Strain-Induced Band Gap Narrowing in Crumpled MoS_2 for Geometry-Controlled Exclusive Photon Management and NIR light Detection

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Developing flexible/stretchable optoelectronic devices like imaging systems, photodetectors, and light-emitting devices, which can operate in a wide wavelength range including near-infra-red (NIR) spectrum is of immense interest for security, telecommunications, and biomedical applications [1]. The direct band gap nature of MoS_2 makes it a promising material in the field of optoelectronics with high light absorption efficiency and superior mechanical and electrical properties [2,3]. Although MoS_2 is extensively used in flexible electronics, the optical activity of MoS_2-based devices is fundamentally limited in visible wavelength range by its optical band gap (1.86 eV). In this study, we report the reduction in the band gap of metal organic chemical vapour deposition (MOCVD)-grown MoS_2 with the application of tensile strain into its lattice by creating crumpled structures via transferring MoS_2 on a stretchable elastomeric substrate (Figure 1a). The photo sensing unit was designed as graphene/MoS_2/graphene metal–semiconductor-metal (MSM) configuration on a polymeric substrate (Figure 1b). Here, monolayer MoS_2 used as the active sensing material, whereas, CVD-grown graphene serves as contact electrodes with supplying the necessary mechanical flexibility to the device. The NIR light sensing capability of strained MoS_2 was utilized to develop a prototype NIR image sensor by arranging crumpled MoS_2-based photo-sensing pixels in 6×6 array. The geometry-controlled, self-sustained strain induction in MoS_2 provided exclusive photon management with the shortening of the optical band gap and enhanced photoresponse beyond the conventional absorption limit of MoS_2 (Figure 1c). The combination of mechanical resilience of MoS_2 and graphene with self-sustained strain induction in the crumpled structures provide a new approach in the development of NIR detectors for future imaging devices on mechanically flexible and stretchable platforms.

References

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[2] Kean You Thai et al. ACS Nano 15, (2021) 12836–12846.
[3] Anh Tuan Hoang et al. Nature Nanotechnology, 18 (2023) 1439–1447.

Figures

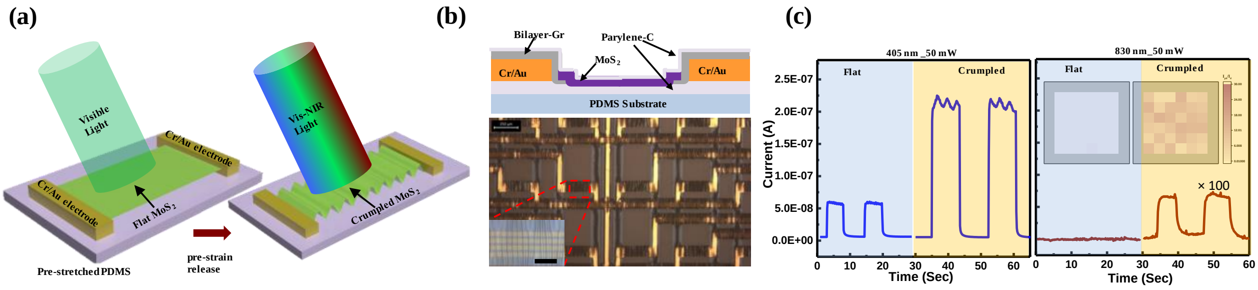

Figure 1: (a) Schematic representation of visible to NIR light detection in crumpled MoS_2 device, (b) Device structure, (c) Observed photocurrent plots with 405 and 830 nm light exposure.