Characterization of Carbon Nanomaterials with a Confocal Raman AFM

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Carbon is known to exist in a number of allotropes which range from single crystalline diamond - the hardest of all known materials, to the soft, layer based graphite. The discovery by Novoselov and Geim [1] of a simple method to transfer a single atomic layer of carbon from the c-face of graphite to a substrate suitable for measurements of its electrical and optical properties has led to an increased interest in studying and employing two-dimensional model systems. An overview of electron and phonon properties of graphene and their relationship to the one-dimensional form of carbon known as nanotubes can be found in [2]. The unique chemical, mechanical, electrical, and optical properties of graphene lead to its many application possibilities such as: single molecule detectors, high-strength low-weight new materials, design of new semiconductor devices, etc.

An important goal however, is the detection of such angstrom-thick two dimensional sheets and precisely determine the number of layers forming the graphene flake. The aim of this contribution is to show how a confocal Raman AFM 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 on the nanometer scale, 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 0.02 μm^3, thus leading to the ability to acquire Raman images with diffraction limited resolution from very flat surfaces [3, 4]. The combination of confocal Raman microscopy with Atomic Force Microscopy (AFM) is a breakthrough in microscopy. Using such a combination, the high spatial and topographical resolution obtained with an AFM can be directly linked to the chemical information provided by confocal Raman spectroscopy [5].

An example of a confocal Raman-AFM measurement is illustrated in the figures of this abstract. Fig. 1 shows the AFM topography image of a graphene flake deposited on a Si substrate. This image was recorded in AFM AC mode and it reveals the presence of mono-, bi- and multi-layers of carbon, as highlighted in the two cross sections. A Raman image was recorded from the same sample area by acquiring a spectral array of 85x50 complete Raman spectra. A typical Raman spectrum of graphene deposited on a Si-substrate is shown in Fig. 2. The thousands of Raman spectra were evaluated using peak fitting algorithms, which are very sensitive to small variations of Raman band position and width. The Raman image presented in Fig. 2 highlights the variations of the G-band within the analyzed graphene. The mono-layer of graphene (brown color) can be clearly discriminated from a graphene bi-layer (pink color). In yellow color a flipped over graphene sheet is presented.

The various data acquisition and evaluation methods will be discussed in this contribution.

References

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Figures

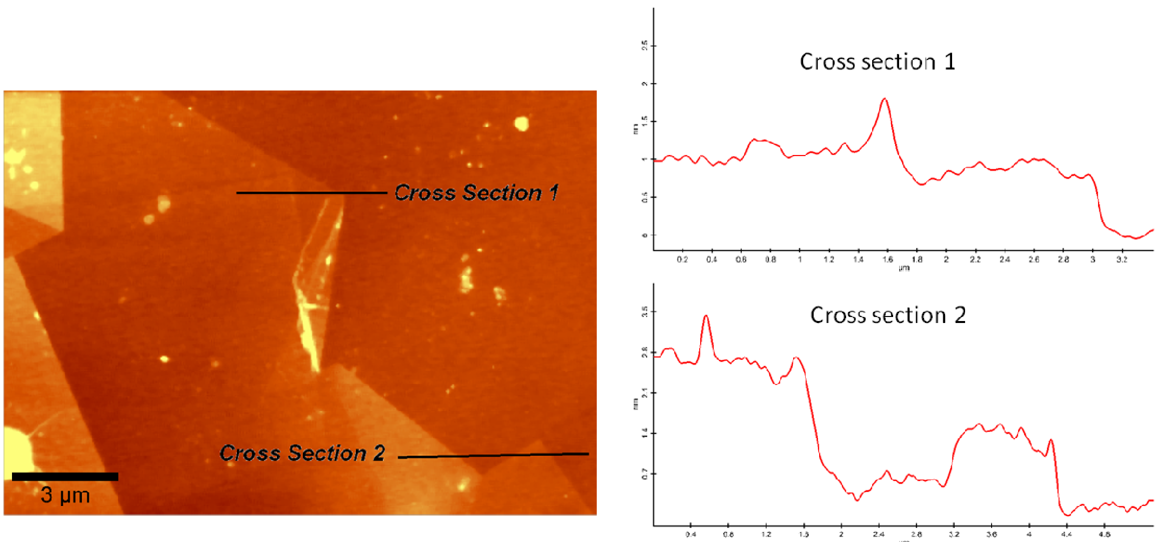

Fig. 1: AFM topography image of a graphene flake deposited on a Si substrate (left) and cross sections along the two directions marked in the topography image (right).

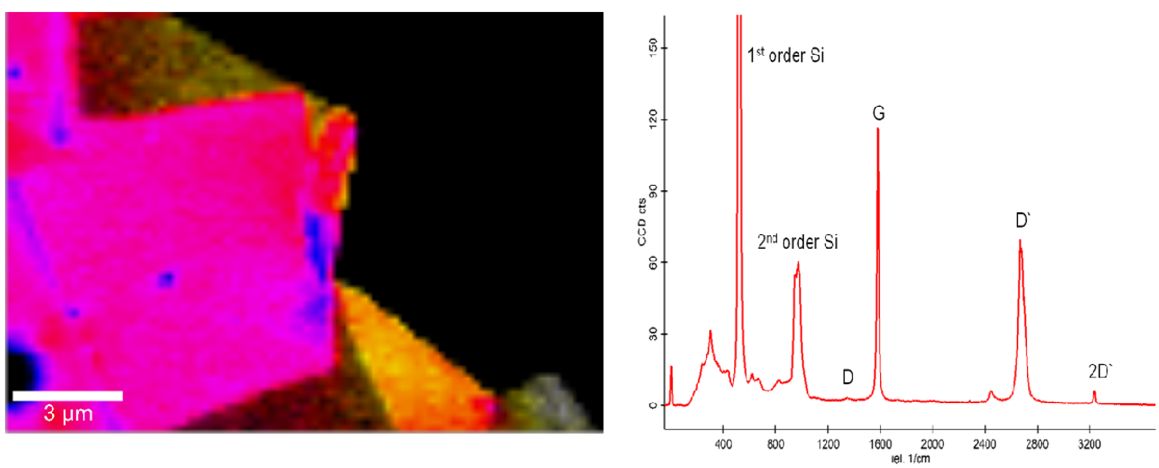

Fig. 2: Confocal Raman image of the same graphene flake as in Fig. 1, revealing the optical properties of the various graphene layers (left) and averaged Raman spectrum of the graphene flake.