Nanomaterials Properties and Applications

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Collaborators

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Research Interest:

1. Preparations of Nanomaterials And Exploring Optical, Electric, Dielectric & Magnetic Properties.

2. Applications In Electro-Chemical Sensing, Photo Catalysis , Waste Water Treatment.

3. Effect of light and swift heavy ion irradiations on the various aspects of Nanomaterials.

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In his talk entitled " There's a plenty of room at the bottom ", R. Feynmann in 1959 raised questions like, why can't we write all human history on the head of the pin, why can't machines be as fast as humans, why can't we tailor the matter at atomic & molecular level the way we desire, why can't we replace an organ (which is basically a machines say kidney, heart, liver etc etc) by a mechanical machine which may effectively and efficiently working as the in build organ of the human being.

Two dreams by two great scientists, one by Einstein (1905) about the prediction of gravitational waves which were detected after more than a centuries time in 2016 and the other by R. Feynmann (1959) about the plenty of room at the bottom is about to prove some times in near future in the name of NanoScience NanoTechnology where his desires, questions are expected to see the answer in the form of efficient devices made of nanomaterials.

Interest started to grow more after the accidental discovery of Carbon Nanotube nanomaterials by Japanis Scientist Iijima. Discovery of "Grapheme" a atom thick carbon sheet won the 2010 Nobel prize and latter lot of more nanomaterials have been prepared, These nanomaterials have shown different properties & applications than their counterpart bulk materials. This reason in this context is assigned to very large surface to volume ratio and quantum mechanical phenomenon at this nanoscale. Lot of research activities have been carried out by interdisciplinary (Physicists, Chemists, Biologists & Technocrats) research scientists in the field which resulted in number of journals, publications, patents in this area of interest.

Initially myself as a PhD Scholar worked on Metal Oxide Nanostructures and Their Applications, where in we prepared various materials using various available methods, characterized in terms of morphology, topography and structure using various tools like SEM, TEM, XRD etc. The as synthesized nanomaterials were further explored for their role in sensing, solar and degradations of harmful dye applications as is reflected in the form of various publications below.

Our Research interests are carried out in the lines as below…..

1. **Study of pure and ion embedded iron oxide nanostructures for sensing and removal of hazardous wastes from water**- A DST Sponsored project (Mr. Shuja Bashir Malik working as JRF)

Continuous degradation of the water resources has led researchers to think of alternative technologies for cleaning the water bodies. Providing potable water to the booming human population is of great concern. Classical/orthodox technologies employed for wastewater treatment are costly and hazardous to the environment. A range of cleaning technologies have been developed for wastewater treatment. Most promising technology is the one employing nanomaterials for cleaning wastewater. Use of nanomaterials for water treatment has received considerable attention in recent times due to unique and remarkable properties of nanomaterials. Iron oxide nanomaterials are at the top of the list of nanomaterials being employed for the treatment of water. Iron oxide nanomaterials specifically received the tremendous attention of researchers for their unique properties; biocompatibility, high surface to volume ratio, excellent magnetic properties, and surface modifiability.

Under this project, main focus is given to the synthesis techniques, morphology control, surface modifications (chemical and SHI-swift heavy ion irradiation) and applications of iron oxide nanomaterials for water treatment. A considerable focus is given to the outlook of potential applications and further challenges iron oxide nanomaterials-based technology is facing in water treatment. Also, gaps which hinder the large-scale field applications of iron oxide nanomaterials are also given a considerable attention.

Synthesis of the iron oxide nanomaterials to be used for water treatment research will be carried following a facile, environment-friendly and easy on budget route keeping in view the industrial and commercial applications of the end results. Pure, transition metal/ lanthanide doped iron oxide nanostructures will be prepared mostly by sol-gel, hydrothermal and co-precipitation methods. The samples will be irradiated with heavy swift ions. This will improve the adsorption properties of the iron nanostructures for water treatment. At the later stage of the project, sensing applications of the iron oxide nanostructures will be tested.

2. **Effect of Light and Heavy ion Irradiation on Pure and Transition Metal doped Iron oxide Thin films**, (Mr. Mubashir Qayoom working as PhD Student as well as working on IUAC Sponsored Project)

Nanotechnology is relatively a new science and engineering that presents new opportunities for improving the quality of life. Iron oxides are common natural compounds and can also easily be synthesized in the laboratory. Iron oxide nanoparticles have attracted considerable interest due to their super paramagnetic properties and their potential biomedical applications arising from its bio-compatibility and non-toxicity.

Ion beams have been of increasing focus in fundamental and applied research in material science. Swift heavy ions have a unique feature of depositing a large energy density in materials which can drive the material far from equilibrium, resulting in modifications in materials, difficult to achieve by other means. Broadly the ion beam, depending on the energy regime, can play different roles in material science such as synthesis, modification and characterizations. Low energy from a few keV to a few MeV is useful in synthesis of materials. A few MeV to hundreds of MeV is employed for the synthesis of materials. Ions of all possible energies are useful in the modification and tailoring the properties of materials; understanding of this aspect can help in engineering the properties of materials.

The work in this area is being conducted under an IUAC (Inter university accelerator centre) sponsored project “Effect of Light and Heavy ion Irradiation on Pure and Transition Metal doped Iron oxide Thin films’’ granted to Dr. Ghulam Nabi Dar (Sr. Assistant Prof) in collaboration with Dr. Arafat (Co-PI-1) & Collaborators Dr. Asokan Kandasami and Dr. Reema (IUAC).

In this work we plan to study the Magnetic properties, Dielectric properties and structural properties of Iron oxide thin films before and after ion irradiation. We will also study the optical and electrical properties of Iron oxide thin films at different fluencies of energy. Also we plan to probe Electronic

excitation-induced structural, optical, and magnetic properties of transition metal doped Iron oxide thin films.

3. **Study of Pure and Doped Magnetic Nanostructures (Iron Oxide)**: (Ms: Ruqiya Bhat, PhD Student working on Maulana Azad Fellowship)

As the fields of nano-science and nanotechnology continue to blossom from their early seeds with promising applications extending from biological to material sciences. Nanomaterials are classified as semiconducting, Insulating and metal nanomaterials. The basic difference among them is to show different and revolutionary set of properties at different length scales comparable to de-Broglie wavelength of electrons and holes or of excitons depending as the case may be. Among the nanomaterials, metal oxide nanostructures possess particular importance because of their significant physical and chemical properties which allowed them to be used for the fabrication of highly efficient Nanodevices. The metal oxide nanomaterials are widely used for catalysis, sensing, and electronic devices, and so on. The magnetic nanostructures as functional materials are attracting growing interest ranging from their promising performance in pollutant removal or toxicity mitigation to memory devices, contrast agents in magnetic resonance imaging (MRI), hyperthermia and drug delivery.

We are presently working on the topic entitled “Studies on Magnetic, Electrical and Optical properties of Pure and Doped Magnetic Nanostructures. We have synthesized pure and lanthanide (Ho^{+3}, Dy^{+3} and Er^{+3}) doped iron oxide (hematite) nanoparticles with solgel method. Also Ho^{+3} ion doped iron oxide nanoparticles have been characterized with different characterization techniques including XRD, FESEM, EDX, TEM, for structural and morphological analysis. Also Electrical and Magnetic properties have been studied and it is observed that both resistivity and magnetization enhances with Ho^{+3} ion doping. Research paper entitled “Probing of Electric and Magnetic Properties of Holmium Doped Iron Oxide Nanoparticles” has been communicated to the journal of materials research bulletin”. Moreover, optical characterizations have been performed including UV-VIS Spectroscopy, Raman Spectroscopy, Fourier Transform Infrared Spectroscopy and photoluminescence. Another research paper on optical studies has been prepared and will be communicate very soon. At present we are involved in the analysis of electrical, magnetic and optical properties of Dy^{+3} ion doped iron oxide (hematite) nanoparticles. Also we have to characterize Er^{+3} ion doped iron oxide nanoparticles. Also we are expecting to investigate the feasibility of using pure and lanthanide (Ho^{+3}, Dy^{+3} and Er^{+3}) doped iron oxide nanomaterials for waste water treatment like sensing and removal of toxic metal ions such as Cr, Pb, Ni, Cu, As, Hg from aqueous solution by chemisorption / adsorption process.

Publications:

[1]. A. Umar, M.S. Akhtar, A. Al-Hajry, M.S. Al-Assiri, **G.N. Dar**, M.S. Islam, "**Enhanced photocatalytic degradation of harmful dye and phenyl hydrazine chemical sensing using ZnO nanourchins**" Chemical Engineering Journal 262, 588-596 (2015)

[2]. S.H. Al-Heniti, A. Umar, H.M. Zaki, **G.N. Dar,** AA Al-Ghamdi, SH Kim, " **Synthesis and characterizations of ferrite nanomaterials for phenyl hydrazine chemical sensor applications**" Journal of nanoscience and nanotechnology 14 (5), 3765-3770 (2014)

[3]. A Umar, MS Akhtar, GN Dar, S Baskoutas, **Low-temperature synthesis of α-Fe2O3 hexagonal nanoparticles for environmental remediation and smart sensor applications**, Talanta 116, 1060-1066 (2013).

[4]. Ahmad Umar, M. S. Akhtar, **G. N. Dar**, M. Abaker, A. Al-Hajry, S. Baskoutas, "**Visible-light-driven photocatalytic and Chemical Sensing Properties of SnS_2 nano-flakes**", Talanta, 114, 183-190 (2013).