

Aberration-corrected microscopy of nanostructured materials and interfaces

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Aberration-corrected microscopy and new generations of instruments have the potential of significantly improve the development of nanoscale materials by providing improved imaging resolution, stability and spectroscopic capabilities. Applications of these techniques in the area of catalyst materials, functional oxides and electronic materials have emerged since the first aberration-corrected microscopes were developed over 10 years ago. New developments in commercial instruments have, however, made it possible to significantly broaden the impact of these new technological developments. Here we report on examples where aberration-corrected instruments have provided significant benefits in various areas of applications related to the study of nanoscale materials such as carbon nanotubes, electronic oxides (ferroelectrics, metallic oxides), quantum wire structures, and biological nanostructures.

Experiments were carried out with a FEI Titan 80-300 Cubed equipped with two aberration correctors and a monochromator. This instrument achieved an information limit of 0.65-0.6Å, a STEM information transfer of better than 0.7Å and an energy resolution in EELS of 0.13eV. This instrument was recently installed at the Canadian Centre for Electron Microscopy and complements a suite of instruments with a range of capabilities.

With the highly stable instrumentation within the Centre, it is possible to study details of the interfaces between substrates and oxide thin films in a variety of systems and study the roughness at the atomic level. For example, in metallic oxide thin films and ferroelectrics deposited on a variety of substrates, we demonstrate that single atomic steps (or roughness of about one unit cell) can easily be detected and we show how these steps are the source of defects propagating on the thin films. With such instrumentation it is also possible to measure gate oxides widths to one monolayer precision. Based on the improved resolution and with the improved transfer function of the microscope, it is also possible to determine size of nanoparticles within an amorphous matrix with much higher accuracy while defects (such as twins, ledges) can be much more readily identified. With the analytical capabilities of the instrumentation, significant improvements in the resolution of the compositional measurements are possible. Finally, we will demonstrate examples where a resolution for chemical analysis of one single unit cell can be achieved.

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