Highest resolution confocal Raman-AFM-SNOM: advantages and new insights for the characterization of novel 2D materials

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Abstract The unique chemical, mechanical, electrical, and optical properties of two dimensional materials, like graphene[1-3], h-BN[4], MoS_2[5], etc, lead to their many application possibilities such as: single molecule detectors, new high-strength low-weight materials, design of new semiconductor devices, to name but a few. An important goal however, is the detection of such few angstrom-thick two dimensional sheets and precisely determine the number of layers forming the 2D flake. The aim of this contribution is to show how the combination of confocal Raman, AFM and SNOM can contribute to the characterization of such small materials and devices. In the past two decades, AFM (Atomic Force Microscopy) was one of the main techniques used to characterize the morphology of nano-materials spread on nanometer-flat substrates. From such images it is possible to gain information about the physical dimensions of the material, without additional information about their chemical composition, crystallinity or stress state. On the other hand, Raman spectroscopy is known to be used to unequivocally determine the chemical composition of a material. By combining the chemical sensitive Raman spectroscopy with high resolution confocal optical microscopy, the analyzed material volume can be reduced below ~250 and 800 in lateral and vertical dimensions, thus leading to the ability to acquire Raman images with diffraction limited resolution from very flat surfaces [6, 7]. Using SNOM (Scanning Near-field Optical Microscopy) technology, it will furthermore be shown how the transparency of different graphene sheets is changing as a function of the number of layers with a lateral resolution well below the diffraction limit. With the combination of confocal Raman microscopy with AFM and SNOM, the high spatial and topographical resolution obtained with an AFM can be directly linked to the chemical information about 2D materials provided by confocal Raman spectroscopy and their optical properties obtained with SNOM. A representative characterization for MoS_2 with various layers by a confocal Raman-AFM measurement is illustrated in Fig. 1.

References

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Figure

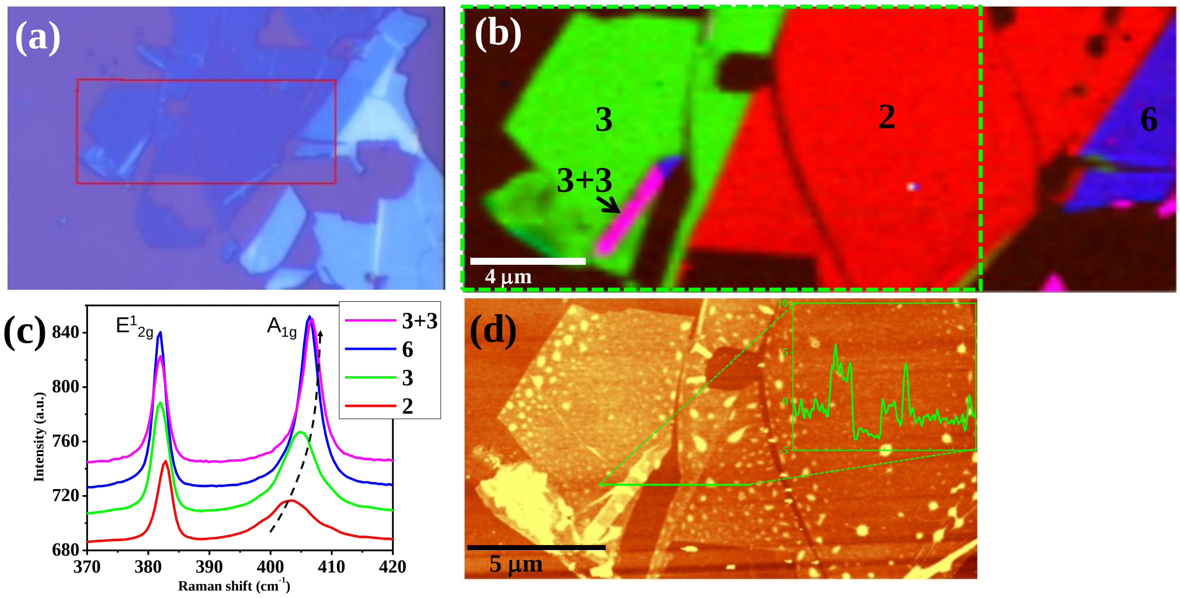

Figure 1. (a) Optical image of MoS_2 sheet with various layers on SiO2/Si substrate. (b) Color coded Raman image based on Raman spectra of MoS_2 as shown in (c), Red: 2 layers; Green: 3 layers; Blue: 6 layers; Magenta: 3+3 layers. With increasing number of MoS_2 layers, the peak position of A_{1g} mode gradually shifts to higher wavenumbers. Importantly, comparing to 6 layers, it is the first time to observe the additional blue shift of A_{1g} mode in 3+3 folded layers. (d) The correlated AFM topography image of the selected area (green dashed frame in (b)) for Raman study. The insert indicates the height profile of MoS_2 sheet along the green line. The combination of Raman and AFM techniques could benefit to a comprehensive understanding about chemical and topographic properties of such sub-nm-thick 2D materials, like sample quality, stacking order, domains in CVD growth, edge chirality etc. (Samples: courtesy of Dr. Sun Linfeng, Division of Physics and Applied Physics, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore.)