Low-Energy Electron Diffractive Imaging Based on a Single-Atom Electron Source

I. -S. Hwang, W.-T. Chang, C.-Y. Lin, W.-H. Hsu, M.-T. Chang, Y.-S. Chen and T. T. Tsong

Institute of Physics, Academia Sinica, Nankang, Taipei, Taiwan
hsuwh@phys.sinica.edu.tw

A single-atom tip (SAT) can be an ideal field emitter of electron beams. It has been shown that noble-metal covered W(111) SATs can be reliably prepared[1,2] with several controllable profiles[3]. The growth of the faceted pyramidal tips is a thermodynamic process. These SATs are both physically and chemically stable and can be regenerated through a simple annealing in vacuum, ensuring a long operation lifetime. Both the brightness and spatial coherency of these single-atom electron sources are orders of magnitude better than those of the state-of-the-art electron sources used in current electron microscopes[4].

We have built a low-energy electron point projection microscope (PPM) to image nano-objects. A schematic is shown in Fig. 1. The PPM is a shadow microscope where an object is placed between an electron point source and a detector screen. A higher magnification image is obtained as the tip approaches the object (smaller ***d***) or as the detector is retracted (larger ***D***). When the detector is retracted, the bright-field projection images can be obtained; when the detector is moved close to the sample (small ***D***), the dark-field diffraction patterns of the sample at large angles can be recorded. Figs. 2(a) and 2(b) show a projection image and the corresponding diffraction pattern of a graphene sample, respectively. Fine structures inside each diffraction disk of graphene can be clearly seen. We will discuss the meaning of the diffraction pattern.

Fig. 3 illustrates a new design of a low-energy electron diffraction microscope based on a single-atom electron gun and a focusing lens. It allows different imaging modes, including SEM imaging, coherent electron diffraction imaging, and PPM imaging. This new instrument may allow determination of the atomic structures of individual thin nano-objects, such as graphene, carbon nanotubes, DNA molecules, or protein molecules.

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[2] H.-S. Kuo, I.-S. Hwang, T.-Y. Fu, Y.-C. Lin, C.-C. Chang, T. T. Tsong, Jap. J. Appl. Phys. **45**, 8972 (2006).
[3] W.-T. Chang, I.-S. Hwang, M.-T. Chang, C.-Y. Lin, W.-H. Hsu, J.-L. Hou, Rev. Sci. Instrum. **83**, 083704 (2012).
[4] C.-C. Chang, H.-S. Kuo, I.-S. Hwang, T. T. Tsong, Nanotechnology **20**, 115401(2009).

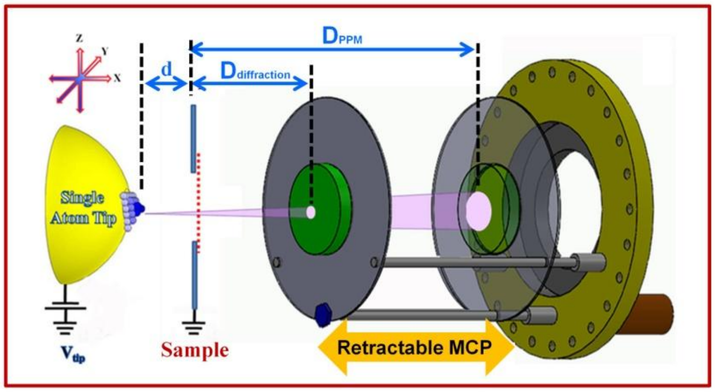

Figure 1: Schematic of an electron point projection microscope with a retractable MCP. The bright-field projection images is obtained when $\boldsymbol{D} = \boldsymbol{D}_{PPM}$ =13 cm, and the diffraction patterns of the object at large angles can be recorded when $\boldsymbol{D} = \boldsymbol{D}_{diffraction}$ = 3 cm. The magnification of the bright-field image is $\boldsymbol{M = (D+d)/d}$.

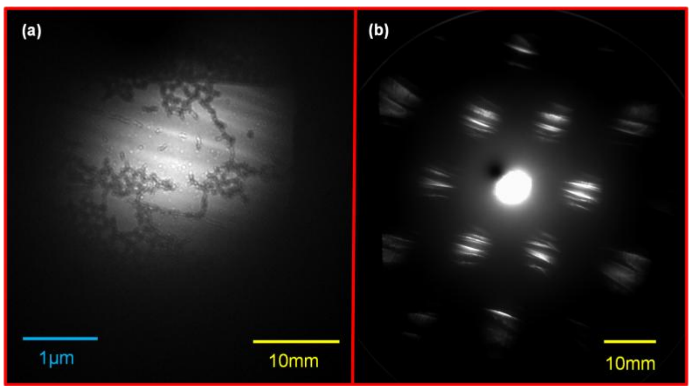

Figure 2: Study of a suspended graphene sheet. (a) Bright-field PPM image taken at $\boldsymbol{D} = \boldsymbol{D}_{PPM}$. (b) Diffraction pattern taken at $\boldsymbol{D} = \boldsymbol{D}_{diffraction}$. The yellow scale bar at the lower right-hand corner indicates a length on the screen; the blue scale bar at the lower left-hand corner indicates a length on the sample plane.

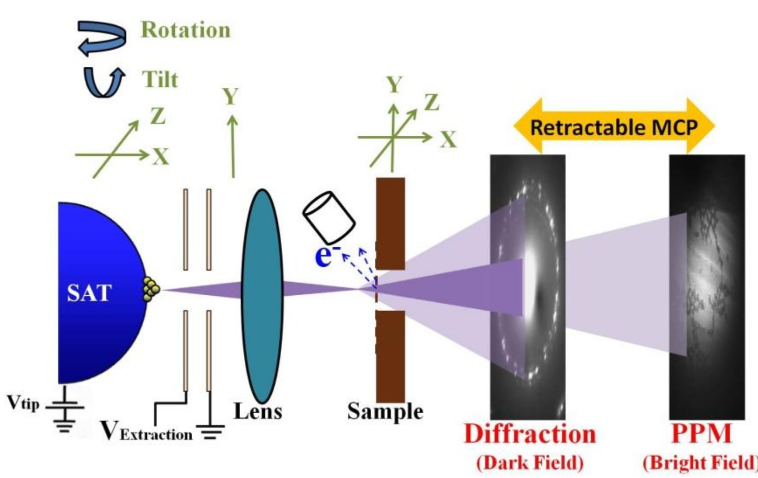

Figure 3: Schematic of a low-energy electron diffraction microscope.