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Photoluminescence of Transition Metal Dichalcogenides Depending on the Surface Polarity of GaN Support Substrate

Optical properties of monolayer (1L) transition metal dichalcogenides (TMDs) are attractive due to their direct bandgap response [1], strong light-matter interactions [2], large excitonic effects [3,4] and valley polarization effects [5]. Stacking of TMDs and functional substrates is an effective approach to control these optical properties. One report demonstrated that CVD grown 1L-MoS_2 on GaN shows large valley polarization (~0.4) even at room temperature [6] but the detailed mechanism is unclear. Here, we have studied the photoluminescence (PL) properties of 1L-TMDs exfoliated onto free-standing GaN substrates, especially focusing on the polarity of GaN surface.

1L-MoS_2 were prepared on the +c or -c surface of the free-standing GaN (Chino Nitrides Co.) from natural crystal using a conventional transfer method using a scotch tape and a polymer sheet. The optical properties of 1L-MoS_2 were prepared on the standard SiO_2/Si substrates were also studied as references. The PL intensity of 1L-MoS_2 on GaN substrates becomes weak around quarter as compared with that on SiO_2/Si as shown in Figs. 1 probably reflecting the photocarrier transfer between MoS_2 and GaN surface at room temperature. Note that this quenching behavior does not depends on the difference of surface polarity of GaN.

On the other hand, the PL properties (intensities and emission energies) of excitons and trions (charged excitons), are changed depending on the surface direction of GaN at room temperature. Both exciton and trion PL were observed from the 1L-MoS_2 on the Ga polar (+c) surface while trion PL was mainly observed from that on the N polar (-c) surface as shown in Figure 1 (b) and (c). We also carried out the valley polarized PL measurement with changing temperature. Excitation laser energy is 1.96 eV and monitored trion PL around 1.9 eV. Trion valley polarization behavior of 1L-MoS_2 also depends on the surface polarity. The degree of valley polarization of MoS_2 on the Ga polar (+c) surface is finite until 200 K while that on the N polar (-c) surface is quenched around 150 K as shown in Fig. 2.

These differences might be caused by the direction of spontaneous polarization of GaN. Strong polarization field of GaN could modulate the density of initially-doped carriers in the 1L-MoS_2. The Induced holes compensate the initially doped electrons in the MoS_2 on the Ga polar (+c) surface. On the other hand, additional electrons are induced in the MoS_2 on the N polar (-c) surface. This difference of carrier distribution of 1L- MoS_2 depending on the surface polarity would affect the PL properties including valley polarization behavior through trion populations and lifetime.

Further studies on trion properties including the PL properties of different TMDs ($MoSe_2$ and WSe_2) on freestanding GaN will be discussed in the presentation. These results suggest that the polarity of semiconductor is important to control optical properties of TMDs combined into a polar semiconductor based luminescent devices.

References

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Figures

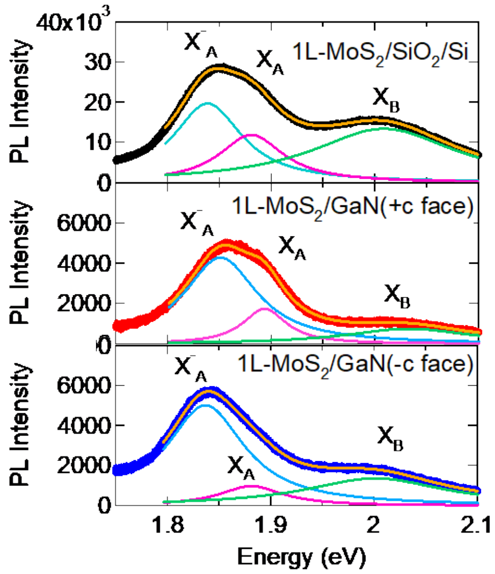

Figure 1: PL spectra of 1L-MoS_2 on SiO_2/Si (a) + c face GaN (b), and on - c face GaN (c) measued at room temperature.

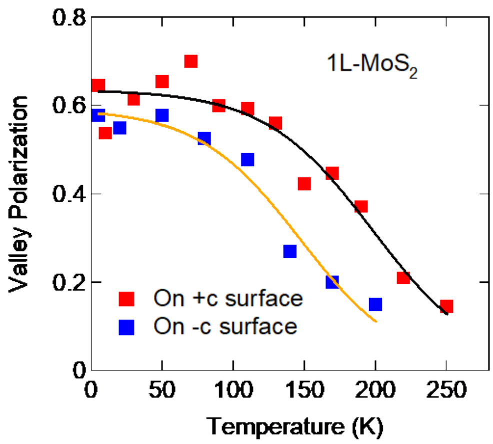

Figure 2: The degree of valley polarization of 1L-MoS_2 on +c and-c surface of freestanding GaN surface.