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Application of energy low loss backscattered electrons in material characterization and analysis

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With the continuous size and structure shrinkage in semiconductor and electronic devices, the final performance and properties of the materials are dominated by the surface and interface layers. This requires scanning electron microscope (SEM) as a most conventional technical method in material characterization and analysis not only to be able to visualize and image such nanostructures with the secondary electron imaging under a low energy beam but also to analyze the tiny compositional differences like doping contrast, oxidation states of elements, small phases of hybrids or function group in polymers etc., which are not available via the classical backscattered electron imaging or other Energy-dispersive X-ray spectroscopy methods. Although the classical backscattered electron (BSE) imaging are from the multiple inelastic scattering process which could provide density related contrast like channeling contrast at high energy beam, the backscattering coefficient shows non-linear behavior and get very complicated [1].

In the classical backscattering process (Rutherford scattering), the backscattered electrons are mainly from the scattering of the high energy primary electrons with the nucleus charge or inner electron shells of the material. In such a case the contrast or brightness of the BSE imaging scale with material density, atomic number (Z). However the scattering between the primary beam with the outer electron shells of the materials at low impact energy (below 3 kV) region is not any more negligible which even becomes more dominant where the surface plasma resonance and ionization loss could happen and contribute to in the total contrast mechanism [2].

The unique design of the Gemini® lens integrated with a beam booster in the beam path not only maintains the brightness of the downward primary electron beam at low energies but also has a dispersion function for the generated reverse electron signals backward into the column. It means that the secondary electrons and backscattered electrons with a small energy and angle differences could be amplified and separated by the Gemini® lens in real time and space without converting the signals or by applying any additional stage bias. The separated backscattered electrons could be further filtered with an energy filtering grid and projected back into the corresponding detector. Backscattered electrons with a specific energy low loss could be picked out for imaging by setting an appropriate threshold potential to the filtering grid. After the grid filter the multiple inelastic scattered electrons could be cut away and the signal is consisted of the so-called energy low loss backscattered electrons which reveals some characteristic resonance of the materials.

Herein, a few typical materials have been investigated with the energy low loss backscattered imaging and the corresponding results will be presented and discussed. We found the Ce nanoclusters and Ce ions catalyst highly dispersed inside the mesoporous silica as could be easily characterized. As the first report, the different phases separation of ZnO_xS_{1-x} thin film on insulating Al_2O_3 substrate due to the different of band gap could be revealed at a certain low beam energy which is agreed with the results from the UV-Vis spectroscopy where there different phases give corresponding adsorption peaks at individual wavelength or energy.

1. L. Reimer, Scanning electron microscopy, 2nd edition. Springer-Verlag, 1998, Berlin Heidelberg New York.
2. H. Jaksch, Contrast mechanisms of low loss backscattered electrons in field emission SEM, EMAS conference, May 2011, France

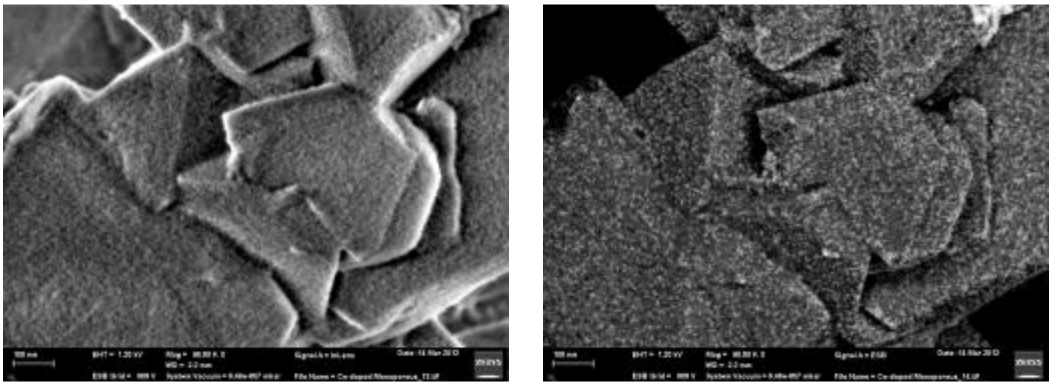

Figure 1. The SE1 image (left) and corresponding LL-BSE image (right) of the Ce incorporated into mesoporous silica as catalyst where the Ce ions and nanoclusters give high brightness.

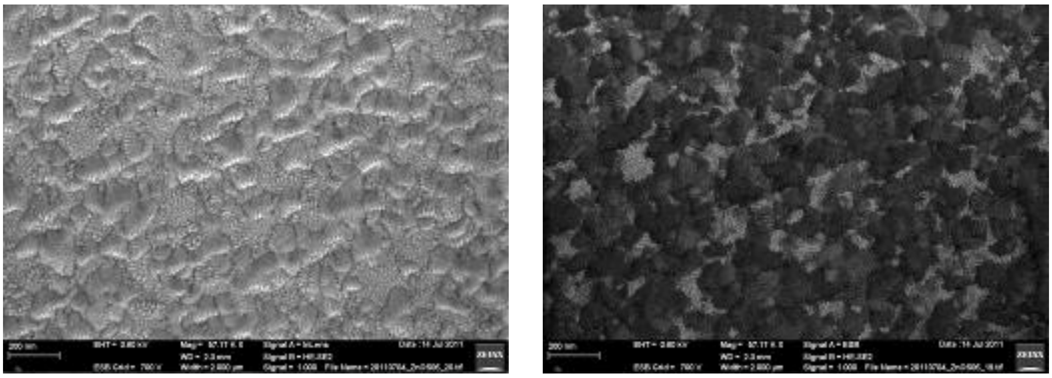

Figure 2. The SE1 image (left) and corresponding LL-BSE image (right) of the ZnS_xO_{1-x} thin film on Al_2O_3 substrate where the LL-BSE image is from the low loss BSEs with an energy between 700 eV and 800 eV.

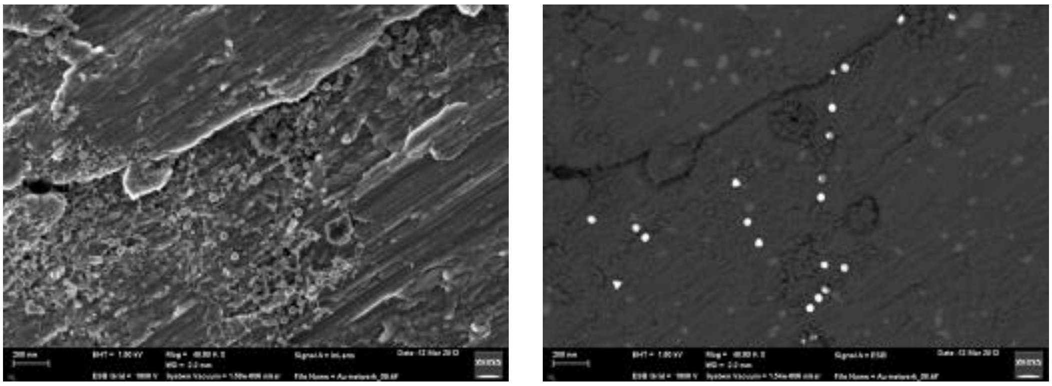

Figure 3. The SE1 image (left) and corresponding LL-BSE image (right) of Au nanoparticles stabilized with organic ligands and networks.