Defect formation in monolayer MoS_2 by electron irradiation at low electron accelerating voltages

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Two-dimensional (2D) transition metal dichalcogenides (TMDs) are excellent platforms to study atomic details of defects created by electron/ion beam irradiation due to their extreme thinness. Post-synthesis processing of 2D TMDs by electron beam irradiation, primarily above knock-on accelerating voltages (> 80 kV), provides ease of controlling defect density and position [1,2]. Defects in TMDs can be used for various applications, especially as single-photon emitters (SPEs) [3]. Low accelerating voltages are expected to create localized defects with minimal surrounding lattice damage, which is ideal for SPEs. For creating superior performance SPEs, it is critical to understand the defect formation mechanism below knock-on voltage. This work investigates defect formation in mechanically exfoliated monolayer MoS_2 (a prototypical TMD) by electron irradiation in a scanning electron microscope (SEM, 3-5 kV), well below the knock-on voltage. Post-irradiation, Raman and photoluminescence (PL) spectroscopy were used to characterize the defects. The observed frequency shifts and change in full-width half-maximum of prominent Raman modes E^1_{2g} and A_{1g} indicate defect formation in irradiated samples (Figure 1b). Further, quenching in PL intensity and appearance of low-energy peaks in the PL spectrum of the irradiated samples support our claim of defect formation (Figure 1c). We further correlate Raman and PL spectra changes to doping effects due to electron beam and carbonaceous contaminants deposited during irradiation. Our work demonstrates defect tailoring of 2D TMDs by electron irradiation at low electron accelerating voltages.

References

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[2] Sun, L., Banhart, F. & Warner, J., MRS bulletin **40**, 29-37 (2015)
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Figures

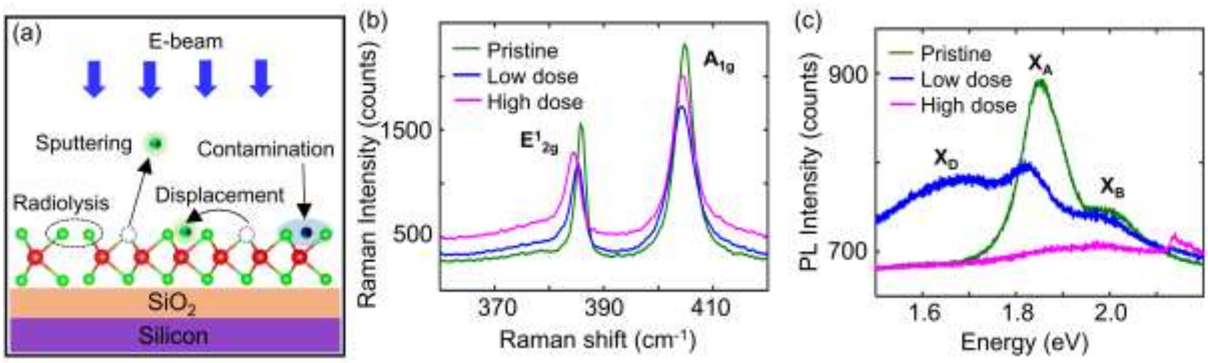

Figure 1: (a) illustrates electron beam-induced processes in 2D TMDs, including radiolysis, sputtering, displacement, and hydrocarbon contamination. The evolution of Raman and PL spectra of monolayer MoS_2 with electron dose are shown in (b) and (c), respectively. High and low dose corresponds to 2.6×10^4 and 2.3×10^5 e^- nm^{-2}, respectively. X_A, X_B, and X_D denote A-exciton, B-exciton, and low energy peak, respectively. All spectra are recorded at room temperature.