Editorial

Dear Reader:

Cooperative phenomena originate from the interaction between macroscopically many particles. These collective effects are often associated with long-range order of the microscopic degrees of freedom of the many-body system. In solids the spin, charge, and angular momentum of the electrons as well as the coordinates of the lattice ions are the relevant degrees of freedom. In the case of the transition-metal oxides and chalcogenides a particularly complex situation arises due to the strong coupling of all of those degrees of freedom. Research during the last 15 years has shown that this may lead to an extreme sensitivity of these materials upon changes of external parameters such as the temperature, pressure, magnetic field, or doping. Dramatic consequences are, for example, extremely strong resistivity and volume changes, colossal magnetoresistance, strong thermoelectric and pronounced non-linear optical effects as well as extraordinarily high transition temperatures as in the cuprate superconductors. For these reasons materials with strong electronic correlations are not only of great interest for basic research but also for applications and technology.

The strong mutual coupling of the spin, charge, and angular momentum of the electrons and their interaction with the ionic lattice leads to highly unusual, often "exotic" ground states in transition-metal oxides such as spin and orbital liquids, multi-ferroic phases, electronic ferroelectricity, and intrinsically inhomogeneous states with electronic phase separation. Strong electronic correlations and interactions with the lattice are also the origin of very remarkable effects at surfaces and interfaces and in inhomogeneous systems, e.g., they can lead to highly anomalous transport properties.

The Augsburg Collaborative Research Center (SFB) 484 *Cooperative Phenomena in Solids: Metal-Insulator Transitions and Ordering of Microscopic Degrees of Freedom* which was financed by the German Research Foundation (Deutsche Forschungsgemeinschaft) from 2000 to 2009, focussed on the investigation of cooperative phenomena in quantum mechanical, many-particle systems in solid-state physics. The main purpose of the research activities of the SFB 484 was to clarify how the interaction and the collective behavior of the microscopic degrees of freedom of electrons and lattice lead to ordering phenomena and metal-insulator transitions. Transition-metal oxides were found to be an ideal class of materials to study these issues and hence represented the basis for the systems under investigation. By applying the most advanced experimental and theoretical methods, the Collaborative Research Center SFB 484 was engaged in the examination of the microscopic foundations of the above phenomena and, simultaneously, in establishing connections with application oriented topics.

During the final funding period (2006–2009) the SFB 484 concentrated on the following two project areas:

- Complex structures on atomic scales
- Dynamics of microscopic degrees of freedom

with a total of 15 experimental and theoretical subprojects.

To investigate the dynamics and the spatial correlations of the microscopic degrees of freedom the SFB 484 employed a wide range of experimental equipment. Various spectroscopic methods such as photoemission spectroscopy, optical spectroscopy, x-ray absorption spectroscopy, and dielectric measuring techniques permitted the exploration of a dynamic range of 20 decades of frequency, which is an internationally outstanding feature of the Institute of Physics in Augsburg. Broad-band spectroscopy for the measurement of charge carrier dynamics was supplemented by elastic and inelastic neutron scattering as well as magnetic resonance techniques which allowed for comprehensive studies of the dynamics and structure of complex ground states. Furthermore, transmission electron microscopy was able to detect the structure of the materials under investigation down to atomic resolution.

For the theoretical investigation of the interactions between the microscopic degrees of freedom and the resulting ordering phenomena a broad range of techniques were available which were specifically developed in the SFB 484. For example, during the last ten years progress in the development of the LDA+DMFT approach – a fusion of density-functional theory in the local-density approximation (LDA) with the dynamical mean-field theory (DMFT) – provided a new *ab initio* computational scheme for the investigation of electronically correlated materials. A generalization of the DMFT to non-equilibrium situations laid the foundations for future applications of the DMFT to describe correlated systems out of equilibrium.

The articles in this issue cover, in particular, the following topics:

(a) Electronic Correlations in Materials
(b) Electronic Correlations with Disorder and Dissipation
(c) Low-Dimensional Systems
(d) Correlated Systems in Nonequilibrium

In the first six papers, part (a), some of our theoretical and experimental studies with explicit relation to concrete materials are described: the above mentioned LDA+DMFT approach [J. Kuneš *et al.*], the effects of doping and external pressure on the Mott insulators TiOCl and TiOBr [C.A. Kuntscher *et al.*], the coupling between spins and phonons in transition-metal monoxides [Ch. Kant *et al.*], investigations of colossal dielectric constants [P. Lunkenheimer *et al.*], frustration in novel perovskite-related phases [S.G. Ebbinghaus *et al.*], and on the transport properties of CuPc based organic devices [C. Schuster *et al.*].

The following two theoretical papers, part (b), discuss the interplay between correlations and (static) disorder [K. Byczuk *et al.*], and correlations and (dynamic) fluctuations which lead to dissipative effects [R. Bulla]. In part (c) the present understanding of quantum spin chains from the magnetic resonance point of view is reviewed [H.-A. Krug von Nidda *et al.*], and the flux periodicity in small loops of d-wave superconductors is discussed [F. Loder *et al.*]. Finally, part (d) is devoted to new theoretical techniques for correlated systems out of equilibrium [M. Eckstein *et al.*], and to detailed studies of time-dependent phenomena in quantum spin chains [F. Galve *et al.*].

In retrospect, the success of the Collaborative Research Center SFB 484 is, to a large extent, due to the very fruitful cooperations between experimental and theoretical physicists and solid state chemists. Furthermore, the numerous significant contributions by young researchers have been decisive. For detailed information, we invite you to visit the SFB 484 homepage:

`http://www.physik.uni-augsburg.de/sfb484/`

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