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Review on Ferrites and its Application for Environmental Remediation

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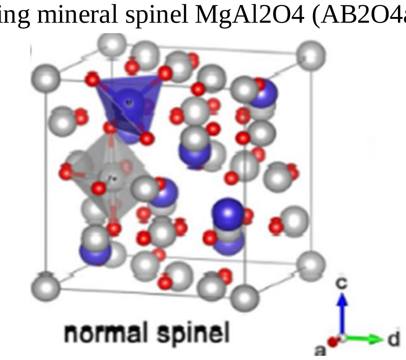
Abstract: During the recent couple of years, there has been an increased level of interest in ferrites. The attractive electrical, optical and different properties of ferrites made them center of attraction because of their utilization in different day to day applications, for example, energy devices like supercapacitors and batteries, water treatment, sun based energy gadgets and attractive liquids. This is the review paper about the ferrites, their current status and development of ferrite technology which is used in various day to day applications.

I. INTRODUCTION

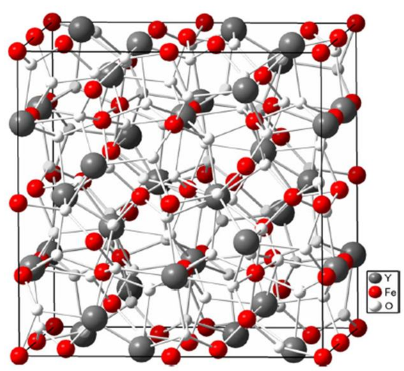
From the cosmos to the computer, from roller-coaster to refrigerators, magnets exert their invisible yet intelligible influence. They surround us and empower us as a crucial driving force in our lives. We rely upon magnets. They are everywhere playing key role in every kind of technology from microwave ovens to computers, to our cell phones, throughout our house, car and office where dozens and dozens of magnets are doing their work. We use magnets without thinking in our day to day life for example in credit cards which have magnetic strip. Ceramic material oxides with ferromagnetic ordering having main constituent iron (Fe) is called a **ferrite**. Ferrites are characterized based on magnetic properties and crystal structure.

Depending upon their crystal structure:

1) *Spinels* - general chemical formula MFe2O4, M refers to a divalent metal cation, and crystallize in a crystallographic structure isomorphic to that of the naturally occurring mineral spinel MgAl2O4 (AB2O4as general composition).



2) *Garnets* - general chemical formula M3Fe5O12, M is a rare-earth cation, crystallize in the structure of the X3Y2(SiO4)3 silicate mineral garnet, where divalent (Ca2+, Mg2+, Fe2+) and trivalent (Al3+, Fe3+, Cr3+) cations occupy X and Y sites respectively, while the (SiO4)4− units provide a tetrahedral framework.



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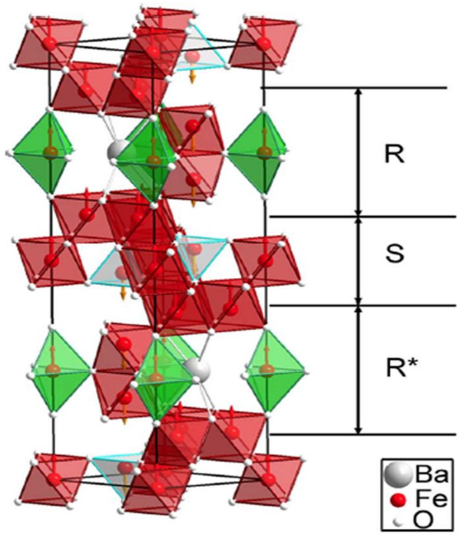
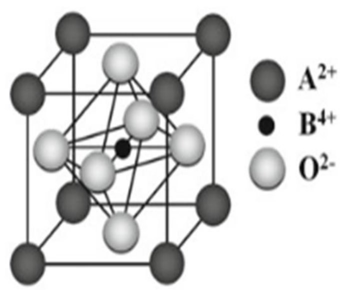
3) *Hexagonal ferrites* - general chemical formula $MFe_{12}O_{19}$, M can be any divalent cation with high ionic radii. Conventionally s-block ions are taken because they have high ionic radii for example Ba^{+2}, Mg^{+2}, Ca^{+2}.



4) *Orthoferrites* – genera formula is $MFeO_3$, M is a large trivalent ion for example rare earth ion or Y, has an orthorhombic unit cell.



Depending upon the magnetic properties, they can be classified as:
• Soft ferrites.
• Hard ferrites.

Soft ferrite	Hard ferrite
High saturation magnetization (1-2T)	High saturation magnetization (0.3-6T)
Low coercivity	High coercivity
High permeability	Not important, but low
Low anisotropy	High anisotropy
Low magnetostriction	Not important
High Curie temperature	High Curie temperature
Low losses	High-energy product
High electrical resistivity	Not important

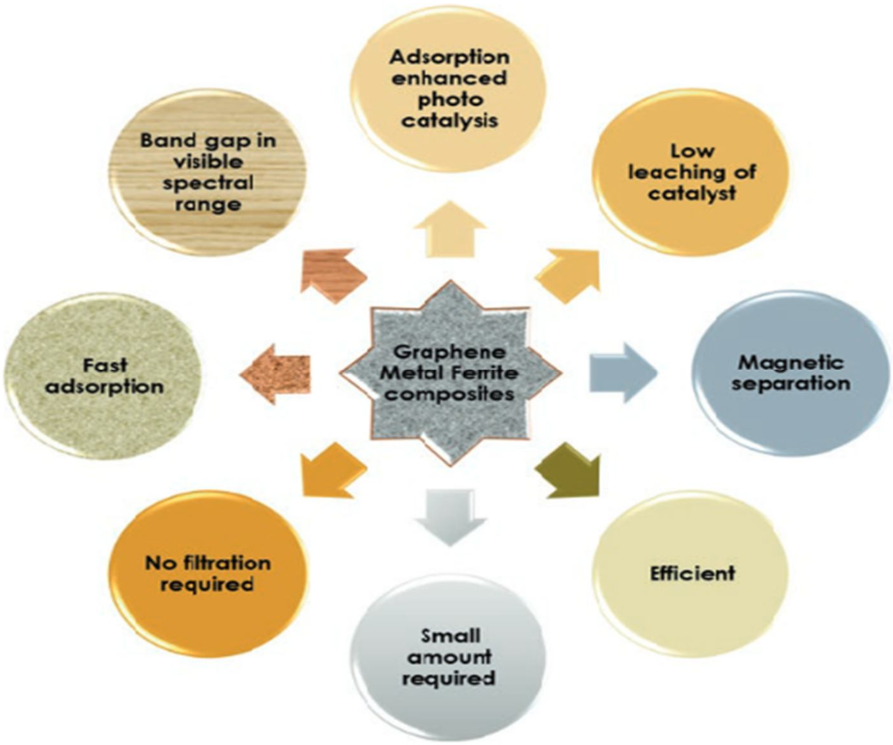
Ever since the discovery of the ferrites there has been a growth in the attractiveness of the ferrites and it is still growing exponentially. Commercially as well as technologically these have become very important materials and thus account for the bulk of the total magnetic materials manufactured globally and these have large number of uses and applications. Ferrite is a likely contender for different applications one of them being as adsorbent in rechargeable batteries, photocatalysis, sensors etc. It is also helpful for the waste-water treatment due to its adsorptive nature.

II. APPLICATION OF FERRITES

A. Metal Ferrite Used For Waste Water Treatment

The latest development in ferrites is the ferrite nanoparticles which has unique physicochemical properties as compared to the bulk material and hence is highly investigated adsorbent material. It is due to the quantum size of the ferrite nanoparticles which makes it different from that of the bulk materials. Adsorption depends on the particle size. Small sized materials having large number of atoms on the particle surface have high adsorption property. Also due to the short interparticle diffusion distance, rapid kinetics, high specific surface area and large number of reactive sites makes ferrite nanoparticles highly adsorptive.

The industrial waste materials like heavy metals (Hg, As, Cu, Cd, Se, Pb etc) present in the water are very harmful for human beings, aquatic life as well as for agricultural sector. Thus large efforts are made for their removal from water. For this purpose nowadays metal ferrites and their grapheme based nanocomposites are used.since grapheme has many marvelous properties and has the ability and affinity to capture particular pollutants.



Fe_3O_4.rGO ferrite was synthesized by Candra and coworker which helped in the removal of As(III) and As(V) (Chandra et al. 2010). Co(II) and Cd(II) ions were removed with the help of grapheme ferrite nanosheets as shown by Wang and coworkers(Zhao et al. 2011). Ferrite grapheme oxide nanosheets fused with magnetic cyclodextrin (MCGN) was synthesized and used by Fan and coworkers for the removal of Cr(IV) ions (Fan et al.2012 a,b).

Graphene ferrite based composites can also be used for the removal of synthetic dyes from the water which are discharged by industries in the water and possess a serious threat to the aquatic and human environment. These have high adsorption capacity because of π-π bond and strong electrostatic interactions between negatively charged GFC (graphene ferrite composites) and positively charged cationic dyes. GFO's are very helpful in the separation of dyes from the mixture with no leaching of catalyst and can be used multiple times with same frequency approximately.

B. Ferrites for Supercapacitors

Today the world is shifting towards renewable energy sources like batteries and supercapacitors which provide us energy by storing the energy in comparison to the fuels which provide us energy by combustion and are thus in the state of being scarce. Electrochemical supercapacitors are being widely used in hybrid electric vehicles, digital cameras, industrial equipments and other storage devices, portable electronic devices such as mobile phones, notebooks, laptops etc because of their outstanding properties like high power density, longer life cycle and stability. Due to these properties, they are nowadays preferred over batteries. Figure below shows power and energy densities of different energy storage devices.

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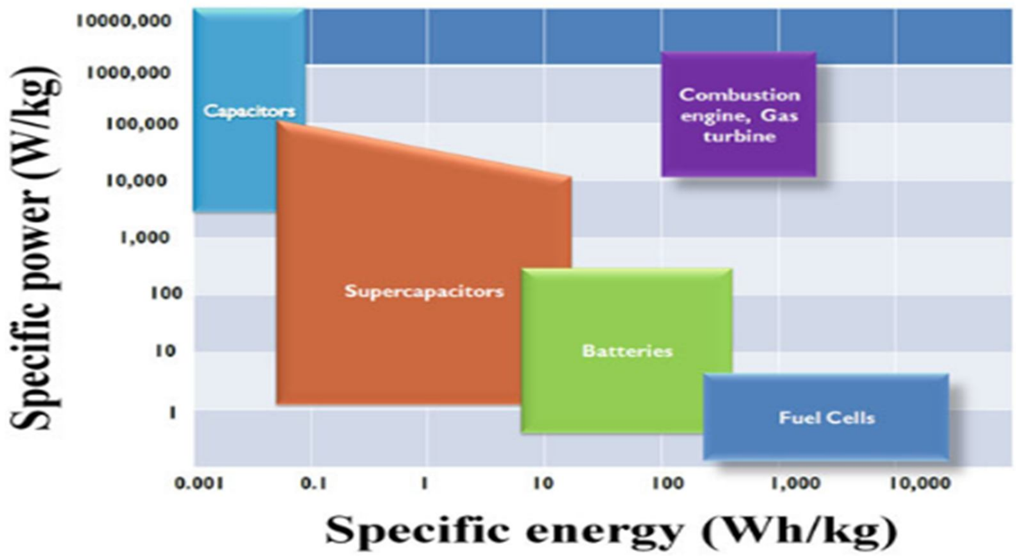


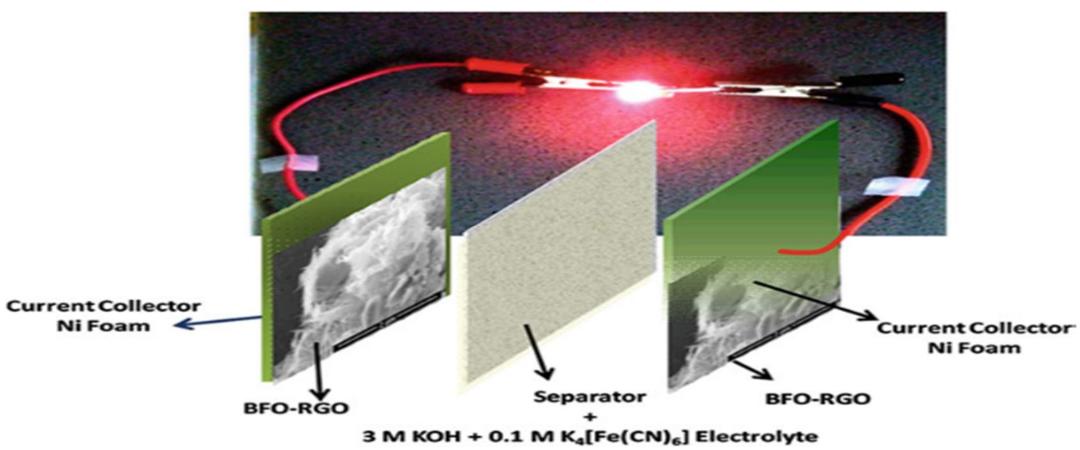
For the fabrication of energy storage device, working electrode with high surface area and conductivity is essential. Ferrite is a good conductor for the electrode material which is suitable for energy storage application. Recent studies have shown that Bismuth ferrites, Spinel ferrites and Nickel ferrites are mostly preferred contenders for supercapacitor electrodes because of them being naturally abundant, cost effective and having eco-friendly nature.

BFO shows excellent electrochemical properties which gives it an upper hand for renewable energy sources. Bismuth Ferrite Oxides (BFO) belongs to multiferroic class i.e having ferroelasticity, ferromagnetism and ferroelectricity all together. It exhibits exotic properties at the nanoscale.

BFO($BiFeO_3$) graphene nanocomposite synthesized using sol-gel method is an efficient electrode for supercapacitor application. With expanding annealing temperature, the contact angle decreases due to relatively hydrophilic surface formation of BFO electrode material. Hydrophilic surface of the ferrite electrode facilitates several redox reactions for better electrochemical performance.

The study of BFO nanocomposite (symmetric two electrode system) was done by Nath Gosh and in his study he showed the excellent cyclic stability of BFO nanocomposite with high energy density of 950 WKg^{-1}. His study showed that these are the excellent electrode material for supercapacitor application.

Real time application of BFO as supercapacitor device done by Nath Gosh is shown below:



Two symmetric cells are connected in series which were charged from 9 volt battery for 10 minutes. After 10 minutes when cell was charged a red LED (Light emitting diode) glowed successfully for 6 minutes.

There is a large scope of development in the Bismuth ferrite based supercapacitors especially in modern time the hybrid supercapacitors have gained large importance in the hybrid energy vehicles.

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