40th Leeds-Lyon Symposium on Tribology &TribochemistryForum 2013
September 4-6, 2013, Lyon, France

Exfoliation of Graphene from C_{60} monolayer

K. Miura[1*], M. Ishikawa[1], M.Ichikawa[1], N.Sasaki[2]

[1)] Department of Physics, Aichi University of Education, Hirosawa, Igayacho, Kariya-shi, Aichi 448-8542, Japan
[2)] Department of Materials and Life Science, Faculty of Science and Technology, Seikei University, 3-3-1 Kichijoji-Kitamachi, Musashino, Tokyo 180-8633, Japan
[*]Corresponding author: kmiura@auecc.aichi-edu.ac.jp

1. Introduction

Detachment and exfoliation experiments areexpected to provide information on the adhesion forces andenergies of solid surfaces in contact with each other.However, it was not easy to scientifically solve exfoliation and fracture, because we could not approach them at the atomic scale.Recently, it has been reported that carbon nanotube arrays with curved entangled tops exhibit a macroscopic adhesive force of approximately 100N/cm^2, almost 10 times as large as that of a gecko foot, and a shear force much stronger than the normal adhesion force[1,2].

Wefocus our attention on the elementary processes involved in the exfoliation of a graphene on the C_{60} monolayer.

2. Experimental setup

First, we account for the preparation of a single-layer graphene (SL-graphene) and a graphene tip. Graphene films were prepared by the mechanical exfoliation (repeated peeling) of highly oriented pyrolytic graphite. Figure 1(a) shows an optical microscopy image of a relatively large multilayer graphene (ML-graphene) on top of an oxidized Si wafer that locally includes an SL-graphene.The position of the SL-graphene on the oxidized Si wafer was estimated from the shape of the G' band of Raman spectroscopy,as shown in Fig. 1(b), because atomic force microscopy (AFM) was not sufficient for identifying the SL-graphene on the oxidized Si wafer. The thickness of the SL-graphene on the oxidized Si wafer was estimated to be approximately 0.8 nm using AFM, corresponding to the height difference between X and Y at the bottom of Fig. 1(c), although the thickness of the SL-graphene on another SL-graphene (or an ML-graphene) was estimated to be approximately 0.3 nm, corresponding to the height difference between Y and Z, because the force between the graphene and the oxidized Si wafer is different from that between graphenes. Here, a glass sphere (diameter: 40 μm) with a two-component epoxy resin adhesive was used to bond the SL- or ML-grapheneson the oxidized Si wafer to the AFM tip. We call this a graphene tip. The junction formed between the AFM tip and the graphene is sufficiently mechanically rigid to measure the elasticity of the SL- or ML-graphene during the exfoliation process. Figure 1(d) shows a scanning electron microscopy (SEM) image of the ML-graphene tip. We set the graphene tip on the AFM instrument under ambient conditions and obtained the vertical force-distance curve. Figure 1(e) depicts a schematic of the exfoliation experiment.

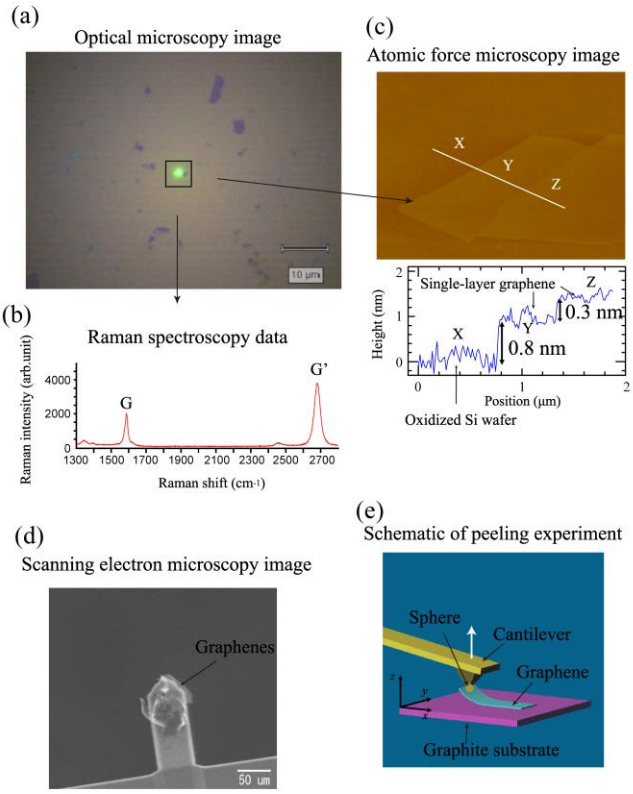

Fig. 1 Preparation of single layer (SL-) graphene and graphene tip. (a) Optical microscopy image of relatively large multilayer graphene (ML-graphene) on top of oxidized Si wafer that locally includes SL-graphene. (b)and(c) Raman spectroscopy data and atomic force microscopy (AFM) image of SL-graphene on oxidized Si wafer, respectively. (d)Scanning electron microscopy (SEM) image of graphene tip. (e) Schematic of exfoliation (peeling) experiment.

3. References

[1] Qu,L. Dai,L. Stone,M. Xia, Z.and Wang, Z. L.,"Cabon nanotube arrays with strong shear biding-on
and easy normal lifting-off", Science,322, 2008, 238-242.

[2] Ishikawa, M.Harada, R.Sasaki,N. and Miura, K., "Adhesion and peeling forces of carbon nanotubes on a substrate",Phys. Rev. , B 80 ,2009, 193406.