Estimation of Young's Modulus by Raman Spectroscopy on Biaxially Strained Graphene

Jae-Ung Lee, Duhee Yoon, Hyeonsik Cheong

Department of Physics, Sogang University, Seoul 121-742, Korea
hcheong@sogang.ac.kr

The Young's modulus of single layer graphene is estimated by measuring the strain applied by a pressure difference across graphene membranes using Raman spectroscopy. The mechanical properties of graphene are interesting research subjects because its Young's modulus and strength are extremely high. Values of ~1 TPa for the Young's modulus have been reported [1,2]. Raman spectroscopy is a very powerful tool for investigating the intrinsic properties of graphene. Especially, the Raman spectrum of graphene is very sensitive to the change of mechanical deformation. Since the graphene membrane is impermeable to any gas [3], it is possible to apply strain on graphene by applying a net gas pressure across a suspended graphene. Several groups have studied such graphene balloons [4]. We directly measured the strain induced on the pressurized graphene balloons by Raman spectroscopy. Graphene samples were prepared on the pre-patterned silicon substrates covered with 300-nm thick SiO_2 layer. The substrates were patterned by round holes with various diameters by photolithography and dry etching. The depth of the holes is ~5 μm, and the diameters are 2.0, 3.1, 4.2, 5.3, 6.4 and 7.3 μm. The graphene samples were prepared directly on the cleaned substrate by mechanical exfoliation from natural graphite flakes. The samples were placed into a chamber, and a pressure difference was applied across the graphene membrane by evacuating the chamber. This pressure difference makes the graphene membrane bulge upward like a balloon. By measuring the shifts of the Raman G and 2D bands, we estimated the amount of strain on the graphene membrane. To estimate the amounts of strain from the Raman spectrum, we use the reported value of the Grüneisen parameters [5,6]. We estimated the biaxial strain on the center of graphene membrane to be about 0.19%. The strain at the center of the hole tends to increase as a function of the diameter of the hole. By comparing the strain estimated from the Raman measurements with numerical simulations based on the finite element method, we obtained the Young's modulus of graphene.

References

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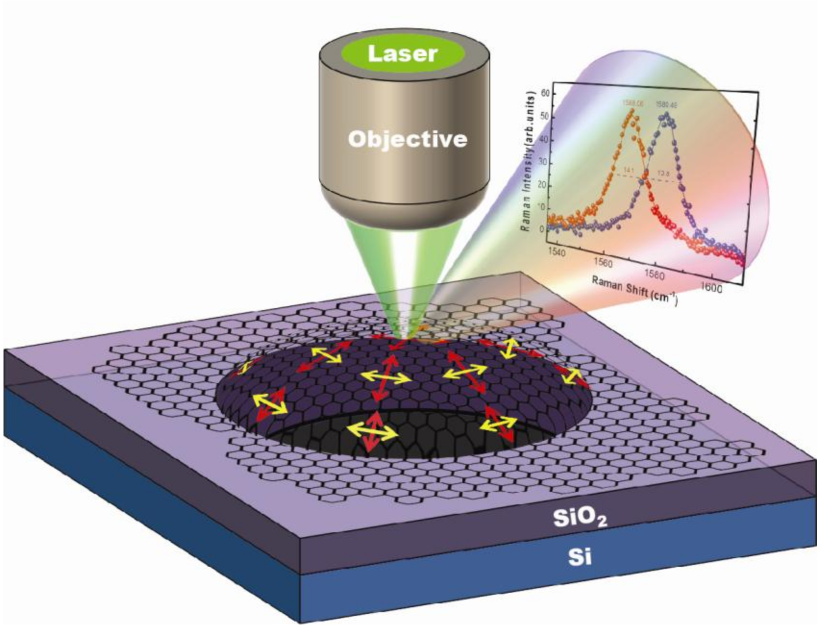
Figures



Schematic diagram of experimental setup.