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Thermoelectric Power of Ni-Mg-Zn-Cu ferrites

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Abstract*: Hermoelectrical studies of Ni substituted Ni– Mg–Zn–Cu ferrites of various compositions were studied from room temperature to well beyond the Curie temperature by differential method. The series of samples were prepared by standard double sintering ceramic method. The Seebeck coefficient was measured as a function of temperature and found to be negative for all compositions showing that these ferrites are n-type semiconductors. The variation of thermoelectric power as a function temperature is discussed based on obtained results.

***Keywords*: Ferrites, Ceramic method, thermoelectric power, Seebeck coefficient, Curie temperature.**

I. INTRODUCTION

Spinel ferrites are found to be interesting due to their ability to accommodate different captions into their tetrahedral and octahedral sites. This suggests an opportunity to selectively improve the properties to match the numerous applications. The high electrical resistivity, low dielectric losses, high Curie temperature, good magnetic properties, material hardness, chemical stability, cost effectiveness etc makes them useful in many technological applications such as mobile phones, video cameras, note book computers, magneto-optical displays, microwave absorbers, wave guides and so on (1, 2).

It is well-known that the materials with high thermoelectric efficiency close to the room temperature are more popular due their potential applications in electronic refrigerators, air conditioners and power generators. Thermoelectric materials can generate the electric energy and serve to as electric heat pump. Thermoelectric cooling is an ecofriendly approach used for large scale in computers, infrared detectors, electronics and optoelectronics (3).

In present work, we report the results on thermoelectric power (i.e. Seebeck coefficient) measurements of Ni– Mg–Zn–Cu ferrites as a function of composition and temperature. Thermoelectric power can provide the information on the conduction carriers and the conduction mechanism.

II. EXPERIMENTAL

In the present work, the ferrites with general formula NixMg0.5-xCu0.1Zn0.4Fe2O4 with x = 0.1, 0.2, 0.3, 0.4 and 0.5 were prepared by standard double sintering ceramic method. The stoichiometric mixtures were pre-sintered at 700oC for 12h. The fine powder was used for the preparation of pellets having 1.5 cm diameter and 0.3 cm thickness using hydraulic press by applying adequate pressure. The compacts so prepared were subjected to final sintering at 1050oC for 24h in programmable furnace and slow cooled to room temperature to yield the final product. The details of the method of the preparation have been given in earlier publication (4).

The Seebeck coefficients were measured by a differential method (5) from room temperature to well beyond the Curie temperature. To measure the thermoelectric power of ferrites, a temperature gradient between two ends of a sample is maintained so that the thermally activated charge carriers move from high to low temperature end producing the thermoelectric power. The samples in the form of pellets having 1.5 cm. diameter and 0.3 cm thick were used for the measurement. The surfaces of the pellets were polished and silver paste was applied.

Silver foils were placed on either sides of the pellet to which external connections were made to measure the rmoemf. Pellet and foils were inserted into the gap between two cylindrical rods and tightened.

The upper rod was wound with resistive heating element to maintain a temperature gradient with lower cylindrical rod. The whole assembly was kept inside a furnace and the temperature was varied from room temperature to 7500 K. A temperature gradient of 200K was maintained between upper (hot) and lower (cold) ends throughout the measured temperature range. The temperature gradient across the sample was measured using thermocouple.

The thermoelectric power (i.e. Seebeck coefficient S) was calculated using the relation

$$S = \pm(\Delta E/\Delta T)$$

where, ΔE is the thermo e.m.f. produced across the sample due to temperature difference ΔT.

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III.RESULT AND DISCUSSIONS

Thermoelectric power and Hall Effect are the important properties and widely used to understand the conduction mechanism in semiconductors. In case of low mobility materials like ferrites, it is sometime difficult to measure the Hall Effect. In such situations, the thermoelectric power measurement is the only alternative. Furthermore, the sign of thermoemf gives very useful information about the type of conduction in semiconductors, whether it is p-type or n-type. Another important significance of thermoemf is that it serves to calculate the values of Fermi-energy that help in the determination of the various regions, viz. impurity conduction, impurity exhaustion and intrinsic conduction regions of the semiconductor (6).

The variation of Seebeck coefficient with temperature for all Ni-Mg-Cu-Zn ferrites samples is shown in Figure 1. The graph revealed that all the samples exhibit similar thermal variation with negative Seebeck coefficient. This indicates that the charge carriers in the prepared ferrite samples are n-type in the entire range of temperature. This is because the Ni ferrite, Mg ferrite and Zn ferrite are of n-type. All the Ni-Mg-Cu-Zn ferrite samples exhibit an increase in the Seebeck coefficient with rise in temperature up to certain value of temperature. The value of this temperature is designated as Seebeck coefficient transition temperature (Ts). This clearly suggests that numerous n-type charge carriers are generated with rise in temperature. The decrease in Seebeck coefficient is observed on further increase in temperature and thereafter remains almost constant.

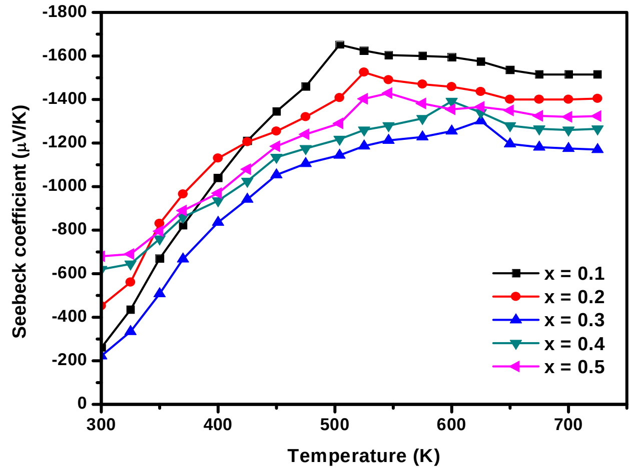
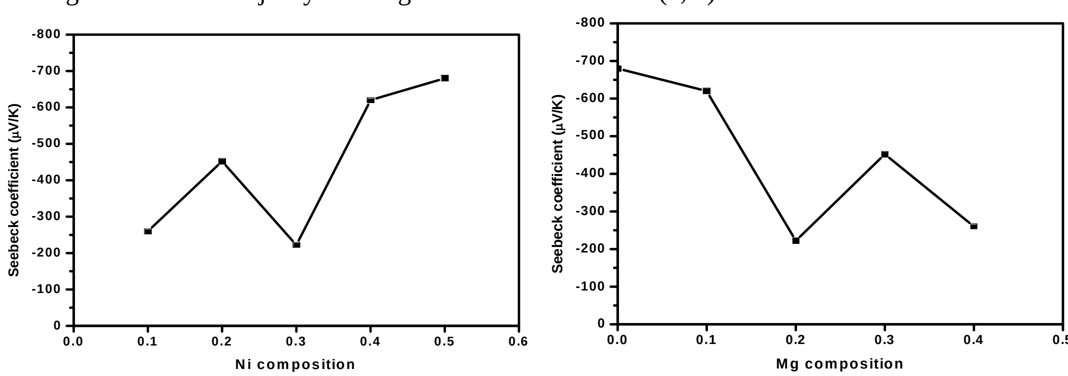


Fig.1 Plot of Seebeck coefficient (S) against temperature for Ni-Mg-Cu-Zn ferrites.

The variation of Seebeck coefficient with variation in Ni and Mg content is shown in Figure 2. It is observed that the Seebeck coefficient increases with Mg content and decreases with increase in Ni content at room temperature. For the sample x=0.3; the decrease in the Seebeck coefficient is observed, which is attributed to preparation conditions and microstructure. N. Varalaxmi et. al.(6) observed that in MgCuZn ferrites, the Seebeck coefficient is negative and increases with increase in Mg content at room temperature. Therefore, an increase in Seebeck coefficient on addition of Mg suggest that Mg2^{+} ions has effect of reducing the number of Fe2^{+} ions on the site. It is observed that thermoelectric power is found to be negative in the entire temperature range under study. This designates that the majority of charge carriers are electrons (2, 7).



(a) (b)

Fig. 2 Variation of Seebeck coefficient with variation in (a) Ni contnet and (b) Mg content.

The values of T_s for each composition are listed in table 1. The Curie temperature (T_c) values determined by other methods are also included in the table for comparison (8). The table clearly shows that the values of T_c and T_s are in good agreement, thereby indicating that change in the behaviour of the Seebeck coefficient with temperature may be due to magnetic transition where the materials becomes paramagnetic. It is clear in this case that ferrites are exhibiting a clear-cut transition at Curie temperature like magnetic properties such as permeability and susceptibility. The values of Seebeck coefficient show maximum values at T_c indicate that the magnetic ordering has a significant influence on thermoelectric property of these ferrite samples under investigation.

TABLE I

Composition (x)	Seebeck coefficient (S) [µV/K]	Seebeck coefficient transition temperature T_S (K)	Curie temperature (T_C) ^{0}C		
			By DC resistivity	By Permeability	By AC Susceptibility
0.1	-260	500	509	513	516
0.2	-452	525	525	530	526
0.3	-380	550	543	548	538
0.4	-620	600	598	587	606
0.5	-680	625	628	633	630

IV. CONCLUSIONS

Ni-Mg-Cu-Zn ferrites having general formula $Ni_xMg_{0.5-x}Cu_{0.1}Zn_{0.4}Fe_2O_4$ (where x = 0.1, 0.2, 0.3, 0.4 and 0.5) were prepared by a ceramic method. The seebeck coefficient varies with temperature and is found negative for all samples under investigation, indicating that the ferrites are n-type semiconductors. The composition of Ni and Mg affects the Seebeck coefficient.

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