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Synthetic View of Zinc and Cadmium Ferrite Nanoparticles

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ABSTRACT

Magnetic metal nanoparticles have been an attractive material for chemists and physicists alike. Metal nanoparticles like nickel have innumerable applications in the form of magnetostrictive transducers, as filler material in making nanocomposites, and also as catalysts for chemical reactions. The synthesis of nickel nanoparticles is often tricky and details are not available in the literature. Moreover, highly reactive nature of the nanoparticles is a cause of worry since they oxidize to form their corresponding oxides and are rendered useless as far as applications are concerned.

1. Introduction

The story of magnetism can be traced to the discovery of loadstone around 2000 years ago and since then magnetism and magnetic materials have been playing a lead role in making life more humane. Considering the proliferation of new gadgets and devices based on magnetic materials sooner or later the magnetic industry will outgrow the semiconductor industry.

The advent of nanoscience and nanotechnology as a major discipline has provided further impetus to the already burgeoning research activities in the area of magnetic materials. This has given birth to a new area of nanomagnetic materials. With the advances made in nanomagnetic materials, the size of the hard disk has been shrunk, the density of the hard disk has been tripled in accordance with the Moore's predictions, the retrieval rate from a hard disk has been increased several times and a new concept based on magnetic spintronics called MRAM has already become a reality.

2. Objectives

Thus the objectives of the present work can be summarized and are listed as follows.

1. Preparation and characterization of zinc and cadmium ferrite nanoparticles
2. Evaluation ofstructural, morphological and magnetic properties on size reduction by high energy ball-milling .
3. Synthesis of magnetic nickel nanoparticles
4. Structural, morphological and magnetic studies on nickel nanoparticles
5. Synthesis of rubber-nickel nanocomposites
6. Structural and morphological evaluation .

It is with this motive that a systematic study on the structural and magnetic properties were envisaged a part of this paper . Zinc aluminate belongs to a non-magnetic family of spinels and it ~.ould be interesting to investigate the structural and electrical properties when they are crystallized in the nano-regime. So zinc aluminate is also investigated with emphasis on finding out possible cation redistribution when prepared in the nano-regime. Hence one of the objectives of this particular investigation was to prepare self-protected nickel nanoparticles by a novel method and use these particles as filler for preparing nanocomposites based on natural rubber as well as synthetic rubber.

3. Method

Experimental method has been used for the study

4. Experiments

Such is the pace with which this field is advancing that it is only natural that materials scientists, physicists and chemists delve more and more into these phenomena and materials in order to improve upon the existing and find newer materials to remove obsolescence. Thus the area of magnetism and magnetics is an evergreen area for the scientists, the more they delve into the physics the more remains to be understood at the bottom! Ferrites played an important role in the 50s and 60s in realizing many devices namely high frequency transformers, radio frequency and microwave antenna, radiation absorbers, magnetic recording media and core memories. In that spinel ferrites played a seminal role. They are sought after because the properties can be tailored to suit various applications by simple chemical means. Spinel ferrites comprises of two types, the normal spinel and the inverse spinels. Normal spinels with cations having tetrahedral site preference were found to be non-magnetic.

However these materials have been continuously improved upon since their catalytic properties are of interest to chemical engineers. The recent findings of many researchers including some of the earlier work carried out in this laboratory has shown that normal spinels when prepared in the nano-regime exhibit magnetic properties. This has been puzzling scientists and many hypotheses needs testing like why a normal spinel which has no A-B interaction should lead to ferrimagnetism or is it because of formation of spin clusters or is it because of cation redistribution? Zinc ferrite and cadmium ferrite are normal spinels in the micron regime and are non magnetic. However, when they are prepared in the nano regime, they are reported to be exhibiting a net magnetization at room temperature. Hence zinc ferrite and cadmium ferrites are ideal templates to test various hypotheses. If a systematic investigation on these materials in the nano regime is conducted, many of the unanswered questions will find suitable answers.

This was attempted because the incorporation of nanoparticles like nickel in a matrix like rubber not only imparts the required magnetic property to a lossy dielectric but also reinforces the polymer as well. Thus the incorporation of nickel nanopartic1es in polymer matrixes like natural rubber and

neoprene rubber will lead to microwave absorbers based on them. So the preparation of nanocomposites based on rubber and nickel is another objective of this investigation. Any study on the magnetic, electric and structural properties will only be complete if they are properly characterized and results explained based on the analysis of the results. Various models are available for predicting the magnetic and electrical properties of these composites which will lead to the origin of a good electromagnetic wave absorbers. The magnetic permeability and dielectric permittivity in various frequency bands like radiofrequency, S and X are to be evaluated and modeled based on the surface impedance equation. This is another motivation of the present investigation.

Evaluation of dielectric and magnetic properties in rf, S and X band frequencies Salient features of the present work 1 Studies on sol-gel synthesized and ball milled zinc ferrite and cadmium ferrite In general the exhibition of room temperature magnetism in nanosized zinc ferrites otherwise non-magnetic in the micron region are attributed to the inversion in spinel structure, and the reason for this inversion with particle size reduction is not clear. Zinc ferrite can be synthesized using conventional ceramic methods, and the size reduction can be achieved by the high energy ball-milling. The structural inversion could be one of the reasons for high magnetic moment at room temperature exhibited by nanosized zinc ferrite. But this inversion can be a consequence of the size reduction of the particles to nanometer regime. This also can be due to the disturbance in equilibrium of lattice energy due to energy transfer during the milling process. One way of examining this effect is to synthesize normal spinel ferrites like zinc ferrite using methods like sol-gel synthesis in reduced particle size.

5. Results

A sol-gel auto-combustion method has been employed to synthesize spinels. The size-range of the particles obtained is nearly 50 nm for both zinc ferrite and cadmium ferrite. The samples synthesized using sol-gel process have a much reduced grain size even without ball milling. The same effects produced by prolonged high energy ball milling can be brought about faster if the samples are synthesized using this method.

This possibility has been looked into in the experimental work presented in this paper . Cadmium ferrite and zinc ferrite are two closely similar systems. Both Zn and Cd cations do not have any net magnetic moment since their d shells are completely filled and have no unpaired electrons and no magnetic moment as a result. Their ionic sizes are comparable (0.74 A and 0.97 A respectively) and both these atoms have a tetrahedral site preference in spinel structured crystals and form normal spinels. These studies reveal that both zinc and cadmium ferrite in the nano regime exhibit magnetism at room temperature and a 'plausible mechanism is proposed in the paper.

2 Synthesis of nickel nanoparticles and rubber-nickel composites and their characterization studies Nickel assumes an important role among all metallic magnetic elements. Nickel nanoparticles have a number of technological applications. But the synthesis of nickel nanoparticles is normally a time consuming process because of the nature of the chemical processes involved.

6. Conclusion

Precipitation methods can yield very fine nickel particles but the yield is very small. Further these methods require repeated filtering and washing because the particles of nickel are usually formed as a precipitate in an organic solvent. In these circumstances it has been realized that a dry procedure to synthesize nickel nanoparticles will be very much helpful, especially if nickel is to be used in the preparation of magnetic composites. Literature survey revealed that so far only one report has described the synthesis of nickel nanoparticles in a dry combustion process. This process is a dry method, and nickel nanoparticles are formed in a chemical reaction of the nature of an oxidation, and this combustion process is assisted by the fuel urea, and initiated by microwaves. The attempt to further simplify the process was successful and a a very simple process had been devised to produce nickel nanoparticles in bulk quantities. The synthesized powder had been thoroughly characterized using various analytical tools and found that these particles are comparable in quality with commercially available samples. These nanoparticles are self protected due to the formation of a small oxide coating at the time of synthesis. These precharacterized nickel nanoparticles were used in the preparation of rubber-nickel nanocomposites and they have many important technological applications. Two kinds of composites were prepared using two different rubber varieties (natural rubber and neoprene rubber) and they were characterized thoroughly. Their dielectric and magnetic properties in the radio frequencies as well as in the S and X band microwave frequencies were determined and their microwave absorbing properties were evaluated based on the surface impedance equation. In addition to these sections listed above, an annexure is incorporated, which the gist of the investigations is carried out on zinc aluminate nanoparticles synthesized using sol-gel autocombustion method. The significance of this study is that, it helped a great deal in optimizing the method ofsol-gel combustion method. Zinc aluminate is not a magnetic material, and does not fit into the main theme ofthe research work and hence its inclusion as an annexure.

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