American Mineralogist, Volume 98, pages 601–608, 2013

Elasticity of franklinite and trends for transition-metal oxide spinels

HANS J. REICHMANN,[1,*] STEVEN D. JACOBSEN,[2] AND TIZIANA BOFFA BALLARAN[3]

[1]Helmholtz Centre Potsdam, German Research Centre for Geosciences GFZ, 14473 Potsdam, Germany
[2]Department of Earth and Planetary Sciences, Northwestern University, Evanston, Illinois 60208
[3]Bayerisches Geoinstitut, Universität Bayreuth, D-95440 Bayreuth, Germany

ABSTRACT

The pressure dependence of single-crystal elastic moduli of a natural Mn-rich franklinite, $(Mn_{0.40}Fe^{2+}_{0.16}Zn_{0.37}Mg_{0.03})(Fe^{3+}_{1.94}Al_{0.08})O_4$, has been determined by GHz-ultrasonic interferometry in a diamond-anvil cell to 9.8 GPa. The room-pressure elastic constants of franklinite are C_{11} = 244(3) GPa, C_{12} = 142(4) GPa, and C_{44} = 77(2) GPa. Linear pressure derivatives of C_{11} and C_{12} are 4.3(3) and 3.8(3), respectively, whereas the C_{44} modulus exhibits softening, fitted in the $P \leq 10$ GPa pressure range to $C_{44} = 77(2) + 0.29(2)P - 0.018(2)P^2$ GPa. The average of Hashin-Shtrikman bounds on the adiabatic bulk modulus (K_{S0}) of franklinite is 175(3) GPa, with pressure derivative K'_S = 4.3(3), and the shear modulus G_0 = 66(2) GPa with G' = 0.09(3). The isothermal compressibility of franklinite was determined from a separate high-pressure, single-crystal X-ray diffraction experiment to 7.8 GPa, yielding K_{T0} = 173.5(7) GPa fitted with a fixed pressure derivative of K'_T = 4. When K' is fixed to the ultrasonic value of 4.3, we obtain K_{T0} = 172.2(7) GPa. In contrast to iron-free gahnite ($ZnAl_2O_4$), franklinite exhibits pressure-induced mode softening of C_{44} similar to magnetite (Fe_3O_4). Between end-member compositions $ZnFe_2O_4$ (franklinite) and $MnFe_2O_4$ (jacobsite), the bulk modulus decreases linearly with increasing %Mn, however we observe non-linear behavior in other elastic moduli, especially C_{44}, which displays a pronounced negative anomaly for the mid-range Mn composition. Applying Birch's law to AB_2O_4-type spinels reveals that oxide spinels containing transition metals on both *A* and *B* sites follow a distinct trend from other spinels.

Keywords: Spinel, elasticity, transition metals, equation of state