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Charge contrast imaging of geological materials in the environmental scanning electron microscope

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ABSTRACT

The environmental scanning electron microscope (ESEM) allows high-resolution, high-magnification imaging of conductivity differences in uncoated geological samples. Under normal ESEM operating conditions, negative charge buildup at the sample surface (from bombardment by the electron beam) is prevented by the presence of a gas (usually water vapor) in the sample chamber. Backscattered and secondary electrons from the sample ionize this chamber gas, and the resultant positively charged gaseous ions migrate toward the negatively charged sample. When chamber gas pressures lower than approximately 250 Pa are used, however, charging of the sample can occur because insufficient charge balancing positively charged gaseous ions are produced. Charge implantation in the sample alters secondary electron emission, and, because intracrystalline conductivity contrasts occur in response to variations in defect density, secondary electron images reflect compositional variations and/or microstructural features. These secondary electron images are referred to as charge contrast images (CCI). To demonstrate potential geological applications of CCI, we present images of growth zones, microfractures, differential diffusion domains, pleochroic haloes, and relict fluid pathways from zircon (strongly luminescent), quartz (weakly luminescent), and biotite and cordierite (non-luminescent). CCI detect defects in a similar way to cathodoluminescence (CL), but have a higher resolution because the CCI signal is composed of secondary electrons that are generated from a much smaller interaction volume than photons utilized in CL. CCI imaging also can be applied to a wider variety of geological samples than CL, because electronic charge trapping is not restricted to wide-band gap electronic configurations. One of the most important potential applications of the CCI technique may lie in the direct imaging of relict fluid pathways in rocks that have experienced metasomatism or alteration.