Laser-Assisted Treatment of MoS_2 Monolayers and Its Impact on Photoluminescence Properties

Rayan Jamil
Van-Hoan Le, Nicolas Gauthier, Stephane Cadot, Irma Custovic, Peter Reiss, Paul Brunet, Lucie Le Van-Jodin, Denis Mariolle, Raphael Ramos, Sauvagnargues Eric, Lucie Le Van-Jodin, Thibaut Meyer, Bérangère Hyot.
1 Univ. Grenoble Alpes, CEA, Leti, F-38000 Grenoble, France
2 Univ. Grenoble Alpes, CEA, IRIG, F-38000 Grenoble, France
(rayan.jamil@cea.fr)

Despite having characteristics that make them ideal for optoelectronics, monolayer transition metal dichalcogenides (TMDCs) have shown low luminescence quantum yield, primarily due defect-mediated nonradiative recombination. Several treatments have been used to passivate defects and improve the photoluminescence (PL) characteristics of MoS_2 monolayers [1]. Most studies have exclusively focused on mechanically exfoliated (ME) and CVD MoS_2. In this study, we focus on MoS_2 grown via Two-Step ALD Process (ALD), a wafer-scale technique capable of growing homogeneous monolayer and few layers (up to 300 mm) [2]. The ALD MoS_2 is known to have smaller crystallite size (~ few tens of nm) and a relatively higher density of defects compared to ME MoS_2. In this study, we examine how the combination of continuous and different laser power irradiation in presence of specific environment (denoted hereafter as X) in a sealed-cell can passivate defect sites and strongly enhance the PL properties of ME and ALD-grown MoS_2 monolayers. ME MoS_2 showed strong site-selective PL enhancement on the laser irradiated part associated with large blueshift and narrowing of A-exciton peak, while ALD-grown MoS_2 showed uniform and slight enhancement across the entire sample with no significant shift. This can be explained by the ability of this environment to selectively passivate particular defect types, which may be more widespread in exfoliated MoS_2 monolayers than in ALD-grown ones. To further assess any properties modifications, Raman, XPS and AFM analyses are performed on both ME and ALD MoS_2 samples before and after treatment. Our study introduces a new methodology for the easier treatment and reveals the defect-dependent nature of chemical passivation on ME and ALD MoS_2.

References

[1] Kim, Eunpa, et al. "Site selective doping of ultrathin metal dichalcogenides by laser-assisted reaction." Adv. Mater 28.2 (2016): 341-346.
[2] Cadot, Stéphane, et al. "A novel 2-step ALD route to ultra-thin MoS 2 films on SiO 2 through a surface organometallic intermediate." Nanoscale 9.2 (2017): 538-546.

Figures

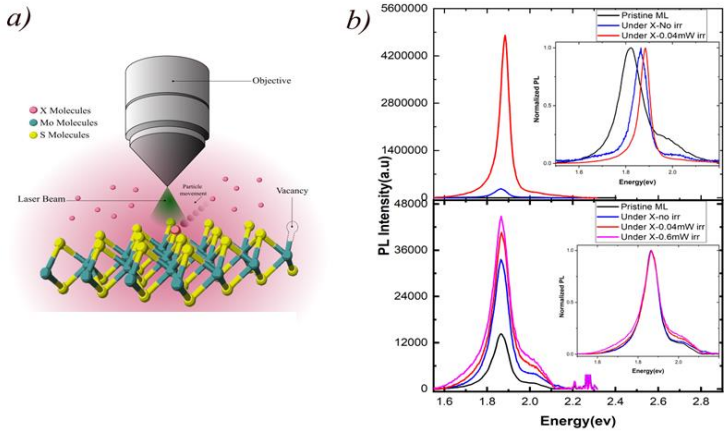

Figure 1: a) Passivation schematic. b) PL Enhancement of MoS2 ML under X environment, up: exfoliated ML, down: ALD ML .The inset shows normalized spectra.