Capillary Transfer of Epitaxial WS_2 Grown by Metalorganic Chemical Vapour Deposition

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Since the isolation and characterization of graphene in 2004, the study of low-dimensional materials has garnered the interest of many researchers across the globe. In particular, the transition metal dichalcogenides (TMDs) have emerged within the class of so-called "2D materials" as promising candidates for the design of next-generation optoelectronic devices. Whether exfoliated from bulk material or grown epitaxially using techniques such as metalorganic chemical vapour deposition (MOCVD), the potential of these few-atom thick semiconductors is greatly enhanced if a non-destructive transfer method exists to enable sample manipulation from one substrate to the next. One such transfer method was proposed by Zhang et al., where the successful transfer of MOCVD-grown WSe_2 was achieved using capillary forces in a hot water bath [1].

In the present work this transfer method was successfully reproduced for full-wafer WS_2 films grown on 2" sapphire substrates in a commercial Aixtron CCS3X2 MOCVD system. An 11% poly-methyl-methacrylate (PMMA) (950K amu) solution in anisole was spin-coated onto each epitaxial wafer to act as a few-micron thick scaffold during the transfer process. The wafers were then submerged in $\sim$80°C de-ionized (DI) water for 15 minutes, before being dipped into room-temperature DI water at an angle of 45°. Film delamination from the sapphire growth substrate was observed, and the floating assembly was picked up with a 300nm SiO_2-coated silicon target wafer.

Normal incidence spectral reflectance and photoluminescence (PL) spectroscopy were used to confirm the expected layer stacking at various points during the transfer process. The single-point PL spectra in Figs. 1 and 2 were taken from the center of their respective wafers after capillary transfer is performed, demonstrating that the 620nm PL peak observed in room temperature monolayer WS_2 is gone from the sapphire growth substrate, but present on the target SiO_2-coated silicon wafer. Spectral reflectance analysis independently established that the WS_2 and PMMA stack was present on the target wafer. The successful transfer of epitaxially-grown WS_2 was followed with a 50 minute acetone soak for PMMA removal, resulting in the disappearance of the thin film reflectance oscillations associated with PMMA. Full-wafer PL mapping was conducted before capillary transfer, following transfer, and after the acetone soak to non-destructively characterize the PL uniformity at various process stages.

Together, the full-wafer epitaxial growth of 2D-TMDs and the full-wafer transfer process provide a highly-desirable capability for innovative device fabrication using these novel materials.

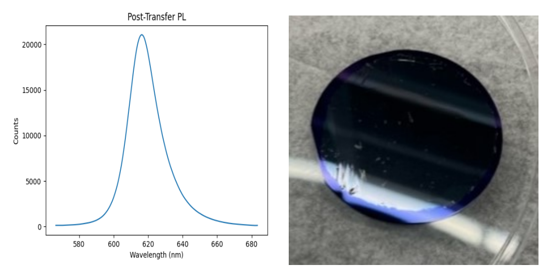

Fig. 1. A strong photoluminescence signal characteristic of monolayer WS_2 is measured on the target wafer.

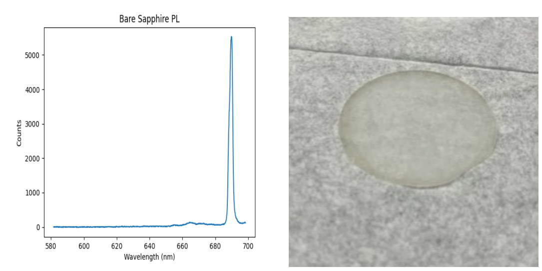

Fig. 2. PL analysis shows the absence of the expected WS_2 signal near 620nm, but includes the 690nm peak from the sapphire substrate.

References

[1] F. Zhang et al., Nanotechnology **29**, 025602 (2018).

[2] H. Gutierrez et al., Nano Lett. **13**, 3447-3454 (2013)