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Full wafer-scale characterization method for 2D materials

Uniform large-scale growth poses a significant challenge for 2D integration in microelectronic devices. Recently, teams have demonstrated their ability to process 200 mm or 300 mm wafers of MoS_2 or WS_2 [1, 2]. Nevertheless, in the most cases, only local characterizations are conducted, and the provided data do not accurately reflect the overall quality of the entire wafer. Comprehensive characterization of the full-size wafer is, therefore, essential to monitor the quality and uniformity of both the growth and integration processes, especially for large-scale applications.
This study focuses on wafer-scale characterization of MoS_2 grown by ALD on 200 mm SiO_2 wafer in clean room [3]. Wafer-scale Raman spectroscopy, photoluminescence, Wavelength Dispersive X-Ray Fluorescence (WDXRF), and Atomic Force Microscopy are systematically performed. Data processing, including spectrum decomposition [4], is automated (Fig. 1), followed by the subsequent plotting of mappings for each of the previously mentioned large-scale methods (Fig. 2). The thickness (*i.e.*, number of monolayers) is calculated using WDXRF. Raman and photoluminescence signatures are monitored across the entire wafer, enabling statistical analysis and providing insights of the MoS_2 uniformity. A non-destructive high-speed method has been developed for mapping 2D materials on 200 mm MoS_2 wafers, facilitating wafer-scale analysis within cleanroom environments. This characterization protocol is also applied to 300 mm wafers.

References

[1] O'Brien KP, Dorow CJ, Penumatcha A, Maxey K, Lee S, Naylor CH, *et al.* IEEE International Electron Devices Meeting (IEDM). San Francisco, CA, USA (2021) 711-714.
[2] Schram T, Sutar S, Radu I, Asselberghs I. Adv Mater. (2022) 2109796.
[3] Cadot S, Renault O, Frégnaux M, Rouchon D, Nolot E, Szeto K, *et al.* Nanoscale. 9(2) (2017) 538-46.
[4] Publication in review (based on https://github.com/CEA-MetroCarac/fitspy)

Figures

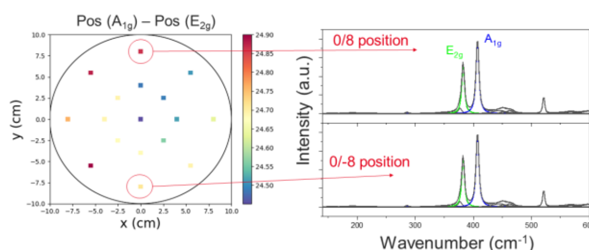

Figure 1: Example of Raman mapping (without interpolation) on 200 mm wafer.

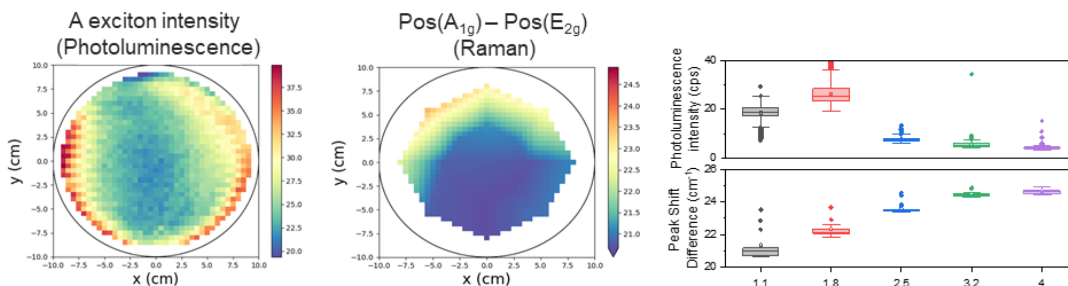

Figure 2: Characterization of 1-4 monolayers of MoS_2 across 200 mm wafers. A *linear interpolation was employed for Raman analysis. Peak Shift Difference = Pos (A_{1g})-Pos (E_{2g})*