

Low-voltage coherent electron microscopy based on a highly coherent electron source

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Developing low-voltage electron microscopes has been a general trend due to high imaging contrast and low radiation damage. Recently, atomic-lattice-resolved transmission electron microscopes with voltages as low as 15-40 kV have been demonstrated. However, achieving atomic resolution at voltages lower than 10 kV is extremely difficult. An alternative approach is coherent imaging or phase retrieval imaging, which requires a sufficiently coherent source as well as detection of high-angle scattering patterns. Experimental schemes of both lens-less and lens-containing designs and preliminary results based on a highly coherent single-atom electron source are presented [1, 2].

Electron point projection microscopy (PPM) is a lens-less technique to implement coherent imaging. Fig. 1 shows a schematic of a PPM with a retractable detector. High-magnification PPM images can be directly obtained when the detector is moved to the far end. If the detector is moved close to the sample to increase the collection angle, diffraction patterns can be recorded. Three-dimensional displacement of atoms as small as 1 Å can be detected through low-energy divergent beam electron diffraction [3].

The lens-less scheme is simple and can achieve a high imaging contrast due to the use of low-energy electrons (20-500 eV). However, it can only be applied to samples of thickness less than 1 nm. Thus, a low-kilovolt electron diffraction microscope with energies between 1 and 10 keV was developed. Fig. 2(a) shows a schematic of a low-kilovolt CDI instrument. High-angle coherent diffraction patterns of a suspended graphene sample corresponding to $(0.62 \text{ \AA})^{-1}$ were recorded, as shown in Fig. 2(b). With a sufficiently small detection area on the sample to fulfill sampling requirements of coherent diffractive imaging (CDI), atomic structures of the sample may be reconstructed. The ultimate goal is to achieve high-contrast and high-spatial-resolution imaging of thin materials, such as two-dimensional materials, or molecules, such as organic or biological molecules, under low-dose conditions

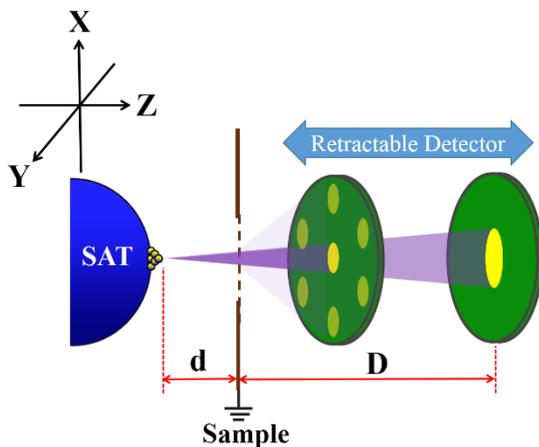


Fig. 1: Schematic of an electron PPM with a retractable detector.

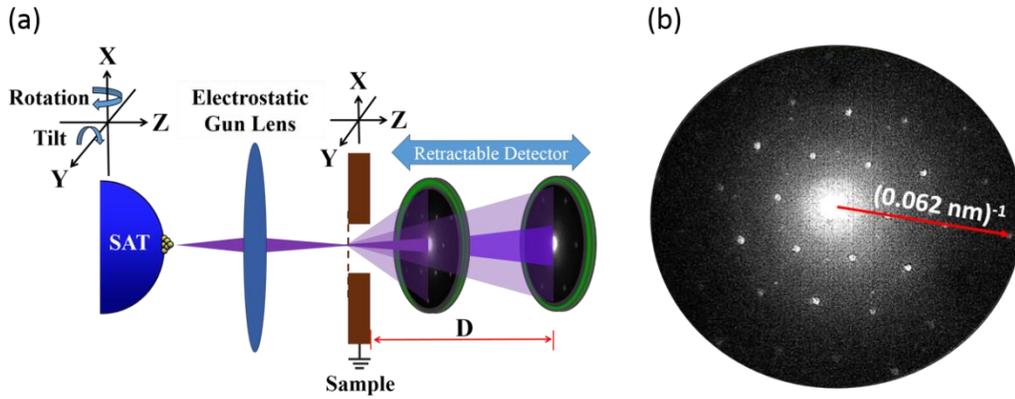


Fig. 2: (a) Schematic of a low-kilovolt CDI instrument. (b) Coherent electron diffraction pattern of a suspended graphene. The outmost diffraction spots corresponds to $(0.062 \text{ nm})^{-1}$ [1].

References:

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