

NT-MDT — Integrated Solutions for Nanotechnology

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NT-MDT is a global company that provides integrated solutions for nanotechnology. In this article we would like to present one of the most advanced systems — NTEGRA Spectra — with an example of application — graphene characterization. For more details about systems and other applications please contact us or visit our webpage www.ntmdt.com.

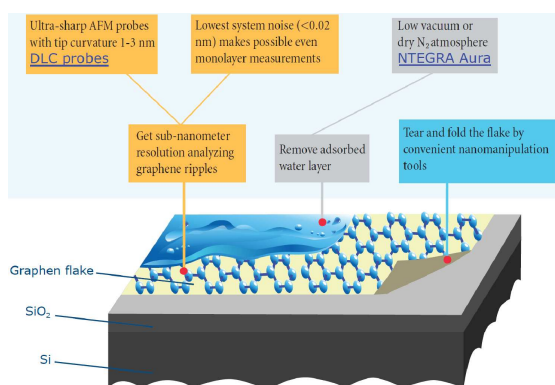
1. Introduction

The interest in graphene is continuously rising among science communities. Applied physicists, new material designers, and nanotechnology engineers are attracted by its unique properties such as electrical and thermal conductivity. Fundamental physicists are enchanted by the possibility of exploring quantum relativistic phenomena on 2-dimensional crystals that have a unusual electronic spectrum. In order to manipulate a single-atom-thin structure, one needs a reliable high precision tool.

In this article two experimental examples are presented. The first one shows the advantages of the NTEGRA based atomic force microscopy (AFM) and how it can reveal the fine structure of graphene flakes. The second example shows how the NTEGRA combines scanning probe microscopy (SPM) with the Raman spectroscopy to become a NanoLaboratory with advanced analytical capability.

2. AFM experiments

Scheme of the layers is shown in the figure.

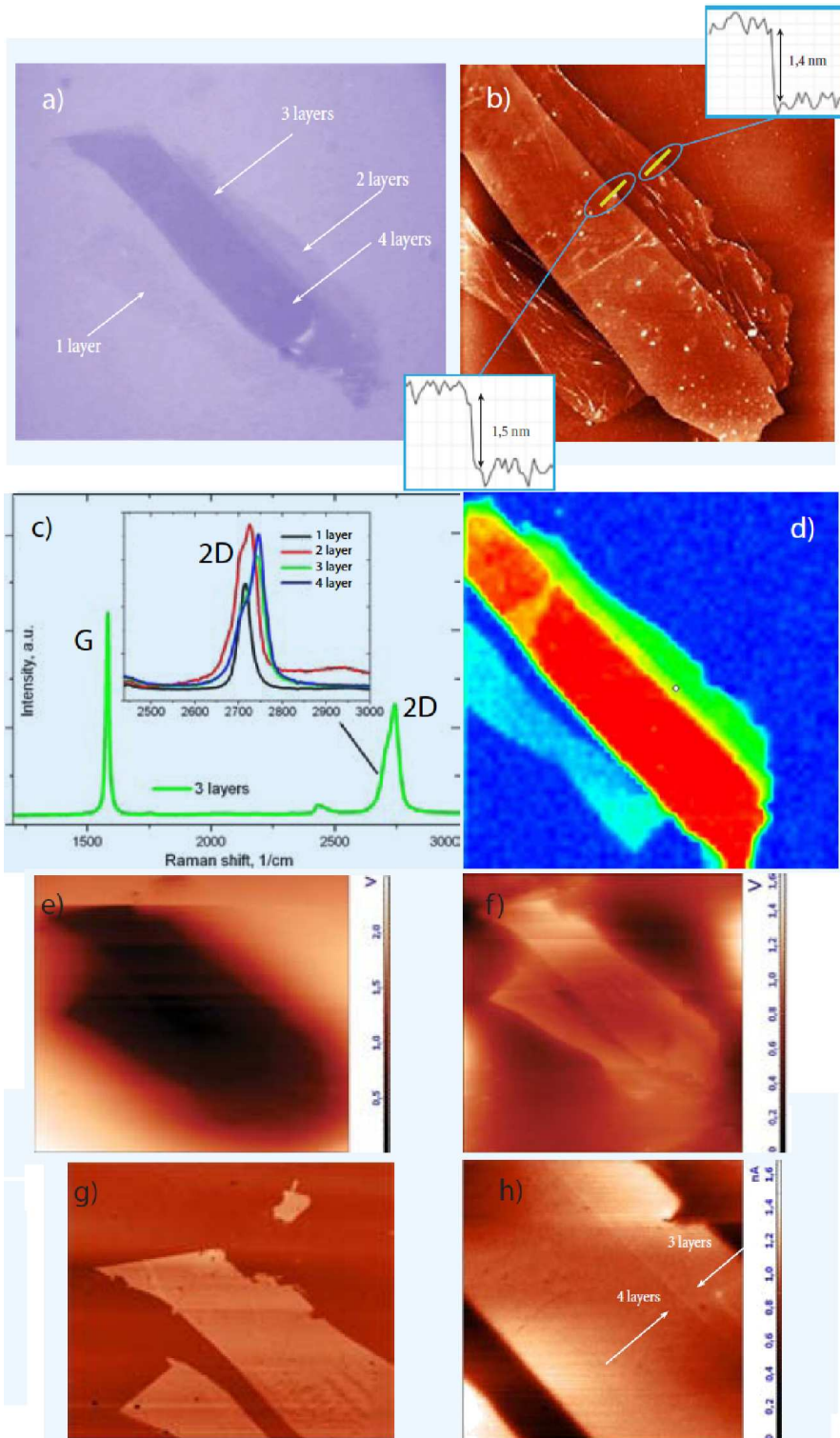


3. Complex experiment: Raman spectroscopy + SPM NanoLaboratory NTEGRA spectra

The powerful analytical capabilities of scanning probe microscopy and Raman microscopy have been successfully integrated with NTEGRA Spectra NanoLaboratory.



The NTEGRA Spectra provides a comprehensive characterization of the graphene specimen. Shown are images and quantitative data (the figure on the next page) obtained from the same graphene sample (placed on Si/SiO₂ substrate) obtained in a single experiment using the AFM — Raman setup [1]. (a) White light image of multi-layer graphene sample obtained with high resolution 100 \times , 0.7 NA objective. 1-, 2-, 3-, and 4-layered flakes are observed. Image size 120 \times 110 μm . (b) AFM topography of the same sample with corresponding line profiles. Scan size 50 \times 50 μm . (c) Raman spectra of graphene flakes. 2D (G') Raman peak changes in shape width and position for an increasing number of layers reflecting a change in electron band structure. (d) Confocal Raman map (2D band center of mass position). 1-, 2-, 3-, and 4-layered flakes can be easily distinguished when using a color palette scale. (e) and (f) Scanning Kelvin probe microscopy of negatively and positively charged graphene. The flakes were charged by applying +3 V (e) or -3 V (f) voltage with conductive cantilever. Scan size 90 \times 80 μm . (g) Electrostatic force microscopy of the same sample. Scan size 65 \times 55 μm . (h) Scanning capacitance microscopy image. Singularity in capacitance distribution can be seen at the edge of the layer reflecting graphene electron edge states. Scan size 25 \times 25 μm .



References

- [1] Details of original experiment, see F.V. Tikhonenko, D.W. Horsell, R.V. Gorbachev, A.K. Savchenko, *Phys. Rev. Lett.* **100**, 056802 (2008).