Electronics Characterization of Al and Co doped Lithium Cermagnet

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ABSTRACT

A new compound of Lithium hexaferrites with general chemical formula \( \text{Li}_{0.5}\text{Fe}_{0.5+x}\text{Al}_{12-2x}\text{Co}_x\text{O}_{19} \) where \( x = 2, 3, 4, 5 \) and \( 6 \), were synthesized by standard ceramic technique using stoichiometric proportion. The lattice parameters of the multicrystalline materials have been determined and characterized by X-ray diffraction technique (XRD). From XRD data shows the formation of samples of a single phase hexagonal M-type ferrites with a space group \( P6_3/mmc \) (194). The electrical conduction was carried out over the temperature range from 27\(^\circ\)C - 800\(^\circ\)C. The electrical conduction in the ferrites was explained on the basis of Verwey models. A Seebeck study reveals that all samples are N-type semiconductors.

Keywords: Magnetoplumbite, Hexaferrites, electrical conductivity, Seebeck coefficient etc.

INTRODUCTION

Among the family of hexagonal ferrites, the Mangnetoplumbite hexaferrites (M-Type) created much attention due to wide range of application in industries and created potential to interest in technological and scientific research due to their application importance such as high density magnetic recording, microwave device materials, in computer system etc. The application need particularly magnetic and electrical specification with the view, many attempt have been improved the properties of hexagonal ferrites using different tract of additives. The Calcium hexaferrites [1-9] have magnetic properties comparable to BaM and SrM. In calcium ferrites many attempt has been made to replace \( \text{Fe}^{3+} \) ions with \( \text{Al}^{3+} \), \( \text{Cr}^{3+} \) and \( \text{Co}^{3+} \) etc. A compound with the combination of bivalent-tetravalent cation was also used to replace \( \text{Fe}^{3+} \) ion such as Cu-Ti, Co-Ti, Co-Sn, Zn-Sn etc [10-12] without any appreciable change in BaM structure. When \( \text{Fe}^{3+} \) ions are replace by non magnetic ions like Ti\(^{4+}\) and Sn\(^{4+}\) etc. In the same way Lithium ferrites substituted with Al and Co has been studied structurally, electrically and magnetically [13] In the present study a series of five sample with chemical formula \( \text{Li}_{0.5}\text{Fe}_{0.5+x}\text{Al}_{12-2x}\text{Co}_x\text{O}_{19} \) where \( x=2, 3, 4, 5 \) and \( 6 \) were prepared. Lithium ferrites have attracted considerable attention because of the squareness of hysteresis loop coupled with superior temperature performance the crystal structure of M-type like compound with a space group \( P6_3/mmc \) (194) can be described as superposition of two structure block namely R-block with composition \( \text{BaFe}_6\text{O}_{11} \) and S-block with composition \( \text{Fe}_6\text{O}_8 \) [14] in the stoichiometric ratio.

MATERIALS AND METHODS

All the multicrystalline powder sample were synthesized by high temperature solid state reaction using A.R grade oxides of stoichiometric ratio \( \text{Li}_2\text{O}, \text{Fe}_2\text{O}_3, \text{Al}_2\text{O}_3 \) and \( \text{Co}_2\text{O}_3 \) mixture. \( \text{Li}_2\text{O} \) oxide was carefully dehydrated before the mixing procedure. After grinding the mixture under acetone acid for six hours, the preparation of pellets of thoroughly grounded mixture in the proper molar ratio with 5% of PVA as a binder are prepared by applying 10 tone
pressure per square inch. These pallets slowly heated in the furnace at 600 °C for 5-6 hours to remove binder [15]. Then it was fired at 1200 °C for 120 hours continuously, after that the furnace were cooled at the rate of 20°C per hours up to 1000 °C and then 50°C per hours and then cooled in natural way the phase of final sample were verified by Philips X-ray diffractometry using N-filter copper radiation. The mean grain size of multicrystalline samples was in the range 150-200 Å. All the samples show single phase formation with a space group P63/mmc (194).

The d.c. electrical conductivity was measured by the methods using LCR meter. The end faces of pellets were coated with thin layer of conducting silver paste and measurement were made from room temperature to 800 K. Thermoelectric power measurement were carried out after sandwiching the thick pellet between two copper rod from room temperature to 550°C.

RESULT AND DISCUSSION

In the present work cobalt and aluminium substituted lithium hexaferrites were introduced with general formula Li_{0.5} Fe_{6.5-x} Al_{2x} Co_{x} O_{19} where x =2, 3, 4, 5 and 6. The ions in Ba-M compounds can be replaced partly by Co^{3+} or completely Li^{+} and combination of Fe^{3+} and Al^{3+} ions without changing the crystal lattice symmetry [16]. In all the specimens substituted ions would be chosen to keep electrical neutrality and to have similar ionic radii in these ferrites. The cobalt and aluminium play an important role in the property variation. The XRD technique is used to confirms the formation of hexagonal magnetoplumbite structure of compounds belonging to a space group P63/mmc (194). A X-ray diffraction pattern of the compound Li_{0.5} Fe_{6.5} Co_{6} O_{19} is shown in Fig.1.

Due to the resemblance of ionic radii of Fe^{3+} with Co^{3+} and Al^{3+} ions, the ferrites ions will replace by cobalt and aluminium. It is seen that former ions are very easily replaced at any substituted variation in all specimens. The hexagonal lattice parameters ‘a’ and ‘c’ decreases linearly with the substitution variation Co^{3+} and Fe^{3+} concentration in all specimens. The decreases in lattice parameters due to close packing of lattices in the materials [17]. The decrease in lattice parameter and cell volume agree with result for Ba and Sr ferrite [18]. The numerical values of compositional data such as lattice constant, cell volume and X-ray density are tabulated in table -1. The observed value of electrical conductivity, and activation energy for specimens are also tabulated in table -2.
In the present work of lithium ferrites, is to check the formation of ferrite containing Al. Darokar S.S, Rewatkar K.G, Chowkase M.S and Kulkarni D K, work in laboratory. charge distribution but the site distribution is change due to strichiometric changes. Author is thankful to UGC New Delhi for providing financial assistance to carry out the work under minor research project scheme. Author is also thankful to D.K Kulkarni and J.M.Khobragade to guide and given a facility to do the work in laboratory.

### Conclusions

The plot of ln Ω vs (1/ T) x 10⁻³ Ω for the entire sample was almost linear. The electrical conductivity of these ferrites increases with increasing ferrite ion concentration. The electrical conductivity of sintered specimens varies from 2.193 x 10⁻¹² (Ω cm)⁻¹ to 5.78 x 10⁻⁶ (Ω cm)⁻¹ of these ferrites [20], the electrical conductivity values obtained by Reddy et al 1981 is 2.3 x 10⁻⁵ (Ωcm)⁻¹ cm and 2x10⁻¹(Ωcm)⁻¹ Rezlesen et al 1974 for lithium ferrite.

In the present work the electrical conductivity value obtained for the compounds are 2.193 x 10⁻¹² (Ωcm)⁻¹ to 5.78 x 10⁻⁶ (Ωcm)⁻¹. The value of the conductivity may be partly attributed to the low evaporation of lithium from the sample prepared different from these of Rozlescu et al 1974 and Venugopal Reddy 1981. The variation of activation energy with the substitutional variable parameters x -may be explain on the basis of Verway model [21] a small.

### Acknowledgement

Author is thankful to UGC New Delhi for providing financial assistance to carry out the work under minor research project scheme. Author is also thankful to D.K Kulkarni and J.M.Khobragade to guide and given a facility to do the work in laboratory.

### References


**Table – 1 Consolidated structural data of lithium ferrites**

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Lattice parameters (Å)</th>
<th>CellVolume (Å³)</th>
<th>Mol.Wt (gm)</th>
<th>X-Ray Density (gm/cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Li_2Fe_2AlCoO_8$</td>
<td>5.859 22.323</td>
<td>663.81</td>
<td>780.89</td>
<td>3.9065</td>
</tr>
<tr>
<td>$Li_2Fe_2AlCoO_8$</td>
<td>5.818 21.879</td>
<td>641.48</td>
<td>841.79</td>
<td>4.3578</td>
</tr>
<tr>
<td>$Li_2Fe_2AlCoO_8$</td>
<td>5.807 21.841</td>
<td>637.90</td>
<td>902.66</td>
<td>4.6932</td>
</tr>
<tr>
<td>$Li_2Fe_2AlCoO_8$</td>
<td>5.794 21.807</td>
<td>633.96</td>
<td>93.54</td>
<td>5.0473</td>
</tr>
<tr>
<td>$Li_2Fe_2AlCoO_8$</td>
<td>5.695 21.262</td>
<td>597.22</td>
<td>1024.42</td>
<td>5.6963</td>
</tr>
</tbody>
</table>

**Table – 2 Electrical conductivity of lithium ferrites**

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Electrical Resistivity at room temperature (Ω cm)</th>
<th>Activation energy E in (ev)</th>
<th>Electrical Conductivity at room temperature (Ω cm)⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Li_2Fe_2AlCoO_8$</td>
<td>4.599 x 10⁻⁶</td>
<td>0.77</td>
<td>2.193 x 10⁻¹²</td>
</tr>
<tr>
<td>$Li_2Fe_2AlCoO_8$</td>
<td>3.21 x 10⁻⁷</td>
<td>0.63</td>
<td>3.11 x 10⁻¹⁰</td>
</tr>
<tr>
<td>$Li_2Fe_2AlCoO_8$</td>
<td>4.65 x 10⁻⁷</td>
<td>0.52</td>
<td>2.148 x 10⁻⁸</td>
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<tr>
<td>$Li_2Fe_2AlCoO_8$</td>
<td>6.84 x 10⁻⁷</td>
<td>0.48</td>
<td>1.46 x 10⁻⁸</td>
</tr>
<tr>
<td>$Li_2Fe_2CoO_8$</td>
<td>1.72 x 10⁻⁷</td>
<td>0.39</td>
<td>5.78 x 10⁻⁷</td>
</tr>
</tbody>
</table>