Atomic Layer Deposition of Large-Area Polycrystalline Transition Metal Dichalcogenides at 100 °C

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Synthesis of high-quality, large-area transition metal dichalcogenide (TMDC) films under industrially relevant conditions is a considerable challenge. This is especially true for applications based on plastic substrates, such as flexible electronics.[1] Atomic layer deposition (ALD) is an industry-approved gas phase thin film deposition method based on self-limiting surface reactions of alternately pulsed precursors that can be used for low-temperature deposition of TMDCs.[2,3]

We have deposited polycrystalline MoS_2, TiS_2, and WS_2 films of accurately controlled thickness using plasma-enhanced ALD (PEALD). Deposition at record-low temperatures down to 100 °C is enabled by highly reactive, plasma-generated radicals as well as tailoring of plasma chemistry by addition of H_2 into the plasma feed gas. The latter is a crucial factor in controlling the stoichiometry and consequently crystallinity of the deposited films (Figure 1a,b). At 100 °C, MoS_2 films can be directly deposited on plastic substrates, such as poly(ethylene terephthalate) (PET, Figure 1c) as well as Si wafers (Figure 1d). In addition to detailed characterization of film growth, morphology, crystallinity, and composition, electrical properties of MoS_2 films deposited at 100 °C have been studied.

References

[1] Yao and Gang, *J. Appl. Phys.*, 127 (2020) 030902
[2] Mattinen et al., *Adv. Mater. Interfaces.*, 8 (2021) 2001677
[3] Kim et al., *Adv. Mater.*, 33 (2021) 2005907

Figures

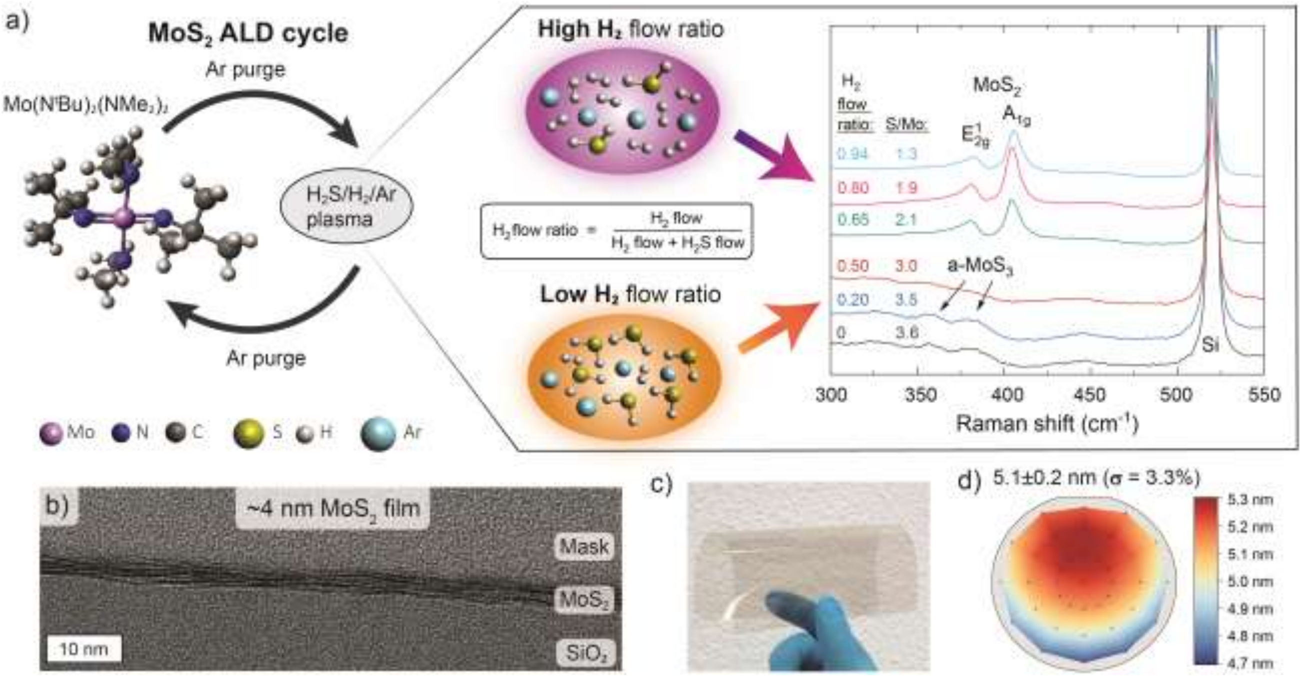

Figure 1: a) Schematic of the PEALD process and the effect of H_2 flow ratio in controlling crystallinity (Raman spectra) and stoichiometry (XPS) at 150 °C. b) Cross-sectional TEM image, c) photograph of ~5 nm MoS_2 on PET (15×15 cm), and d) thickness map on 4" SiO_2/Si wafer of 100 °C MoS_2 films.