Director's Message

The Center for Superconductivity Research (CSR) at the University of Maryland conducts interdisciplinary research in the fields of superconductivity, magnetism, ferroelectricity, quantum computation, nanoscale electronics, the synthesis of advanced electronic materials, and the development of scanning probe microscopies. Our research impacts technology in areas such as communications, digital and analog electronics, medical instrumentation, and computers. The experimental and theoretical research programs at CSR are carried out by approximately 20 scientists and engineers of whom 10 are also teaching faculty members of the Department of Physics, Electrical Engineering, or Materials Science and Engineering. Approximately 30 graduate students are working on their research dissertation projects with members of the CSR faculty. A significant number of undergraduate students and visiting scientists also participate in research projects.

One important goal of the CSR is to train students with the expertise necessary to make contributions to advancing technology in the State of Maryland and elsewhere in the United States. The CSR provides a unique interdisciplinary education that gives our students a diversity of experimental skills as well as a broad and flexible perspective of how scientific knowledge can be used to impact technological development. Our Ph.D. and M.S. graduates have found rewarding positions with industry, government laboratories, and universities.

Annual external federal support of CSR research programs was about $4.3 million for FY03. Moreover, some of our faculty are an important part of a Maryland collaboration which was awarded a prestigious NSF Materials Research Science and Engineering Center (MRSEC). This $10 million, 5 year, grant is supporting our research efforts in magnetic and ferroelectric thin film oxides. One of our faculty is a co-PI on a recently awarded five-year, $3.5 million NSF grant to establish an International Materials Institute for combinational sciences and materials informatics. In addition, we have joint science and technology programs with industry and government laboratories. Many of our patents have been licensed to companies for product development and royalties continue to be returned to the University and the inventors.

The research programs in CSR encompass a wide range of interdisciplinary areas: fundamental physical properties of novel superconductors, ferromagnets and ferroelectrics; thin film preparation, characterization and device structures of complex oxide materials; properties and technology of SQUIDS and single electron transistor devices; dynamical properties of vortices in superconductors; properties of spintronic materials; electronic and electromechanical properties of novel nanometer-scale devices; physics of mesoscopic metals; development of scanning microwave microscopy and other novel scanning probes of materials; development of solid state quantum computers; and synthesis of new materials by conventional solid state chemistry and by novel combinatorial methods. Details of this research can be found on our website **www.csr.umd.edu**

Some highlights of CSR Research in FY 2003 are:

- Professor R. Ramesh was honored by his selection as a Maryland Distinguished University Professor.

- The first successful creation of entangled macroscopic quantum states in two superconducting qubits was achieved. The system was composed of two Josephson-junction qubits coupled by a capacitor. The entangled state extended over the 0.7 mm distance between the two qubits. The observation of entanglement over such a large, macroscopic, distance is a very encouraging step towards the goal of an operational solid state quantum computer. Details of this work can be found in Science **300**, 1548 (2003).

- A large enhancement of polarization and related properties was discovered in heteroepitaxial thin films of the ferroelectromagnet (multiferroic), $BiFeO_3$. The films displayed a room-temperature spontaneous polarization almost an order of magnitude higher than found in bulk samples. The observed enhancement was corroborated by first-principles calculations and found to originate from a huge sensitivity of the polarization to small changes in lattice parameters. For details, see Science **299**, 1719 (2003).

- Room temperature ferromagnetism with a giant magnetic moment (7.5 μ_B/Co), possibly reflecting an extra contribution of the unquenched orbital moment, was realized in the case of Cobalt doped SnO_2 in its optically transparent semi-conducting state.

- The issue of dopant clustering was investigated in the context of the observed high temperature ferromagnetism in Cobalt doped anatase TiO_2, and conditions for achieving a intrinsic diluted magnetic oxide ferromagnet were identified.

- $LuMnO_3$, which is a hexagonal multiferroic (ferroelectric and antiferromagnetic) material in its bulk ground state, was substrate-stabilized in its high pressure perovskite phase by pulsed laser deposition on $LaAlO_3$ and $SrTiO_3$. This opens up the possibility of interesting doping studies in this metastable phase. (In collaboration with S. -W. Cheong, Rutgers University).

- The critical current density of high-quality epitaxial MgB_2 thin films (grown by X. X. Xi, Penn State) was shown to be enhanced by almost an order of magnitude over a certain magnetic field range by defect clusters induced by heavy ion irradiation.

- High-quality epitaxial thin films of $Y_1Ba_2Cu_3O_7$, (Tc ~ 91K, Jc > MA/cm^2 at 4.2K), transparent conducting oxide SnO_2, and wide bandgap semiconductor ZnO were grown by the technique of pulsed electron beam deposition or PED. (In collaboration with Neocera Inc.).

- Complete bandgap tuning and continuous phase evolution were mapped out in the $Zn_{1-x}Mg_xO$ system using thin-film composition spreads. By fabricating an array of photodetectors across the bandgap changing spread, we have demonstrated a "composition-spread" device for the first time, in the form of a broadband UV detector. In a composition-spread device, the entire spread acts simultaneously as one device deriving its "broadband functionality" from the continuously changing physical property mapped on the spread.

- Using a thin-film composition spread technique, novel compositions of Ni-Mn-Ga ferromagnetic shape-memory alloys were identified. A scanning SQUID microscope, developed in the CSR, was crucial for quantitative magnetization mapping of the new alloy. For details see Nature Materials **2**, 180 (2003).

- We found that when a ferroelectric film (PZT) is patterned into discrete islands, the clamping (by the substrate) of domain wall motion is significantly reduced. This results in a significant enhancement in the piezoelectric response of the film. For details see Nature Materials **2**, 43 (2003).

Richard L. Greene
Director