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Development of a fast CCD Camera for Electron Diffraction Imaging in Conventional TEM

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Electron diffraction in transmission electron microscopes (TEM) is a powerful technique for characterizing crystal structures and defects in the sample. The ease of producing diffraction patterns in the TEM and using the data to understand crystal structures has made diffraction analysis a powerful tool that material science laboratories routinely perform in their investigation of crystalline materials[1-2]. Special software applications have been developed to facilitate the data analysis, allowing quicker and more accurate results. Despite the success in developing CCD cameras for recording electron microscope images and the progress in software development, viewing and recording electron diffraction patterns with CCD cameras still remain challenging tasks. In this presentation, we will describe our latest effort in developing a fast CCD camera to meet the challenge in imaging electron diffraction patterns.

Electron diffraction patterns as normally observed consist of a bright central transmitted beam and the diffracted beams surrounding it (Fig. 1). The intensity in the transmitted beam can be several orders of magnitude higher than the diffracted beams. The major concern with using CCD cameras to capture diffraction patterns is damage to the CCD and scintillator by the intense transmitted beam. There are two types of artefacts that can be present in diffraction imaging. One is streaking and the other is blooming. For streaking, the artefact appears as a thin line above and below the central spot in the direction of CCD charge transfer (Fig. 2). This streak results from light leakage into the vertical shift registers as a charge packet is clocked through a brightly illuminated area. Blooming occurs under conditions where a CCD pixel is exposed to very high intensity illumination, exhausting the storage capacity of that CCD pixel with excess charges overflowing into the adjacent pixels (often in the direction of charge transfer). Diffraction patterns that have central or other strong diffraction spots taking on tear drop shapes are one example of this artefact.

Our recent effort in developing a system suitable for diffraction applications has resulted in a totally digital lens-coupled CCD imaging system capable of acquiring images up to true TV rate, i.e. 30 frames per second (fps). The camera has a damage-resistant transmission scintillator design and excellent anti-blooming capabilities. High speed and low noise are achieved by optimizing CCD readout timing within a flexible 30MHz camera controller. The advanced CCD electronics have been developed to handle the large amount of excess charge in the saturated CCD pixels by effectively trapping and draining the charges before overflowing to the neighbouring pixels (anti-blooming). Additionally, new software algorithms using post acquisition image processing have been developed to prevent any streaking artefact from occurring. This resulted in a new patent pending technology to produce streak-free diffraction patterns. A custom designed lens assembly is used that gives a large uniform illumination across the field of view of the CCD sensor with optimization of the collecting angles for incoming light (high NA, numerical aperture).

Using a commercially available cross grating replica (2160 lines per mm) we recorded selected area electron diffraction patterns (SAED) under various beam conditions. Figure 3 shows a pair of patterns observed in the live View mode (full CCD and 4x binning) for an extreme condition using a large spot size #1 (3a) and a more suitable size #4 (3b) on a 200kV LaB6 TEM with parallel beam and a large SAED aperture (800µ). These patterns are displayed in reverse contrast in order to better show any CCD streaking effect. In both cases, although the central spot is saturated, no streaking is observed in the vertical direction when using the software correction algorithm. Figure 4 shows the corresponding diffraction pattern recorded in full resolution mode (full CCD and 1x binning).

In summary, although rapid progress has been made in digital imaging technology, viewing and recording electron diffraction patterns (especially streak-free) with CCD cameras without the concern of damaging the scintillator remains a big challenge. With the use of this new ORIUS® SC200D camera this challenge has been met with a robust and easy to use CCD camera, freeing the user from concerns of damage and artifacts when recording diffraction patterns.

1. Leonid A. Bendersky and Frank W. Gayle "*Electron Diffraction Using Transmission Electron Microscopy*", J. Res. Natl. Inst. Stand. Technol. 106, 997–1012 (2001).
2. Electron Diffraction Techniques, J. M. Cowley, ed., International Union of Crystallography, Oxford University Press (1992)

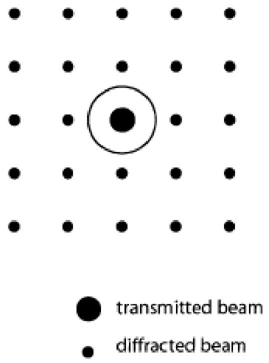

Figure 1 Observed diffraction pattern showing the transmitted and diffracted beams

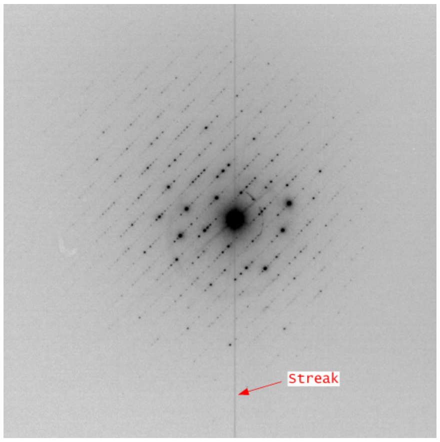

Figure 2 Diffraction pattern showing streaking artefact

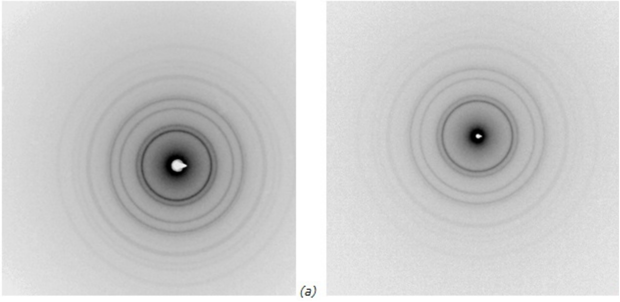

Figure 3 (a) view mode with spot size 1. (b) spot size 4

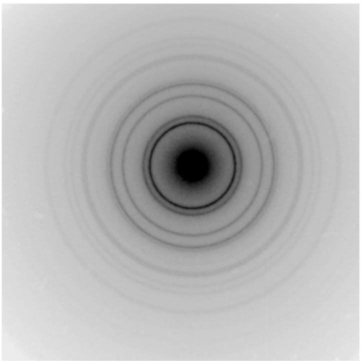

Figure 4 Diffraction pattern recorded in full resolution. Spot size #4 and 10 sec exposure.