Electronically induced phenomena: low temperature aspects

(Preface)

Electronic excitations of insulators and semiconductors initiate a complex sequence of transport and relaxation processes involving both the electronic and the nuclear subsystem. Under certain conditions they may result in a diversity of dramatic changes of the local atomic arrangements of bulk materials as well as of surfaces and interfaces. These effects are based on the concentration of the electronic excitation energy within a volume of the order of a unit cell as a result of localization. From the point of view of condensed matter theory, investigations of electronically induced phenomena are of great importance for elucidating the problem of non-radiative transitions in solids and the physics of non-equilibrium processes.

A fundamental understanding of the mechanisms and elementary steps of these transport and relaxation processes may open new ways for many novel technological applications including electronically induced reactions on the atomic scale in material and surface sciences, micro- and nanoelectronics, photochemistry and biology. This promises, on the one hand, to avoid troublesome irradiation induced deterioration and damages of materials and devices, and on the other hand, to benefit from material modification induced by electronic excitations and to find approaches to the use of these techniques in full potential. The material modification via excitation of the electronic subsystem is a topic of active current research covering a variety of materials including insulators, semiconductors, molecular systems as biomolecules, HTSCs, and others.

The electronically induced processes give rise to a diversity of microscopic phenomena such as mass diffusion, charge transport, defect formation, bond breaking and bond creation, and desorption of different species from surfaces (molecules, fragments, and atoms, either neutral or charged). In all these cases the dynamical processes in the excited states, their interplay and the conversion of electronic energy into kinetic energy of the lattice atoms are of primary importance. Very often these phenomena are used as an efficient tool for studies of solids, adsorbed layers and clusters. Considering the high current interest in nanoparticles, the investigation of electronically induced phenomena in these structures is particularly promising.

The most efficisent experimental approach is a combined employment of selective excitation and selective analysis techniques. Impressive progress has been made using narrow bandwidth synchrotron radiation and short laser pulses. Tunable light in a wide spectral range opened new avenues for detailed studies of processes induced by excitations in the excitonic range, in the range of band-to-band transitions, and in the inner shell region. The pulse structure of synchrotron radiation made it possible to combine energy- and time-resolved measurements. Recent progress in laser technology enabled researchers to investigate fast dynamics by pump and probe techniques on a femto- and picosecond time scale. The photon stimulated desorption (PSD) is investigated for a wide spectral range from infrared (IR) over vacuum ultraviolet (VUV) to x-rays with registration of ions, neutrals, and metastables. The electron stimulated desorption (ESD), and especially its angularly resolved variation ESDIAD (electron stimulated desorption ion angular distribution), provides interesting information on dynamics and the directions of chemical bonds. Electron ion coincidence techniques (EICO) link the primary excitation and the products, enabling an unambiguous analysis of the electronic evolution. High potential in studies of electron transport in condensed matter was demonstrated by the muon spin relaxation (μSR) technique. Scanning microscopy (STM and AFM) and the spectrocopic techniques related to them allow an unsurpassed view on the microscopic details of surfaces in real space.

Low temperature studies are of considerable importance to gain a better insight into the mechanisms of electronically induced phenomena since they allow to minimize the influence of thermally stimulated processes. Moreover, there exists a special group of low temperature solids, the van der Waals condensates. Mainly wide band gap insulators with weak inter particle interaction, they are accepted as unique model systems for unveiling elementary steps of the electronic evolution including transport, localization, and coupling to the nuclei. This is why this special issue is devoted to electronically induced phenomena performed at low temperatures and in cryogenic systems.

The paper by Bargheer and Schwentner is focused on the mass transport in rare gas solids studied by ultrafast spectroscopy. The theoretical article by Ratner deals with the energy transport properties of two-atom excitons and holes. Electron transport phenomena in cryogenic solids and liquids are explored by Eshchenko et al. by advanced μSR techniques, while the paper by Lastapis et al. concentrates on electron transport on semiconductor surfaces studied by STM techniques. Bass and Sanche review reactions induced by slow electrons in cryogenic films of molecular systems, including species of biophysics interest. The effect of electron irradiation on structure and bonding of SF_6 is the topic of the contribution of Faradzhev et al. Soft landing of size-selected clusters in cryogenic layers is investigated by Lau et al. Bond breaking by excitation of deep core levels monitored by ion desorption from a number of condensed and adsorbed molecules is reviewed by Baba. The article of Mase et al. reports on the potential of the EICO technique for the investigation of electronically induced bond breaking in condensates and physisorbates. The paper by Arakawa et al. concerns the metastable particles desorption from rare gas solids. The authors were able to measure absolute yields of the metastable atoms. The formation of biexcitons in Ne layers condensed on a metal substrate is explored by Wiethoff et al. in a PSD experiments. The paper by Savchenko et al. concentrates on the creation of permanent lattice defects via excitonic mechanisms.

Though a single issue cannot cover all aspects of the research, we do hope to give the reader a brief overview of the current research in this field and to show to some extent «a making up» of the basis for controlled modifications of lattice structures, and for surface-sensitive technological processes.

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