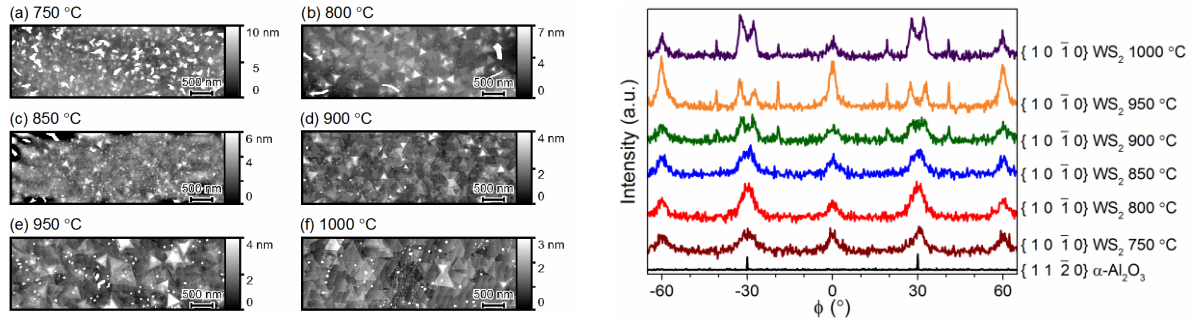


Wafer Scale Epitaxial Growth of Monolayer and Few-Layer WS₂ by Gas Source Chemical Vapor Deposition

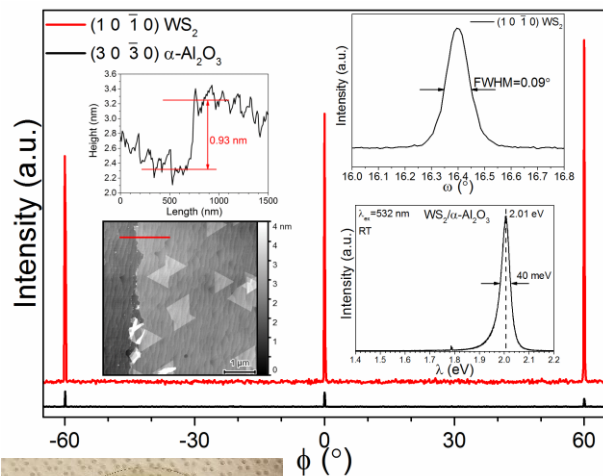
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Surface morphology of WS₂ samples deposited in a temperature range between 750 °C (a) and 1000 °C (f) is presented in a set of AFM images to the left. Figure illustrates the evolution of the surface morphology where increase of WS₂ domains is observed with increasing temperature as well as decrease in out of plane growth. Presence of different orientations is observed from the orientation of triangles. In-plane X-ray diffraction measurement conducted on the samples deposited at different growth temperatures (same samples as in AFM before) presented in the figure on the right. Figure shows ϕ -scans for $\{10\bar{1}0\}$ planes of WS₂. Presence of various orientations are observed as well as evolution of orientations with the increase of the deposition temperature.



Main figure represents XRD ϕ -scan of $\{10\bar{1}0\}$ planes of WS₂ recorded in in-plane showing presence of only one crystal orientation of WS₂ and reveals the epitaxial relation between the substrate and the film. The epitaxial relation is $(10\bar{1}0)$ WS₂ \parallel $(10\bar{1}0)$ α -Al₂O₃. Inserts show AFM image of the sample with a scratch and a height profile along the red line. Height profile shows step height of 0.9 nm which is close to a monolayer value. Other inserts show ω -scan of $10\bar{1}0$ peak of WS₂ showing FWHM value of 0.09° (324 arcsec) which is representative of the twist of the crystal suggesting well oriented film and can serve as an estimation of edge dislocations density. Finally, the insert in the right bottom corner shows room temperature PL spectrum of WS₂ where high intensity peak positioned at 2.01 eV with FWHM of 40 meV is observed. Photoluminescence was excited by 532 nm laser.

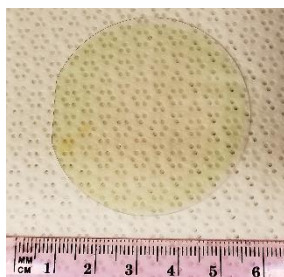


Photo of 2 inch c-plane sapphire wafer with continuous monolayer WS₂ film.