# Probing Substrate-induced Optical Signatures of Excitons in Monolayer $MoS_2$

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Abstract

Chemical vapor deposition (CVD) using $MoO_3$ precursor provides a scalable route for producing device-grade monolayer $MoS_2$ for next-generation optoelectronic applications, although intermediate $Mo^{6+}$ states are often unavoidable[1]. For practical device integration, transferring $MoS_2$ onto dielectric substrates is necessary. In this study, we systematically investigate substrate–$MoS_2$ coupling by comparing transferred monolayers on ALD-grown $HfO_2$ and $AlO_x$ with the as-grown film on c-plane sapphire. Photoluminescence (PL) analysis reveals a pronounced increase in the trion-to-exciton population ratio, with extracted electron densities as high as $33.2\times10^{13}$ $cm^{-2}$ ($MoS_2/HfO_2$) and $10.8\times10^{13}$ $cm^{-2}$ ($MoS_2/AlO_x$), compared to $0.7\times10^{13}$ $cm^{-2}$ in the as-grown film at 93K. An accompanying ~10 meV trion binding energy enhancement is observed for $MoS_2/HfO_2$ along with the red shift in B exciton. The valence band spectra and photoluminescence mapping of suspended regions confirm that the observed spectral shifts originate from substrate-induced charges. Furthermore, XPS analysis verifies the disappearance of the $Mo^{6+}$ oxidation state following the transfer process, indicating chemical restoration of the $MoS_2$ surface. Finally, we demonstrate that the modified electronic environment significantly alters resonance Raman scattering and the $E^1_{2g}$ to $A_{1g}$ intensity ratio. This study clarifies substrate-driven electronic modulation in monolayer $MoS_2$ for future optoelectronic design.

References

[1] Ponnusamy, K. M.; Bong, J.; Lee, H.; Choi, J.H.; Pandit, B.; Ghods, S.; Durairaj, S.; Park, J. B.; Lee, Y.K.; Lee, T.; Lee, J.-H.; Jang, H.-S.; Chandramohan, S.; Heon, K. ACS Appl. Mater, Interfaces **2026**, 18 (1), 1995-2008.

Figures

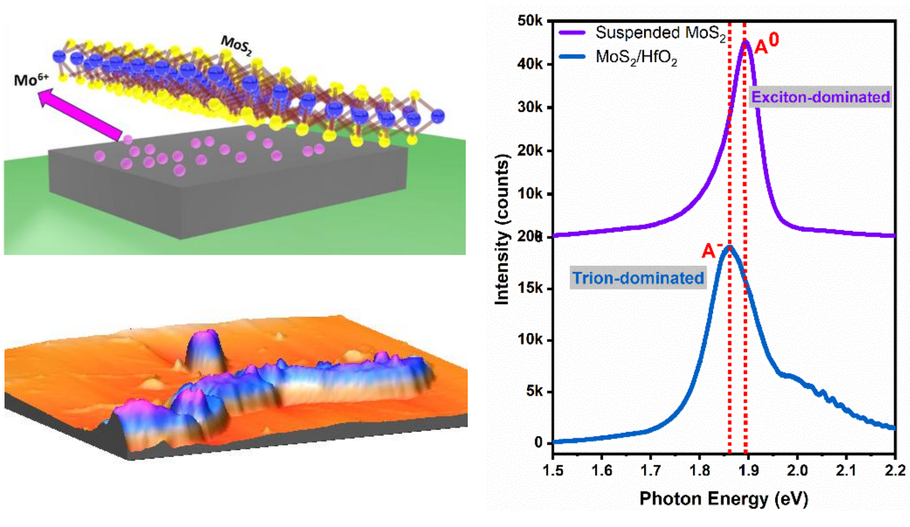


**Figure 1:** (left) Schematic illustration of delamination of $MoS_2$ from sapphire where unreacted $MoO_3$ ($Mo^{6+}$) vanishes. AFM image of a transferred film. (right) The PL emission from supported and unsupported regions of monolayer $MoS_2$.