American Mineralogist, Volume 89, pages 547–553, 2004

A new nondestructive X-ray method for the determination of the 3D mineralogy at the micrometer scale

Laurence Lemelle,[1,*] Alexandre Simionovici,[1,2] Robert Truche,[3] Christophe Rau,[2] Marina Chukalina,[2,4] and Philippe Gillet[1]

[1]Laboratoire de Sciences de la Terre, ENS Lyon, CNRS, UMR5570, 46 allée d'Italie, 69007, Lyon, France
[2]ID22 group, European Synchrotron Radiation Facility (ESRF), 6 rue J. Horowitz, BP 220, F-38043 Grenoble Cedex, France
[3]CEA-DRT-LETI, CEA-Grenoble, 17 rue des Martyrs 38054 Grenoble Cedex 9, France
[4]Institute of Microelectronics Technology RAS, 142432 Chernogolovka, Russia

Abstract

The combination of synchrotron-based X-ray absorption and fluorescence computed tomographies (CT) is a new method allowing a noninvasive and nondestructive determination of the three-dimensional (3D) mineralogy with micrometer resolution of sub-millimeter silicate grains, possibly stored in a silica holder. These CT were performed with beams of a few tens of keV from a third-generation synchrotron source on one olivine grain of the NWA817 Martian meteorite presenting a reddish alteration phase. The reconstructed sections show a network of fractures and a few micrometer-thick layers formed on one grain. The 3D facet orientation and the X-ray attenuation coefficient indicate that this grain is an $Fo_{44\pm9}$ olivine crystal. The fluorescence section reveals rims enriched in Fe (a major element) or depleted in Ca (a minor element). This CT combination shows that the micrometer-thick layer is preferentially formed on the (010) olivine face and has a lower density (3.5 ± 0.4 g/cm^3) than the olivine, even though it is enriched in Fe. Its complex nano-petrography and the distributions of nanometer-sized voids and fractures in such a micrometer thick layer, first observed by scanning electron microscopy on focused ion-beam cuts, is not shown by CT. The precision presently achieved, although moderate, is sufficient to obtain a 3D semi-quantitative view of the mineralogy consistent with the one previously established by electron probe microanalyses (Sautter et al. 2002).