

DISCOVERY OF KANGITE, (Sc,Ti,Al,Zr,Mg,Ca, \square)₂O₃, A NEW ULTRA-REFRACTORY MINERAL IN ALLENDE

Chi Ma^{1*}, Oliver Tschauer^{1,2}, John R. Beckett¹, George R. Rossman¹, Wenjun Liu³. ¹Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125, USA; ²High Pressure Science and Engineering Center and Department of Geoscience, University of Nevada, Las Vegas, NV 89154, USA; ³Advanced Photon Source, Argonne National Laboratory, Argonne, IL 60439, USA. *chi@gps.caltech.edu

Introduction: During a nano-mineralogy investigation of the Allende CV3 carbonaceous chondrite, we identified a new scandia mineral named “kangite” in an irregular ultra-refractory inclusion. It has a cubic *Ia3* bixbyite-type structure and a formula unit (Sc,Ti,Al,Zr,Mg,Ca, \square)₂O₃. Field-emission SEM with EDS and electron back-scatter diffraction, electron microprobe and synchrotron micro-Laue diffraction were used to characterize the composition and structure. We report here the first occurrence of kangite in nature, as a new ultra-refractory oxide among the earliest solids formed in the solar nebula, and discuss its origin and significance for nebular processes. The mineral and the mineral name (kangite) have been approved by the Commission on New Minerals, Nomenclature and Classification of the International Mineralogical Association (IMA 2011-092).

Occurrence, Chemistry, and Crystallography: Kangite (26.6 wt% Sc₂O₃) appears as four irregular to subhedral grains, 1 to 4 μ m in size, alone or in contact with REE-rich perovskite and MgAl-spinel in type davisite (up to 17.7 wt% Sc₂O₃) [1]. Type kangite formula is [(Sc_{0.52}Al_{0.21}Y_{0.06}V_{0.02}Gd_{0.01}Dy_{0.01}Er_{0.01})³⁺ _{Σ 0.84}(Ti_{0.61}Zr_{0.13}Si_{0.03})⁴⁺ _{Σ 0.77}(Mg_{0.11}Ca_{0.10}Fe_{0.01})²⁺ _{Σ 0.22} \square _{0.19}] _{Σ 2.00}O₃, where Sc³⁺ is the dominant trivalent component and the trivalent cations are dominant in the cation site. Based on oxygen analysis, Ti in kangite is dominantly 4+. Synchrotron micro-Laue diffraction reveals that kangite has a cation-deficient *Ia3* bixbyite-type structure with unit cell dimensions: $a = 9.842(1)$ Å, $V = 953.3(1)$ Å³, $Z = 16$. The related panguite structure with similar cation deficient relative to occupancies expected for bixbyite shows a reduction in symmetry to the orthorhombic *Pbca* [2].

Origin and Significance: With the discovery of kangite, the Sc-, Zr-rich phases in carbonaceous chondrites now includes, kangite, panguite [(Ti,Sc,Al,Mg)_{1.8}O₃] [2], davisite (CaScAlSiO₆) [1], allendeite (Sc₄Zr₃O₁₂) [3], tazheranite (Sc-, Y- and/or Ca-stabilized cubic zirconia) [3,4,5], lakargiite (CaZrO₃) [5], and thortveitite (Sc₂Si₂O₇) [6], each reflecting differing formation conditions and/or bulk compositions. Kangite is compositionally complex and the pertinent phase relations are poorly constrained. Based mostly on binary systems within Sc₂O₃-TiO₂-ZrO₂-Y₂O₃, one or more intermediate oxides such as allendeite might be expected to form instead of kangite but these are not observed, which may be a consequence of kinetics due to faster cooling. Kangite with the bixbyite structure is expected to form at a higher temperature than allendeite. As in panguite [2], Ti in kangite is dominantly 4+, suggesting highly oxidizing conditions, but it coexists with Ti³⁺-rich davisite, indicating highly reducing conditions. Kangite may have no genetic relationship with host davisite.

References: [1] Ma C. and Rossman G.R. 2009. *Am. Miner.* 94, 845-848. [2] Ma C. et al. 2011. *42nd LPSC*, Abstract #1276. [3] Ma C. et al. 2009. *40th LPSC*, Abstract #1402. [4] Ma C. and Rossman G.R. 2008. *GCA* 72, 12S, A577. [5] Ma C. 2011. *MAPS* 46, S1, A144. [6] Ma C. et al. 2011. *MAPS* 46, S1, A144.