High-temperature ferroelastic strain below the $I2/c$–$I1$ transition in Ca$_{1-x}$Sr$_x$Al$_2$Si$_2$O$_8$ feldspars

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Abstract: Lattice parameters of feldspars of composition Ca$_{1-x}$Sr$_x$Al$_2$Si$_2$O$_8$, ($x = 0.85, 0.80$, and $0.75$) have been measured as a function of temperature ($T$) from room-$T$ to $950$ °C. At room-$T$ each is triclinic ($I1$), undergoing a continuous ferroelastic displacive transition to a monoclinic phase ($I2/c$) on heating. The observed critical temperature ($T_c$) increases as Ca content increases. The thermodynamic character of the transition also changes, from near-second-order at $x = 0.85$, approaching tricritical as Ca content increases. Curvature of the transition line through composition ($X$)–$T$ space suggests the importance of high-order coupling between $X$ and the order parameter. Strain-tails in $\alpha$ and $\gamma$ close to $T_c$ are interpreted in terms of inhomogeneity of the $M$-cation distribution, related to tweed microstructures noted in previous investigations. A Landau model is derived which describes the observed transition-related phenomena in the system Ca$_{1-x}$Sr$_x$Al$_2$Si$_2$O$_8$ as a function of $T$ and $X$.

Key-words: Ca-Sr feldspars, high-temperature X-ray diffraction, phase transition, ferroelasticity, Landau theory.

Introduction

The ordered room-temperature structure of anorthite is triclinic, $P\bar{1}$. Substitution of the larger cation Sr$^{2+}$ for Ca$^{2+}$ in the $M$-sites induces a structural instability of the aluminosilicate framework which undergoes a structural phase transition to a more open monoclinic structure (space group $I2/c$). The point-group symmetry relations of the two structures correspond to Aizu species $2/mF\bar{1}$ (Aizu, 1969) and the transition is potentially ferroelastic. A related transition is observed as a function of temperature ($T$) in albite, and is responsible for the ferroelastic microstructure, albite-twinning, which is observed in albites at room-$T$. The corresponding transition is not observed in anorthite and Ca-rich plagioclases, however, as the transition temperature, $T_c$, lies above the melting point at these compositions. Nonetheless, this transition, and the spontaneous strain associated with it, could still exert a considerable influence on the sub-solidus thermodynamic properties of anorthite and Ca-rich plagioclases. Of particular interest is the degree to which the ferroelastic process couples, via common strain terms, to the degree of Al/Si order and the co-elastic $I\bar{1}$–$P\bar{1}$ displacive transition in anorthite. Such coupling terms can have profound effects on the phase relations in a particular system, thereby affecting any thermodynamic models of its free energy (Salje, 1990).

Carpenter (1992) suggests a $T_c$ of around 2770°C for the $2/m$–$I1$ transition in pure anorthite, based on an extrapolation of the $T_s$ displayed by