

Detectors for resonant soft X-ray scattering: current capabilities and future directions

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Resonant soft X-ray scattering (RSoXS) combines the chemical sensitivity of X-ray absorption spectroscopy and the nanometer-scale spatial resolution of small-angle scattering to elucidate the structure of various soft materials. The ability of RSoXS to map both the composition and molecular orientations in these materials without chemical labeling offers unique insights that are less readily accessible by other characterization techniques. These insights are promising in the development of next-generation materials for nanolithography, ion/electron transport, and drug delivery. Realizing the full potential of RSoXS requires high-performance detection.

The National Institute of Standards and Technology owns an RSoXS measurement station at the Spectroscopy Soft and Tender beamline suite at Brookhaven National Laboratory. This station currently uses a 16MP soft X-ray sensitized charge-coupled device (CCD) camera. The large sensor area along with low noise have allowed wide angular ranges to be captured in minimal frames, enabling the construction of real-space structure maps across a large range of length scales. Combining multiple images at the same beam conditions have further enhanced signal-to-noise sensitivity, unlocking the detection of weak molecular orientation anisotropy in dilute liquid solutions and amorphous polymers. These detection capabilities have expanded the scope of materials that can benefit from RSoXS characterization.

Continued advancements in RSoXS require upgraded detector technologies. As the type of samples interrogated by RSoXS become more diverse, it is increasingly important to minimize X-ray dose such that the samples experience minimal radiation damage. In the near term, increased dynamic range with high linearity along with reduced noise and high quantum efficiencies across the full soft X-ray energy range (100 eV to 2000 eV) can aid the quantification of sample structures at multiple length scales with reduced X-ray exposure. Ideally, if the upper end of the dynamic range were sufficiently robust to withstand direct beam and not require a beamstop, the opportunity to analyze total scattered intensity could be realized. As flyscanning developments enable higher-throughput energy scans, detector readout times must be decreased to reduce measurement time overhead. Electronic gating of the sensor can eliminate the need for a physical shutter to block photons during the readout time to further simplify the measurement workflow. In the longer term, quantitative analysis of RSoXS data can benefit from sensors with energy sensitivity that can discriminate fluorescence from scattered X-rays and polarization sensitivity that can deconstruct the radiation emitted by the sample.

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