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Single crystal elasticity of (Mg,Fe)Al_2O_4 spinels: the effect of cationic ordering

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Understanding the effects of Mg – Fe substitution on the elastic properties of major mantle minerals is necessary to quantitatively interpret seismological models of the Earth interiors. Here we present the results of an experimental study of the elastic properties of synthetic spinel crystals in the series $MgAl_2O_4$ (Spinel s.s.)-$FeAl_2O_4$ (Hercynite), which are relevant Earth's materials being important components of the uppermost mantle peridotites. In the spinel-hercynite system the effect of cation ordering has to be taken into account, because this series is characterized by a large variation of cationic ordering as a function of composition and equilibration temperature. The majority of the experimental data available in the literature is based on measurements performed on spinels synthesized at high temperature (above 1500 K), which are highly disordered. We have measured acoustic velocity by Brillouin scattering at ambient condition on single crystals spinels in the join ($Mg_{1-y}Fe_y^{2+}$)Al_2O_4 ($0 < y < 0.5$) equilibrated at low temperature (about 1100 K). The density, chemical composition and structure of our samples were determined in a previous study (Andreozzi and Lucchesi, American Mineralogist, 87, 1113-1120, 2002). We determined the full elastic tensor from the acoustic velocity measurements and density. Our results clearly show that the compositional dependence of the elastic properties of low-temperature and high-temperature spinels follow distinctly different trends. In the low temperature series the constants c_{11} and $c_{44}$of the $MgAl_2O_4$ increase by 7% and 6% respectively and their compositional derivatives ($\partial c_{11}/\partial X_{Fe}$ and $\partial c_{44}/\partial X_{Fe}$) increase by 400% and 200% respectively. The absolute value and the compositional dependence of c_{12} are substantially unmodified. Our overall results indicate that, at constant composition, cation ordering controls the elastic properties of spinels. Our results also suggest that a complete knowledge of the structure and cation ordering is required to construct a correct model of the elasticity of spinel-structured materials, such as ringwoodite, γ-$(Mg,Fe)_2SiO_4$, the most abundant component of the lower part of the mantle transition zone..