

Experiment Brief

K3 IS Camera

Title

Imaging of graphene at 200 kV using electron counting

Gatan Instrument Used

The K3[®] IS camera delivers simultaneous low-dose imaging via real-time electron counting, fast continuous data capture, and a large field of view.

Background

2D materials like graphene are increasingly studied for their unique and tunable properties. Typically, due to its sensitivity to electron beam irradiation, graphene is only studied using 80 kV or lower accelerating voltages. This low accelerating voltage makes it more challenging to observe graphene at the atomic scale using a transmission electron microscope (TEM) without using a monochromator or aberration correction. Instead, it may be possible to observe graphene and other 2D materials using lower dose rates, though these are limited by the inherently low contrast of single-layer graphene.

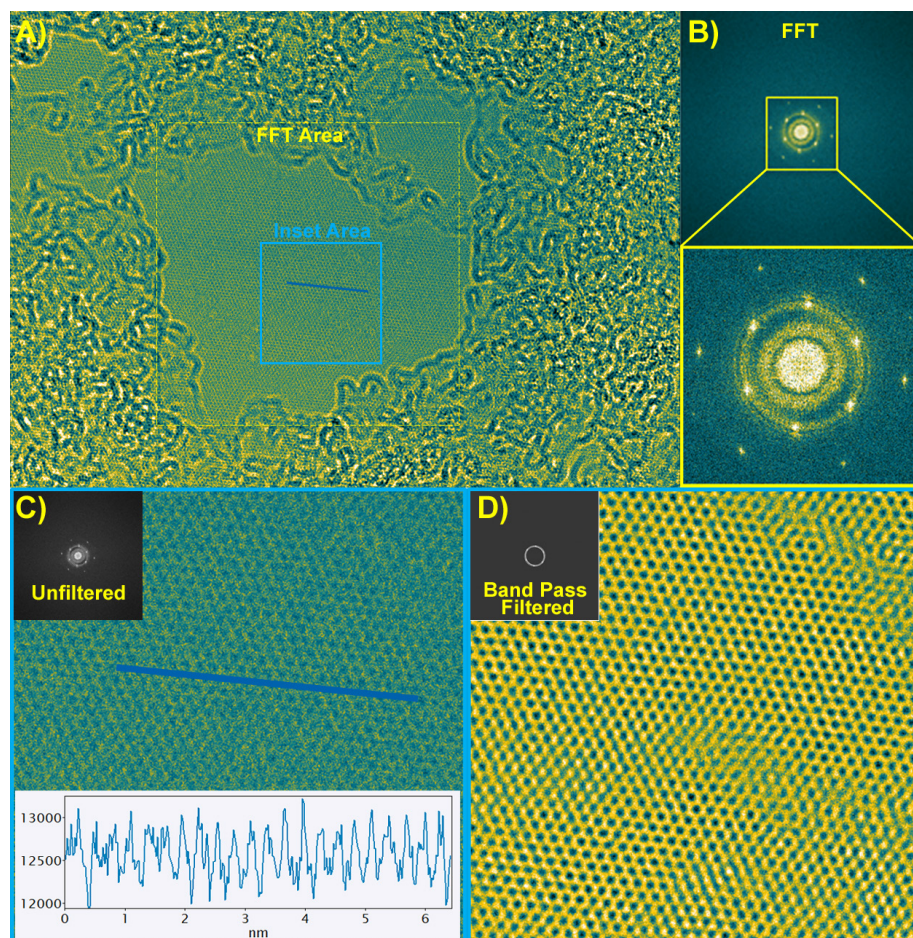


Figure 1. Graphene imaged at 200 kV. A) The full image area, with yellow and blue boxes showing where data was taken for B-D. B) Full FFT and zoomed central region of FFT showing 2 sets of 6 spots from the graphene sample. C) Magnified view of the region inside the blue box in A, the corresponding FFT, and a profile summed over 7 pixels from the location indicated by the blue line. D) The same region as C, but with a bandpass filter applied, as shown in the FFT.

Gatan, Inc. is the world's leading manufacturer of instrumentation and software used to enhance and extend electron microscopes—from specimen preparation and manipulation to imaging and analysis.

Materials and Methods

The TEM used to capture the data was an uncorrected JEOL F200 with a cold field emission gun, operated at 200 kV. Images were collected with a K3 IS camera in counted mode, a dose rate of 23.29 e⁻/pix/s, and 2,736 e⁻/Å²/s on the sample. Each pixel is just 0.09 Å. The image in Figure 1 used a 5 s exposure time, a sum of 150 counted images aligned after acquisition. These 150 counted images were generated during acquisition from the original 7500 counted frames from the sensor. The data was binned by 2 after acquisition to produce the 2880 x 2046 pixel image.

Summary

Low dose imaging using the counted mode of the K3 camera-enabled TEM imaging of single-layer graphene, even at 200 kV. The min-to-max contrast in the single-layer region is only about 10% of the mean intensity as seen in the profile of Figure 1C, so despite the good signal to noise performance of the camera and the sufficient resolution provided by the microscope, it is still challenging to image defects in the graphene single layer. Bandpass filtering can nonetheless be used to draw out features that deviate from the perfect lattice.