Pronounced Photovoltaic response from PN-junctions of Multilayered $MoSe_2$ on *h*-BN

Pradhan, N.R.; Memaran, S.; Lu, Z.; Rhodes, D.; Ludwig, J.; Zhou, Q. (NHMFL); Ajayan, P.M. (Rice U.); Smirnov, D.; Balicas, L. (NHMFL)

Introduction

Transition metal dichalcogenides (TMDs) are emerging as a major research frontier due to their unique electronic and optical properties. Monolayer TMDs display unique optical as well as optoelectronic properties, while heterostructures incorporating with graphene display pronounced photoconducting and photovoltaic responses. Here we investigated the diode rectification and enhanced photoconducting as well as photovoltaic, in lateral PN junctions based on multilayered ambipolar MoSe2 crystals stacked on to *h*-BN. Our PN junction composed of 10 atomic layers are translucent enough to yield photoresponsivity of 1A/W, external quantum efficiency exceeding 30%, short circuit currents exceeding 10^3 A/cm^2 and photovoltaic efficiencies surpassing 5% with fill factor of 70%. These values compare favorably for promising transparent photovoltaic cells.

Experimental

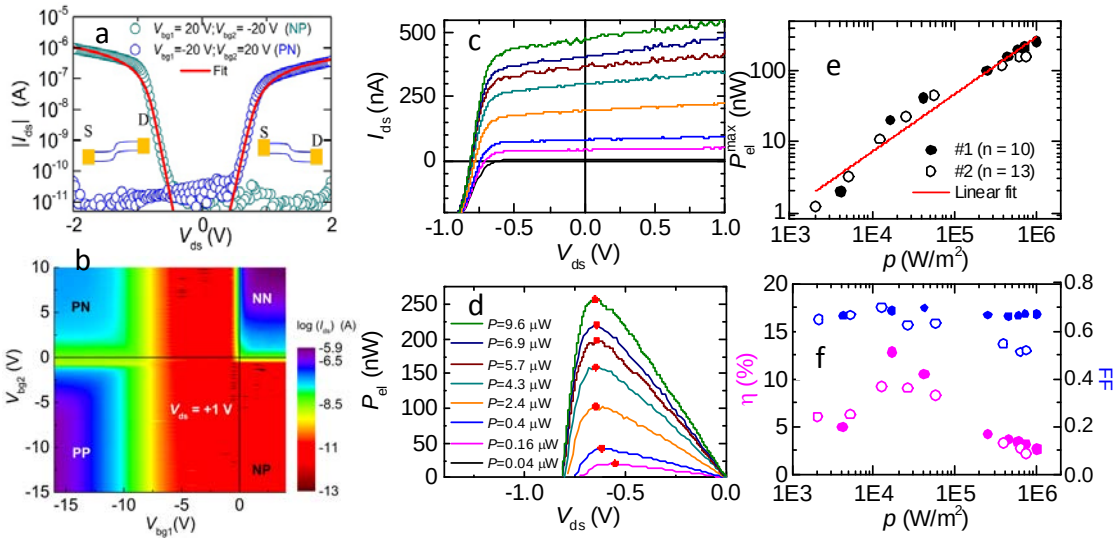

Figure (**a**) Diode response in semi Logarithmic scale, drain to source current I_{ds} as a function of excitation voltage V_{ds} for two configuration of the back gate voltages i.e. $V_{bg1} = V_{bg2} = \pm 20$V (for NP) and $V_{bg2} = V_{bg1} = \pm 20$V (for PN). N stand for electron accumulation and P stand for hole accumulation at the interface. Red solid lines are the theoretical fit to Shockley diode equation. The ideality factor obtained from these fits are 1.6 and 1.8 respectively for V_{ds} <0 and V_{ds} >0. (**b**) Contour plot of the diode response PN, NP, PP and NN in logarithmic I_{ds} as a function of both back gate voltages V_{bg1} and V_{bg2} at excitation voltage V_{ds} = 1V. Color represents the magnitude of current through the device. (**c**) Represents the photovoltaic response of the PN junction diode, I_{ds} vs V_{ds} with several illumination laser power *P*. (e) Photogenerated output electrical power $P_{el} = I_{ds} \times V_{ds}$ as a function of V_{ds} with several illumination laser power estimated from fig. (c). (d) Log-log plot of maximum extracted output electrical power P_{el}^{max} as a function of input optical power density *p* for two devices shows linear response with power law $p^{0.8}$. (f) Photovoltaic efficiency $\eta = P_{el}^{max}/P$ for both samples (magenta markers) and photovoltaic fill-factor $FF = P_{el}^{max}/(I_{ds} \times V_{oc})$ (blue markers) as a function of *p*. The maximum efficiency reaches ~13% and decreases as the illumination power density increases.

Conclusions

We observed sizable photovoltaic effect with efficiency > 10% on few atomic layer thick, nearly transparent ambipolar $MoSe_2$ PN junction devices on *h*-BN substrate. The diode rectification is ~10^5 and ideality factor is 1.6. These results show promising application of $MoSe_2$ as a photovoltaic power generation with additional improvement of device quality and using plasmonic nanostructure to enhance the efficiency.

Acknowledgements

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References:

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