

Cu_{1-x}Ni_xCr₂O₄

*

1.0 0.8 0.7 0.6 0.5 0.3 0.2 0 x Cu_{1-x}Ni_xCr₂O₄

.550 K 300 K

1.0 0.8 0.7 x

450 K 350 K 315 K

(Free energy)

[Srivastava et al., 1986]

(Normal Spinel) :

A²⁺

B A) AB₂O₄

B³⁺

(

(A²⁺)_{tetra}[B³⁺]_{octa}O₄²⁻

.(1)

()

(Inverse

.NiCr₂O₄

CuCr₂O₄

A²⁺

Spinel)

(Chromites)

(Ferrites)

B³⁺

[Gehring et al., (Manganites)

(Aluminates)

(B³⁺)_{tetra}[A²⁺B³⁺]_{octa}O₄²⁻

32 :

56

.1975]

16

8

.FeO Fe₂O₃

(Mn-ferrites)

(Intermediate Spinel)

(Tetrahedral)

A

[Cullity, 1972] (Mg-ferrites)

(x=1 x=0) NiCr₂O₄ CuCr₂O₄

B

Ni²⁺ Cu²⁺

Cr³⁺

B A

(Octahedral)

Ni²⁺[Cr₂³⁺]_{octa}O₄²⁻ Cu²⁺[Cr₂³⁺]_{octa}O₄²⁻ :

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		c/a < 1	310 K	860 K
	[Kshirsagar, 1969]	Kanamori et]		c/a > 1
	Cu _{1-x} Ni _x Mn ₂ O ₄	Cu _{1-x} Ni _x Cr ₂ O ₄		[al., 1968
	Mn ⁴⁺ , Mn ³⁺	x = 1 x = 0	c/a < 1	
	Cu ¹⁺ , Cu ²⁺	(Orthorhombic)		
	Mn _{2-x} Co _{2x} Ni _{1-x} O ₄		[Katauka et al., 1972]	x _C = 0.85
	[Yokayama et al., 1996]			
	MnO, CoO, NiO, CuO		Cu _{1-x} Ni _x Cr ₂ O ₄	
		Ni ²⁺		Cu ²⁺
	[Mohammed et al., 2002]	Ni ²⁺ Cu ²⁺		
	[Ali, 2002]			
	Cu _{1-x} Ni _x Fe ₂ O ₄	(Elongation)		(Compression)
	-	[Atanasov et	Ni ²⁺ Cu ²⁺	
	. x			.al., 1993]
		()		
	[Ata- [Mazen et al., 1999] [El-Saadawy et al., 2000]			
	[Ravinder, 2000] Allah et al., 2000]	:		
		[Goodenough et al., 1955] covalency		
		[Dunitz et al., crystalline field theory		
		microscopic		1957]
		[Lenglet et [Katauka et al.,1972] hamiltonian		
		Ni _x Cu _{1-x} Cr ₂ O ₄	c/a<1	al., 1986]
			0.20 < x < 0.50	
	.550K 300 K	(spin-orbit coupling -) Ni ²⁺		
		.() Cu ²⁺		
		Cu _{1-x} Ni _x Cr ₂ O ₄		
	0.3 0.2 0 x	[Ohnishi CuCr ₂ O ₄		
		[Kim et al., 1976] NiCr ₂ O ₄		et al., 1961]
	1.0 0.8 0.7 0.6 0.5			
	ceramic) (solid state reaction)	[Siratori et al., 1965]		
	[Atanasov et al., 1993 and Inaba et al., 1986](method	.NiCr ₂ O ₄		
	:	NiCr ₂ O ₄ CuCr ₂ O ₄		[Kino et al., 1972]
		NiCr ₂ O ₄ CuCr ₂ O ₄		Ni _x Zn _{1-x} Cr ₂ O ₄
	CuO			
	.Cr ₂ O ₃ NiO			
	373 K			[Inaba et al., 1986]
				Cu _{1-x} Ni _x Cr ₂ O ₄

(heater) CuCr₂O₄ Cr₂O₃ NiO Cr₂O₃ CuO NiCr₂O₄

300 K 24 1273 K

: [Yokayama et al., (sintering process) .1996]

(proper Cu_{1-x}Ni_xCr₂O₄ NiCr₂O₄ CuCr₂O₄ ratios)

(pellets) x ratios)

0.65cm .10 ton /cm² 0.3cm

(annealing process)

24 1273 K

(± 6%)

[Cullity, 1972]

(Keithley 177 Microvolt DMM)

ΔT ΔV (hot probe method)

: x Cu_{1-x}Ni_xCr₂O₄ (holes)

T₂ T₁ .1 [Abdel-Rab, 2002]

ΔT = T₂-T₁ T = (T₁ + T₂) / 2 :

ΔV .2

S = ΔV / : .3 0.3mm (Copper-Constantan)

. ΔT . 0.5mm

()

S (3)

.T

() p-
 [Kshirsagar, 1969; Dordor () n- S 0.7 0.8 1.0
 .et al., 1986] 350 315 S
 300 K 450K
 S Cu_{1-x}Ni_xMn₂O₄ 673 K
) (4)
 ([Inaba et al., 1986]
 Cu_{1-x}Ni_xCr₂O₄
 :
 S = a - b T S .[Kataoka et al., 1972]
 a b a
 (1020± 20) μV/K (180 ± 20) μV/K
 b .1 0 x p- n-
 . T S
 0.85 ± 0.1 b
 Cu_{0.5}Ni_{0.5}Cr₂O₄
 . [Kanai et al., 2000] σ
 [Islam et al., 2003]
 [Chung et al., 2001] [Islam et al., 2003] (majority carriers)
 Mg_{1-x}Zn_xFe₂O₄ -
 -
 - Ni_{0.8}Zn_{0.2}Cu_xTi_xFe_{2-2x}O₄ Hall effect
 (single crystal) Mg_{0.45}Zn_{0.43}Fe_{2.12}O₄ [Abdel-Rab, 2002]
 .p- (degenerate) x
 (1) (4)
 Ni³⁺
 [Verwey et al., 1947] S
 S . NiCr₂O₄
 : Ni Cr₂O₄ CuCr₂O₄ Abdel-Rahman,
 Cu²⁺ + Cu¹⁺ → Cu¹⁺ + Cu²⁺ [1998]
 Ni²⁺ + Ni³⁺ → Ni³⁺ + Ni²⁺ [Srinivasan et al., 1981]
 (electron-hole pair) - .[Devale et al., 1982]

S

S T ()

[Isawa et al., 1998] [Keem et al., 1975]

S_d S = S_d+S_p+S_m : [Gillot, 1982; Kanai et al., 2000]

S_m S_p

f.c.c.

: Heikes

$$S = \frac{k_B}{q} \left[\text{Ln} \frac{N - N_0}{N_0} + \frac{S^*}{k_B} \right]$$

450 350 315

0.7 0.8 1

(density of states) N₀ N

Cu²⁺ N

[Isawa et al., 1993] Ni³⁺ N Cu¹⁺

(entropy) :S* Ni²⁺

10 μV/K

S*

-1

$$S = \frac{k_B}{q} \text{Ln} \left[\frac{\text{Cu}^{2+}}{\text{Cu}^{1+}} \right]$$

-2 NiCr₂O₄

Ni³⁺

.S

S

-3

$$S = \frac{k_B}{q} \text{Ln} \left[\frac{\text{Ni}^{2+}}{\text{Ni}^{3+}} \right]$$

-4

86.4 μV/K k_B/q

1.0 0.0 = x S

-5

4.5 400 K

Ni³⁺/Ni²⁺ Cu²⁺/Cu¹⁺

3.7 x 10⁻⁵

0.8 1.0 x -6
0.7
450 K 350 K 315 K

.(Christmann, 1988) : (1)
: (2)

T S : (3)
.Cu_{1-x}Ni_xCr₂O₄
x S : (4)
.Cu_{1-x}Ni_xCr₂O₄

- Islam, M. U., Abbasi, A. Y., Abbasi, T., Chaudhry, M. A. and Chaudhry, A. Z. 2003. *J. Res. Sci.*, 14: 103 (Bahauddin Zakariya University, PAKISTAN).
- Islam, M. U., Chaudhry M. A., Abbasi, T., Abbasi, A., Hashmi, K. A. and Khan, S. 2003. *J. Res. Sci.*, 14: 241 (Bahauddin Zakariya University, PAKISTAN).
- Kanai, H., Hashimoto, T., Tagawa, H. and Mizusaki, J. 2000. *Technical Paper*, 68: 507.
- Kanamori, J., Kataoka, M. and Itoh, Y. 1968. *J. Appl. Phys.*, 39: 688.
- Kataoka, M., and Kanamori, J. 1972. *J. Phys. Soc. Japan*, 32: 113.
- Keem, J. E. and Honig, J. M. 1975. *Phys. Stat. Sol. (a)*, 28: 335.
- Kim, G., Sakurai, J. and Komura, Y. 1976. *Jap. J. Appl. Phys.*, 15: 411.
- Kino, Y., Luthi, B. and Mullen, M. E. 1972. *J. Phys. Soc. Japan*, 33: 687.
- Kshirsagar, S.T. 1969. *J. Phys. Soc. Japan*, 27: 1164.
- Lenglet, M., d'Huysser, A., Arsene, J., Bonnelle, J. P. and Jørgensen, C. K. 1986. *J. Phys. C.*, 19: L 363.
- Mazen, S. A. and Elfalaky, A. 1999. *J. Magn. Magn. Mater.* 195: 148.
- Mohammed, K. A. and Shareef, J. M. 2001. *Dirasat*, 28: 155 (in Arabic).
- Mohammed, K. A. and Shareef, J. M. 2002. *Dirasat*, 29: 139 (in Arabic).
- Ohnishi, H. and Teranishi, T. 1961. *J. Phys. Soc. Japan*, Vol. 16, P. 35.
- Siratori, K., Tsushida, A. and Tomeno, Y. 1965. *J. Appl. Phys.*, 36
- Srivastava, J. K., Dang, K. Le and Veillet, P. 1986. *J. Phys. C.*, 19: 599.
- Verwey, E. J. W. and Heilman, E. L. 1947. *J. Chem. Phys.*, 15: 174.
- Yokayama, R. and Abe, Y. 1996. *Jap. J. of Appl. Phys.* 35: 5775.
- Abdel-Rab, M. S. 2002. M. Sc. Thesis, University of Mosul (in Arabic).
- Abdel-Rahman, M. 1998. *Indian J. Pure and Appl. Phys.* 36: 533.
- Ali, K. K. 2002. M. Sc. Thesis, University of Mosul (in Arabic).
- Ata-Allah, S. S. and Fayek, M. K. 2000. *J. Phys. Chem. Solids.*, 61: 1529.
- Atanasov M., Kesper U., Ramakrishna B. L. and Reinen D. 1993. *J. Solid State Chem.*, 105: 1.
- Christmann, J. R. 1988. *Fundamental of Solid State Physics (1st Ed.)*, John Wiley (New York).
- Chung, Y-C and Yoo Han-III. 2001. *J. Mater. Res.*, 16: 774.
- Cullity, B. D. 1972. *Introduction to Magnetic Materials*, Addison-Wesley (USA).
- Devale, A. B. and Kulkarni, D. K. 1982. *J. Phys. C.*, 15: 899.
- Dordor, P., Joirets, S., Doumeric, J. P., Launay, J. C., Claverie, J. and Hagenmuller, P. 1986. *Phys. Stat. Sol. (a)*, 93: 321.
- Dunitz, J. D. and Orgel, L. E. 1957. *J. Phys. Chem. Solids*, 3: 20.
- El-Saadawy, M. 2000. *J. Magn. Magn. Mater.* 219: 69.
- Gehring, G. A. and Gehring, K. A. 1975. *Rep. Prog. Phys.*, 38: 1.
- Gillot, B. 1982. *Phys. Stat. Sol. (a)*, 69: 719.
- Goodenough, J. B. and Loeb, A. L. 1955. *Phys. Rev.*, 98: 391.
- Inaba, H., Yagi, H. and Naito, K. 1986. *J. Solid State Chem.*, 64: 67.
- Isawa, K., Yaegashi, Y., Ogota, S., Nagano, M. and Sudo, S. 1998. *Phys. Rev. B.*, 57: 7950.
- Isawa, K., Sugiyama, J. and Yamauchi, H. 1993. *Phys. Rev. B.*, 47: 11426.

Thermoelectric Power of the Copper-Nickel Chromite



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ABSTRACT

The thermoelectric power of the copper-nickel chromite system $\text{Cu}_{1-x}\text{Ni}_x\text{Cr}_2\text{O}_4$ ($0 \leq x \leq 1$) has been measured over the temperature range from 300 K to 550 K. These compounds have been prepared using the solid state reaction method. Values of the thermoelectric power are relatively high and remain almost constant as temperature rises. These behaviours have been attributed to the charge carrier concentrations, which remain constant as expected from the hopping conduction mechanism. Samples with 1.0, 0.8 and 0.7 of Ni content at temperatures 315 K, 350 K and 450 K have shown clear variation in values of the thermoelectric power, respectively. These variations have been attributed to the cubic-tetragonal structural phase transformation, which is caused by the cooperative Jahn Teller effect.

Keywords : Thermoelectric power, Seebeck Effect, Jahn Teller Effect, Copper-Nickel Chromites.

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