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Electric Double Layer Light-Emitting Diodes of Transition Metal Dichalcogenide Monolayers

Transition metal dichalcogenide (TMDC) monolayers, such as molybdenum disulfide (MoS_2) and tungsten diselenide (WSe_2), have attracted strong attention as novel graphene-like materials due to their large bandgap (1−2 eV) and excellent transport properties. Moreover, the thickness of monolayer TMDCs is less than 1 nm, which is one of the thinnest materials, and it leads to strong confinement effects, resulting in large binding energy of exciton (> 100 meV) and formation of charged excitons. Particularly, due to their layered structure, there are no dangling-bond states on the surface of TMDC monolayers and it could be an ideal quantum well, providing potential as novel optoelectronic functionalities and devices [1,2].

Although the optical properties of TMDCs are very promising, light-emitting devices require intentional doping techniques to form p-n junction [3]. However, reliable doping methods for TMDCs have not yet been fully established. Therefore, the fabrication of TMDC light-emitting devices are still limited, and this fundamental barrier has made investigating electroluminescence (EL) properties of TMDCs inevitably difficult.

To overcome this issue, we recently proposed electric double layer light-emitting diodes (EDLEDs) [4] based on the electrolyte-gating method [5-10], which is very similar to the light-emitting electrochemical cell of organic polymeric materials [11,12]. I will explain the detail operational mechanism of EDLEDs and our recent progress. Here, we use this technique to form p-n junction (Fig. 1) and apply this method into various forms of TMDCs, such as monolayer polycrystalline films (Fig. 2), single crystalline flakes, and lateral heterojunctions (Fig. 3), to achieve photo-detection (Fig. 4) [13] and EL emission [4,14,15]. Particularly, using single crystal and lateral heterojunctions samples, we have performed temperature and position dependent measurements of EL and investigated their optical properties. Very interestingly, we observed robust circularly polarized EL emission, arising from spin-valley coupling in TMDCs. Finally, we clarified that these results are explained by the strain induced valley selection, resulting in chiral EL at room temperature. Our approach paves a versatile way for using TMDCs in discovering new functional optoelectronic and valleytronic devices.

References

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Figures

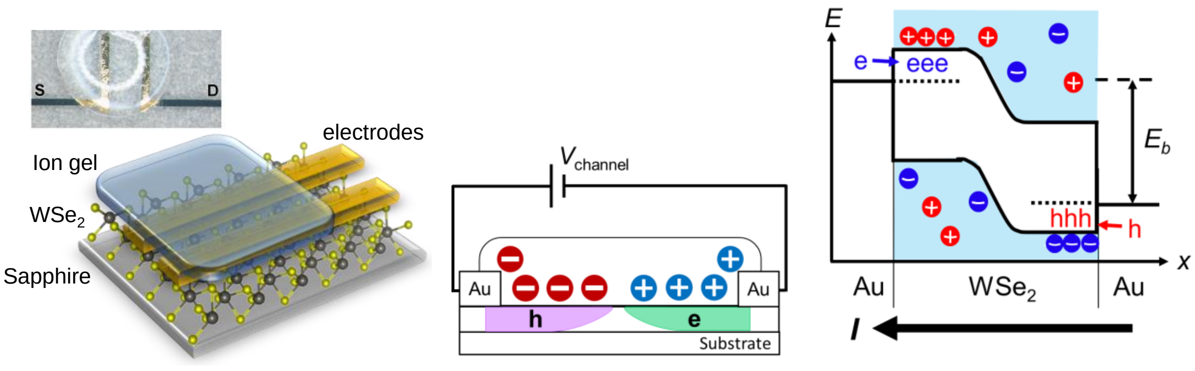

Figure 1: Schematic representation of electric double layer light-emitting diodes (EDLEDs)

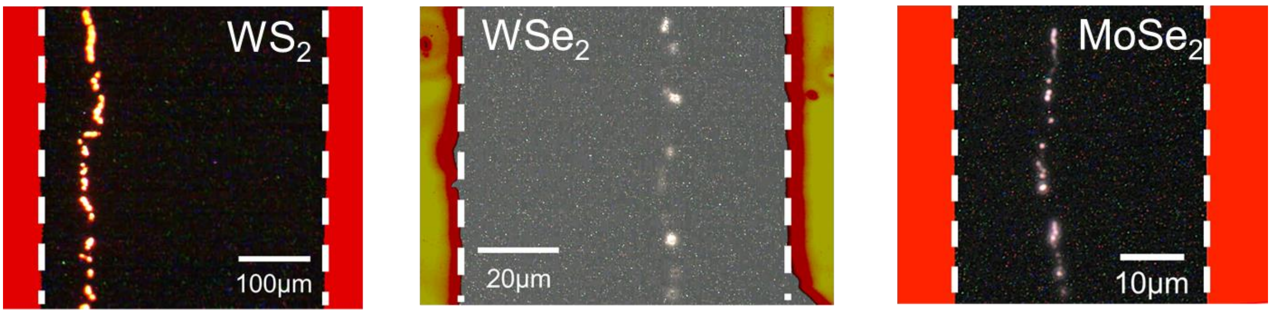

Figure 2: Electroluminescence (EL) from monolayer polycrystalline films such as WS_2, WSe_2 and $MoSe_2$

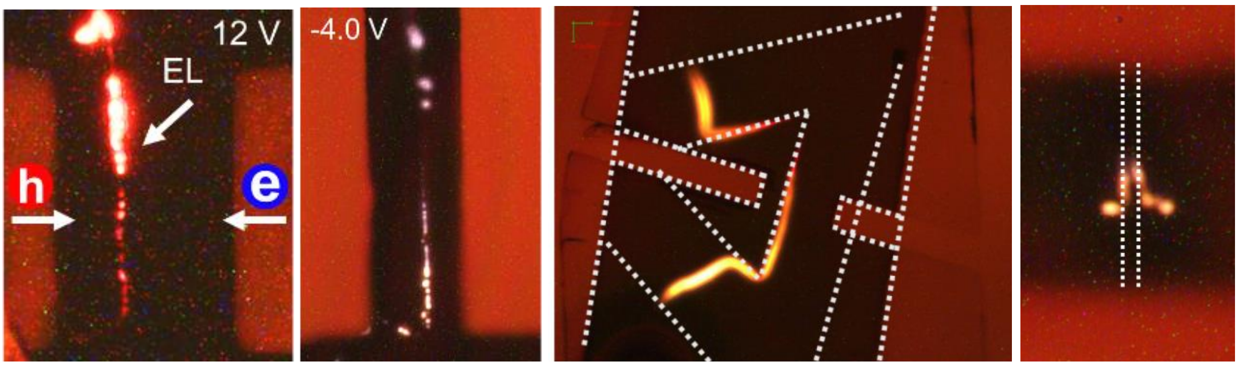

Figure 3: Electroluminescence (EL) from lateral heterojunctions such as WS_2/MoS_2, $WSe_2/MoSe_2$ and WS_2/WSe_2

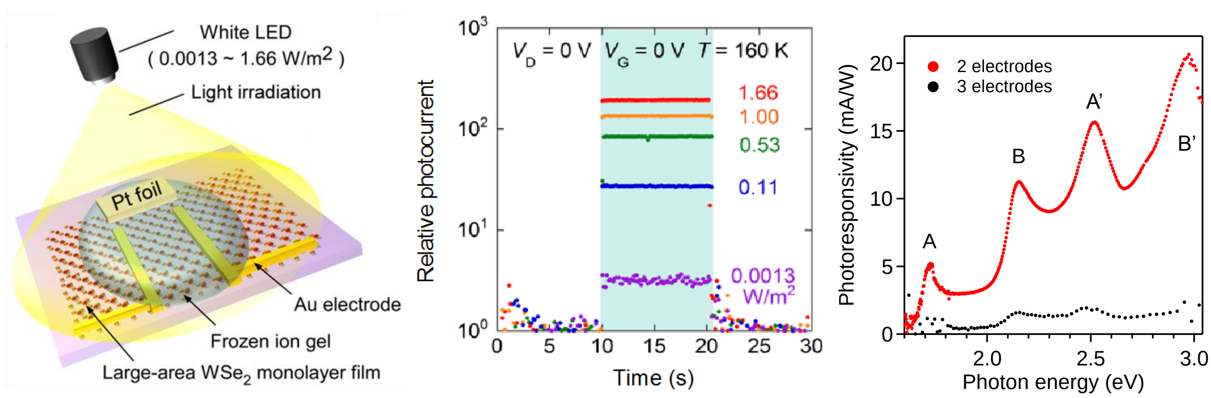

Figure 4: Photo-detection based on electric double layer light-emitting diodes (EDLEDs)