Optical study of graphene: from fundamental studies to applications

Zexiang Shen, Professor
Division of Physics and Applied Physics, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore 637371

Graphene exhibits many exciting properties, such as anomalously quantized Hall effects, massless Dirac-Fermions like charge carrier, existence of a minimum conductivity, which make it promising material for the future nano-electronic devices. All these properties are originated from its unique band structure whose conical valence and conduction bands meet at the Dirac point in Brillouin zone. Due to the resonance and double resonance effects with the visible light, Raman spectroscopy has been historically used to probe not only structural information but also the electronic characteristics of carbon materials.

In our group, we use Raman spectroscopy and imaging to study graphene in the following aspects. (1) Raman imaging in together with contrast imaging can be used to unambiguously determine the graphene thickness. Determining the thickness of a 1-atomic thick sample is non trivial and a fast, reliable and easy-to-use technique is critically important for graphene study. (2) In addition to its own usefulness, graphene is also a model material for a host of technologically important systems. For example, graphite can be constructed by AB stacking of graphene layers. Graphene nanoribbons can be obtained by cutting a narrow strip of graphene along certain crystal axes. Carbon nanotubes and C60 can be obtained by appropriate cutting and folding of graphene. Their properties strongly depend on the cutting direction. Hence crystal axes determination of graphene is of fundamentally important. We show that the crystallographic axes of graphene samples can be determined by using the defect-related D band (Figure 1). (3) Raman imaging of folded graphene sheets has revealed the two dimensional Dirac-like (single layer graphene-like) character of electronic states and with reduction of Fermi velocity (Figure 2). (4) We have also studied the effect of top insulator layer deposition (SiO_2, HfO_2, PMMA) with different techniques (ALD, PLD, Sputtering, spin coating) on the properties of graphene. The effect of high temperature annealing and molecular doping is also studied. (5) Uniaxial strain is applied on graphene, and the strain is detected by Raman spectroscopy and imaging. Bandgap opening on graphene, which is critical to its application, is possible by applying such strain. The results obtained here by Raman imaging help on the better understood of fundamental properties of graphene and might speed up its application on future electronic devices.

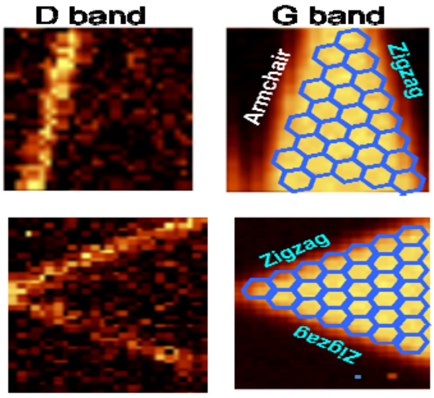

Figure 1. Raman images of two graphene samples that consist of 30 and 60 degree edges The image using the G band intensity shows the graphene samples. The intensity of the D band (defect bands) shows the edges of the graphene samples. The D band intensity for the arm chair edges are stronger than those for zigzag edges.

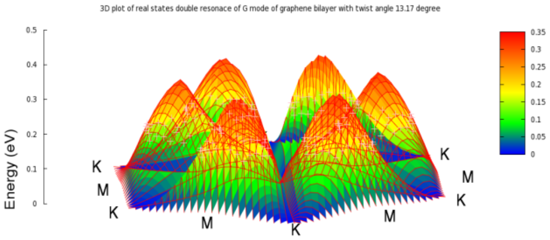

Figure 2. Calculate band structure of a folded graphene sample

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