A Synoptic Look on Characterization Techniques of Graphene and its Derivatives and Analogues

Gerald Kada, Jing-jiang Yu, Shijie Wu, Christian Rankl, Jining Xie, Ferry Kienberger

Agilent Technologies, Nanoscale Sciences Division, 4330 W Chandler Blvd, Chandler, AZ, USA
Gerald_Kada@Agilent.com

Abstract

Graphene consisting of a monolayer of sp^2-bonded carbon atoms is a relatively new member of the carbon family. But owing to its unique structure, exceptional electrical, optical and mechanical properties, graphene is a rapidly rising star on the horizon of materials science and condensed matter physics [1]. Since its discovery, optical microscopy, atomic force microscopy (AFM), scanning electron microscopy (SEM), transmission electron microscopy (TEM) and micro-Raman spectroscopy have been widely employed to investigate its optical properties, determine its thickness, resolve its atomic arrangement, and detect its film quality, respectively.

We have applied several of those imaging and characterization techniques to investigate surface morphology and electronic properties of graphene, selected derivatives like graphene oxide (GO) or silanized graphene, graphene-metal nanoparticle composites as well as graphene analogues like hexagonal boron-nitride (h-BN)

a) Imaging graphene with a low beam voltage field emission scanning electron microscope (LV FE-SEM) is very promising because of its unique combination of high resolution, a small bean/specimen interaction volume, enhanced contrasts and the capability of revealing more surface details [2]. Three typical contrasts in SEM imaging of graphene including surface roughness contrast, edge contrast, and thickness contrast will be discussed in detail (see fig. 1).
b) An Atomic force microscopy (AFM)-based technique called Kelvin force microscopy (KFM) is an experimental means to investigate the local properties of both single-layer graphene (SLG) as well as few-layer graphene (FLG) and graphene oxide. The effect of film thickness on the surface potential is detected and quantitative measurements are readily obtained (see fig. 2). Other AFM based techniques like current sensing AFM or electrostatic force microscopy (EFM) are applied as well on graphene, GO, and h-BN, respectively [3].
c) A unique and novel AFM-based technique is using a combination of near-field electromagnetic field in the microwave regime to probe both local topographical and mechanical properties with a scanning AFM tip, and simultaneously recording capacitance, dopant profile changes and impurities of underlying layers of material [4]. This technique is called scanning microwave microscopy (SMM), and first applications on detecting differences in electronic properties of graphene oxide and boron nitride will be introduced to this scientific audience.
d) Micro-Raman spectroscopy has been used already to distinguish layers of SLG from few layers of graphene. We will demonstrate the use of a combination of a micro-Raman inverted light microscope in combination with an AFM in order to correlate both Raman maps and topographical or mechanical maps of the very same area [5].

References

[1] A.K. Geim and K.S. Novoselov, Nature Materials, **6** (2007) 183.
[2] J. Xie and J.P. Spellas, Agilent Technologies Application Note (2012), 5991-0782EN.
[3] S.S. Datta, D.R. Strachan, E.J. Mele, A.T.C. Johnson, Nano Letters, **9** (2009), 7.
[4] H.P. Huber, I. Humer, M. Hochleitner, M. Fenner, M. Moertelmaier, C. Rankl, A. Imtiaz, T. M. Wallis, H. Tanbakuchi, P. Hinterdorfer, P. Kabos, J. Smoliner, J. J. Kopanski, and F. Kienberger, J Applied Physics**, 111** (2012), 014301.
[5] R.D. Rodriguez, E. Sheremet, S. Müller, O.D. Gordan, A. Villabona, S. Schulze,M. Hietschold, D.R.T. Zahn, Rev Sci Instr, **83** (2012), 123708.

Figures

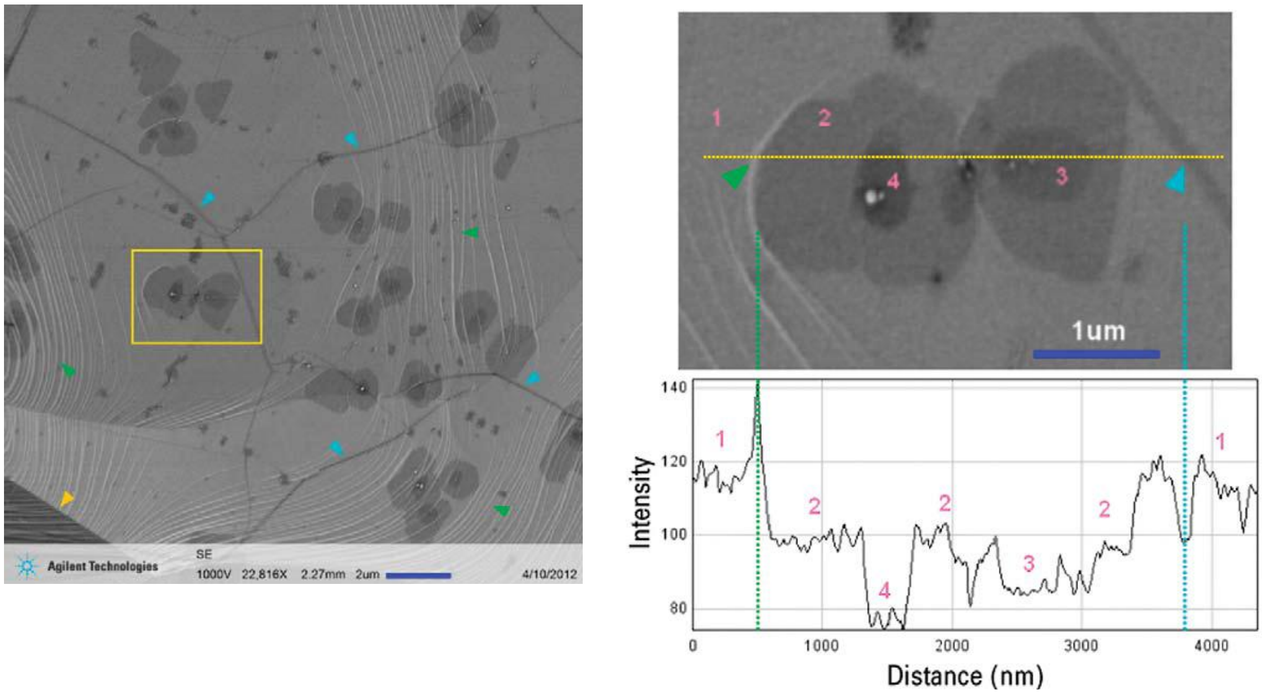

Figure 1 left) A typical SEM micrograph of CVD synthesized graphene on Cu foil; right) magnified image of the yellow box in a) showing different contrast in certain areas; right bottom) the intensity profile along the yellow line in the top right image clearly displaying four plateaus representing monolayer, bilayer, trilayer and quadrilayer graphene.

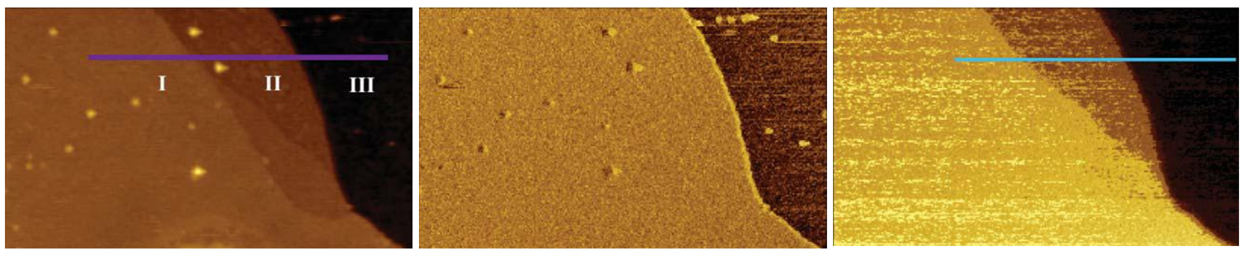

Figure 2 Topography (left), Capacitance gradient (dC/dZ; middle), and Surface Potential (Right) images recorded in single-pass Kelvin Force Microscopy (KFM) of few-layer graphene on silica surface.