

Modifying Properties of Graphene – a Raman Microscopic Study

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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. Raman spectroscopy/imaging has proven to be a very important tool for the study of nano carbon materials. Due to the resonance and double resonance effects with the visible light, Raman spectroscopy has been used to probe not only structural information but also the electronic characteristics of carbon materials. In this talk, we will present our Raman imaging study of graphene [1-4].

Raman imaging as an easy to use technique to determine the graphene thickness and the graphene axes. 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[1,4]. 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. We show that the crystallographic axes of graphene samples can be determined by using the defect-related D band (Figure 1)[2]. Raman imaging of folded graphene sheets reveal the two dimensional Dirac-like, i.e. single layer graphene (SLG)-like. For applications in nano-electronic devices and energy harvesting, opening of the band gap is needed. On the other hand, many of the unique properties of graphene are accorded to that of SLG. But it is very difficult to fabricate large single crystalline SLG samples for practical applications. It would be most desirable to modify few-layer graphene (FLG) samples so that they have similar properties as that of SLG. Figure 2 shows the results of FeCl₃-based few-layer graphene intercalation compound, which clearly resolves the Raman peaks due to the top and bottoms graphene layers. We will also present our results in modifying graphene for various applications, including modifying edge chirality, intercalation, hydrogenation, and studies of graphene with mis-oriented layers.

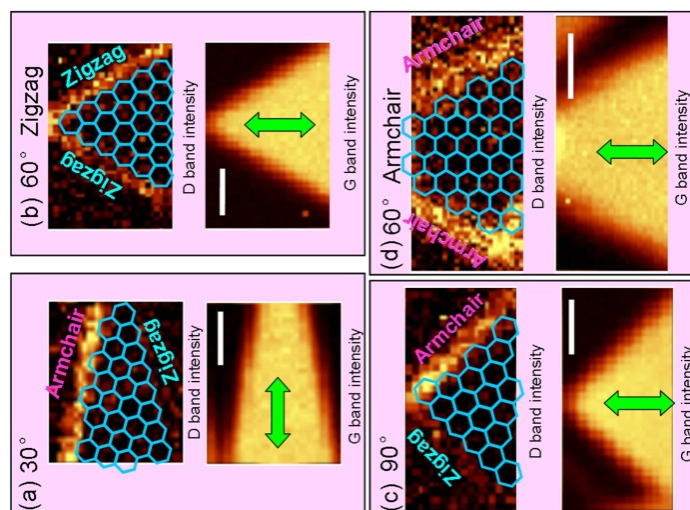


FIGURE 1. Raman images of graphene samples that consist of 30, 60 and 90 degree edges. The image using the G band intensity shows the graphene samples. The intensity of the D band (defect bands) shows the edges of the graphene samples. The D band intensity for the arm chair edges is stronger than those for zigzag edges.

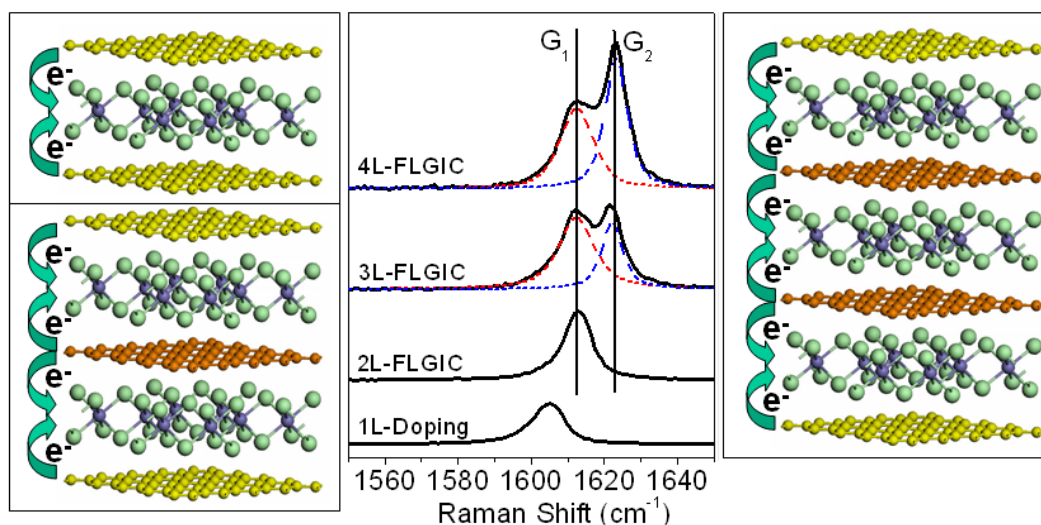


FIGURE 2. The Raman G peak of 1L doped graphene and 2L- to 4L- FLGIC and their schematic crystal structures. The 2L-FLGIC shows a singlet G peak (G_1) at $\sim 1612 \text{ cm}^{-1}$, while 3L- and 4L-FLGIC show doublet G peaks (G_1 and G_2 peaks locate at $\sim 1612 \text{ cm}^{-1}$ and $\sim 1623 \text{ cm}^{-1}$, respectively) with different intensity ratio. The G_1 and G_2 peaks are fitted with dashed red and blue curves, respectively.

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