微小加工法および高分解能電顕法の先鋭化と資源地質学への応用可能性
Development of nano-fabrication and high-resolution electron microscopy techniques: their possible applications to resource geology

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In order to explore accessible and profitable natural resources, scientific elucidation of their origin and evolution are an essential issue. The natural resources often have fine-grained textures and minute mineral/fluid inclusions in the host minerals. Therefore, microanalysis is required to clarify their mineralogical and geochemical characteristics in detail. Focused-ion beam (FIB) microfabrication and transmission electron microscopy (TEM) are potentially effective techniques for this purpose. FIB allows to precisely extract portions of interest in sub-micron scale from various types of samples. Using TEM, microtextural, chemical, and crystallographic information can be obtained in nano-scale spatial resolution from ultrathin-film (100–200 nm) samples. With taking these technical advantages, state-of-the-art FIB and TEM at JAMSTEC KOCHI have been applied to a variety of geosciences including clay mineralogy [1], biomineralization [2], mantle rheology [3], and meteoritics [4].

One of uniqueness of the FIB/TEM laboratory at KOCHI is a combined FIB-FESEM instrument equipped with an energy dispersive spectrometer (EDS) and a cryo-holder system [5]. We are currently developing a FIB-fabrication scheme of fluid inclusions in minerals such as olivine and halite, so that those fluids are exposed in frozen state for their in-situ chemical analysis including X-ray elemental mapping using EDS [6]. 3D tomography by micro X-ray CT is effective to visualize distribution of fluid inclusions especially in nontransparent minerals prior to nanofabrication and analysis by the FIB-FESEM system.

The nanoscale occurrence of fluid (as voids) and mineral inclusions can be further characterized by high-resolution TEM. This technique would be useful for mineralogical analysis of fine-grained resource materials such as deep-sea mud containing abundant rare-earth elements [7] and manganese deposits. As a typical example, we have mineralogically characterized several-micron-sized Mn-rich microparticles recently discovered in seafloor sediments, and found vernadite-like mineral therein based on their electron diffraction patterns and elemental mappings [8]. We are further developing the linkage fabrication/analysis scheme to extend toward more comprehensive sample analysis including trace elemental and isotopic analyses using NanoSIMS [9]. These microanalysis techniques would play a key role for our better understanding of environments for the formation of resource materials.

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