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them employable in the present knowledge based world. Such skilled population will in turn contribute to the human capital of the economy. The Government has to put massive effort to form better educational structure especially for skill development sector comprising of industry-oriented training. Skills and knowledge are the driving force of economic growth and social development of any country.

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History, Development and Applications of Ferrites

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Abstract:

Ferrites are ferrimagnetic in structure in which magnetic moments of the atoms on different sub lattices are opposite to each other. The opposing moments are unequal and spontaneous magnetization remains. The simplest ferromagnetic material is spinel ferrite. The first natural magnetic material known was ferrous ferrite (Fe_3O_4) known as magnetite. The extensive studies on development of new ferrites and their applications have been made by number of workers. Applying the molecular field theory, Neel was the first to give basic theory of ferrimagnetism and concept of magnetic sublattices. Yafet and Kittel extended Neel's theory by postulating triangular spins. There are many applications of ferrites in different branches of science and technology due to their high resistivity in comparison with other magnetic materials.

Keywords: Ferrite, magnetic moment, sublattice, resistivity.

Introduction:

The magnetic properties of solids are of interest and concern to a wide range of scientists and technologists. Depending upon to the response to the applied magnetic field and net resultant magnetization, which is usually expressed in terms of magnetization per unit magnetic field i.e. susceptibility, the magnetic materials are distinguished as diamagnetic (MgO), paramagnetic (Gd_2O_3),



ferromagnetic (EuO), ferromagnetic (Fe₃O₄), and antiferromagnetic (Cr₂O₃). Among these groups, ferro and ferromagnetic materials find extensive technological applications. The magnetic oxides, which are commonly known as ferrites are ferromagnetic in structure as originally proposed by Neel [1]. The first magnetic material known to man is magnetite (Fe₃O₄), the ferrous ferrite.

A ferromagnetic material is one in which the magnetic moments of the atoms on different sublattices oppose as in antiferromagnets, but the opposing moments are unequal and spontaneous magnetization remains. This behavior was first recognized in the technological group of material called ferrites. Iron oxide and metal oxides are the main constituents of the ferrites. The simplest ferromagnetic material is spinel ferrite. Other materials in the same class are the hexagonal such as barium ferrite BaFe₁₂O₁₉ and ferromagnetic garnets such as Yttrium iron garnet YIG.

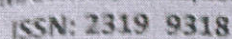
Ferrite has been recognized as one of the most important electroceramic in modern industry. Its processing and application technologies have been improved incessantly in the last thirty years. There are several types of ferrite materials being used in microwave components for obtaining non reciprocal device action like isolation and phase shifting. The properties of the ferrites for use in devices at different frequency ranges are mostly designed by substituting diamagnetic metal ions for Fe³⁺ ion in the chemical formula unit of the ferrite.

History and Development of Ferrites:

The first natural magnetic material known from prehistoric times was magnetite (Fe₃O₄), the ferrous ferrite. In twelfth century, Chinese used lodestone (Fe₃O₄) in compasses for navigation. Ferrite were first developed by Snoke [2] and his associates. The extensive studies on development of new ferrites and their applications have been made by number of workers [3-5]. Saturation magnetization of

magnetite was first measured by De.Bois [6]. The studies on structural properties of spinel crystals were carried out by Barth et.al. [7] with the help of X-rays. They found that in case of spinel ferrites, it is necessary to assume that the divalent metal ions and trivalent iron ions interchange their positions in the crystal. The credit of chemical synthesis of magnetic materials goes to Hilpert [8], who in Bell laboratories prepared magnetite with the view point of reducing eddy current losses. The spinel ferrites have been classified into three categories depending upon distribution of cations on tetrahedral and octahedral sites: 1) Normal spinel ferrite 2) Inverse spinel ferrite and 3) Intermediate spinel ferrite. Verwey et.al. [9] reported that the electrical conductivity of ferrites is mainly due to hopping of electrons (the exchange of electrons between Fe²⁺ and Fe³⁺ ions) through the crystal lattice. His studies on crystal structure of various ferrites showed that the ferrites with inverted spinel structure in magnetic. Whereas ferrites with normal spinel structure is non-magnetic. Verwey, de-Boer and van Santen [10] conducted their X-ray study on a number of oxides having spinel structure and concluded that Mn, Fe, Co, Cu and Ni ferrites, which are magnetic have inverted spinel structure whereas Zn and Cd ferrites which are non-magnetic, have a normal spinel structure.

Neel [1] was the first to give basic theory of ferrimagnetism. Applying the molecular field theory to ferrites, he gave the concept of magnetic sub lattices. Neel's direct mechanism of interaction was found to be inadequate. So a more detailed examination was made by Anderson [11] and Van-Vleck [12] and introduced to two sub-lattices which improved the model. Yafet and Kittel [13] extended Neel's theory by postulating a triangular or canted arrangement of spin, when antiferromagnetic exchange interaction between sub-lattices is comparable to that among the spin moments within the



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applications are substituted Yttrium iron garnets such as YAlG, YGdIG, YAlGdIG and spinel ferrites such as Ni-Zn, Mg-Zn, Mg-Mn, Cu-Zn, Cu-Al, Co-Al and Co-Cr ferrites.

By virtue of its low cost and being suitable (BH)_{max} for isotropic and anisotropic hexaferrites, it finds wide applications in motors, generators, loudspeakers, telephones, meter switches, magnetic separators, toys, flexible and magnets, magnetic latch and magnetic levitation. Among the recording materials, the most commercial materials are the discrete particles of magnetic oxides such as γ -Fe₂O₃ or Co-doped γ -Fe₂O₃ and CrO₂ [19]. In digital computers the ferrite cores are used as the switching and memory elements for transmitting, storing and recording the signal pulse in few microseconds [20].

The multilayer soft ferrite chip inductors are used in cordless telephones, video equipments, headphone stereos, T.V. hard disk and personal computers [21]. Mg-based ferrites are used as humidity sensors, carrier for intensifying X-rays in the human system and spinel ferrites are used as rechargeable Lithium batteries. The ferrites are also used in microwave communications e.g. Mg-Mn, Ni-Zn and Lithium ferrites etc. Thin films of defect spinel ferrite are used as write-once read-many media working with blue wavelength. There are several Japanese installations which use precipitation of ferrite precursors to scavenge pollutant materials such as mercury from waste stream. The ferrites produced can be removed magnetically along with the pollutant.

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