American Mineralogist, Volume 105, pages 239–243, 2020

Machiite, $Al_2Ti_3O_9$, a new oxide mineral from the Murchison carbonaceous chondrite: A new ultra-refractory phase from the solar nebula

Alexander N. Krot[1,*], Kazuhide Nagashima[1], and George R. Rossman[2]

[1]Hawai'i Institute of Geophysics and Planetology, University of Hawai'i at Mānoa, Honolulu, Hawai'i 96822, U.S.A.
[2]Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, California 91125, U.S.A.

Abstract

Machiite (IMA 2016-067), $Al_2Ti_3O_9$, is a new mineral that occurs as a single euhedral crystal, 4.4 μm in size, in contact with an euhedral corundum grain, 12 μm in size, in a matrix of the Murchison CM2 carbonaceous chondrite. The mean chemical composition of holotype machiite by electron probe microanalysis is (wt%) TiO_2 59.75, Al_2O_3 15.97, Sc_2O_3 10.29, ZrO_2 9.18, Y_2O_3 2.86, FeO 1.09, CaO 0.44, SiO_2 0.20, MgO 0.10, total 99.87, giving rise to an empirical formula (based on 9 oxygen atoms pfu) of $(Al_{1.17}Sc_{0.56}Y_{0.10}Ti^{4+}_{0.08}Fe_{0.06}Ca_{0.03}Mg_{0.01})(Ti^{4+}_{2.71}Zr_{0.28}Si_{0.01})O_9$. The general formula is $(Al,Sc)_2(Ti^{4+},Zr)_3O_9$. The end-member formula is $Al_2Ti_3O_9$. Machiite has the *C*2/*c* schreyerite-type structure with $a = 17.10$ Å, $b = 5.03$ Å, $c = 7.06$ Å, $\beta = 107°$, $V = 581$ Å^3, and $Z = 4$, as revealed by electron backscatter diffraction. The calculated density using the measured composition is 4.27 g/cm^3. The machiite crystal is highly ^{16}O-depleted relative to the coexisting corundum grain ($\Delta^{17}O = –0.2 \pm 2.4$‰ and $–24.1 \pm 2.6$‰, respectively; where $\Delta^{17}O = \delta^{17}O – 0.52 \times \delta^{18}O$). Machiite is a new member of the schreyerite ($V_2Ti_3O_9$) group and a new Sc,Zr-rich ultrarefractory phase formed in the solar nebula, either by gas-solid condensation or as a result of crystallization from a Ca,Al-rich melt having solar-like oxygen isotopic composition ($\Delta^{17}O \sim –25$‰) under high-temperature (~1400–1500 °C) and low-pressure (~10^{-4}–10^{-5} bar) conditions in the CAI-forming region near the protosun. The currently observed disequilibrium oxygen isotopic composition between machiite and corundum may indicate that machiite subsequently experienced oxygen isotopic exchange with a planetary-like ^{16}O-poor gaseous reservoir either in the solar nebula or on the CM chondrite parent body. The name machiite is in honor of Chi Ma, mineralogist at California Institute of Technology, for his contributions to meteorite mineralogy and discovery of many new minerals representing extreme conditions of formation.

Keywords: Machiite, $Al_2Ti_3O_9$, $(Al,Sc)_2(Ti^{4+},Zr)_3O_9$, new mineral, Zr,Sc-rich phase, schreyerite group, ultrarefractory phase, Ca-Al-rich inclusion, Murchison meteorite, CM2 carbonaceous chondrite, oxygen isotopes