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Applications of scanning electron microscopy in Mineral Nanomaterials

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Mineral nanomaterials, referring to its mineral grain fineness in three-dimensional space with at least one dimension is within the range of 0.1 ~ 100nm scale or mineral material itself contains nano-particles. The scanning electron microscopy (SEM) is a nanotechnology research tool for mineral materials. In recent years, with the rapid development of science and technology, the brightness of the field emission gun is approximately 1000 times greater than that of tungsten emission. Using the field emission gun, a monochromator, low-aberration objective lens and high-sensitivity signal detector in the instrument, a resolution of 1 nm is achieved with field-emission SEM. Even under a low voltage (e.g., 1kV), SEM imaging still performs well. Thus, we can obtain mineral information at the nanoscale level.

Mineral nanomaterials in the application of SEM have the following several aspects:

1. Generally equipped with energy dispersive X-ray spectroscopy (EDS), SEM can perform composition analysis during morphological observation. Massive, powder or thin-section samples can be directly observed. the X-ray spectrum analysis of SEM has several advantages: (1) high analysis speed, it generally only needs several seconds to several minutes to complete a full-spectrum analysis; (2) small beam spot, it can perform a micro-area analysis of samples ranging from several micrometers to hundreds of nanometers with a high spatial resolution of the component analysis; (3) it can perform an integrated analysis of the sample's composition, morphology and structure. In addition, atomic number contrast can clearly distinguish different mineral phases and different compositions of one mineral grain in the backscatter detector (BSE) image.

2. Cathodoluminescence spectrometry (CL) analysis. CL spectrometry can be operated in panchromatic or monochromatic mode. The wavelength is in the range of 200– 2100 nm. We can obtain panchromatic/monochromatic imaging and spectra using the CL spectrometer. Moreover, CL can be performed at the micron or nanometer scales. CL can clearly reflect the internal structure of the mineral. The CL spectrum can reflect lattice defects and the presence of impurities. Furthermore, the luminescence of mineral impurities can reflect the physical chemistry environment when the lattice is formed.

3. Electron back-scattering diffraction (EBSD) technology makes possible the *in situ* and microscale research of rock and mineral, allowing determination of the mineral phase and yielding crystal-structure information. Based on backscatter diffraction pattern spectrum analysis, we can quickly

identify the crystal face symbol, mineral crystal, crystal belt and cell parameters.

In short, SEM can quickly and accurately measure the micro components of the samples. At the same time, we can obtain element distributions of the samples through line scanning and maps, helping showcase the element changes and migration patterns of the mineral phases and explore the growth conditions and deuteric alteration of the minerals. Combined with EBSD, SEM is able to identify the mineral phase changes and obtain *in situ* and micro-scale information of crystal structure and grain orientation.