Supporting Information

Enhanced current rectification and self-powered photoresponse in multilayer p-$MoTe_2$/n-MoS_2 van der Waals heterojunctions

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Experimental section:

Device Fabrication. The multilayer $MoTe_2/MoS_2$ heterojunctions were fabricated by the dry transfer method. Firstly, both multilayer MoS_2 and $MoTe_2$ flakes were exfoliated by micromechanical cleavage approach from bulk MoS_2 and $MoTe_2$ crystals and transferred onto two separate pieces of Si substrates coating with 300 nm-thick SiO_2 layer. And then, the polymethyl methacrylate (PMMA) solution was spin-coated onto the substrate with MoS_2 multilayer, using rotating speed of 3000 rpm/s. After annealing at 180 ℃ for 10 minutes, the PMMA-coated substrate was immersed in 5 M NaOH solution at 60 ℃ and PMMA would be floating with multilayer MoS_2 subsequently. After that, the PMMA/MoS_2 film was transferred onto another substrate with $MoTe_2$ multilayer to superimpose them together, by adjusting the position of flakes under the microscope. Finally, the entire substrate was soaked with acetone to remove the PMMA, leaving the $MoTe_2/MoS_2$ heterojunctions on the substrate.

The FETs of $MoTe_2/MoS_2$ heterojunctions were fabricated using electron-beam lithography (Raith150). Then 20-nm-thick Ni layer followed by 50-nm-thick Au layer was deposited to fabricate contact metal electrodes by electron beam evaporation (EB700-I) and they were lift-off in acetone.

Characterizations and measurements. The TEM images were

obtained using a JEM-2100F at an acceleration voltage of 200 KV. The selected area electron diffraction (SAED) patterns were also collected by the TEM setup. The Raman measurements were performed by Raman spectrometer (Renishaw Model inVia-Reflex) with the excitation of He–Ne laser (532 nm). Samples were further characterized by Atomic force microscope (ICON) to confirm the thickness of layers. Electrical and optoelectronic behaviors were measured using a semiconductor parameter analyzer and shielded probe station.

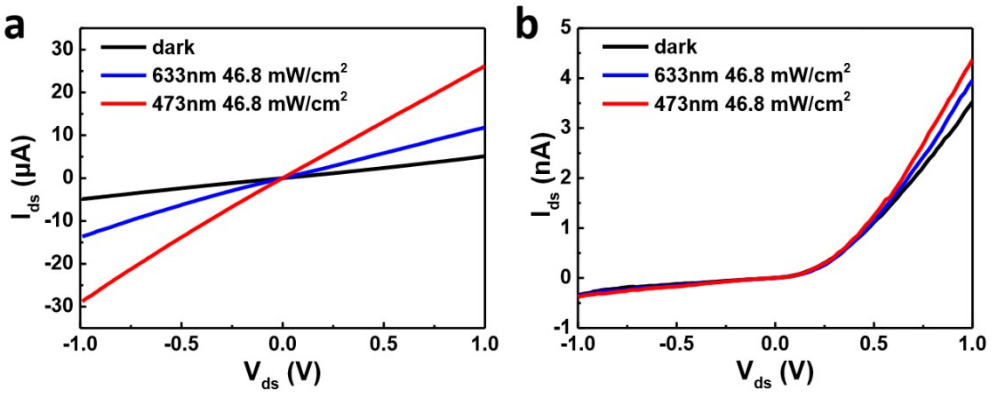

Fig. S1. I_{ds} - V_{ds} characteristics of the individual (a) MoS_2 flakes and (b) $MoTe_2$ flakes under dark and different laser radiation.

For MoS_2, the linear I_{ds} - V_{ds} curves indicate that the contact between MoS_2 and Ni/Au electrodes are well ohmic. And I_{ds} increases under light illumination, with on/off ratio of 2.32 and 5.14 at laser wavelength of 633 nm and 473 nm, respectively. For $MoTe_2$, the nonlinear I_{ds}-V_{ds} characteristics suggest that Schottky contacts are formed between the Ni/Au metal pads and $MoTe_2$, with a current on/off ratio of ~10. Under illumination, the increase rate of I_{ds} is smaller than that of individual MoS_2.

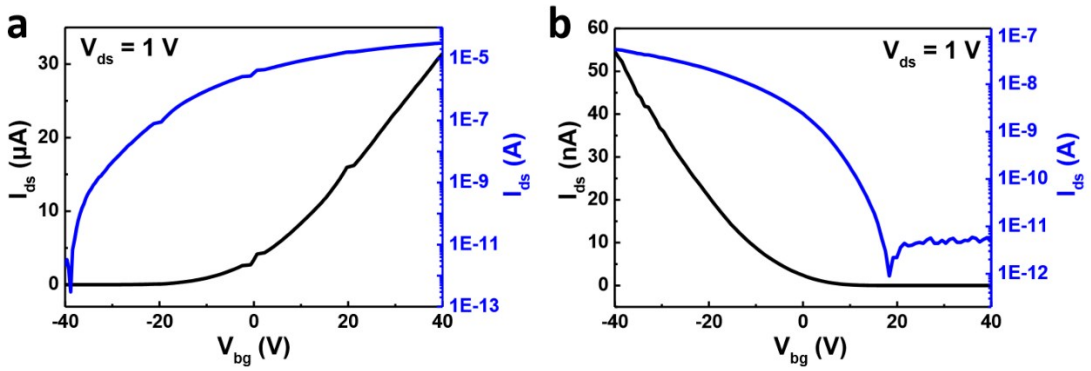

Fig. S2. Transfer characteristics of individual (a) MoS_2 flakes (V_{ds} = 1 V) and (b) $MoTe_2$ flakes (V_{ds} = 1 V).

For MoS_2, I_{ds} increases with increasing of V_{bg}, indicating that MoS_2 flakes possess obvious n-type behavior. On the contrary, $MoTe_2$ flakes show p-type behavior, since I_{ds} decreases with increase of V_{bg}.

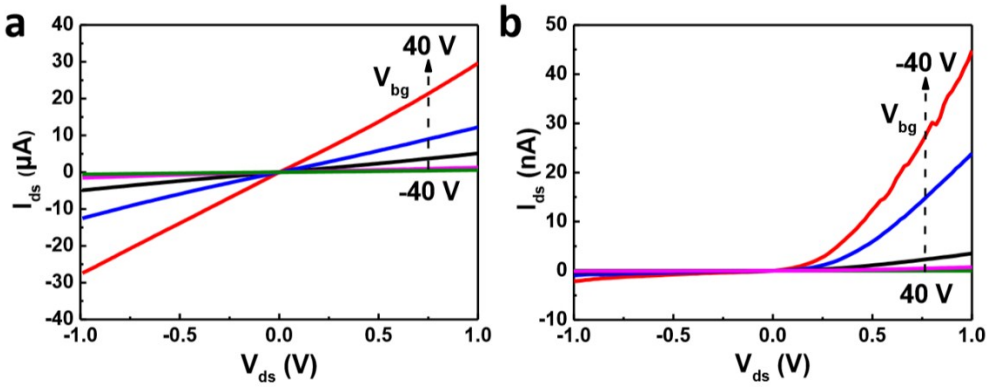

Fig. S3. Output characteristics of the individual (a) MoS_2 flakes and (b) $MoTe_2$ flakes (V_{bg} = -40 ~ 40 V).