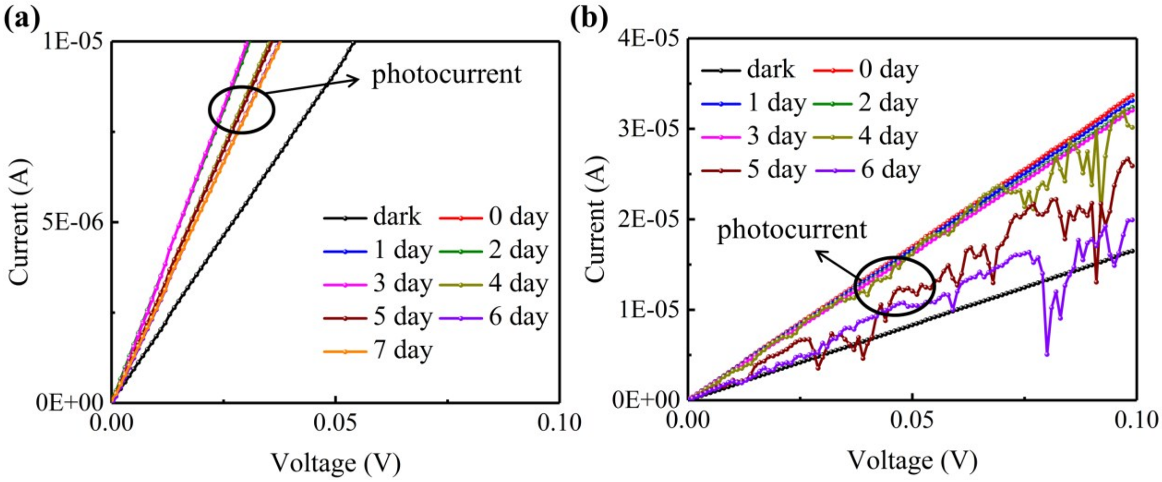

Fig. S6. Stabilities of (a) $CH_3NH_3PbI_3$ based PD under ambient air at ~10% humidity and (b) $CH_3NH_3PbI_3$ based PD under ambient air at 50%~55% humidity.

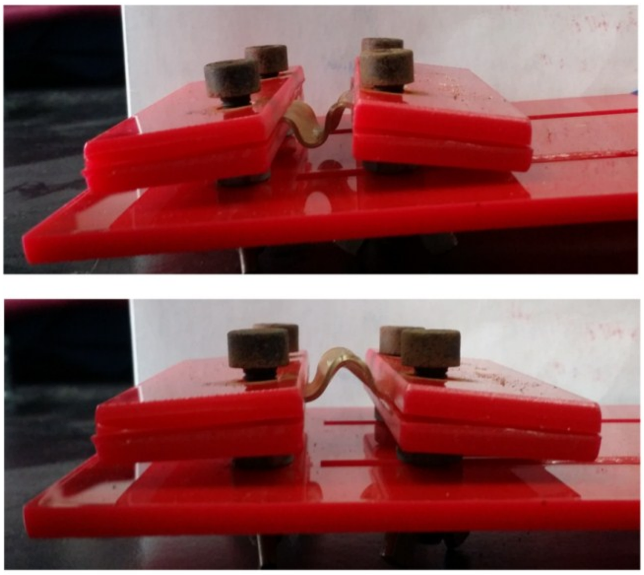

Fig. S7. Photographs of the flexible $CH_3NH_3PbI_3$ microwires PD under (a) concave and (b) convex bending strain with a bending radius of 6 mm.

The change of the normalized photocurrent under 0%, 10%, 30%, 50%, 100% strain respectively under 633 nm light illumination is shown in Fig. S5. It declined from 1 to 0.2 when stretching the device from 0% strain to 100% strain. The photocurrent of the PD was reduced by 80%, which could also be attributed to the two reasons noted in the main text. In addition, the device responses after 100 cycles of stretching to 50% strain under 375, 532, 633 nm light illumination separately are shown in Fig. S6. These results demonstrate the good repeatability and broadband response of the PD.

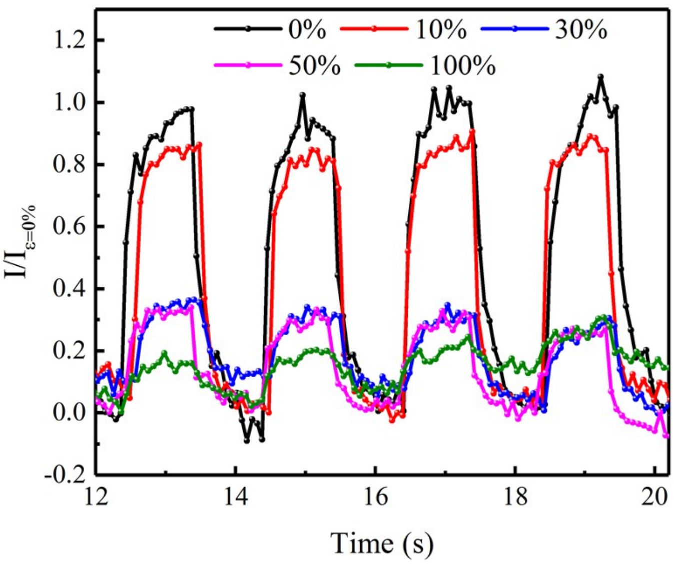

Fig. S8. Photoresponse of the PD under 633 nm light illumination when stretching from 0% strain to 100% strain.

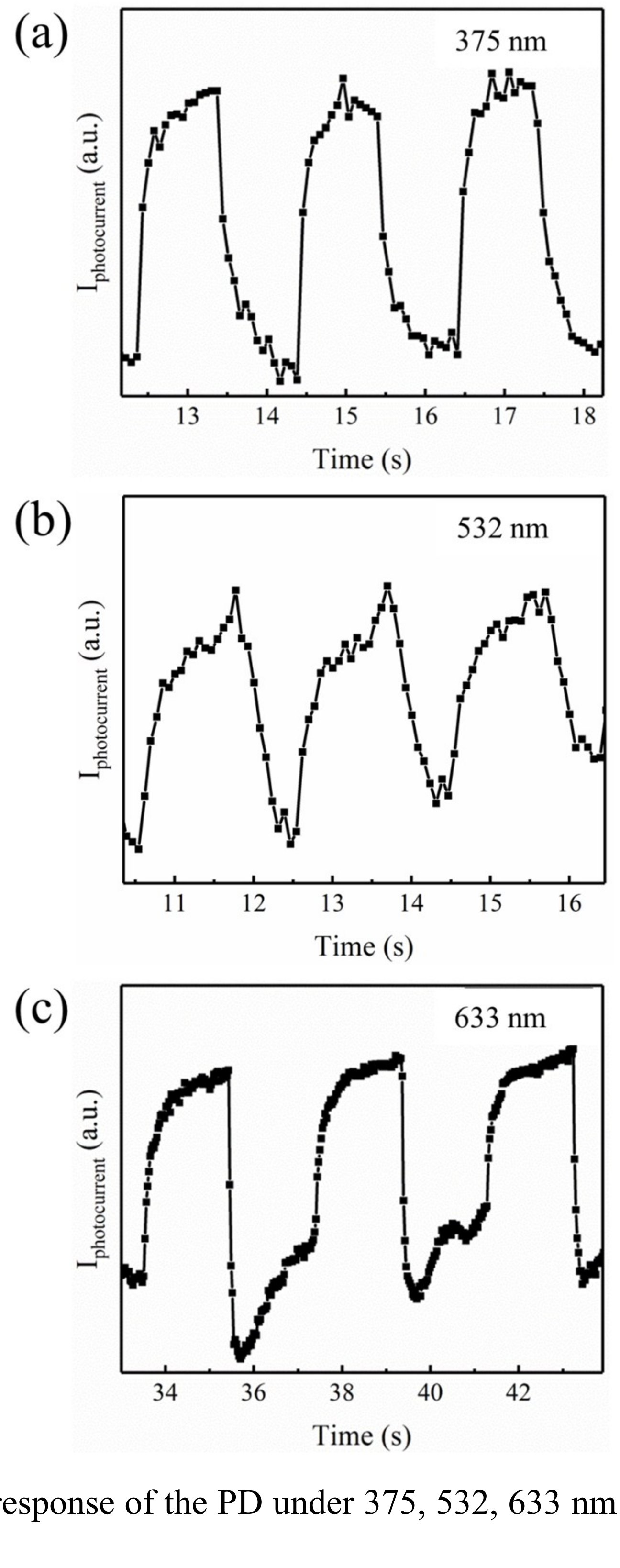

Fig. S9. Photoresponse of the PD under 375, 532, 633 nm light after 100-cycle stretching to 50% strain.

The external quantum efficiency can be defined as: $EQE = \frac{Rhc}{e\lambda}$, where R is the responsivity, h is the Planck's constant, c is the velocity of light, e is the electron charge, λ is the wavelength of incident light. The *EQE* declined from 0.36% to 0.09% under irradiance power from 270 $mW \cdot cm^{-2}$ to 13.5 $mW \cdot cm^{-2}$ as shown in Fig. S10.

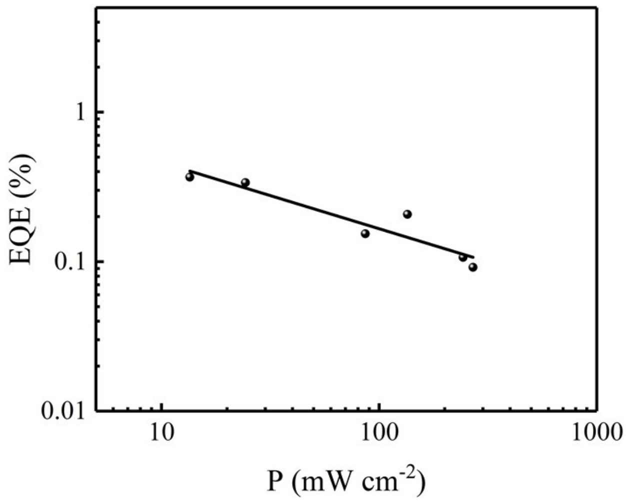

Fig. S10. *EQE* of the device under varying irradiance power densities.

We measured the noise current of the devices using a lock-in amplifier. The *NEP* of the device can be expressed as $NEP = \frac{i_n}{R_\lambda}$, where i_n is the dark current noise and R_λ is the responsivityof the devices. The noise spectra of stretchable device at frequencies from 1 to 5 Hz are shown in Fig. S11. The *NEP* of devices for a bandwidth of 1 Hz at 532 nm are calculated to be 1.69×10^{-6} A/Hz^{-1}. Compared with photodetectors with different active area, the device active area should be considered. Thus, we can obtain the specific detectivity $D^* = \frac{\sqrt{AB}}{NEP}$, where A is the device area. Hence, the D^* are calculated to be 1.78×10^5 cm $Hz^{1/2}$ W^{-1}.

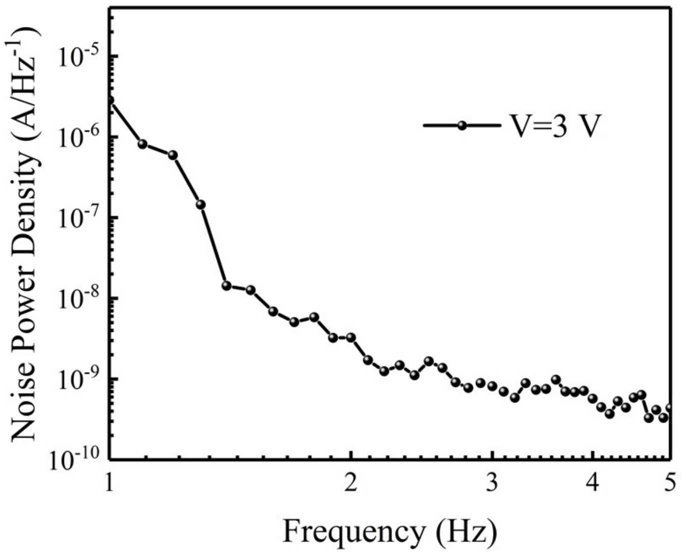

Fig. S11. Noise spectrum of the device under 3 V bias.

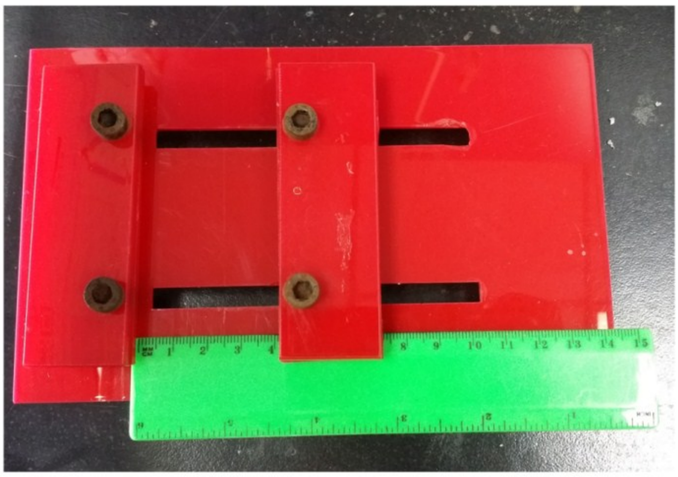

Fig. S12. Photograph of the homemade stretching instrument.