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Probing strain on graphene flake using polarized Raman spectroscopy

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ABSTRACT

We presented an approach to measure the strain on graphene by using the polarized Raman spectroscopy with two excited sources and lineshape analysis, and studied the strain effect due to golden nanoparticles on graphene flake with it. The surface enhanced Raman spectroscopy (SERS) can effectively enhance Raman signals, but depositing metallic films or nanoparticles on graphene is needed. We compared the Raman signal intensity using Raman spectroscopy and SERS, and fitted the lineshape into the combined Lorentzian profiles. The strain effect due to golden nanoparticles can be neglected in our experimental design. The distribution of golden nanoparticles can be regarded as random. The technique of SERS can enhance Raman signal and not cause strain changing. At the same time, the Raman signal intensity of graphene flake with 532-nm laser excitation is larger than one with 632-nm laser approximately 10 times. Expectedly, we used the way of 532-nm excited laser and technique of SERS to greatly enhance measuring efficiency.

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1. Introduction

Graphene is one of the most popular materials in recent years. Because of its unique electrical and optical properties, it is of interest to many scientists and technologists [1,2]. For realizing the characteristics of graphene, scientists use a lot of detection technologies. Currently, Raman spectroscopy is one of the most important detection technology for distinguishing the properties of graphene. It can provide useful information and interesting phenomena of graphene, such as number of layers [3], edges [4], and strain. Strain is a factor which can change the Raman spectrum of graphene. In order to study the Raman spectrum of graphene due to the strain, scientists tried to bend or stretch the graphene flakes, and analyzed the corresponding Raman spectra [5]. Then, the strain effect is angle-dependent, this measurement can be observed by polarized Raman spectroscopy [5]. Although the strain can be investigated, this method cannot measure unknown intrinsic strain on graphene. The intrinsic strain on graphene is a very important phenomenon and deserved to be investigated, because strain or stress can transform the properties of graphene, such as band structure of graphene [6], the performance related components were inevitably affected by the strain. Thus, realizing the intrinsic strain on graphene is very important.

Monolayer graphene sheets were received by using the method of micromechanical cleavage, which were exfoliated from highly oriented pyrolytic graphite using a 3 M tape and transported on the SiO_2/Si substrate. The graphene sheets are usually fabricated on the SiO_2/Si substrate because it can be observed visibly by optical microscopy [7]. The thickness of SiO_2, ~300 nm, is calculated and measured to the best performance of Raman signal intensity [8]. Scientists introduced the concept of surface plasmon resonance to increase the measured Raman spectrum, known as Surface enhanced Raman spectroscopy (SERS) [9–12]. We measured the graphene which was prepared by mechanical exfoliation and used the thermal evaporator deposition system to deposit the thickness of 5 nm Au film on graphene, and then annealing 300 °C. The average diameter of Au nanoparticles (NPs) is ~10 nm approximately.

In this work, we used the polarized Raman system with two excited laser source to obtain the Raman spectra of graphene flakes with undirected strain. Then, we can identify the strain direction and the strain levels, and found the data sets excited by two lasers were consistent, and the 532-nm laser can help the Raman system to generate 10-times stronger signal intensities.

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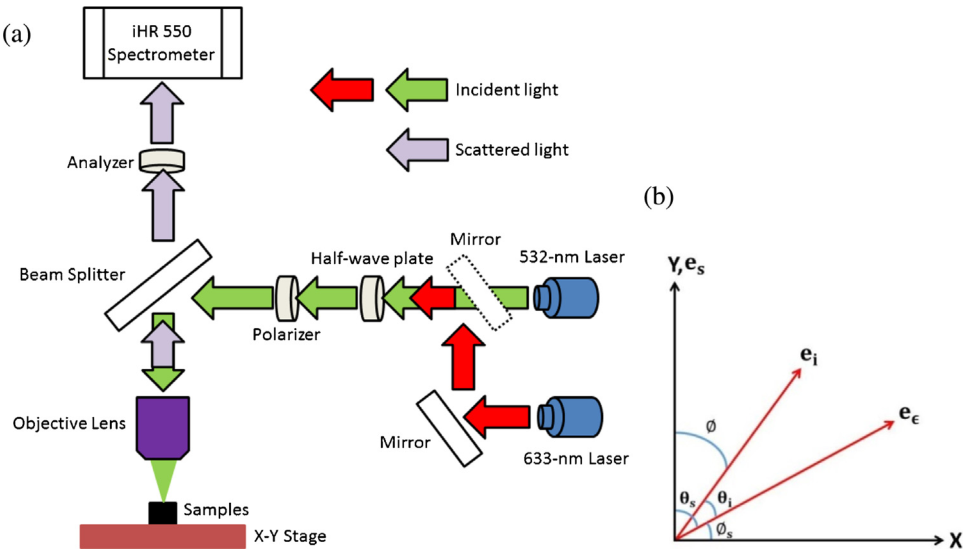

Fig. 1. (a) The scheme of the polarized Raman system. (b) Define the measuring axes.

2. Experimental

The polarized Raman system is shown in Fig. 1(a). A 30-mW 532-nm diode-pumped solid-state (DPSS) laser (Genuine Lasers, Taiwan) and a 12-mW 633-nm He–Ne laser were employed as the excitation sources. A set of a polarizer and a half-wave plate (HWP) was used to control the incident polarization direction and keep the incident laser power as 8 mW for two excitation laser sources. The laser power on graphene surface is 0.45 mW after delivery path. We selected 50× microscope objective lens (NA = 0.75) to focus the laser beam onto the sample and to collect the scattered light. The laser beam was focused to the samples with focal spot diameter of ~0.5 μm. The scattered signal was collected with a 55-cm Raman spectrometer (iHR550 Jovinyvon) and detected with a liquid-nitrogen cooled CCD detector. The grating is set as 1800 grooves/mm and spectral resolution was 0.7 cm^{-1}. The polarization direction of the scattered light was fixed using an analyzer. Here, the measured point was arranged in experiment, and we defined the axes shown in Fig. 1(b), a symbol of e_j is incident light direction, a symbol of e_ε is strain direction, and a symbol of e_s is scattered light direction, the measured polarization range is 0–180°, step of polarization is 15°, the integrate time is 60 s in Raman spectroscopy and 15 s in SERS measurements.

3. Results and discussion

The relations between Raman spectra of graphene of G peak and polarization in 532-nm DPSS laser measurements were illustrated in Fig. 2(a). The G peak was shifted with incident laser polarizations (ϕ), and can be regarded as the composition of two individual submodes. Fig. 2(b) showed the maximal red-shift of G peak at $\phi = 15°$ and the maximal blue-shift of G peak at $\phi = 105°$. We obtained two sub-mode of G band (G_- and G_+) using these two maximal profile fitted with single-Lorentzian. The frequency of red-shifted G submode at $\phi = 15°$ is 1578.6 cm^{-1} and the frequency of blue-shifted

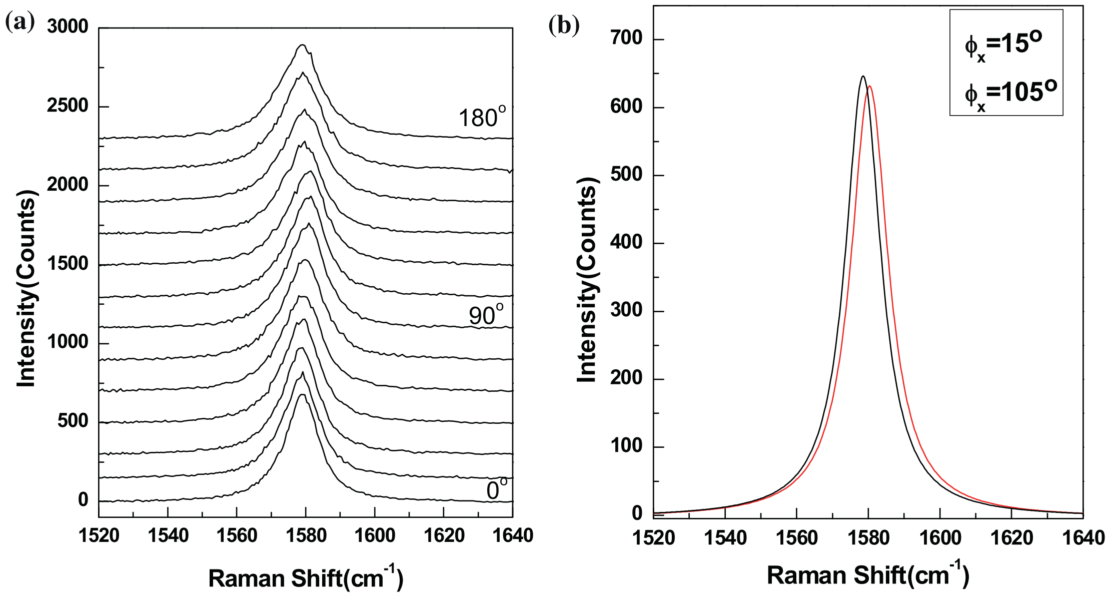

Fig. 2. (a) Relation between G band and polarization in 532-nm DPSS laser measurement. (b) The maximal red-shift of G peak at $\phi = 15°$ and the maximal blue-shift of G peak at $\phi = 105°$ in 532-nm DPSS laser measurement.

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