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# Advances in Tender-Energy Microspectroscopy for Synchrotron Enviromental Science

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With advances in capabilities for tender-energy microspectroscopy, there is increasing interest in the local microscale chemistry and speciation of lighter elements in environmental science, and this has subsequently led to further advances in data analysis and interpretation. These lighter elements include the nutrients **P, Mg, S, K** and **Ca**; redox-sensitive **S**; problematic environmental pollutants like **P**; important soil constituents **Si, Al, Ca**; pH-sensitive species of **Ca**; and elements like **Cl, S** and **Ca** related to sea level rise. In addition, this energy range enables access to the uniquely sensitive L and M edges of heavier elements like **U, Pb, Zr, Y,** and **Ag**.

Advances in instrumentation over the past 12 years include the prototyping of NSLS-II's TES microspectroscopy beamline at NSLS in 2013-14, followed by a new tender-energy beamline at SSRL, installation and commissioning of TES at NSLS-II in 2016-17, facility developments at CLS and elsewhere, and recent extension of XFM capabilities down into the tender range. This led to an increasing number of publications and skyrocketing demand from users in environmental science, a field that is particularly well-suited to use tender-energy microspectroscopy for characterization of heterogeneous materials.

As this activity increased, it spurred simultaneous advances in the technique itself, data collection and data analysis. *Speciation imaging*, tuning the incident beam energy to that of specific XANES features characteristic of a given oxidation state or chemical species, enables mapping of the relative distribution of different species of a given element. Advances in XANES and EXAFS data analysis, specifically applicable to this energy range, improve applicability and versatility. *Spectral feature analysis* (SFA) enables identification and quantification of different P and S species, and can do so in cases where linear combination fitting fails. Advanced SFA is particularly useful in relating microscale and bulk speciation of lighter elements in heterogeneous environmental materials.