X-ray Fluorescence Microscopy Brightens up Biological and Medical Research

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Synchrotron-based X-ray techniques have transformed a wide range of scientific disciplines, from biology and medicine to materials engineering and environmental research. Advances in X-ray nanofocusing optics, detection systems, sample motion, and metrology, along with upgrades to synchrotron facilities, have significantly enhanced the resolution and efficiency of scanning X-ray microscopes.

These innovations had greatest impact on scanning X-ray fluorescence microscopy (XFM), enabling the imaging and analysis of both essential and trace metal elements crucial to life, medicine, and technology. In life sciences, certain metals are essential to all known life forms and have a profound impact on human health, influencing everything from natural biological processes, such as cell cycle, development, biomineralization, to the efficacy of therapeutic drugs and implant materials, as well as, the progression of neurodegenerative diseases and oncology. Variety of transition elements and their colocalization are also crucial for energy harvesting and storage materials.

The technological improvements are reshaping experimental approaches, allowing for more detailed sample analysis at higher spatial resolutions, with larger fields of view, greater throughput, and enhanced sensitivity to transition elements, crucial for biomedical research. Given the complex composition of biological and medical samples, integrating XFM data with other X-ray modalities and analytical techniques is highly advantageous. Recent advances in X-ray fluorescence microscopy, data analysis methods, correlative imaging, ptychography, spectroscopy, X-ray fluorescence micro-tomography and laminography provide unique opportunities for comprehensive evaluation of samples. This approach enables structural and functional analysis of a diverse array of specimens, ranging from single cells to organ sections and from nanoparticle-drug composites to tissue-implant interfaces.