Electrochemically doped light-emitting devices of transition metal dichalcogenide monolayers

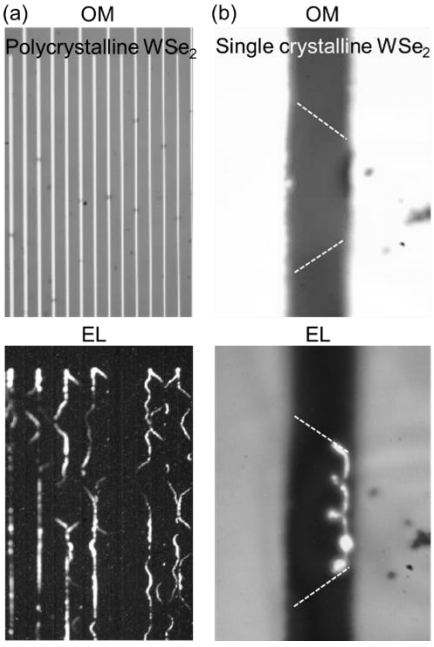
Taishi Takenobu

Department of Applied Physics, Nagoya University, Nagoya 464-8603, Japan

Recently, 2D layered materials have attracted much attention for exploring new electronic, optoelectronic, and photonic applications. Particularly, direct bandgap and unique electronic structure in monolayer transition metal dichalcogenides (TMDCs) provides a platform for exploring novel optoelectronic functionalities and devices [1,2]. One of the most interesting properties of TMDCs is topological features, such as a non-centrosymmetric two-dimensional crystal and spin-valley coupling [3], and circularly polarized light emission has been demonstrated [4,5].

Although the optical properties of TMDCs are very promising, light-emitting devices require intentional doping techniques to form p-n junction. 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 [2].

To overcome this issue, we recently developed the electrochemical method to dope both holes and electrons [6-10], and proposed a simple approach to form p-n junction universally in TMDCs [11,12]. Here, we apply this method into various forms of TMDCs, such as monolayer polycrystalline films (Fig. 1(a)) and single crystalline flakes (Fig. 1(b)), to achieve EL emission. Particularly, using single crystal 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. Our approach paves a versatile way for using TMDCs in discovering new functional optoelectronic devices.



[1] X. Xu, *et al*. Nat. Phys. **10**, 343 (2014).
[2] J. Pu and T. Takenobu, Adv. Mater. just accepted.
[3] D. Xiao, *et al.*, Phys. Rev. Lett. **108**, 196802 (2012).
[4] K. F. Mak *et al.*, Nat. Nanotechnol. **7**, 494 (2012).
[5] Y. J. Zhang, *et al*. Science **344**, 725 (2014).
[6] J. Pu, T. Takenobu, *et al.*, Nano Lett. **12**, 4013 (2012).
[7] J.-K. Huang, T. Takenobu, *et al.*, ACS Nano. **8**, 923 (2014).
[8] J. Pu, T. Takenobu, *et al*., Appl. Phys. Lett., **103**, 23505 (2013).
[9] Y.-H. Chang, T. Takenobu, *et al.*, ACS Nano. **8**, 8582 (2014).
[10] J. Pu, T. Takenobu, *et al.*, Adv. Mater. **28**, 4111 (2016).
[11] D. Kozawa, T. Takenobu, *et al*., Appl. Phys. Lett., **109**, 201107 (2016).
[12] J. Pu, T. Takenobu, *et al*. Adv. Mater. **29**, 1606918 (2017).