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Effect of Pb^{2+} Doped in Co Nanoferrite on Magnetic Properties Synthesized by Sol-gel Technique

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ABSTRACT

Lead doped (Pb^{2+}) – cobalt (Co) nanoferrite as Co1-xPbxFe2O4 (were x = 0.1, 0.2, 0.3, 0.4, 0.5) were synthesized by a simple cost effective method involving sol-gel auto combustion method. Synthesized samples were sintered at 600 ^{0}C temperature. The Magnetic properties are studied using hysteresis loop terser field of 10 kOe. The magnetization of the prepared nanoparticles was investigated, and the saturation magnetization (M_s), remanence (M_r), and coercivity (H_c) were derived from the hysteresis loops. The results revealed that as the (Pb^{2+}) Lead substitution in (Co) cobalt nano ferrite increases the magnetic properties remanence (M_r), and coercivity (H_c) goes on decreasing, the saturation magnetization (M_s), first it is increases upto x = 0.3 and then decreases for higher Pb^{2+} substitution such changes in magnetic properties may be due to the exchange interaction between the tetrahedral and the octahedral sites. From the magnetic properties it is clear that the synthesized materials shifted from hard to soft ferrit.

Key words: sol-gel, Cobalt nanoferrite, magnetization (M_s), remanence (M_r), and coercivity (H_c)

INTRODUCTION

Nanocrystalline ferrites are currently the subject of interest because of its wide application in industrial as well as research areas. They are attractive because of their importance in ferrofluids , magnetic drug delivery, hyperthermia for cancer treatment, etc. [1].An interesting ex-ample is that of CoFe2O4 which is a familiar hard magnetic material with high saturation magnetization (Ms), high coercivity (Hc) among all the ferrite family[2].These properties along with its great physical and chemical stabilities make Co-ferrite nano-particles be suitable for many technical applications[3]. Their applications include high frequency devices, memory cores, high density information storage and also in biomedical field [4]. It is well known that several chemical techniques, such as hydrothermal, co-precipitation and sol-gel synthesis have been used to prepare ultrafine ferrite powders. Among these techniques, sol-gel method offers high degree of compositional homogeneity content in a relatively short processing time at a very low temperature. An understanding of the magnetic properties is essential in order to design new magnetic materials .The present work deals with the synthesis of nano particles of lead substituted cobalt ferrite (Co1-xPbxFe2O4 where x = 0.1, 0.2, 0.3, 0.4, and 0.5) via sol-gel method. Magnetic measurements are done with the help of VSM. This work is an attempt to investigate the magnetic properties of lead substituted cobalt ferrites.

METHODOLOGY

Pb substituted in Co-ferrite powders were synthesized by sol-gel auto combustion method at low temperature for different compositions Co1-xPbxFe2O4 (where x = 0.1, 0.2, 0.3, 0.4, and 0.5) raw material are used in experiments are AR grade nitrate (Co(No3)2.6H2o, Pb(No3)2, Fe2(No3)2 and C6H8O7) is used as fuel in the ratio 1:3, all from Merck co. using stoichiometric ratio and dissolved in distilled water. the mixture of the raw material was stirred at low temperature on hot plate magneto –stirrer .after maintaining the PH at 7 solution temperature raise up to 800^{0}C, it was continuously stirred to obtain uniform gel. After 3-4 hours it converts from gel to ash form,

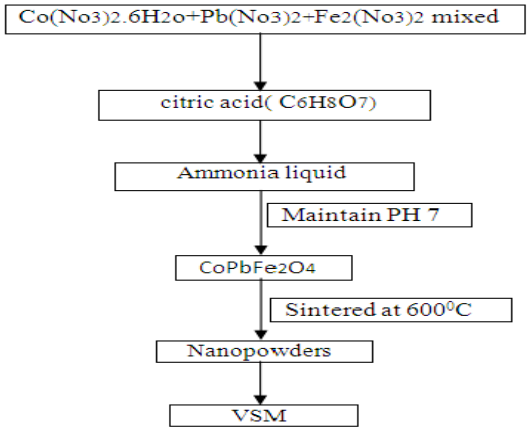

Figure 1. Sol-gel method for the preparation of ferrites

which was sintered at 600^{0}C.from VSM the magnetic properties of the samples show remarkable changes with change of Pb percentage.

RESULTS AND DISCUSSION

Typical hysteresis loops of CoPbFe2O4 as obtained and after sintering of sample at 600^{0}c.Typical hysteresis loops for the samples Co0.9Pb0.1 Fe2O4, Co0.8Pb0.2Fe2O4, Co0.7Pb0.3Fe2O4, Co0.6Pb0 .4Fe2O4, Co0.5Pb0.5Fe2O4 are shown in **Figure 2**

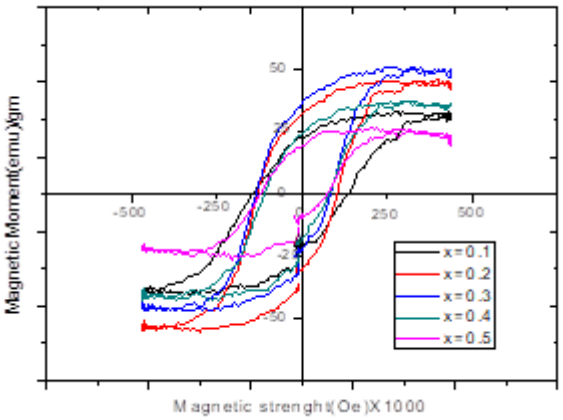

Figure 2. Hysterisis loop of Co1-xPbxFe2O4 where x = 0.1, 0.2, 0.3, 0.4, and 0.5after sintering at 600°C

In a cubic system of ferromagnetic spinels, the magnetic order is mainly due to a super exchange interaction mechanism occurring between the metal ion in the A and B sub lattices. The substitution of

nonmagnetic ion such as lead, which has a preferentially A site occupancy results in the reduction of the exchange interaction between A and B sites. Hence, by varying the amount of lead substitution, it should possible to vary magnetic properties of the samples.

The saturation magnetization for all the ferrites after sintering is listed in **Table 1** it is clear that for the samples Co0.9Pb0.1 Fe2O4, Co0.8Pb0.2Fe2O4, Co0.7 Pb0.3Fe2O4 the saturation magnetization increases from 33.15-50.96 emu/gm. This could be due to Pb^{2+} (with zero magnetic moment) replace ion on the tetrahedral A–sites, causing the decrease of magnetic moment in the sub lattice M_A, resulting in the increase magnetic moment which increases saturation magnetization. On further increase of lead substitution in Co0.6Pb0.4Fe2O4 and Co0.5Pb0. 5Fe2O4 the saturation magnetization decreases from 37.48-22.41 emu/gm. This could be due to further increase in the concentration of Pb2+ (more than 0.4), the exchange interaction between A and B sites gets lowered resulting in strengthening of B-B interaction and weakening of A-B interaction, which leads to decrease of saturation magnetization.

Table 1:

Sr No.	composition	Hc (Oe)	Mr (emu/gm)	Ms (emu/gm)
1	Co0.9Pb0.1 Fe2O4	134.610	22.67	33.15
2	Co0.8Pb0.2Fe2O4	110.801	30.09	46.09
3	Co0.7Pb0.3Fe2O4	106.249	32.4	50.96
4	Co0.6Pb0.4Fe2O4	91.15	22.2	37.48
5	Co0.5Pb0.5Fe2O4	90.53	15.53	22.41

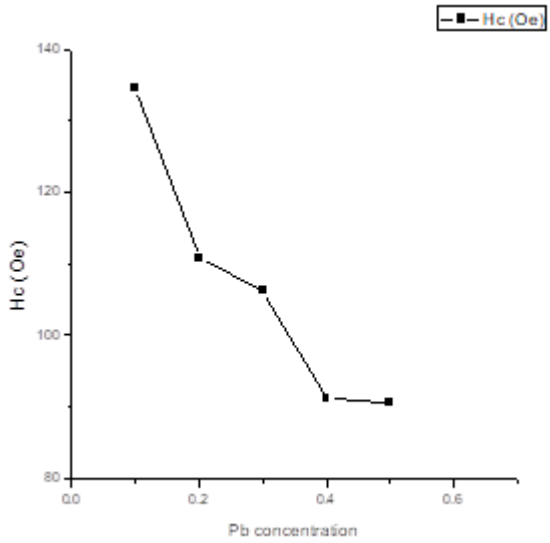

Fig. 3(a) Variation of coercivity (*Hc*) with Pb concentration (*x*).

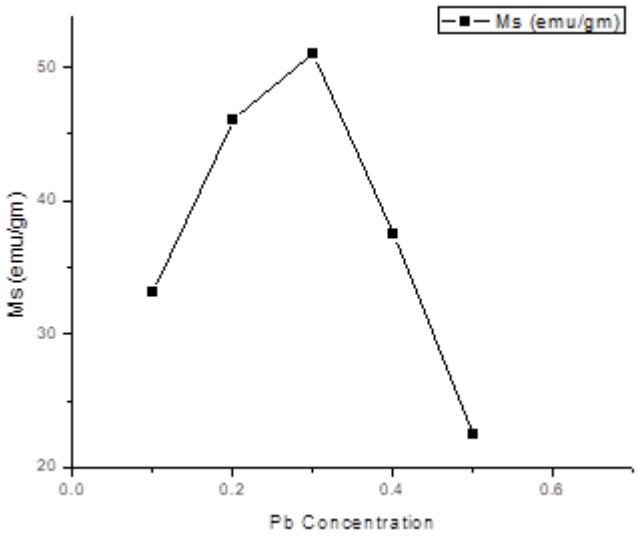

Fig. 3(b) Variation of saturation magnetization (*Ms*) with Pb concentration (*x*);

From the hysteresis loop taken of different sample of CoPbFe2O4 it is found that with increasing concentration of $Pb^{2+,}$ coercivity (H_c) goes on decreasing these can be utilized to change magnetic properties of cobalt ferrite and hard magnetic material can be converted to soft magnetic material.

CONCLUSION

Lead substituted cobalt ferrite nanoparticles ($Co_{1-x}Pb_xFe_2O_4$ with x = 0.1, 0.2, 0.3, 0.4, and 0.5) were prepared via sol-gel auto combustion route. From VSM it is clear that for the samples $Co_{0.9}Pb_{0.1}$ Fe_2O_4, $Co_{0.8}Pb_{0.2}Fe_2O_4$, $Co_{0.7}Pb_{0.3}Fe_2O_4$ the saturation magne-

tization increases from 33.15-50.96 emu/gm. On further increase of lead substitution in $Co_{0.6}Pb_{0.4}Fe_2O_4$ and $Co_{0.5}Pb_{0.5}Fe_2O_4$ the saturation magnetization decreases from 37.48-22.41 emu/gm. It was found that with increasing concentration of Pb^{2+}, coercivity (H_c) goes on decreasing these can be utilized hard magnetic cobalt ferrite can be converted to soft magnetic material. DC electrical resistivity study of the samples was found to be increases with increasing $Pb^{2+}$from $x = 0.1$ to $x = 0.5$. That means the conductivity decreases with increasing concentration of lead but it increases with increasing voltage.

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