Thermoelectric Properties of $Sr_6Co_5O_{15-\delta}$ Single Crystal

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1. Introduction

Thermoelectric materials have attracted attentions from the standpoint of efficient use of energy since they convert waste heat into electrical energy. In the oxide ceramics, Na_xCoO_2 is known to show high thermoelectric properties (Fig. 1) [1]. The high electrical conductivity and Seebeck coefficient is attributed to the Co-O triangular lattice, in which CoO_6 octahedra share their edges, thus, the relation between the electrical properties and Co-O polyhedra are of interest.

$Sr_6Co_5O_{15}$ has a pseudo one-dimensional structure consisting of Co-O chains and alkaline earth atoms, in which four CoO_6 octahedra and one CoO_6 trigonal prism share their faces and alkaline earth atoms isolate the Co-O chains (Fig. 1) [2]. In this study, we prepare the single crystal of $Sr_6Co_5O_{15-\delta}$, and investigated the thermoelectric properties along the Co-O chains.

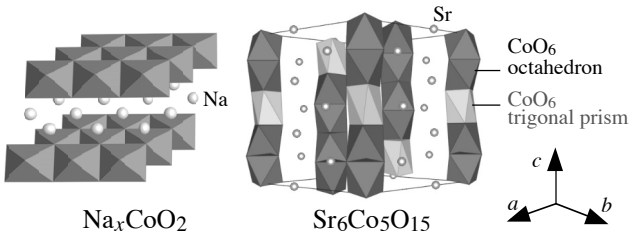

Fig. 1. Crystal structures of Na_xCoO_2 and $Sr_6Co_5O_{15}$.

2. Experimental

Rod-like single crystals of $Sr_6Co_5O_{14.3}$ (a = 9.4434(11) Å and c = 12.5026(9) Å) were grown by the flux method. K_2CO_3 and $SrCl_2$ powders were used as the flux, and Co_3O_4 and $SrCO_3$ powders were used as starting materials. These powders were put into an Al_2O_3 crucible. The sample was heated at 1243 K for 2h in air, cooled to 1153 K at a cooling rate of 0.3 Kh^{-1}, and cooled to room temperature inside the furnace by turning off the power. Rod-like crystals were obtained by rinsing the flux with distilled water. The oxygen content was estimated from the relationship between the lattice parameters and δ in $Sr_6Co_5O_{15-\delta}$, [3]. The X-ray diffraction method indicated that the rod-like crystals grew along the Co-O chains (c-axis) (Fig. 2).

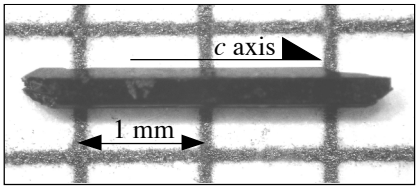

Fig. 2. SEM image for $Sr_6Co_5O_{14.3}$ crystal.

3. Results and Discussion

Figure 3 shows the electrical conductivity (σ) of the $Sr_6Co_5O_{14.3}$ single crystal along the Co-O chains (c-axis). The electrical conductivity of $Sr_6Co_5O_{14.3}$ exhibited semiconducting behavior from 2.6 to 96 Scm^{-1} in 300 - 900 K. The $\log\sigma$ was proportional to $1/T$ above 400 K, and the activation energy, E_a, was estimated to be 0.11 eV.

Figure 4 shows the Seebeck coefficient (S) of the $Sr_6Co_5O_{14.3}$ single crystal along the Co-O chains (c-axis). The Seebeck coefficient was positive, and it decreased with increasing temperature. The increase of σ and the decrease of S were attributable to the increase of carrier density by thermal activation.

The power factor (σS^2) of the $Sr_6Co_5O_{14.3}$ single crystal increased with increasing temperature, and reached 1.9×10^{-4} $Wm^{-1}K^{-2}$ at 900 K. However, the power factor was about one order of magnitude smaller than that of Na_xCoO_2 along the Co-O triangular lattice. The difference was mainly due to the high electrical conductivity of Na_xCoO_2.

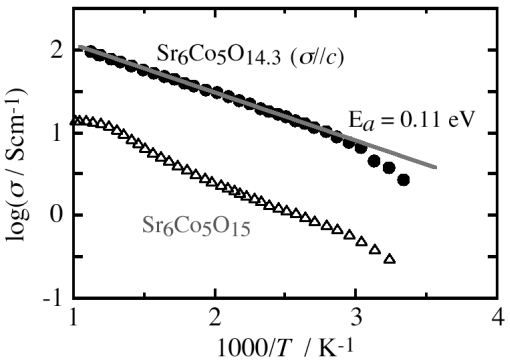

Fig. 3. Electrical conductivity for $Sr_6Co_5O_{14.3}$ single crystal and polycrystalline $Sr_6Co_5O_{15}$.

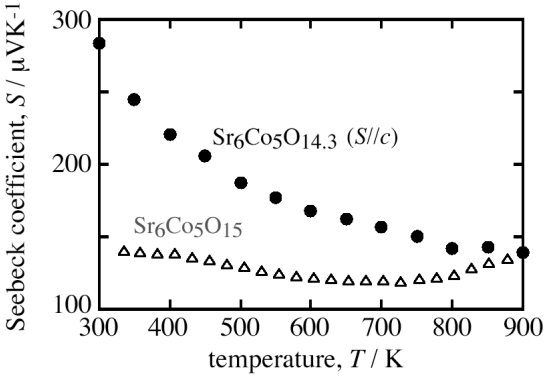

Fig. 4. Seebeck coefficient for $Sr_6Co_5O_{14.3}$ single crystal and polycrystalline $Sr_6Co_5O_{15}$.

References

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About Myself

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