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ELECTRIC AND THERMOELECTRIC PROPERTIES OF NATURAL CRYSTALS OF HEMATITE

A. K. MUKERJEE

DEPARTMENT OF MAGNETISM
INDIAN ASSOCIATION FOR THE CULTIVATION OF SCIENCE,
CALCUTTA-32, INDIA

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The electrical conductivity (σ) and Seebeck voltage (with respect to Pt) (θ) of crystals of a sample of naturally occuring hematite (Brazil : Fe_2O_3 95.5%, FeO .5%, SiO_2 1.7%, TiO_2 1.9%, MgO .2%, Al_2O_3 .13%, S .1%, H_2O .15%) were measured both along the trigonal axis and the basal plane between 100°K and 1000°K for fresh as well as heat treated samples (figures. 1 and 2). These were found to be n-type semiconductors and the conductivity can be represented by

$$\sigma = \sigma_0 \exp -\Delta E/kT$$

where the symbols have their usual meaning. The values for ΔE and σ_0 are given in table 1.

Table 1. ΔE and σ_0 in different temperature regions

Crystal samples	Fresh (a)			Heat treated (b)		
	ΔE in e.v.	σ_0 Ω^{-1} cm^{-1}	Temp. range °K	ΔE in e.v.	σ_0 Ω^{-1} cm^{-1}	Temp. range °K
1) In plane	0.079	1.38	<220	0.066	0.026	<270
	0.109	11.5	220<T<585	0.102	0.087	270<T<440
				0.190	1.20	440<T<780
2) ,,	0.066	0.76	<200	0.066	0.026	<270
	0.095	4.80	200<T<450	0.198	8.30	270<T<735
3) Along c-axis	0.074	0.145	<205	0.080	0.0105	<310
	0.189	11.5	205<T<640	0.223	3.63	310<T<700
4) ,,	0.090	0.251	<210	0.095	0.029	<260
	0.238	14.1	210<T<440	0.179	1.14	260<T<400
	0.439	163	440<T<625	0.343	83	400<T<650

An approximate order of the values of effective carrier concentration (n) and mobility (μ) could be obtained from the relations :

$$\theta \approx \frac{k}{e} \log_e \frac{N_0}{n} \text{ (Jonker } et\ al. \text{ 1961, Gardner 1963)}$$

and $\sigma \doteq ne\mu$ where N_0 is the number of available states. At 300°K the values of n and μ are given in Table 2.

Table 2. n and μ at 300°K

Crystal samples	Fresh (a)		Heat treated (b)	
	n per c.c.	μ cm^{2}v^{-1} sec^{-1}	n per c.c.	μ cm^2 v^{-1} sec^{-1}
1) In plane	3.9×10^{20}	2.5×10^{-2}	2×10^{21}	7.8×10^{-5}
2) ,,	2×10^{21}	5.6×10^{-3}	5×10^{20}	5×10^{-4}
3) Along c-axis	1.4×10^{21}	1.4×10^{-3}	9.3×10^{20}	3.7×10^{-5}
5) ,,	1.1×10^{22}	3×10^{-4}	1.2×10^{22}	7.8×10^{-6}

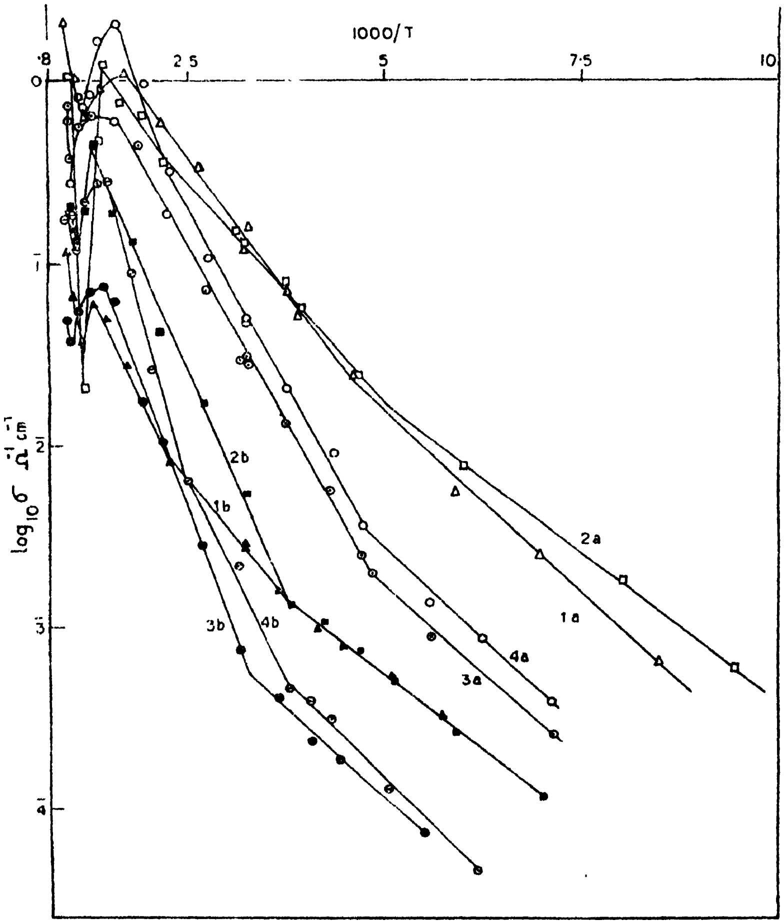

Figure 1. **The conductivity of Hematite. 1 and 2 are along the basal plane, 3 and 4 along the c-axis and (a) and (b) are the fresh and heat treated samples.**

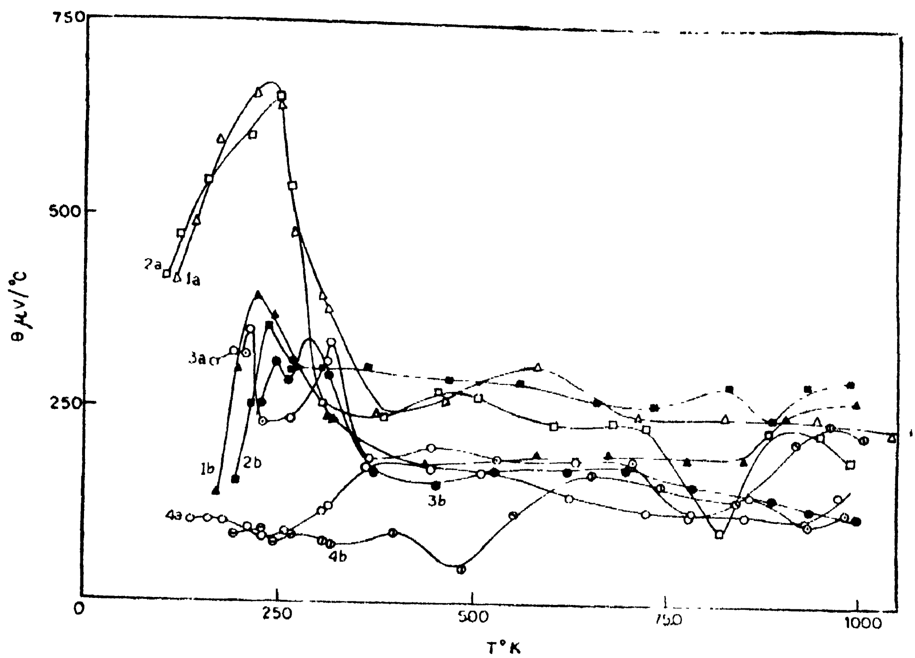

Figure 2. The Seebeck effect of Hematite, magnitude only. 1 and 2 are along the basal plane, 3 and 4 along the c-axis and (a) and (b) are the fresh and heat treated samples.

The behaviour of σ and θ between 600°K and 1000°K (figures 1 and 2) is perhaps due to change from impurity region to intrinsic region, and the permanent change in the values of σ and θ due to heat treatment during the first cycle of measurement is most probably due to the impurities and imperfections present in the natural crystals. ΔE in the intrinsic region is about 1 e.v.

The major impurity Ti is perhaps responsible for the donor centres (Morin 1951, Jonker *et al* 1961), which is again very possibly the source of weak ferromagnetism in it below Morin transition (Mukerjee 1967a).

A study of the values of n and μ and that of chemical analysis however suggest the presence of other types of carriers in it.

From figures 1 and 2 it is observed that there is a conspicuous change in θ at about 250°K, and that also there is a change in the value of ΔE within the temperature range 200°K to 300°K. From earlier observations (Morin 1950, also see Mukerjee 1967b) with purer samples of hematite it has been observed that there is a transition in the magnetic properties at 250°K.

Detailed investigations of these properties on other samples of hematite are in progress and the results will be published soon.

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