Effects of Magnetic Field on Synthesis and Thermoelectric Properties of NaCoO$_2$

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Effects of Magnetic Field on Synthesis and Thermoelectric Properties of NaCoO$_2$

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We synthesized polycrystalline sodium cobalt oxide (NaCoO$_2$) by using solid state reaction (SSR) method in a magnetic field. The powder of Na$_2$CO$_3$ and Co$_3$O$_4$ were mixed by ball milling and compacted in a magnetic field. The characterization of microstructure of powder size and crystal structure were analyzed through XRD. Thermoelectric properties and the lattice parameter of NaCoO$_2$ showed little change in magnetic field. The lattice parameters of NaCoO$_2$ are $a = 2.8443 \text{ Å}$, $b = 2.8443 \text{ Å}$, and $c = 10.8091 \text{ Å}$ in the hexagonal structure ($a = b \neq c$).

Keywords  Applied solid state reaction; magnetic field; NaCoO$_2$

1. Introduction

In recent years, the NaCoO$_2$ compound has been studied extensively due to their exotic features, such as a large and unusual thermo power and strange magnetic order [1]. The sodium 22 deintercalation of layered Na$_x$CoO$_2$ found in this study was interesting properties in cobalt 23 oxides within magnetic properties. The highly hygroscopic material makes it very unstable 24 under ambient conditions, and unavoidable Na evaporation during high-temperature. The 25 essential requirements are high Seebeck coefficient ($S$) and low electrical resistivity ($\rho$). 26 The performance of thermoelectric materials, measured by using dimensionless figure of 27 merit, $(ZT = S^2T/\rho\kappa)$ where $T$ is absolute temperature, and $\kappa$ represents thermal conductivity with values close to unity, is considered good thermoelectric materials [2, 3]. In this 29 work, we synthesized the NaCoO$_2$ by using solid state reaction method in magnetic field, 30 and analyzed crystal structure by using XRD, and SEM for measuring thermoelectric properties, such as the Seebeck coefficient and electrical conductivity for possible development 32 of p-type thermoelectric leg modules.
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Figure 2. (a) Crushed powder samples of NaCoO$_2$, (b) ball milling in magnetic ring of NaCoO$_2$, (c) pressured in magnetic ring by hydraulic at 77 MPa, (d) pellet after sintered of NaCoO$_2$.

2. Experimental Details

The NaCoO$_2$ was synthesized from powder precursor of Na$_2$CO$_3$ and Co$_3$O$_4$ in stoichiometric proportions by using solid-state reaction method [3]. The powder precursor was mixed by hand crushing for 1 hour and ball milling for 1 hour and calcine at 800°C for 12 hours in air. The calcine powder was pressured in magnetic ring by single hydraulic at 77 MPa into the pellet and sintered at 900°C for 24 hours in air. X-ray diffraction data were collected at ambient temperature from 10° to 70° with a step of 2° using a Shimadzu 41 diffractometer equipped with Cu K$_\alpha$ radiation. The thermoelectric properties were measured by using X-ray diffraction (XRD) [4].

3. Results and Discussion

The results revealed as shown in Figure 3, the x-ray diffraction patterns for mixed powder calcine at 800°C for 12 hours in air, and in Figure 4, the x-ray diffraction patterns for sintered at 900°C for 24 hours in air. However, the effect of oxygen annealing was found to
change the magnetic properties of the material, especially at low temperature which will be discussed in details later. Normally, sintering performing on pellets improves the compound formation, but in this case Co$_3$O$_4$ impurity phase was observed in sintered pellets due to the slow reaction in the core of the pellet, compared to the outer surface area. The x-ray intensity and $2\theta$ [4] significance corresponded with PDF card 27-0682. The NaCoO$_2$ has been crystal structure of hexagonal structure with high intensity in (hkl) of (002), and

![X-ray diffraction patterns](image)

**Figure 3.** X-ray diffraction patterns of the NaCoO$_2$ calcined as verified from PDF card 27-0628.
Figure 4. X-ray diffraction patterns of the NaCoO$_2$ sintered as verified from PDF card 27-0628.

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Figure 5. Temperature dependence on the Seebeck coefficient of NaCoO$_2$.

obtained the lattice parameters of $a = 2.8443$ Å, $b = 2.8443$ Å, $c = 10.8091$ Å ($a = b \neq c$) as confirmed by TEM result.
So that, the angle of structure \( a = 2.8443 \, \text{Å}, \, b = 2.8443 \, \text{Å}, \, c = 10.8091 \, \text{Å} \) of hexagonal 58 structure \((a = b \neq c)\). These lattice parameters are in good agreement with the previously 59 reports [5]. The crystal size of NaCoO\(_2\) prepared with magnetic field is 776.48 Å, 1520.5 60 Å and crystal size of NaCoO\(_2\) nonmagnetic field is 737.59 Å, 1071.5 Å. The lattice strain 61 of NaCoO\(_2\) prepared with magnetic field is 0.0074, 0.0019 and NaCoO\(_2\) nonmagnetic field 62 is 0.0078, 0.0027. Stress of NaCoO\(_2\) is 13.9 Pa.

63 Figure 5 shows the temperature dependence on the Seebeck coefficient of NaCoO\(_2\). 64 The Seebeck coefficient values of NaCoO\(_2\) showed positive value which indicated p-type 65 thermoelectric material.

66 Figure 6 shows the temperature dependence on electrical resistivity of NaCoO\(_2\). The 67 electrical resistivity has been decreased with increasing temperature, resulting in semimetal

![Figure 6. Temperature dependence of electrical resistivity of NaCoO\(_2\).](image)

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4. Conclusion

We synthesize NaCoO\(_2\) polycrystalline by using solid state reaction method in a magnetic 72 field. The crystal structure of NaCoO\(_2\) sample is in hexagonal structure [8]. The electrical 73 resistivity was 0.1 mΩcm at 463.15 K, and then decreased with increasing temperature, 74 resulting in the semimetal behavior. The Seebeck coefficient of NaCoO\(_2\) was 30 μV/K, 75 and then increased with increasing temperature which corresponded to increase grain size. 76 The Seebeck coefficient positive values resulting from thermoelectric materials, [9] but the 77 performance of NaCoO\(_2\) was not good if we prepared in magnetic field.

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References

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