Applications of Sub-Sampling and Inpainting for High Resolution, In-situ and Ultrafast TEM/STEM

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Abstract: For many imaging and microanalysis experiments in high-resolution/in-situ/operando scanning transmission electron microscopy (STEM), the resolution and precision of the final result is primarily determined by the tolerance of the sample to the applied electron beam dose. If the dose is not controlled, the stability of structures and the kinetics of dynamic observations can be dramatically changed by the beam, leading to a different structure and/or chemistry than would be expected from an ex-situ experiment under similar reaction conditions. Recent results at the University of Liverpool (UoL) have shown that the optimal solution for dose control in any form of scanning/transmission electron microscopy is to form the image from discrete locations of a small electron beam separated by as far as possible in space and time. Instead of forming the image with an extended beam (as with TEM) or from a regular raster pattern (as in conventional STEM) this condition is satisfied ideally by moving the STEM probe over the area of the image using large jumps between the acquisition pixels. This form of STEM imaging presents numerous challenges to the stability of the microscope, but these stability issues can be routinely overcome using either a form of random walk scanning, a calibrated random scanning or a mixture of conventional scanning and rapid beam blanking. The larger than standard jumps between pixel acquisition locations in this methodology creates problems with image interpretation, as the gaps between locations of acquisition are missing information. Fortunately, we can use Inpainting to retrieve the missing information and form a full image. Here I will discuss the methodology of Inpainting, with particular reference to the speed/efficiency of the reconstruction method and the potential for real-time imaging. In addition, the use of simulations to provide a starting point for image interpretation and the use of deep learning approaches to allow the microscope to adapt its own imaging conditions, will be demonstrated. Finally, the integration of these methods into the hardware design for both the new JEOL 300kV AI-STEM at the UoL and the Relativistic Ultrafast Electron Diffraction and Imaging (RUEDI) UK national facility will also be discussed.