(Invited) "Intelligent, Multiscale Microscopy: We Really CAN Have It All"

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In situ transmission electron microscopy (TEM) and electron energy-loss spectroscopy (EELS) are powerful tools for the observation of real-time materials processes. Specifically, in situ TEM is a reliable source for probing dynamic phenomena in order to gain a predictive understanding of myriad materials and use this knowledge to tailor future, improved systems. The development of radiation hard direct detection (DD) electron sensors has enabled improvements in the quality of in situ data for TEM imaging, and recently, we have demonstrated that DD provides far-reaching benefits for EELS. Specifically, the sharper point spread function and reduced pixel size of DD provides a significant improvement in combined energy resolution and field of view (FOV). Using the combined energy resolution and FOV and increased spectrum SNR offered by the DD EELS system, critical issues in both physical and biological sciences can be addressed. Additionally, dynamic ionic or defect-dependent phenomena can be quantified with the combination of in situ methods and the DD EELS system.

This talk reviews recent work with DD EELS in a wide variety of systems, including (1) in situ investigation of chemistry-property relationships in a rapidly emerging family of 2D materials, MXenes, that show for energy storage and electromagnetic interference shielding; scattering and (1) local structure evolution in high entropy alloys. These experiments enable a deeper understanding of these complex materials systems, including the first direct correlation of surface terminations and conductivity in 2D materials and an ability to tailor next generation alloys by coordination chemistry. In addition, an outlook on emerging time resolved studies and key challenges for "big data" will be presented. In particular, high-throughput data analysis and artificial intelligence methodologies with next generation detection systems yielding more data at much faster rates will be discussed.