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Low-Dimensional Superconducting and Magnetic Materials of Proven Technological Relevance

by

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Abstract

Magnetism and Superconductivity are perhaps the most widely studies topics by the physical sciences community particularly after the discovery of oxides-based exotic ferromagnets and superconductors during the past two decades. In the area of superconductivity, a team-effort of professionals with diverse skills has culminated into a magnificent rainbow whose colors include dissipation-less power transmission lines, electrical motors, energy storage devices and high power magnets for futuristic fusion reactors. The key to the realization of these technologies depended on our understanding of the mechanism of energy dissipation in a superconductor and ingenuity in devising ways to arrest it. Similarly, magnetic materials in zero, one and two-dimensional geometries such as clusters consisting of a few thousand atoms, wires of a few nanometers diameter and ultra thin films, respectively, are the basis of a myriad of technologies. This talk is designed to give the audience a flavor of the scientific and technological developments in these areas with specific examples taken from our own research carried out mostly here at IIT Kanpur, with emphasis on synthesis of oxides-based superconducting and magnetic materials in their purest of the pure form followed by tailoring of their properties through defect and interface engineering. Lasers of stupendous power (~ 10 million watts/pulse) have played a pivotal role in the synthesis of these structures. Such laser-based techniques are now commonly used to fabricate kilometers-long super-conducting power transmission cables. We have used these techniques for liquid as well as vapor phase synthesis of colloidal nanoparticles, quantum dot structures supported on substrates and thin film superlattices of magnetic and superconducting materials. We will show that the current carrying capacity of a superconducting film can be enhanced a thousand folds through creation of nanoscale rod-like defects.

Superconductivity and ferromagnetism are two antagonistic quantum phenomena. It is the latter which usually wins because magnetic forces are much more robust than the force that holds two free electrons in a solid together for superconductivity to take place. However, when the interactions that cause these two phenomena are of comparable strength, fascinating consequences of the competition for survival emerge, many of which bear great technological potential provided one is able to synthesize single crystal-like films of these materials. Some of our recent results on high temperature superconductor – manganite heterostructures will be summarized during the talk. These materials belong to a special class of doped Mott Insulators which show competing phases of nearly equal free energy but dramatically different physical properties. A slight electromagnetic perturbation of the system can turn it into the other state with colossal changes in its resistance. We will describe some recent results of electrical switching induced by electric field and short pulses of laser light, and present a microscopic view of the phase change captured with high resolution electron microscopy and electron holography.

About the speaker

Prof. Budhani received his Ph. D. degree in Physics from I. I. T. Delhi in the year 1982. This was followed by four years of research at the University of California Los Angeles, first as a post doctoral fellow and then as member of the research faculty. He moved to Brookhaven National Laboratory in 1988 and worked there as a staff scientist till 1994. He has been a visiting professor at University of Maryland College Park, and continues his association with BNL as a Guest Scientist. He is a Fellow of the American Physical Society, Indian Academy of Sciences and the National Academy of Sciences, and his biography appears in Who’s Who in the World and Who’s Who in Science and Engineering (Marquis, USA). Prof. Budhani has published extensively in the areas of superconductivity and magnetism in correlated electronic systems.