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**Synchrotron Light for Materials Science**

This special issue of *Advanced Materials* celebrates the 5th anniversary of operation of the Shanghai Synchrotron Radiation Facility (SSRF) and the 10th anniversary of its foundation. The SSRF or Shanghai Lightsource is a third-generation synchrotron radiation facility with extremely bright X-rays. The issue reflects cutting-edge research demonstrating the power of synchrotron technologies in materials science, with regard to materials characterization and fabrication, with a focus on functional, biological, energy, optical, and interfacial materials.

**Synchrotron Spectroscopy**

Recent research is briefly reviewed by C. Miron and M. Patanen on page 7911 regarding the use of soft X-ray electron spectroscopy applied to the structural characterization of isolated species of increasing complexity, from molecules and clusters to nanoparticles. Special attention is paid to very high resolution studies of single molecules, revealing electron diffraction and interference effects, as well as detailed information on their potential-energy surfaces.

**Imaging**

The principles of forward-scattering coherent X-ray diffraction image (CDI) and Bragg geometry CDI (BCDI) are introduced by G. Xiong, I. Robinson, and co-workers on page 7747. BCDI exploits the ultrahigh sensitivity of the diffraction pattern to distortions of the crystalline lattice, and has a novel ability of imaging strain on the nanometer scale in three dimensions. The latest progress on the application of BCDI to the investigation of the strain-relaxation behavior in nanoscale-patterened strained silicon-on-insulator materials is presented.

Several types of microscopy used for visualizing specific biomolecular targets, along with recent advances in the design of X-ray-sensitive nanoprobes for applications in synchrotron-based cellular imaging are summarized by Q. Huang, C. Fan, and co-workers on page 7889. There is rapid progress in high-resolution and multicolor X-ray imaging of cells with various types of functional nanoprobes, which is highlighted.

**Imaging**


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The X-ray imaging beamline at the Shanghai Synchrotron Radiation Facility is aimed at developing and evaluating the effectiveness of synchrotron radiation (SR)-based imaging techniques in planar or computed tomography modalities. Several X-ray imaging methods are in use and find extensive applications in many research fields. In this Essay, the status of the methodology development at the beamline is discussed and applications are reviewed.

The possibilities and limitations of the advanced scattering techniques grazing incidence small angle X-ray scattering (GISAXS) and grazing incidence wide angle X-ray scattering (GIWAXS) are reviewed. Basics of both scattering techniques are explained and selected examples from application of GISAXS and for the use of GIWAXS in the analysis OPV device relevant structures are presented.

Recent instrumentation developments have advanced soft X-ray spectroscopic tools for studying real-world samples. Both photon-in-electron-out and photon-in-photon-out spectroscopy can be performed under semi-realistic, and operando conditions through high-efficiency and high-resolution detection systems at high-brightness synchrotron light sources. This Progress Report focuses on many recent advancements on in situ soft X-ray spectroscopic tools and their applications in developing energy materials.

Imaging
R. Chen, P. Liu, T. Xiao,* L. X. Xu* ..................................7688–7691
X-ray Imaging for Non-Destructive Microstructure Analysis at SSRF

Grazing Incidence Scattering
P. Müller-Buschbaum* ..........7692–7709
The Active Layer Morphology of Organic Solar Cells Probed with Grazing Incidence Scattering Techniques

Energy Materials
X. Liu, W. Yang,* Z. Liu*........7710–7729
Recent Progress on Synchrotron-Based In Situ Soft X-ray Spectroscopy for Energy Materials
**PROGRESS REPORTS**

**Spectroscopy**
E. Gallo, P. Glatzel ............... 7730–7746
Valence to Core X-ray Emission Spectroscopy

The chemical bond is usually described in terms of molecular orbitals, which are not physically observable. For transition-metal-based systems, Kβ valence to core X-ray emission spectroscopy combined with ground state density-functional-theory calculations provide the bridge between the real chemical world and the tools we use to describe it. The technique is bulk-sensitive, element-selective, and probes the occupied electronic levels of the material under investigation.

**Imaging**
G. Xiong, O. Moutanabbir, M. Reiche, R. Harder, I. Robinson ......... 7747–7763
Coherent X-Ray Diffraction Imaging and Characterization of Strain in Silicon-on-Insulator Nanostructures

Bragg coherent diffraction imaging (BCDI) exploits the ultrahigh sensitivity of the diffraction pattern to the distortions of crystalline lattice. Its ability of imaging strain on the nanometer scale in three dimensions is highly novel. Here we present its application on investigating the strain relaxation behavior in nanoscale patterned strained silicon-on-insulator (sSOI) materials, aiming to understand and engineer strain for the design and implementation of new generation semiconductor devices.

**REVIEWS**

**Surface Dynamics**
X-ray Photon Correlation Spectroscopy Studies of Surfaces and Thin Films

X-ray Photon Correlation Spectroscopy (XPCS) using coherent beams of X-rays to study the dynamical fluctuations of surfaces and interfaces is reviewed. The XPCS technique is described, together with applications to liquid surfaces, polymeric, surfactant and liquid crystalline films, reconfigurations of metallic surfaces, domain fluctuations in magnetic films, and non-equilibrium phenomena.

**Nanostructures**
Synchrotron Soft X-ray Absorption Spectroscopy Study of Carbon and Silicon Nanostructures for Energy Applications

Synchrotron soft X-ray absorption spectroscopy (XAS) and related techniques, such as X-ray emission spectroscopy (XES) and scanning transmission X-ray microscopy (STXM), are demonstrated as powerful techniques for probing chemical bonding, the electronic structure, and the surface chemistry of carbon and silicon nanomaterials, which can greatly enhance the fundamental understanding and also the applicability of these nanomaterials in energy applications.
The rapid development of synchrotron radiation (SR) based techniques offers tremendous opportunities for brilliant and challenging research in actinide-based materials nowadays. This review addresses recent research progresses in actinide related materials by means of various SR techniques, with emphasis on X-ray absorption spectroscopy, X-ray diffraction and scattering spectroscopy.

Synchrotron-based spectroscopic techniques have been applied to different areas of nucleic acid research. Here, we review the progress in using different types of synchrotron-based spectroscopic techniques for the characterization of structures and folding processes of nucleic acids, as well as nucleic acid-based nanostructures, nucleic acid-functionalized nanomaterials, and nucleic acid-lipid interactions.

The use of synchrotron nanobeams opens new opportunities to investigate nanostructures with high spatial (sub-100 nm) and temporal (sub-50 ps) resolutions. Thanks to the parallel exploitation of multiple analytical tools, we demonstrate how hard X-ray nanobeams are currently used in nanowire research. Direct correlations of composition, structural, and optical properties are obtained, providing new insights into the underlying growth mechanisms.

The charge transfer dynamics at organic/electrode interfaces could be quantified using synchrotron-based core-hole clock spectroscopy. Core-holes are created within organic molecules after excited by synchrotron radiation. Emitting electrons originating from various decay processes after the core-hole creation are collected, from which charge transfer timescale between the organic molecule and the electrode can be extracted using core-hole lifetime of several femtoseconds as an internal reference clock.

Applications of Synchrotron-Based Spectroscopic Techniques in Studying Nucleic Acids and Nucleic Acid-Functionalized Nanomaterials

Exploring Single Semiconductor Nanowires with a Multimodal Hard X-ray Nanoprobe

Quantitative Femtosecond Charge Transfer Dynamics at Organic/Electrode Interfaces Studied by Core-Hole Clock Spectroscopy
It is one of the ultimate goals in cell biology to understand the complex spatio-temporal interplay of biomolecules in the cellular context. While various microscopic techniques have been successfully employed in this regard to gain molecule-level understanding of cellular processes, it remains challenging to monitor multiple molecular targets with the nanometer-scale resolution. In this Research News, we focus on recent advances in the design of X-ray sensitive nanoprobes for applications in synchrotron-based cellular imaging, with the particular attentions on nanometer-resolution and multi-color imaging.

Recent advancements in 2D photon-in/photon-out spectroscopy – a) the 2D display of soft X-ray fluorescence map as a function of excitation energy across the Fe L$_{2,3}$-edge from LiFePO$_4$ and b) the 2D display of optical luminescence from a GaN-ZnO solid solution as a function of excitation energy across the N and the O K-edge.

Recent methodology advances in SAXS data analyses for structure characterization of biomolecular complexes in solution are described. Here, current and recent analytical tools for SAXS data interpretation are discussed, with a key focus on computational modeling of theoretical SAXS calculations, conformation generation, and SAXS-based ensemble optimization.

Synchrotron radiation is an invaluable tool for the characterization of the chemical composition, electronic structure, optical and magnetic properties, and structure of materials. Here, recent research in the use of soft X-ray electron spectroscopy for the characterization of molecular structure, and the potential of isolated species from molecules to nanoparticles are briefly reviewed.