Understanding Ion Matter Interactions Using Synchrotron-Based X-ray Spectroscopic Techniques

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Ion beams play a crucial role in nanoscience and nanotechnology by enabling precise synthesis, modification, and characterization. Ion beam processing is an effective technique for fabricating and tailoring materials through ion–matter interactions, enabling controlled modification of physical properties [1]. When energetic ions interact with solids, they transfer energy through nuclear (S_n) and electronic (S_e) energy loss mechanisms, generating defects such as vacancies, dislocations, clusters, and amorphous regions. At low energy, nuclear energy loss dominates, producing lattice defects, while at higher energies (~1 MeV/nucleon), electronic energy loss prevails through excitation and ionization processes. It enables patterning of nanomaterials and nanostructures. It is suitable for fabricating devices and materials by tailoring optical, magnetic, and electrical properties through processes: ion implantation and ion irradiation. This talk will provide basic information on ion beam interactions and how synchrotron-based X-ray spectroscopic studies, mainly XRD, XAS, XMCD, and PL, unveil the modifications in the structural, optical, magnetic, and electronic properties of materials. This will cover selected experimental results related to energy and magnetic materials [2-5]. The synchrotron-based facilities at KEK, Photon Factory (Japan), Elettra (Italy), and NSRRC (Taiwan) were used for these studies.

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