American Mineralogist, Volume 86, pages 957–964, 2001

Magnetic properties of synthetic $P2_1/c$ (Mg-Fe)SiO_3 clinopyroxenes as observed from their low-temperature Mössbauer spectra and from SQUID magnetization measurements

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ABSTRACT

Magnetic properties of six Ca-free $P2_1/c$ clinopyroxenes along the clinoenstatite-clinoferrosilite join were studied by transmission ^{57}Fe Mössbauer spectroscopy (0.3–4.2 K) and SQUID magnetization measurements (2–300 K). The $Fe_xMg_{1-x}SiO_3$ members were synthesized in a multi-anvil press, and samples with x = 1.00, 0.91, 0.87, 0.78, 0.61, and 0.09 have been considered in this study. The magnetic order-disorder transition temperatures T_N were determined by Mössbauer thermoscanning with zero source velocity. The magnetic Mössbauer spectra were refined using a full hyperfine-interaction Hamiltonian approach assuming different Fe^{2+}-Mg^{2+} next-nearest-neighbor configurations of the probe nuclei to give a distinct spectral component. The different strengths of the M1 and M2 hyperfine fields can be related to the different ^{5}D electronic level schemes as earlier determined from the paramagnetic Mössbauer spectra. The magnetic susceptibility measurements indicate a positive paramagnetic Curie temperature θ_P for $FeSiO_3$ (x = 1) above 50 K and a negative θ_P for $x \leq$ 0.91 above 200 K. The Néel temperatures as determined from the susceptibility curves are equal to those obtained from the thermoscanning, indicating that spin relaxation effects can be ruled out. The macroscopic magnetic results further suggest ferromagnetic ordering of Fe^{2+} ions within ribbons consisting of two linear bands of M2 sites that enclose chains of M1 sites, and antiferromagnetic coupling between neighboring ribbons. Generally spoken the magnetic behavior of Ca-free $P2_1/c$ clinopyroxenes are similar to that of orthopyroxenes with similar (Mg,Fe) compositions.