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Low Dose S/TEM tomography using an electrostatic beam blanker

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Imaging of beam sensitive samples is becoming increasingly important in TEM and STEM modes. Low dose TEM imaging, initially developed for frozen hydrated biological samples, is being applied more often to beam sensitive materials science samples, such as metal organic frameworks (MOFs)[1], and benefits greatly from the recent advances in camera hardware.

Traditionally, achieving low doses in STEM imaging has relied on reducing either the dwell time or the beam intensity (or both)[2]. However, commonly used scan generators are limited to dwell times of approximately 1us, and beam intensity can only be practically reduced so far before it becomes impossible to observe the Ronchigram and hence to ensure correct alignment of the system. Novel methods of low dose STEM imaging have been introduced, using sparse sampling of the material, with inpainting or compressive sensing approaches then employed to recover the missing information[3,4].

The development of an electrostatic beam blanker[5,6] provides an opportunity to precisely set the electron dose and dose rate on the sample, without necessarily employing very short dwell times, or by reducing beam intensity. The beam can be rapidly blanked and unblanked, with the pulse width and period chosen to modulate the intensity down to 1% of its original value. An example of this is shown (Figure 1) for a strontium titanate sample, where the effective intensity of the beam is reduced from 100% to 3%. The resolution obtainable is reduced from 83pm to 159pm, but with a thirty-fold reduction in electron dose.

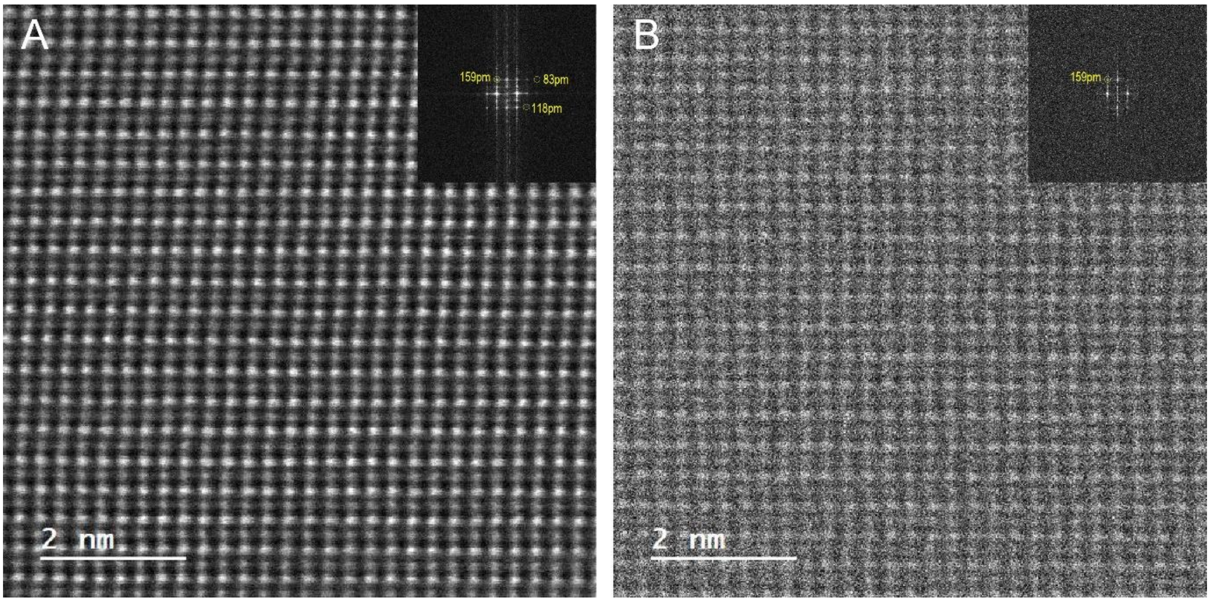
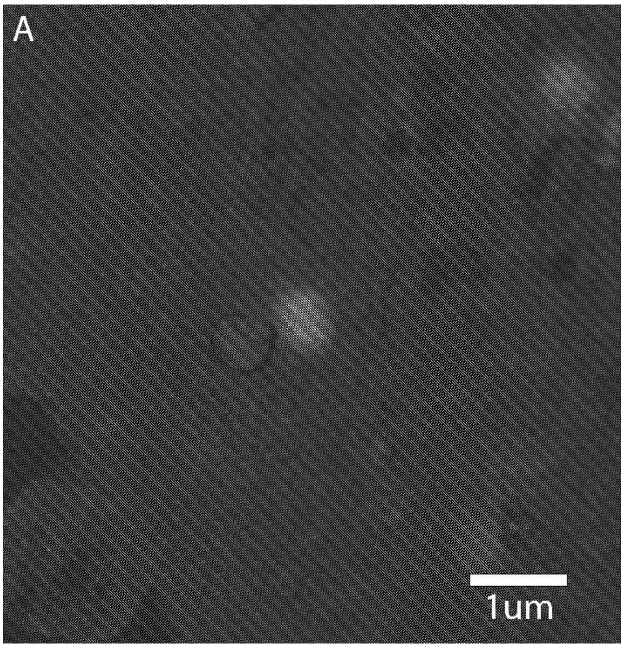


Fig. 1. STEM images of $SrTiO_3$ sample with inset Fourier transforms showing image resolution. (A) is acquired in conventional fashion with 100% beam intensity, whereas (B) is acquired with beam intensity reduced to 3% through the electrostatic beam shutter.

The beam blanker can also be used to acquire sparsely sampled data, with flexibility in the fraction of pixels that are imaged in a single frame. This allows greatly reduced electron doses to be used, with a relatively modest reduction in resolution. The beam blanker can be controlled within the popular tomography acquisition software, SerialEM, and subsampled images for tilt series can be acquired. An example of the raw data and the final reconstruction is shown in Figure 2.



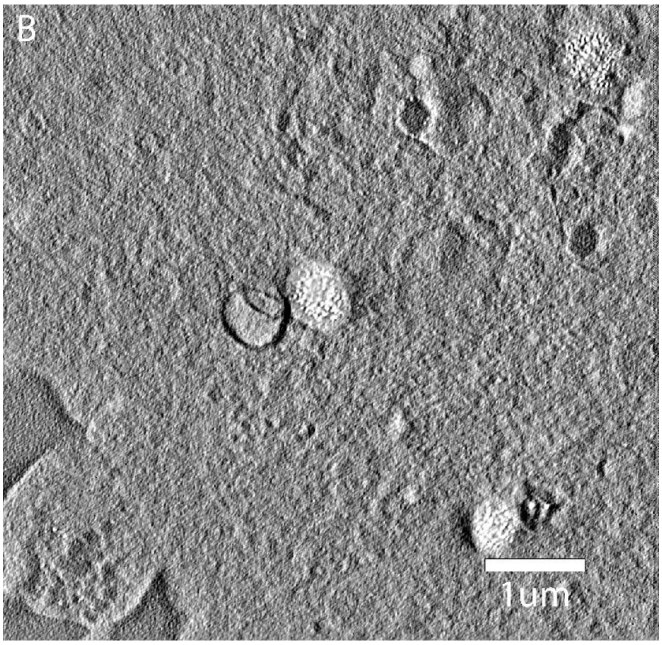


Fig. 2. (A) An individual image from a tilt series, taken at 0° tilt, of resin embedded cells. The electrostatic beam blanker is used to acquire only every fourth pixel. (B) A slice from the tomogram reconstructed from the tilt series, after the individual images were restored through use of an inpainting algorithm.

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