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Room-Temperature Chiral Light-Emitting Devices *via* Strained Monolayer Semiconductors

The valley contrasted electronic structure in monolayer transition metal dichalcogenides (TMDCs) provides unique optical functionalities, such us anomalous Hall effects and circularly polarized light emission [1]. In particular, the electrical control of circularly polarized light emission is one of the most desired device applications toward opto-valleytronics. Although several experimental demonstrations of chiral light-emitting devices have been reported, such as the electrolyte-gated transistors and the spin injections to the heterostructures, they have mostly realized at low temperatures and/or required high magnetic fields [2-4]. Therefore, these techniques have been lack of practical utilities, and thus, the light-emitting devices that can control valley-polarized electroluminescence (EL) at room temperature are significant challenge. Interestingly, we recently found out that the local strains implanted inside CVD-grown TMDC monolayers might serve as a key role to generate circularly polarized EL nearly room temperature [5]. Moreover, the recent paper revealed the strain-induced valley magnetizations in MoS_2, and that magnetization effects were also obtained at room temperature [6]. On the basis of these observations, here, we try to realize the room-temperature chiral light-emitting devices by combining electrolyte-based light-emitting structures with strained TMDC monolayers.

The monolayer WS_2 flakes were grown on sapphire substrates by CVD method, followed by transferring them onto PEN substrates, as shown in Fig. 1a [7,8]. After that, two Au electrodes were deposited on monolayer flakes. Finally, thin ion-gel films, a mixture of ionic liquid, [EMIM][TFSI] (Fig. 1b, left), and tri-block co-polymer, PS-PMMA-PS (Fig. 1b, right), were spin-coated on the surfaces of the monolayers to construct two-terminal light-emitting structures (Fig. 1c) [9,10]. The devices were set on the home-built bending stage with the polarization-resolved optical set-up, where is combined a 1/4 wave plate with a linear polarizer. Just by applying voltage between two electrodes, the EL is generated from the electrolyte-induced p-i-n junctions (Fig. 1c). The helicity of EL (σ^+ and σ^-) were selectively detected by controlling the angle of 1/4 wave plate.

We firstly performed the PL mapping for channel regions of the devices with flat and strained conditions. The obvious red-shifts of PL peak energy were obtained, which directly indicates the strain-induced band shrinkage and corresponds to 1 % uniaxial strain induced in the monolayers. Next, we applied AC voltage to the devices to integrate EL intensity, and finally, a Si photodiode was placed on the top of the devices to collect each helicity of EL as the photocurrents (Fig. 2). It is noted that, the measured photocurrents were integrated by all pulsed voltages to evaluate EL polarizations. As shown in the left panel of Fig. 2, we observed EL polarizations ($P = [\sigma^+ - \sigma^-]/[\sigma^+ + \sigma^-]$) up to +20 % at room temperature, in which the photocurrents of the σ^+ component were greater than those of the σ^- (the shaded area in Fig. 2), with the presence of the strain effects and the electrical currents. On the other hand, there was no chiral EL in the flat conditioned devices. In addition, we also confirmed similar robust EL polarizations in another device, meaning the reproducible performances. Interestingly, we were able to switch EL polarizations (P ~ -6 %) through by inversing the current directions, shown in the right panel of Fig. 2. These results provide the electrical generation and control of valley-polarized EL at room temperature *via* straints, offering a new direction for designing practical chiral light sources based on monolayer semiconductors.

References

[1] X. Xu, *et al., Nat. Phys.* 10 (2014) 343.
[2] Y. J. Zhang, *et al., Science* 344 (2014) 725.
[3] O. L. Sanchez, *et al., Nano Lett.* 16 (2016) 5792.

[4] Y. Ye, *et al.*, *Nat. Nanotechnol.* 11 (2016) 598.
[5] J. Pu, *et al., RPGR2018* Guilin (2018) China.
[6] J. Lee, *et al.*, *Nat. Mater.* 16 (2017) 887.
[7] Y. Kobayashi, *et al., ACS Nano* 9 (2015) 4056.
[8] J. Pu, *et al., Adv. Mater.* 28 (2016) 4111.
[9] J. Pu, *et al., Adv. Mater.* 29 (2017) 1606918.
[10] J. Pu and T. Takenobu, *Adv. Mater.* 30 (2018) 1707627.

Figures

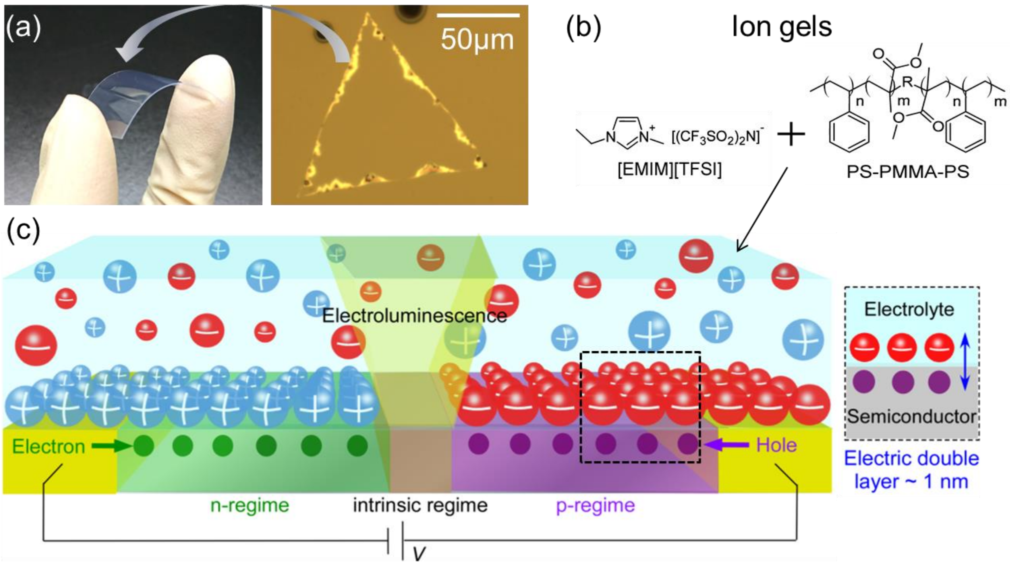

Figure 1: (a) The transferred WS_2 monolayer flakes onto PEN substrates. (b) The chemical structures of an ionic liquid and a tri-block co-polymer. (c) The schematic of the electrolyte-based two-terminal light-emitting structures.

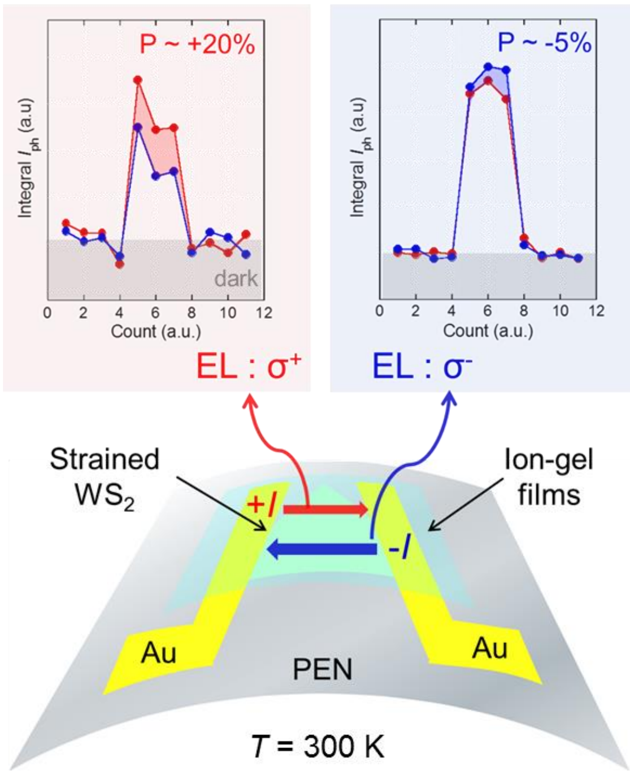

Figure 2: Room-temperature chiral light-emitting devices *via* strained monolayer WS_2. The EL polarization, $P = [\sigma^+ - \sigma^-]/[\sigma^+ + \sigma^-]$, can be electrically switchable by the direction of the electrical currents in the strained devices.