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# Characterization of MoS<sub>2</sub> by Raman and Photoluminescence Spectroscopy: From Growth to Property Enhancement

Two-dimensional transition metal dichalcogenides (TMDs), such as MoS<sub>2</sub>, are promising materials for next-generation nanoelectronics and optoelectronics, owing to their tunable electronic and optical properties and reduced sensitivity to short-channel effects. Realizing their full potential, however, requires scalable fabrication, controlled defect engineering, and reliable characterization across multiple length scales. This presentation highlights how Raman and photoluminescence (PL) spectroscopy, combined with other techniques (including XPS, AFM, STEM) can provide comprehensive insights into MoS<sub>2</sub> from growth to property enhancement.

We first discuss wafer-scale MoS<sub>2</sub> synthesis using a two-step atomic layer deposition (ALD) process [1]. A comprehensive characterization protocol enables the precise identification of ALD cycle thresholds for achieving strict monolayer coverage with high wafer-scale uniformity [1-2]. Here, Raman spectroscopy provides key insights into thickness-dependent vibrational properties through the A<sub>1g</sub> and E<sub>2g</sub> modes and reveal phonon confinement effects in sub-monolayer regimes (below 4 ALD cycles) which correlate well with grain size and disorder [2]. Beyond local characterization, automated wafer-scale Raman and PL mapping provides valuable information on film coverage, uniformity, and optical properties across the wafer. Next, we address defect engineering and optical properties enhancement of exfoliated and ALD-grown MoS<sub>2</sub> through superacid (TFSI) treatment. In contrast to conventional solution-based TFSI treatments reported in literature [3, 4], we developed a novel patented vapor-phase process combined with laser irradiation. This approach enables a stronger and more persistent PL enhancement, reaching up to 600-fold and lasting for several months without any capping layer. Correlative Raman and PL measurements, together with XPS analysis, indicate that the treatment enhances optical emission while preserving the structural integrity of MoS<sub>2</sub>, reducing n-doping and improving the material's structural and chemical properties.

Overall, this work demonstrates the value of Raman and PL spectroscopy as versatile tools for characterizing MoS<sub>2</sub> from the local to the wafer scale. Their correlation with chemical, morphological, and structural information from complementary techniques provides a comprehensive picture of material evolution and offers actionable insights for optimizing MoS<sub>2</sub> growth, processing, and optical performance.

## References

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