AFM electrical characterization of graphene nanoLEDs

C. Munuera[1], M. García-Hernandez[1], A. Bengoechea-Encabo[2], S. Albert[2], M. A. Sanchez-García[2], E. Calleja[2], F. Calle[2], J. Martinez[2]

1. Instituto de Ciencia de Materiales de Madrid (ICMM). Consejo Superior de Investigaciones Científicas (CSIC). Sor Juana Inés de la Cruz 3, 28049 Madrid, Spain
2. ISOM Instituto de Sistemas Optoelectronicos y Microtecnologia, Universidad Politecnica de Madrid, Av. Complutense s/n. Madrid 28040. Spain

cmunuera@icmm.csic.es, javier.martinez@upm.es

Abstract

Graphene has attracted increasing attention in recent years [1] due to its excellent mechanical, optical and electrical properties. Its high theoretical surface area (2630 m^2g^{-1}) and high electrical conductivity make it an attractive material for many industrial applications [2]. Also it is a flexible transparent material that can be used for sensors, solar cells, light emitting diodes (LEDs) and organic LEDS (OLEDs), touchscreens and liquid crystal displays (LCD) [3].

A layer of graphene can be prepared by several techniques: mechanical exfoliation from graphite, precipitation on a silicon carbide surface, reduction of exfoliated graphene oxide, and chemical vapor deposition (CVD) growth on Cu or Ni. For electronics, the most used one is CVD, and the synthesized graphene is commonly grown on a flat metal foil or thin film and transferred to the desired substrate by sping coating of PMMA.

In general, the transparent conducting electrode used for the light emitting diodes (LEDs) is the indium tin oxide (ITO), but this material has a high cost and is unstable in the presence of acids or bases and has poor transparency in the blue and near-infrared light ranges [4]. Furthermore the need to replace ITO is even increasing due to the limited availability of indium on earth [5]. Graphene is the ideal candidate in order to replace the ITO due to its excellent electrical, optical and mechanical properties. So in this work we used graphene as a transparent electrode as a top contact in the nanoLEDs.

All the nanostructures were created in a 2 inch wafer of GaN over a sapphire substrate (Lumilog, France). The sample was patterned by colloidal lithography using 100 nm polystyrene nanospheres and a thin layer of 10 nm of Ti was deposit on top. After removing the nanospheres, the sample was inserted inside a plasma assisted MBE in order to grow the nanocolumns (NCs). With different conditions, one can create NCs with diverse doping (n or p) creating nanoLEDs. These devices are coated with a layer of SiO_2 as isolator. Finally, on top we deposit a layer of graphene as transparent electrode.

The electrical transport properties of the graphene/GaN junction have been characterized by means of conductive Scanning Force Microscopy (c-SFM) measurements. The formation and rupture of nanocontacts is achieved by using the SFM probe as a movable top electrode to individually contact the graphene-covered GaN nanocolumns (Figure 1). By combining multidimensional spectroscopy data acquisition [6] we have studied the influence of the loading force on the current versus voltage characteristics and identified the critical load at which a stable junction is formed and reproducible IV curves are obtained (Figure 2). Analysis of the measured IV curves is performed to extract the relevant parameters (barrier height, ideality factor) of the nanojunction.

References

[1] B. Luo, S. Liu, L. Zhi, Small **8** (2012) 630.
[2] M. D. Stoller, S. Park, Y. Zhu, J. An, R. S. Ruoff, Nano Letter, **8** (2008) 3498.
[3] X. Cao, Y. Shi, W. Shi, G. Lu, X. Huang, Q. Yan, Q. Zhang, and H. Zhang, Small **7** (2011) 3163.
[4] G. Jo, M. Choe, C. Y. Cho, J. H. Kim, W. Park, S. Lee, W. K. Hong, T. W. Kim, S. J. Park, B. H. Hong, Y. H. Kahng, T. Lee, Nanotechnology **21** (2010) 175201.
[5] H. Park, J. A. Rowehl, K. K. Kim, V. Bulovic, J. Kong, Nanotechnology **21** (2010) 505204.
[6] Perez-Garcia et al., Nano Letters, **7** (2007) 1505.

Figures

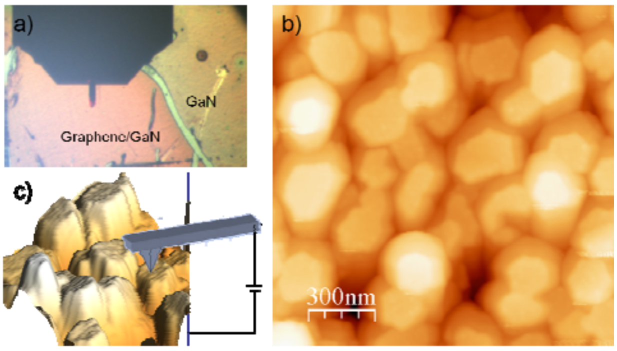

Figure 1: a) Optical image of the graphene-covered and uncovered GaN regions. b) Topographic image of the graphene/GaN nanocolumns surface. c) Schematics of the c-SFM set-up

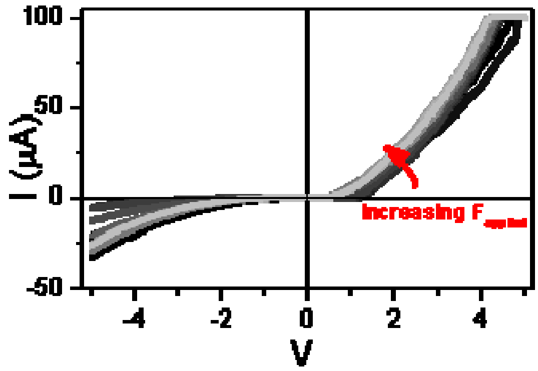

Figure 2: IV curves acquired on top of a graphene/GaN column as a function of the applied load