Electrical properties of $\text{Ba}_{1-x}\text{Bi}_x\text{NiS}_2$ ($0 \leq x \leq 0.1$)

H. Kuriyaki, K. Tokunaga, S. Nishioka, K. Hirakawa

► To cite this version:

H. Kuriyaki, K. Tokunaga, S. Nishioka, K. Hirakawa. Electrical properties of $\text{Ba}_{1-x}\text{Bi}_x\text{NiS}_2$ ($0 \leq x \leq 0.1$). Journal de Physique IV Proceedings, 1993, 03 (C2), pp.C2-277-C2-280. 10.1051/jp4:1993256 . jpa-00251339

HAL Id: jpa-00251339

<https://hal.science/jpa-00251339>

Submitted on 1 Jan 1993

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Electrical properties of $\text{Ba}_{1-x}\text{Bi}_x\text{NiS}_2$ ($0 \leq x \leq 0.1$)

H. KURIYAKI, K. TOKUNAGA, S. NISHIOKA and K. HIRAKAWA

Department of Electronics, Faculty of Engineering, Kyushu University 36, Hakozaki, Higashi-ku, Fukuoka 812, Japan

Abstract

The compounds BaNiS_2 and $\text{Ba}_{1-x}\text{Bi}_x\text{NiS}_2$ ($x = 0.03, 0.07, 0.1$) were prepared and their electrical resistivity, Seebeck coefficient, Hall coefficient and magnetic susceptibility were measured in the temperature range from 4.2 K to 280 K. BaNiS_2 shows metallic behavior with a high anisotropy in resistivity, reflecting the layer structure, and Pauli paramagnetism with a weak temperature dependence. The Seebeck coefficient of BaNiS_2 has a positive broad peak at about 200 K. Substituting of Bi for Ba site the majority charge-carrier changes from hole to electron. It is also noticed that the resistivity on the sample with $x = 0.07$ shows a peculiar step-like change around 220 K, corresponding to the temperature at which the Seebeck coefficient has an abnormal behavior.

1. Introduction

The compound BaNiS_2 has a layer structure with a tetragonal system ($P4/nmm$) as shown in Fig. 1. Its structure consist of puckered two-dimensional layers of edge-sharing square-pyramidal $[\text{NiS}_4/4]_n^{2n-}$ polyhedra parallel to (001), with barium atoms packing between the layers [1]. While in the layers the nickel-sulfur bonds have a length of 2.3 Å, between the layers the nickel atoms are almost 9 Å apart. It is thus expected that the compound has two-dimensional character. From the preliminary experimental results only above 78 K, Gray et. al. suggested that the compound had metallic behavior and Pauli paramagnetism [1]. But, none have been ever reported for the characterization in detail. We tried to prepare BaNiS_2 and $\text{Ba}_{1-x}\text{Bi}_x\text{NiS}_2$ ($x = 0.03, 0.07, 0.1$) and characterized them by electrical resistivity, Seebeck coefficient, Hall coefficient and magnetic susceptibility in the temperature range from 4.2 K to 280 K.

Fig. 1 Perspective view of layer-Structure BaNiS_2 .

2. Experimental

$\text{Ba}_{1-x}\text{Bi}_x\text{NiS}_2$ ($x = 0, 0.03, 0.07, 0.1$) was prepared by following procedures. The reagents BaS (3N), Bi_2S_3 (5N), nickel (3N) and sulfur (5N) were mixed with molar ratio $1-x : x : 1 : 2$. The mixture was heated in a sealed evacuated quartz tube to 720 °C for 7 days, and then cooled down to room temperature. After grinding, the powder was again heated to 700 °C for 5 days. The resultant powder was composed from black and plate-like small crystals. After regrounding, the powder was uniaxially pressed into rectangular plate with the size of about $8 \times 2 \times 0.2 \text{ mm}^3$ and sintered at 680 °C for 4 days. From powder X-ray diffraction analysis, all the samples ($x = 0, 0.03, 0.07, 0.1$) were confirmed to be a single phase of BaNiS_2 -type tetragonal structure.

The electrical resistivity was measured by the standard four-probe technique. It is known that as plate-like powder is uniaxially pressed into a pellet-type of sample, the flat surface of the crystalline powder preferably tends to be arranged parallel to the surface of the sample. We here define the resistivity parallel and perpendicular to the flat plane of the rectangular plate samples, respectively. Owing to the preferential orientation, ρ and ρ^* thus may be considered to be nearly the resistivity parallel and perpendicular to the c -plane of single phase of crystal, respectively. The magnetic susceptibility was measured by a SQUID magnetometer. The Seebeck coefficient obtained by applying a temperature difference of 2 K. The Hall coefficient was measured under the field of 1 T applied perpendicular to the flat plane of the sample.

3. Results and Discussion

The temperature dependence of electrical resistivity, ρ and ρ^* , of BaNiS_2 is shown in Fig. 2. The magnitude of the resistivity, ρ , is of the order of $10^{-3} \Omega\text{cm}$ at room temperature. The resistivity decreases with decreasing temperature from 280 K to 50 K, and with further decreasing temperature the resistivity gradually increases. The anisotropic ratio in the resistivity, ρ^*/ρ , is of the order of 10^3 over the whole temperature range. The resistivity of BaNiS_2 is found to exhibit metallic behavior with two-dimensional character.

Figure 3 shows the magnetic susceptibility, χ , of BaNiS_2 under an applied field of 0.15 T. The data reported by Grey et. al. [1] are also shown by solid triangles in the figure. With decreasing temperature the magnetic susceptibility gradually decreases from 280 K and at about 50 K beginning to increase. This seems to exhibit Pauli paramagnetism with a weak temperature dependence. Below about 50 K, however, the origin of the increment of the magnetic susceptibility is not known at present. The upturn in the magnetic susceptibility seems to be closely related to that in the resistivity shown in Fig. 2. The quite similar relation was observed in 1T-TaS_2 , which is well known to be a layer structure with two-dimensional character [2-4]. In $(\text{La}_{1-x}\text{Sr}_x)_2\text{NiO}_4$ system corresponding to layer-structure K_2NiF_4 , the relation was also observed [5-6]. It was suggested in the papers that the upturn in both of magnetic susceptibility and resistivity was caused by localization from 3d electrons of nickel.

The temperature dependence of the resistivity, ρ , of $\text{Ba}_{1-x}\text{Bi}_x\text{NiS}_2$ ($x = 0, 0.03, 0.07, 0.1$) is shown in Fig. 4. With increasing x , above about 200 K the temperature coefficient of the resistivity changes smoothly from positive to negative except for the sample with $x = 0.07$. Without depending on x the anisotropic ratio, ρ^*/ρ , of all the samples remains to be of the order of 10^3 over the whole temperature range. It is also noticed that the resistivity on the sample with $x = 0.07$ shows a peculiar step-like change around 220 K.

The temperature dependence of the Seebeck coefficient, S , of $\text{Ba}_{1-x}\text{Bi}_x\text{NiS}_2$ ($x = 0, 0.03, 0.07, 0.1$) is shown in Fig. 5. BaNiS_2 shows a positive broad peak ($\approx 30 \mu\text{V/K}$) around 200 K, which the similar behavior was reported in many oxide high T_c -superconductors [7-11]. Bar-ad et. al. proposed that in YBCO superconductor the similar broad peak of Seebeck coefficient can be explain by a narrow-band model [7]. Sera et. al. also suggested that in Bi-oxide superconductor one of the origin is due to an existence of unusual scattering of carriers [11].

Fig. 2 Temperature dependence of the electrical resistivity, ρ , of BaNiS_2 .

Fig. 3 Temperature dependence of the magnetic susceptibility, χ , of BaNiS_2 .

Fig. 4 Temperature dependence of the electrical resistivity, ρ , of $\text{Ba}_{1-x}\text{Bi}_x\text{NiS}_2$ ($x = 0, 0.03, 0.07, 0.1$).

Fig. 5 Temperature dependence of the Seebeck coefficient, S , of $\text{Ba}_{1-x}\text{Bi}_x\text{NiS}_2$ ($x = 0, 0.03, 0.07, 0.1$).

Substituting Bi for Ba site, Seebeck coefficient changes from positive to negative. Over the whole temperature range measured, the sign of Hall coefficient shows positive on the sample with $x = 0$ and negative on that with $x = 0.07$, respectively. From the results of measurement of the Seebeck coefficient and the Hall coefficient, the majority charge-carrier in BaNiS₂ is probably estimated to be hole carrier. However, substituting Bi for Ba site the majority carrier is found to change electron. It seems from this result that electron doping into the Ni-S layers from Ba site effectively occurs due to substitute Bi³⁺ for Ba²⁺ site. The Seebeck coefficient of the sample with $x = 0.07$ is also noticed to exhibit an abnormal behavior at about 220 K, corresponding with the temperature at which the resistivity have a peculiar change. This result may indicate that the substitution of Bi for Ba site not only work as electron doping, but also affect the electron structure.

4. Conclusion

BaNiS₂ shows metallic behavior with a high anisotropy in resistivity and Pauli paramagnetism with a weak temperature dependence. The Seebeck coefficient has a positive broad peak at about 200 K. Substituting of Bi for Ba site the majority charge-carrier changes from hole to electron. It is also noticed that the resistivity on the sample with $x = 0.07$ shows a peculiar step-like change around 220 K, corresponding to the temperature at which the Seebeck coefficient has an abnormal behavior.

References

- [1] I. E. Grey and H. Steinfink, J. Amer. Chem. Soc., **92** (1970) 5093
- [2] F. J. Disalvo and J. U. Waszczak, Phys. Rev., **B22** (1980) 4241
- [3] R. Inada, Y. Onuki and S. Tanuma, J. Phys. Soc. Jpn., **50** (1981) 1217
- [4] H. Kamimura, Phil. Mag., **B42** (1980) 763
- [5] M. Kato, Y. Maeno and T. Fujita, J. Phys. Soc. Jpn., **60** (1991) 1994
- [6] M. Kato, Y. Maeno and T. Fujita, Physica, **C176** (1991) 533
- [7] S. Bar-ad, B. Fisher, J. Ashkenazi J. Genossar, Physica, **C156** (1988) 741
- [8] K. Matsuura, T. Wada, Y. Yaegashi, N. Suzuki, K. Kubo, H. Yamauchi and S. Tanaka, Physica, **C185-189** (1991) 1285
- [9] S. D. Obertelli, J. R. Cooper and J. L. Tallon, Phys. Rev., **B46** (1992) 14928
- [10] J. Sugiyama, K. Matsuura, M. Kosuge, H. Yamauchi and T. Tanaka, Phys. Rev., **B45** (1992) 9951
- [11] M. Sera, S. Tanaka, M. Sato and H. Fujishita, Solid State. Commun., **812** (1992) 415
- [12] Y. Nakamura and S. Uchida, Phys. Rev., **B47** (1993) 8396