Exploring Nanoscale Chemical and Structural Complexities in Minerals with Atom Probe Microscopy

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At a fundamental level, the growth and subsequent modification of mineral elemental and isotopic compositions are governed by a complex range of processes that take place at the atomic scale. The development of instruments capable of increasingly higher spatial resolution analyses provides a new opportunity to study these processes and the interactions between structural defects and geochemistry. The pinnacle of high-spatial resolution compositional analysis is atom probe microscopy (APM), a time-of-flight technique that allows quantitative, 3D, compositional and spatial imaging across the whole periodic table of elements with sub-nanometer resolution. In recent years, rapid progress has been made in applying APM to an increasing number of minerals. These studies demonstrate the widespread occurrence of nm-scale compositional heterogeneities within minerals, and reveal fundamental new insights into the geochemical processes that underpin the interpretation of geochemical data collected at the microscale. Here, we present an overview of the APM technique, highlight the growing field of nanoscale geochemistry and geochronology and showcase some of the novel applications to Earth and planetary sciences.