Ultimate High Conductivity Probed by Multiprobe Scanning Tunneling Potentiometry on a High-Quality Graphite Thin Film

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Graphite is a material that has been used for a long time because of its excellent properties. With the discovery of graphene, further applications of graphite as fabricable electrode materials such as flexible and high mobility electronic devices have been actively studied. Recently, the industrial growth of large-area high-quality graphite films with thicknesses from ~0.5 to ~3 μm has been successfully realized by a polymer pyrolysis method. To advance these applications, it is highly desired to unveil its intrinsic and ultimate conductivity which is not affected by its structural disorders such as steps, grain boundaries, and wrinkles.

In this work, we performed a multiprobe scanning tunneling potentiometry (MP-STP) method with UHV four-probe STM system which is integrated with optical zoom lens. As shown in Fig. 1, we used a stiff electrochemically etched tungsten probe for STM (Tip1) and three Pt/Ir coated conductive cantilevers for making soft mechanical contacts (Tip2, 3 and 4). The constant current was applied from Tip3 to Tip4, and Tip1 probed the surface structure and the surface potential difference between Tip2 and oneself. As a result, the potential mapping could be distributed on the STM topography image as shown in Fig. 2. With the numerical analysis and c-axis directional measurement, we revealed the local conductivity 0.30 ± 0.01 μΩ·m as an ultimate value which was about 30% lower than that (0.427 μΩ·m) obtained by the macroscale van der Pauw method. Then, as shown in Fig. 3, we clarified with a contact four-probe method that one of the reasons for the difference was considered to be wrinkles in microscale [1]. A growth method of eliminating wrinkles is currently underway.

[1] H. Mogi et al, *ACS Appl. Electron. Mater.* 1, 1762-1771 (2019)

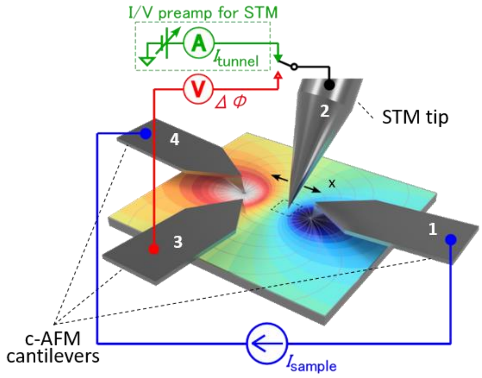

Fig. 1 Schematic diagram of the MP-STP setup

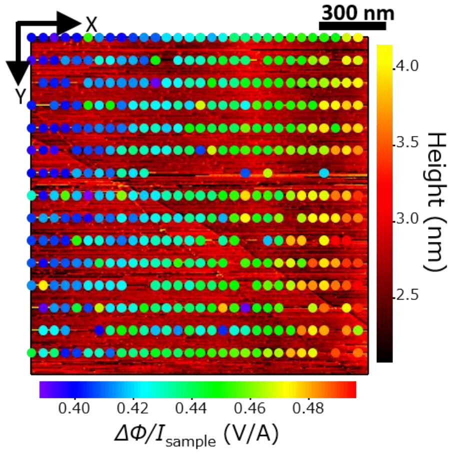

Fig. 2 Topographic image and potential difference mapping

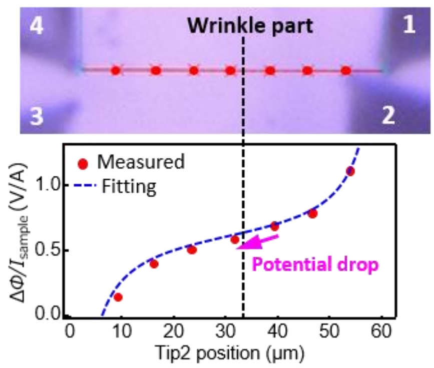

Fig. 3 Potential drop at a wrinkle revealed by a four-probe method