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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_2CO_3 and Co_3O_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 NaCoO2 are $a = 2.8443$ Å, $b = 2.8443$ Å, and $c = 10.8091$ 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 deintercalation of layered Na_xCoO_2 found in this study was interesting properties in cobalt oxides within magnetic properties. The highly hygroscopic material makes it very unstable under ambient conditions, and unavoidable Na evaporation during high-temperature. The essential requirements are high Seebeck coefficient (S) and low electrical resistivity (ρ). The performance of thermoelectric materials, measured by using dimensionless figure of merit, ($ZT = S^2T/\rho\kappa$) where T is absolute temperature, and κ represents thermal conductivity with values close to unity, is considered good thermoelectric materials [2, 3]. In this work, we synthesized the $NaCoO_2$ by using solid state reaction method in magnetic field, and analyzed crystal structure by using XRD, and SEM for measuring thermoelectric properties, such as the Seebeck coefficient and electrical conductivity for possible development of p-type thermoelectric leg modules.

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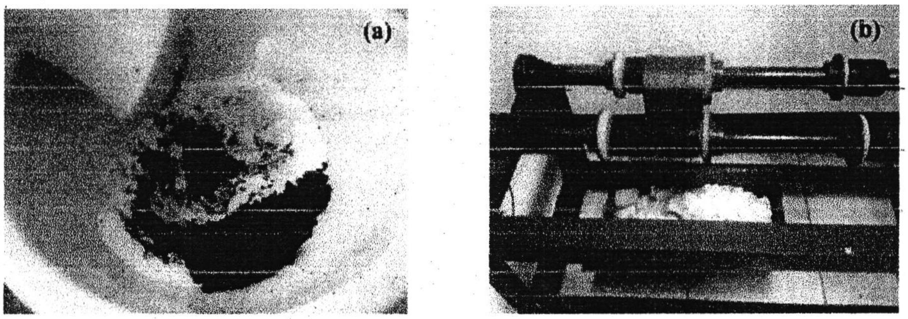

Figure 1. $NaCoO_2$ powder (a) crushing by hand and (b) ball milling in magnetic-ring.

2. Experimental Details

The $NaCoO_2$ was synthesized from powder precursor of Na_2CO_3 and Co_3O_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 as shown in Fig. 1, 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 as shown in Fig. 2. X-ray diffraction data were collected at ambient temperature from 10° to 70° with a step of 2° using a Shimadzu diffractometer equipped with Cu Kα radiation. The thermoelectric properties were measured by ZEM3 ULVAC-RIKO at a temperature range 300–480 K in argon atmosphere. The crystal structure and microstructure of compound were measured and observed by powder by using X-ray diffraction (XRD) [4].

3. Results and Discussion

The results revealed as shown in Fig. 3, the x-ray diffraction patterns for mixed powder calcine at 800°C for 12 hours in air, and in Fig. 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_3O_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 2θ [4] significance corresponded with PDF card 27-0682. The $NaCoO_2$ has been crystal

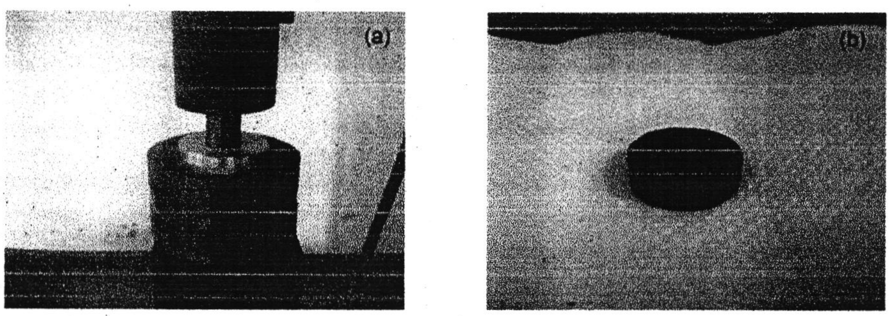

Figure 2. (a) Pressured in magnetic ring by hydraulic at 77 MPa (b) pellet after sintered of $NaCoO_2$.

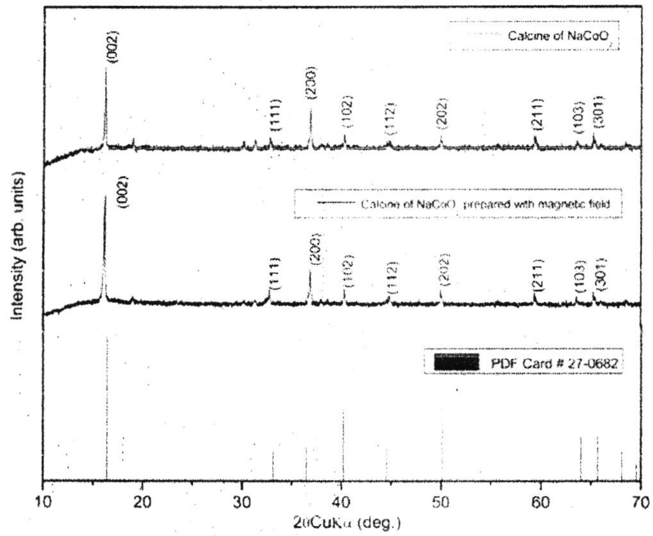

Figure 3. X-ray diffraction patterns of the $NaCoO_2$ calcined as verified from PDF card 27-0628.

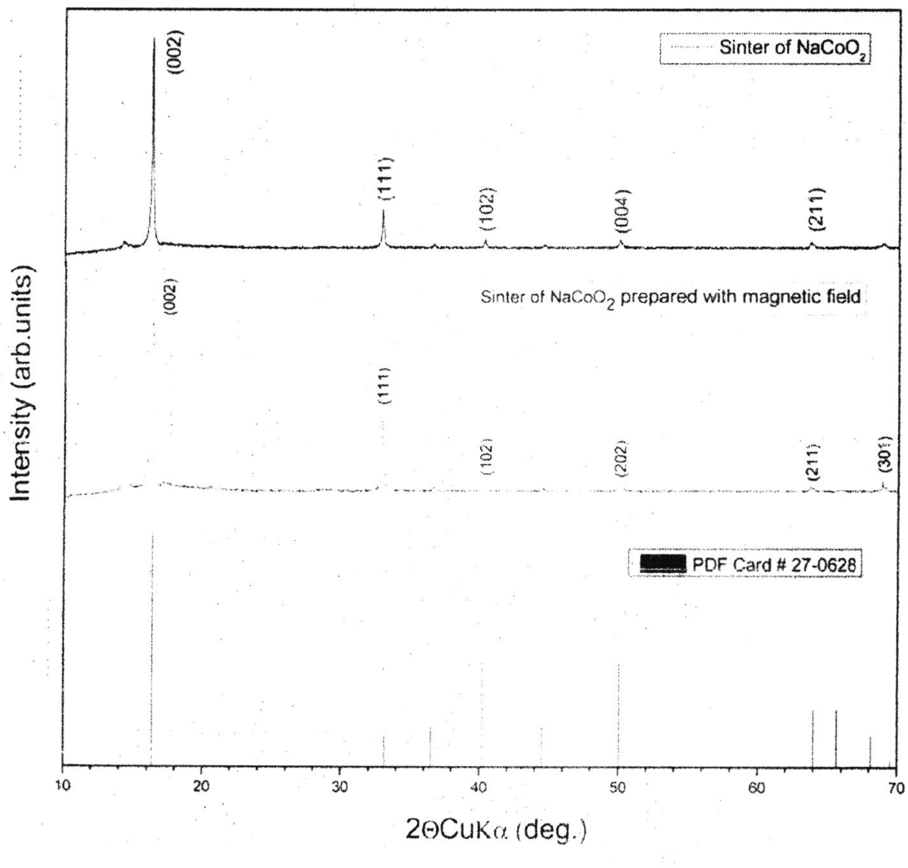

Figure 4. X-ray diffraction patterns of the $NaCoO_2$ sintered as verified from PDF card 27-0628.

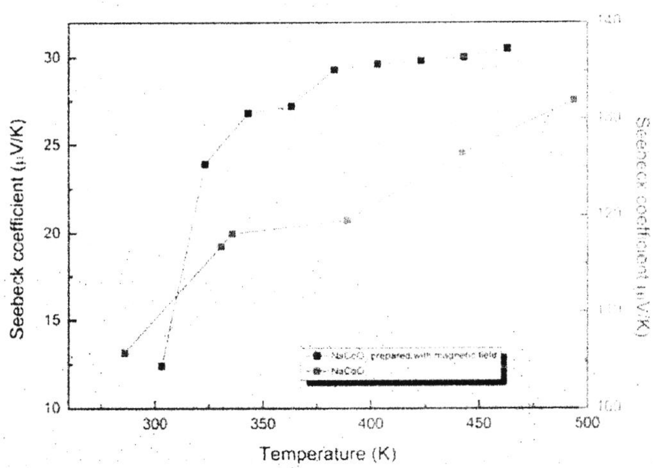

Figure 5. Temperature dependence on the Seebeck coefficient of $NaCoO_2$.

structure of hexagonal structure with high intensity in (hkl) of (002), and 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 Å, b = 2.8443 Å, c = 10.8091 Å of hexagonal structure ($a = b \neq c$). These lattice parameters are in good agreement with the previously reports [5]. The crystal size of $NaCoO_2$ prepared with magnetic field is 776.48 Å, 1520.5 Å and crystal size of $NaCoO_2$ nonmagnetic field is 737.59 Å, 1071.5 Å. The lattice strain of $NaCoO_2$ prepared with magnetic field is 0.0074, 0.0019 and $NaCoO_2$ nonmagnetic field is 0.0078, 0.0027. Stress of $NaCoO_2$ is 13.9 Pa.

Figure 5 shows the temperature dependence on the Seebeck coefficient of $NaCoO_2$. The Seebeck coefficient values of $NaCoO_2$ showed positive value which indicated p-type thermoelectric material.

Figure 6 shows the temperature dependence on electrical resistivity of $NaCoO_2$. The electrical resistivity has been decreased with increasing temperature, resulting in semimetal

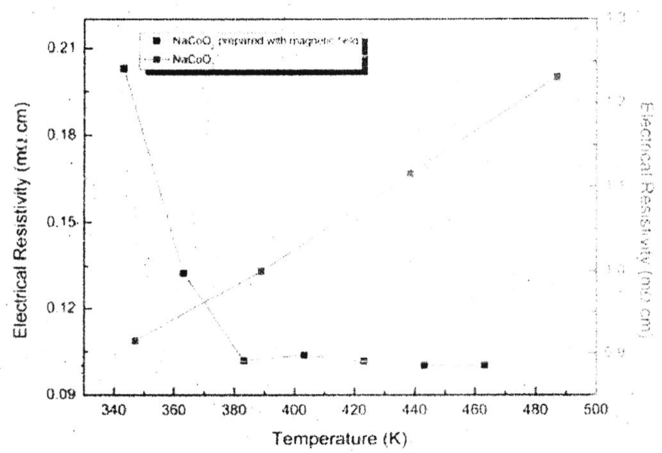

Figure 6. Temperature dependence of electrical resistivity of $NaCoO_2$ [5].

behavior [3]. In addition, the $NaCoO_2$ has semi-metallic behavior due to its metallic behavior as temperature increased.

4. Conclusion

We synthesize $NaCoO_2$ polycrystalline by using solid state reaction method in a magnetic field. The crystal structure of $NaCoO_2$ sample is in hexagonal structure [8]. The electrical resistivity was 0.1 mΩcm at 463.15 K, and then decreased with increasing temperature, resulting in the semimetal behavior. The Seebeck coefficient of $NaCoO_2$ was 30 μV/K, and then increased with increasing temperature which corresponded to increase grain size. The Seebeck coefficient positive values resulting from thermoelectric materials, [9] but the performance of $NaCoO_2$ was not good if we prepared in magnetic field.

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SECTION B: THERMOELECTRIC MATERIALS

Effects of Magnetic Field on Synthesis and Thermoelectric Properties of $NaCoO_2$

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Electronic, Optical and Magnetic Materials	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Q4	Q4	[illegible]	[illegible]	[illegible]
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Control and Systems Engineering	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Q4	[illegible]
Materials Chemistry	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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2009	0.329	71	753
2008	0.242	159	706

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