# ABSTRACT

In recent years, low or non rare earth permanent magnets are under investigation for rotating machine applications. In the permanent magnets, the strontium hexaferrite can find its place owing to its low price and moderate electro-magnetic properties. Wide range of strontium hexaferrites, have been developed, which are promising materials in this area. However, only a limited variety of strontium hexaferrites are commercially available for the development of permanent magnets. High energy product ($(BH)_{max}$) with high curie temperature are the major requirements for rotating machine applications. In the present work, effort has been made to improve the electro-magnetic properties of $SrAl_4Fe_8O_{19}$ hexaferrite, which can be utilized for rotating machine applications.

Initially, optimization of the synthesis process of $SrAl_4Fe_8O_{19}$ hexaferrite has been studied. Then the influence of different cationic (both non-rare earth and rare earth) substitutions in $SrAl_4Fe_8O_{19}$ hexaferrite on the physical and electro-magnetic properties are investigated thoroughly. The aim of this work is to contribute to the understanding of the correlation between the structure and electro-magnetic properties of nanostructured $SrAl_4Fe_8O_{19}$ hexaferrite.

$SrAl_4Fe_8O_{19}$ hexaferrite has been synthesized by three different synthesis method ,i.e., sol-gel auto combustion, co-precipitation and solid state method. The detail analysis of phase, microstructure, density, magnetic and dielectric measurements for this composition are done. The results show that by the sol-gel auto combustion method, $SrAl_4Fe_8O_{19}$ hexaferrite can be synthesized at lower temperature than any other methods. By this method maximum coercivity and $(BH)_{max}$, i.e., 18.15 kOe and 6.03 MGOe, respectively, have been achieved. Further, investigations are extended to prepare cation substitution at Fe site in $SrAl_4Fe_8O_{19}$ hexaferrite. Cations, i.e., Co, Cr–Sn, La–Sm and Y substitution have been prepared by the following sol-gel auto combustion method.

The cobalt substitution in $SrAl_4Fe_{8-x}Co_xO_{19}$ (where, x=0, 0.2, 0.4, 0.6, 0.8, and 1) hexaferrite is increased the densification of the synthesized sample. Rietveld refinement on X-ray diffraction patterns are performed to reveal the phase purity, crystal structure and unit cell parameters. Types of bonds are also verified using Fourier Transform Infrared Spectroscopy. Maximum electromagnetic properties have been observed for $SrAl_4Co_{0.8}Fe_{7.2}O_{19}$ composition. Dielectric constant at 1 MHz frequency is 33.76 along with remanence magnetization (*Br*) (~5.01 kG), coercivity (~0.86 kOe), and $(BH)_{max}$ (~3.68 MGOe) have been observed.

Cr–Sn substitution in $SrAl_4(Cr_{0.5}Sn_{0.5})_xFe_{8-x}O_{19}$ (where, x = 0.0, 0.2, 0.4, 0.6, and 0.8) hexaferrite shows that grains are in well-defined hexagonal platelet shape with clear boundaries. Bulk density and grain size of the ferrites are increased with increasing in Cr–Sn substitution. The relationship among the allocation of cations over the 5 sub-lattices of $Fe^{+3}$ with substitutions is also analyzed. Electro-magnetic properties are maximized in $SrAl_4(Cr_{0.5}Sn_{0.5})_{0.6}Fe_{7.4}O_{19}$ composition. Dielectric constant at 1 MHz frequency is 32.42 along with $(BH)_{max}$ (~7.26 MGOe), remanence magnetization (~6.22 kG) has been found for this composition. The present composition shows significant similar properties with the conventionally produced injection-molded NdFeB bonded magnets, enables effective application towards the rare earth problems.

The yttrium substitution in $SrAl_4Y_xFe_{8-x}O_{19}$ (where, x = 0.0, 0.05, 0.10, 0.20, and 0.30) hexaferrite shows that grain size is decreased with $Y^{+3}$ substitution. The value of dielectric constant is decreased with $Y^{+3}$ content. The Curie temperature & anisotropy field increases with $Y^{+3}$ substitution. Resultant coercivity has remarkably increased up to 36 kOe and curie temperature about to 614 °C for $SrAl_4Y_{0.2}Fe_{7.8}O_{19}$ composition. Resistivity is increased up to $1.16 \times 10^5$ Ω-cm with $Y^{+3}$ substitution.

La–Sm substitution in $SrAl_4(La_{0.5}Sm_{0.5})_xFe_{8-x}O_{19}$ (where, $x$ = 0.0, 0.5, 1.0, and 1.5) hexaferrite forms secondary phase of $SmFeO_3$ at higher concentration. Williamson–Hall plot shows a linear fit, and positive slope for x = 0.0 composition, and negative slope for x = 1.5 specimen. However, bulk density and grain size of the ferrite is increased up to $SrAl_4(La_{0.5}Sm_{0.5})_{1.0}Fe_7O_{19}$ composition. A significant increase in remanence magnetization (~5.18 kG), $(BH)_{max}$ (~6.69 MGOe) and resistivity (~$2.11 \times 10^4$ Ω-cm at 1MHz) are found in $SrAl_4(La_{0.5}Sm_{0.5})_{1.0}Fe_7O_{19}$ composition. The increase in electro-magnetic properties with substitution may be due to the combined effect of increased grain size, increase in densification, decreased anisotropy and increasing in the tensile macro-strain, etc.

The outcome of the results may find a new material with high energy product lying in the gap between Sr ferrite and rare-earth magnets. The possible technology may expect to be the commercially viable for industrial production of ceramic magnet in our country.

***Keywords:***

*Strontium hexaferrite, Sol-gel auto combustion, Substitution, Microstructure, Magnetic properties, $(BH)_{max}$, Electrical properties.*