Abstract – Improving Scanning Electron Microscope Resolution by Computational Means

Scanning electron microscopes (SEMs) are extensively used in many fields including life and materials science, microelectronics and nanotechnology. They fill an important gap between light optical and transmission electron microscopy. Since they first appeared commercially in the mid-nineteen sixties their resolution and the type of information they provide has increased significantly. Much of the improvement in resolution is the result of brighter electron sources as well as well as advances in overall electron optical design. While resolution at higher beam energies is now below 1.0 nm for certain samples this level is more difficult to obtain at beam energies below 1.0 keV needed to avoid sample damage and for higher surface sensitivity. SEM resolution is strongly related to the probe size of the focused electron beam used, however obtaining even finer probes requires very expensive hardware improvements such as electron monochromators and aberration correctors.

Recently my group has developed a new method to determine the spatial distribution of electrons in a focused beam, referred to as the point spread function (PSF). Once the PSF is determined a combination of deconvolution and regularization can be used for computationally based image restoration that is relatively inexpensive, fast, reduces noise and improves resolution. Details of this approach will be presented as well as the associated challenges. Examples of the latter include faster computation through parallel processing, better algorithms for functional minimization, potential applications of wavelet and machine learning approaches, artifact reduction and more quantitative ways to determine resolution improvement.

It should be pointed out that the approach described here is not limited to the SEM, but is already considered or in use at some level for confocal optical microscopy, ion microscopy, x-ray microradiography, and scanning transmission electron microscopy. Many of the methods we have adopted are based on procedures currently used in other fields such as astronomy, medical imaging and surveillance. It is hoped that this introduction will stimulate your interest and lead to some level of cooperative research.