Substrate interaction on local exciton/trion ratio in mono-to few-layer WS_2

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Abstract

Two-dimensional Tungsten Disulfide (WS_2) is a favourable material for optoelectronic devices such as photodetectors, LEDs and solar cells owing to its low dimensionality, flexibility, along with properties such as high photoluminescence yield, tunable bandgap, strong light-matter interaction, quantum confinement and large exciton binding energy. However, high spatial heterogeneity of optoelectronic 2D materials due to nanoscale variations in layer thickness, substrate interaction and local strain limits their large-scale application. Even though these variations can be seen via optical spectroscopy methods such as Photoluminescence (PL) and Raman spectroscopy, these methods lack spatial resolution to resolve such variations on the nanoscale. Therefore, to gain the information regarding the impact of layer thickness, changes in substrate interactions and local strain on the material's optoelectronic response on the nanoscale, we employ electrical atomic force microscopy (AFM) with in-situ illumination. Within our study, we demonstrate the capabilities of photo-Kelvin probe force microscopy (pKPFM) to capture local photo-potential in mono and few-layer WS_2 and correlate the findings to PL spectroscopy. Additionally, the influence of the substrate's work function and nature (metal or semiconductor) on the local charge carriers was investigated.

Figures

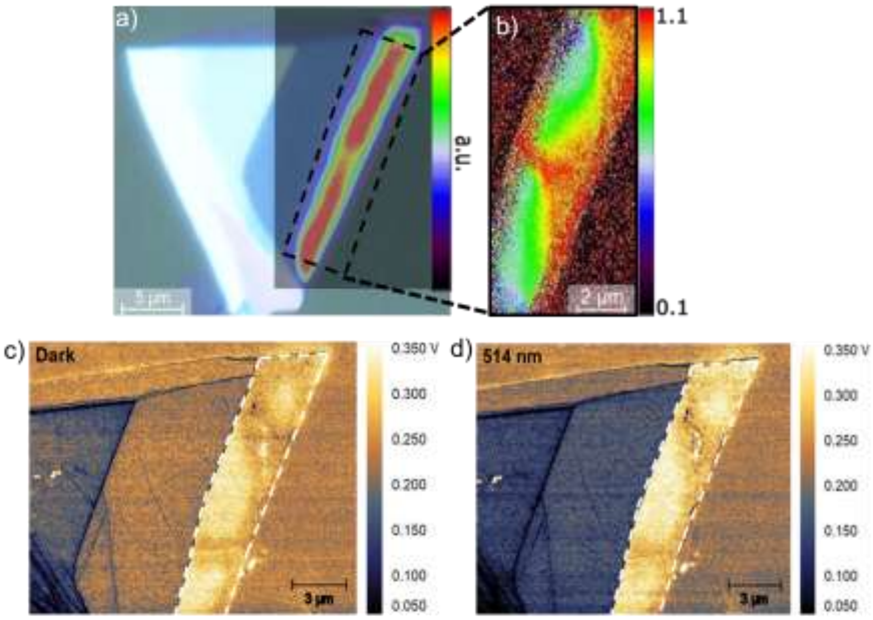

Figure 1: a) Optical image of WS_2 flake with PL intensity overlay for monolayer. b) Neutral Exciton-to-trion PL intensity ratio mapping on the monolayer WS_2, showing regions of neutral excitons (>1) and trions (<1). c, d) KPFM surface potential imaging for dark and 514 nm illumination, clearly able to distinguish neutral exciton and trions on the monolayer as well as different layer thicknesses.