Type of presentation: Poster

IT-1-P-2975 Design and Characterization of a Single-Atom Electron Column

Lin C. Y.[1,2], Chang W. T.[1], Hsu W. H.[1,3], Lai W. C.[1,2], Chen Y. S.[1], Hwang I. S.[1]

[1]Institute of Physics, Academia Sinica, Taipei, Taiwan, [2]Department of Physics, National Taiwan University, Taipei, Taiwan , [3]Department of Materials Science and Engineering, National Tsing Hua University, Hsinchu, Taiwan

Email of the presenting author: cylin@phys.sinica.edu.tw

It has been shown that noble-metal covered W(111) single atom tips (SATs) can be reliably prepared [1,2]. We have demonstrated full spatial coherence of electron beams emitted from the SATs [3]. Thus, single atom electron sources are suitable for phase retrieval imaging methods, such as holography and coherent diffractive imaging. We have proposed a SAT-based low-keV electron microscope that allows different imaging modes, as shown in Fig. 1. For this purpose, we plan to build an electron column with the capability to accelerate electron beams to 1~5 keV and a focused beam spot smaller than 100 nm. The column is composed of two parts: an electron gun and a condenser lens.

The electron gun consists of a SAT, an extractor/suppressor, and an acceleration electrode. The tip is mounted on a holder that can be translated, tilted, and rotated in nanometer scale by piezo-positioners. Therefore, the tip-lens alignment can be done in vacuum without alignment coils. We have recorded the opening angles of the electron beams. As shown in the inset of Fig. 2, the emitter can be moved to different positions with the piezo-positioners and the corresponding beam profiles are recorded. Fig. 2 shows the half opening angles of the beams at an electron energy of 2.5 keV measured at different extraction voltage and different separations. Clearly the beam opening angle varies with the tip position. When the tip is positioned at about -2.5 mm, the half opening angle can be smaller than 1 mrad. We also find that the suppressor design that is often used in normal field emitters is not effective in reducing the beam divergence for the SAT emitter.

The condenser lens consists of a limiting aperture, an einzel lens, and an octupole stigmator. We used Simion 8.1 software to simulate the lens parameters and determine the aperture diameter. In our simulations at the electron energy of 2.5 keV and the working distance of 2 mm, a spot size of 140 nm is obtained when the limiting aperture of 100 μm is used; a spot size of 20 nm is obtained when the limiting aperture of 20 μm is used. Fig. 3(a) shows the whole assembly of our instrument. As shown in Fig. 3(b), we have obtained a diffraction pattern on a small region of a suspended CVD graphene, which show two domains with different orientations. We are also designing a microcolumn based on the MEMS technique. Our ultimate goal is to determine the atomic structures of few-layer two-dimensional structures such as graphene and one-dimensional structures such as carbon nanotubes and bio-molecules.

References

[1] H. S. Kuo et al, Nano Lett. 4(12) (2004), p. 2379.

[2] H. S. Kuo et al, J. J. Appl. Phys. 45 (2006), p. 8972.

[3] C. C. Chang et al, Nanotech. 20 (2009), p. 115401.

Acknowledgement: This work is supported by National Science Council of ROC and Academia Sinica.

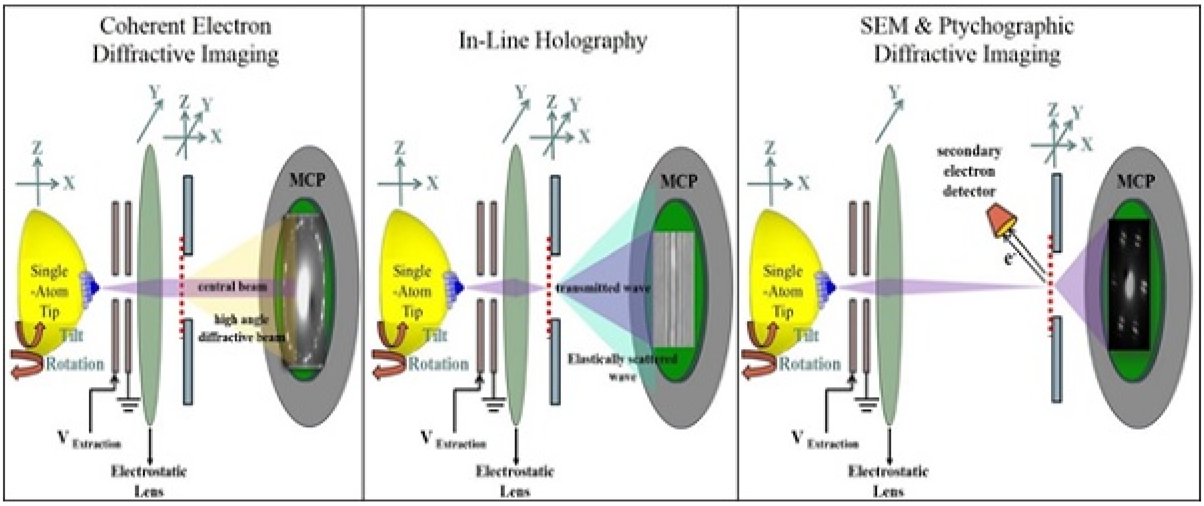

Fig. 1: Schematic of a multi-mode low-keV electron microscope

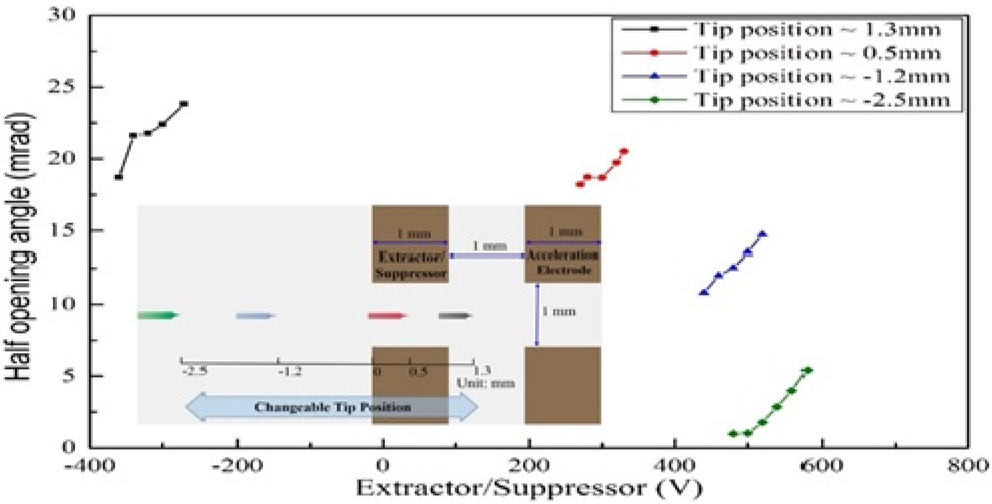

Fig. 2: Beam divergence, measured with the half opening angle at an electron energy of 2.5 keV, versus the extractor/suppressor voltage at different emitter positions. The inset is the schematic for characterization of the beam profile at different emitter positions.

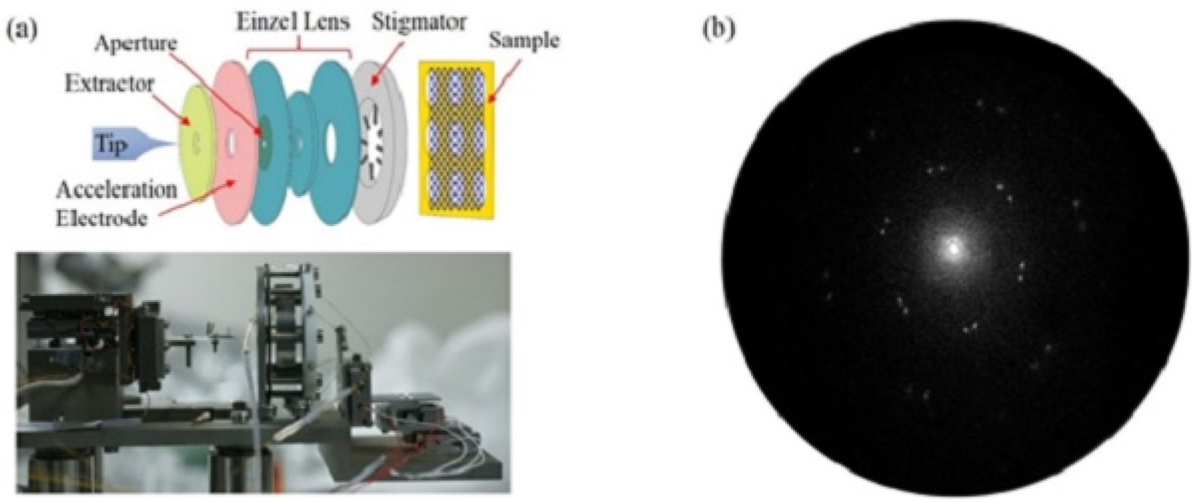

Fig. 3: (a) Illustration and photo of a low-keV electron microscope (b) The diffraction pattern of a CVD graphene sample