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Short Communication

Preparation and Thermoelectric Properties of Nickel Oxide added Strontium Ferrite Nano-Composite

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Abstract

NiO added $SrFeO_{3-\delta}$ nano-composite bulk was synthesized and its electrical and thermoelectric properties were measured. Seebeck coefficient increased by NiO addition over 400°C. The power factors increased to 97.3$Wm^{-1}K^{-2}$, this value is 16 times larger than that of pure $SrFeO_{3-\delta}$ samples. The decreased by NiO addition. So, suitable and selected composition seems to make advantage for thermoelectric performance.

Keywords: Oxide Nano-Composite, Seebeck Coefficient, Thermal Conductivity, Thermoelectric Performance

Introduction

Now-a-days, about 70% of all the first energy, generated in combustion electrical power plants, fabricating stands and automobiles are disposed as waste heats without any use. The generated electrical energy was used in homes, public transportations and companies, and there also the waste heat was generated. Using these abundant large energies makes many solutions, such as the exhaustion of oil sources problem and the global warming problems. However, it is difficult to retrieve wide small spread energies from the around environment. In order to retrieve these waste heats, the thermoelectric system plays an important role, because it is the direct conversion of the heat energy to the electrical one by Seebeck effects without any toxic and warming gases. And the system has also the features of the maintenance free, high density of the energy outputs and compactness. Furthermore it is reported nano-finerising and low-dimensioning makes drastic increasing of performances because of the quantum effects [1], so many exams were tried such as nanodots [2], nanowiyers [3], nanomaterials [4], and nanocomposites [5]. However, the technologies to fabricate nanodots and superlattices, and molecular beam epitaxy are time and cost consuming, so the practical use thought to be difficult.

NiO was not so soluble in transition metals [6]. In this study, $SrFeO_{3-\delta}$ bulk polycrystalline samples and NiO nano-particles composite samples were prepared by an ordinally method and effects of NiO addition on the thermoelectric properties were investigated. The electrical conductivities and Seebeck coefficients of these ceramics samples were measured and the thermal conductivities of the part of the samples were also measured.

Materials and Methods

As the starting materials, $SrCO_3$ (purity was 99.99), Fe_2O_3 (99.9), and NiO 99.9, all chemicals were purchased by Wako Junyaku Industry, Japan) were used. NiO was grinded into nano-particles at 900rpm for 2 h in zirconia pod with EtOH. And then $SrCO_3$ and Fe_2O_3 were weighed with the grinded NiO powders so as to be $SrFeO_3$ + (NiO) × (x = 0, 0.03, 0.05, 0.10, 0.20) and mixed for 1 h using an alumina pestle and mortar with acetone. The dried mixed powders were placed in an alumina crucible, calcined at 1000°C for 8 h. The obtained calcined body was wet pulverized with acetone for 1 h. Approximately 0.6 g of calcined powders were uniaxially pressed at 100 MPa for 5 min, then the samples were cold isostatic pressed at 700 MPa for 10 min. The obtained compact was sintered at 1100°C for 8 h. The sintered bodies obtained as the bar-like samples were polished. In order to confirm chemical composition and nano-composition, an XRD and a SEM-EDS apparatus were used.

For conductivity measurements and Seebeck coefficient measurements, a rectangular sample of about 2 times 4 mm was polished by a sand paper. After a constant DC current was applied, the current versus the measured voltage, the cross-sectional area of the samples, and the distances between the two platinum wires were measured, and then the conductivities were calculated. The Seebeck coefficient was determined when the temperature of both ends of the samples became stable using an air pump. The temperature difference versus Seebeck voltage was plotted, and the slope was taken as the relative Seebeck coefficient. The absolute Seebeck coefficient of the sample was obtained by subtracting the absolute Seebeck coefficient of platinum from the relative Seebeck coefficient of the sample. For the thermal conductivity measurement, samples shaped and sintered so as to have a thickness of about 2 mm using a 15 mm × 15 mm square mold were used. The surface was polished in the same manner as the samples for electrical property measurement. From the measured thermal diffusivity, specific heat, and material density, the thermal conductivity was calculated.

Results and Discussion

Figure 1 shows XRD results. The tetragonal perovskite type $SrFeO_3$ was confirmed in all the samples prepared. In the sample with 5 mol% find the small NiO peaks which can be seen clearly at more NiO samples. And no NiO peak was confirmed with the 3 mol% sample. So, Ni ion should exist as the solid solution below that concentration.

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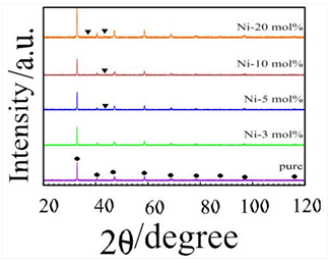

Figure 1: XRD patterns of s intered bodies of SrFeNixO3 ($0 \leq x \leq 20$). ● is SrFeO3 phase, ▼ is NiO phase.

Figure 2 shows the results of line analysis of SEM-EDS. At the position of the nano-particles at the grain boundary of the matrix phase, the peak of Ni atom was confirmed, and point analysis of fine particles between bulks showed the ratio of Ni was high. At the same time, the ratio of Sr and Fe was high in bulks and Ni was low. Sr and Fe are detected at the location of Ni. It is believed that EDS used X-ray and could not look information in the depth direction. Combined with the results of XRD, it was confirmed that nano composite was fabricated by this procedure.

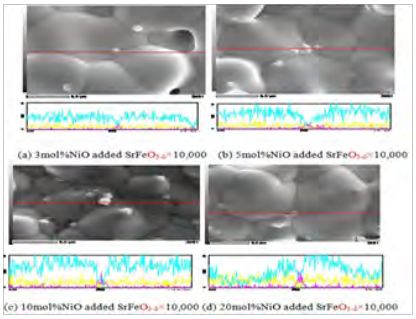

Figure 2: SEM images and line profiles of elements. Cyan, yellow, magentalines correspond to Sr, Fe, and Ni, respectively.

Figure 3 shows the temperature dependence of the conductivities of the samples. Those of all measured samples increased with temperature up to about 400°C, then reversed and decreased. This is thought to be due to the formation of oxygen deficiency of $SrFeO_{3-\delta}$ at about 400°C. In the sample with the addition amount of 10 mol% or less, the conductivity showed almost the same value as that of the sample without addition, but in the sample added with 20 mol%, the conductivity was lower than that of the sample not added in the whole measured temperature range.

Figure 4 shows the temperature dependence of the Seebeck coefficient of the same sample. All specimens increased with temperature, and the tendency was remarkable over 400°C. Also, by adding NiO, the Seebeck coefficient over 400°C was greatly improved, and in the measured temperature range the higher the temperature, the more remarkable the tendency appeared. Furthermore, it was found that the addition of NiO lowers the thermal conductivity at room temperature.

Table 1 shows the results of the thermal conductivity of a sample containing 5 mol% of NiO with different particle sizes. Samples obtained by pulverizing NiO with a planetary ball mill at 900 rpm for 2 h showed lower values than samples not pulverized. It is thought that the small NiO particles at grain boundaries exist as the scattering center of phonon transportation, and the effect was higher as the particle was finer. In addition, it can be considered that addition of NiO suppressed grain growth of the base material.

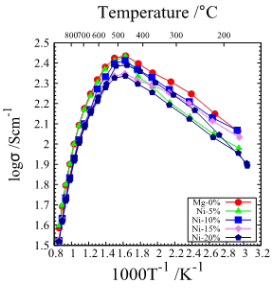

Figure 3: Temperature dependence of the electrical conductivitiy (σ) of SrFeNixO3 ($0 \leq x \leq 20$) samples.

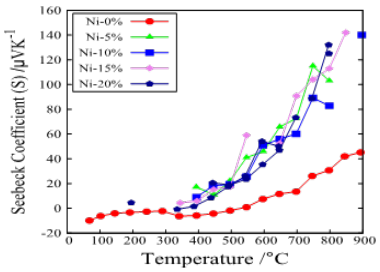

Figure 4: Temperature dependence of Seebeck coefficient (S) of $SrFeNixO_3$ ($0 \leq x \leq 20$) samples.

Specific heat(J/gK)		Thermal diffusivity (cm^2/sec)	Density (g/cm^3)	Thermal conductivity (W/mK)
Ni-5mol% (un milled)	7.529×10^{-2}	1.060×10^{-1}	4.668	3.725
Ni-5mol% (900rpm, 2h)	4.765×10^{-2}	1.127×10^{-1}	4.676	2.511

Table 1: Particle size dependence on thermal conductivity.

Conclusion

Nano-composite bulk materials of $SrFeO_{3-\delta}$ plus NiO were prepared by solid state reaction. Electrical properties and thermal conductivity of these materials were measured to evaluate thermoelectric characteristics. Samples with 5 mol% NiO showed a conductivity of 61.1 Sm^{-1} at 793°C and Seebeck coefficient of 112 VK^{-1}, so the output power factor was 97.3μ$Wm^{-1}K^{-2}$. This is a 16 times larger than that of pure $SrFeO_{3-\delta}$ at the same temperature. Furthermore, it was found that by adding NiO of nano-particles, thermal conductivity can be lowered without changing electrical properties.

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