European Mineralogical Conference
Vol. 1, EMC2012-690, 2012
European Mineralogical Conference 2012

Isotopic and trace element measurements on the nanometer scale - application of 3D Atom Probe Tomography in the geosciences

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In Atom Probe Tomography (APT) a specimen with dimensions of a few hundreds of nanometers is evaporated atom by atom. The original position of each atom is identified, along with its atomic species, and in most cases its isotope. The result is a reconstruction allowing quantitative three-dimensional study of the specimen at the atomic scale, with very low detection limits and high mass resolution.

With the recent introduction of laser thermal pulsing to achieve evaporation, the technique is no longer limited to conductive specimens and there is now the capability to explore the compositional and isotopic structure of insulating materials at sub-nanometer resolution and, in sufficiently large datasets, detection limits in the single ppm.

Many datasets of from 10 million to 70 million atoms have been acquired from zircon in a study of a fossil resorption front included between an unmodified igneous core, and a subsequent metamorphic overgrowth. The distribution of U, Th and radiogenic Pb has been imaged at the atomic scale, as well as the spatial distribution of HREE's and other trace elements. The distribution of Y and P shows significant structural control in the overgrowth.

Atom Probe Tomography brings to the geosciences the capability to study major and trace element distributions at the atomic scale, often with the ability to discriminate among isotopes. Quantitative atomic-scale crystal chemistry becomes possible. The technique is especially well suited to quantitative study of resorption fronts, grain-boundary diffusion, as well as the distribution of radionuclides and daughter products in geochronology.