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$MoSe_2$ semiconductor indirect-to-direct transition by laser induced etching

Toyohashi Univ. Tech. EIIRIS [1], Toyohashi Univ. Tech.[2] ○ Pil Ju Ko[1], Tran Viet Thu[1],

Tsukasa Takmaura[1], Abdelkader Abderrahmane[2], Adarsh Sandhu[1,2]

E-mail: ko@eiiris.tut.ac.jp

Two-dimensional (2D) layered materials like graphene exhibit unique electrical and optoelectronic properties [1-2]. In particular, single layers of transition metal dichalcogenides (TMDS) exhibit more interesting physical properties than bulk TMDS due to the indirect to direct bandgap transition due to quantum confinement [3]. In this research we demonstrate that layer-by-layer laser etching of molybdenum diselenide ($MoSe_2$) flakes leads to indirect to direct bandgap transition with characteristic photoluminescence (PL) spectra.

We prepared $MoSe_2$ flakes on a Si substrate covered with 300 nm of thermally oxidized SiO_2 by mechanical exfoliation of natural $MoSe_2$ using PDMS. The PL measurement and laser etching were carried out by a 532 nm laserwith an estimated laser spot of around 1 μm.

Figure 1 is an optical image of the $MoSe_2$ flake on Si/SiO_2 substrate before and after laser etching. The number of $MoSe_2$ layers was reduced by their optical contrast in the area (red box) at 532 nm, 11 mW, exposure time : 0.04 sec, interval : 0.04 um, laser spot : ~ 1 μm. We observed an increase in the intensity of the $MoSe_2$ (1.54 eV) peak of laser thinned $MoSe_2$ areas by PL speatra (Fig. 2), indicating that the removal of several layers of $MoSe_2$ led to indirect bandgap to direct bandgap [3].

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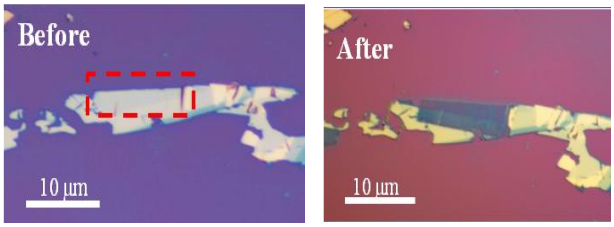

Fig . 1 Optical images of the $MoSe_2$ flake before and after etching.

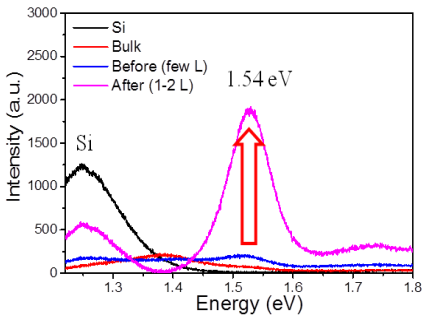

Fig. 2 PL spectra before and after etching.