Raman spectroscopy in bilayer graphene samples with many different twisting angles

H. B. Ribeiro[1], K. Sato[3], G. S. N. Eliel[2], E. A. T. de Souza[1], Po-Wen Chiu[4], R. Saito[3], and M. A. Pimenta[2]

[1]MackGraphe, Mackenzie Presbyterian University, R. da Consolação 896, São Paulo, Brazil
[2]Physics Department, UFMG, Av. Antônio Carlos, 6627, Belo Horizonte, Brazil
[3]Department of Physics, Tohoku University and CREST, Sendai, 980-8578, Japan
[4]Department of Electrical Engineering, National Tsing Hua University, Hsinchu 300, Taiwan
henfisica@gmail.com

Abstract

In this work, we performed a Raman spectroscopy study of bilayer graphene samples with many different twisting angles, using three different laser lines in the visible range. By controlling the growth parameters in the CVD method, it was possible to obtain twisted bilayer graphene samples where both the bottom and top layers exhibit a hexagonal morphology. Therefore, the rotation angles between the two layers were determined by a simple optical analysis for more than 150 samples, as shown in Fig 1.

Raman mapping of the 150 samples were obtained using the 488 nm, 532nm and 633 nm laser lines, and the intensities and FWHM of all Raman features, mainly the G and 2D bands, were analyzed as function of the twisting angle. A huge increase in the G band intensity could be observed for samples with intermediate twisting angles (between 9 and 14 degrees) and the results could be explained in terms of resonances with van Hove singularities [1] that arise from the coupling between the two Dirac cones of the bottom and top layers. For low and large twisting angles, we have observed that the ratio between the G band intensities in the bilayer and single layer regions (I_B/I_S) depends on the laser energy and also exhibit different dependence for low and large twisting angles. We have also analyzed the 2D band shape and intensity as a function of the twisting angle and our results reveals that the Dirac cones of the two layers are coupled for low twisting angles and practically uncoupled for large twisting angles.

Our analysis always allowed us to obtain the twisting angle dependence of the G band FWHM that can be correlated with the G band enhancement due to resonances with van Hove singularities. We will also present results of a number of sharp and extra peaks just above and below the G band position, which are ascribed to the umklapp double resonance process, where the momentum conservation is provided by the wavevector connecting the two Dirac cones of the bottom and top graphene layers.

References

[1] K. Sato, R. Saito, C. Cong, Ting Yu, and Mildred S. Dresselhaus, Phys. Rev. B, **86** (2012) 125414.

Figures

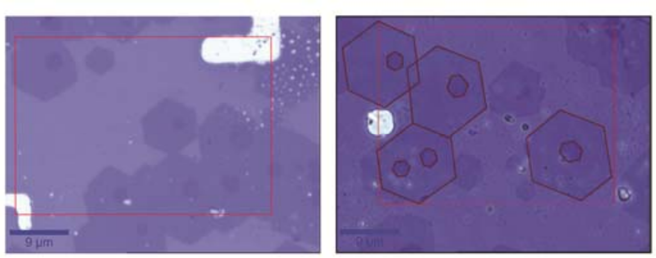

Fig. 1 – Optical image of sample showing the bilayer graphene and the rotation angle between two layers.