Materials Science

Electronic & Magnetic Properties

Materials science focused on electronic and magnetic properties continues to play one of the major roles at SPring-8. This chapter is organized into four parts: (1) inelastic X-ray scattering for investigating dynamical dielectric functions and particle-hole pair excitations in energy and momentum space, (2) fermiology using Compton scattering and angle resolved photoelectron spectroscopy (ARPES) methods applied to strongly correlated and heavy-electron systems, (3) excitation of atoms and molecules for studying decay processes, and (4) studies on magnetic and dielectric materials geared towards to device applications.

Recent progress and development on synchrotron X-ray sources like SPring-8 have encouraged the realization of sophisticated inelastic X-ray scattering and spectroscopic experiments, which have become powerful tools to investigate momentum- and energy-dependent charge and lattice dynamics, and electronic structures. This year, three inelastic X-ray scattering studies are highlighted. One is a non-resonant inelastic X-ray scattering on MgB_2, which was a recently discovered superconductor with a relatively simple crystal structure unlike high-T_C cuprates, to investigate dynamically screened electron-electron and electron-ion interactions. This work has led to the discovery of an interesting momentum dependence of single particle excitation. The second is a resonant inelastic X-ray scattering (RIXS) work on the charge-transfer Mott insulator $LaCuO_4$ with polarization and incident X-ray energy dependences to elucidate not only the nature of particle-hole excitations, but also the RIXS process and cross section. The third is a magnetic Compton scattering on the Perovskite manganites to examine the type of orbital nature in the valence band, which is a central issue in understanding the physical properties of this system. Since SPring-8 has a Compton dedicated beamline, this kind of experimental activity is quite high. Compton experiments can reveal the fermiology of electronic states. Here, we present two studies of ARPES, which is another method for fermiology, on strongly correlated electron and heavy electron systems. Since both works have been carried out with the use of soft X-rays, it can be said that the results are bulk-sensitive; in other words, the results are intrinsic. Then the results can be compared with directly sophisticate theoretical calculations. This opens up new possibilities of comparing theoretical and experimental results quantitatively.

What happens when an electron from an inner-shell orbital localized at a particular atomic site is ionized? The answer is well known in an isolated atom such that the ionized atom undergoes Auger decay. However, it is not so simple if other atoms exist in the vicinity of the excited atom. Morishita *et al.* have identified the interatomic Coulombic decay process, which was proposed theoretically, in the Ar dimer by an electron-ion coincidence technique. Another work on atoms and molecules is gas-phase soft X-ray electron spectroscopy for accurate determination of the vibrational fine structure in molecular core-level photoemission. A new finding, that is, a violation of the Franck-Condon principle, has been discovered experimentally on CH_4. Next, we show studies on magnetism. One is the diffraction work on a frustrated magnetic system under a very high pulsed magnetic field up to 40 T, in which it was found that the stepwise lattice contractions associated with multistep magnetization change in $CuFeO_2$. We show two works oriented to device applications and also related to nanotechnologies. X-ray magnetic circular dichroism (XMCD) is inherently an element specific and orbital selective experimental technique that has greatly contributed to our understanding of electronic structures/properties related to magnetism. XMCD combined with photoelectron emission microscopy (PEEM) has been applied to study the magnetic anisotropy and domain structure of the half-metallic ferromagnetic oxide $(LaSr)MnO_3$, which has been studied extensively for spintronic device applications. Another magnetic material, Mn-Ir/Co-Fe, which is one of the candidates for realizing high-density magnetic storage devices, has been studied to investigate the effect of Mn spins on giant exchange anisotropy by MCD. The last work in this chapter focuses on the effect of the size of dielectric materials on dielectric constant, which has been a topic of long-standing interest, and problems for device applications. Funakubo *et al.* have discovered size-effect-free materials with high dielectric constants in form of a film.

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