Image detector performance requirements for *in situ* electron microscopy

Paul Mooney, Gatan, Inc.

Experimentation *in situ* in an electron microscope presupposes an interest in time- as well as in the usual space- resolved detection of electrons. CCD cameras in electron microscopy have come a long way towards optimizing the latter but with only modest progress towards the former. High-sensitivity video (fiber-optically coupled and sometimes intensified) has served to deliver the needed temporal resolution for the early phases of development of in situ experimentation. With new nano-scale laboratories now under development it is important to consider what detector performance might be needed for delivering high resolution in both time and space – and what it might take to achieve these goals.

Technical challenges divide broadly into three categories: First, electronic bandwidth and sensor architecture are needed which will be capable of delivering more pixels per frame and more frames per second than currently available from high-sensitivity video cameras. Second, software and IT capabilities for managing a higher volume of data and a crossover from the use of videotape to digital media will be needed. Finally, and before the urgency of the first two can be determined, an assessment is needed of the extent to which beam brightness limitations under high-resolution conditions pose a fundamental speed/resolution limitation. Applications demonstrated to be subject to this constraint will require detectors of high efficiency at rendering good signal-to-noise ratio (SNR) in real-time under conditions of low dose per frame, the measure of which is DQE, or, for in situ imaging, "Real-time DQE".

Detector developments aimed at the first issue can address limits imposed by typical fast pixel rates through use of multiple readout channels, but larger sensors and cameras with more channels will come at a price. To the second issue, the moment the information bottleneck at the detector is broken, it will move to the data channel. In the short term, the needs of in situ microscopy may be aptly handled with standard video editing software and digital streaming video from a fast camera and with analog converters to support videotape storage when desired. Once digital format is properly supported, however, the investment would immediately open up powerful possibilities. Examples include linkage of real-time parametric data (temperature, voltage, pressure, etc) to the image data stream, accurate time-axis calibration, motion and difference analysis, particle tracking and integrated space *and* time domain filtering to name a few. To the third issue, addressing the need for higher sensitivity will require solutions to fundamental problems with electron imagers: scintillation noise, poor intensifier quantum efficiency, phosphor lag, image transfer resolution loss, photon noise, time-sharing (switching between electron accumulation and readout) and readout noise.

It will be important to strike the appropriate balance in adding performance on these three axes. The in situ experimenter should be the ultimate arbiter of what is important in this regard.