**Instrument Highlight: ThermoFisher Spectra TEM**

March 29, 2024 | Andrew Barnum, Pinaki Mukherjee, Sara Ostrowski

Last summer, the Stanford Nano Shared Facility (SNSF) added a brand-new, state-of-the-art Scanning Transmission Electron Microscope ((S)TEM). (S)TEM is an advanced imaging technique that can “see” down to the scale of a single atom (~0.05nm) by transmitting a focused beam of high energy electrons through a very thin sample (<100nm). The new (S)TEM instrument at SNSF can detect features that are 4000x smaller than what a basic white light microscope can distinguish! As an analogy on a relative scale, the length we are resolving on the TEM is that of the size of a grain of sand relative to the earth’s diameter(1:10^10).

Many important properties of materials are determined at nanoscale or below. The applications span across diverse fields such as, semiconductor electronics, metallurgy, glass and ceramics, and biology to name a few. Here are some examples: (a) The gates in field effect transistors that are built in our processors or phones have a width ~ 5nm. (b) The strength of metal alloys can be increased significantly if atomic scale defects are introduced in them.(c) Typical size of viruses are below 50nm. If we want to study or manipulate any of these objects we need to “see” them in a TEM. In the advanced analytical TEMs we not only observe the crystal structure and morphology at atomic scale we also obtain their chemical composition and bonding properties using different spectroscopic techniques at these length scales. Some example images/spectroscopic maps at atomic resolution are provided below.

Delving into some more of the technical details, the new instrument is a ThermoFisher Spectra 300 (S)TEM featuring a monochromatic, double aberration corrected source (in other words, it has technology that can focus the electron beam to a really small size). The source can be operated at a variety of accelerating voltages, which makes the microscope adaptable for a wide range of materials and applications. Other attributes of this (S)TEM are listed below.

- Accelerating voltages at 30, 60, 80, and 300 kV
- High Brightness Schottky field emission gun (X-FEG)
- Monochromator
- Cs CETCOR/S-CORR double correctors
- Advanced STEM imaging, 4k×4k STEM data acquisition, EMPAD, 4D STEM
- SuperX energy dispersive spectroscopy (EDS) detectors
- Ceta-S camera with speed enhancement capabilities
- Gatan K3 camera for low dose imaging
- Electron energy loss spectroscopy (EELS) with dual EELS GIF continuum spectrometer
nano@stanford

- TEM, STEM, and EDS tomography with acquisition, reconstruction (Inspect3D) and analysis (Avizo) softwares
- Information Limit (TEM mode): 0.7 Å
- Probe resolution (STEM mode): 0.5 Å
- Energy resolution at 300 kV (with monochromator): 110 meV
- Energy resolution at 60 kV (with monochromator): 20 meV

For more information about the ThermoFisher Spectra 300 (S)TEM, visit the SNSF equipment webpage, ThermoFisher’s product webpage, or contact nano-temstaff@lists.stanford.edu. Training is now open for lab members with previous TEM experience.
**Figure 1:** Atomic resolution high angle annular dark field (HAADF) STEM image of a high-entropy oxide particle. The image shows the spinel crystal structure of the oxide projected along <110> direction with its octahedral and tetrahedral sites occupied by different elements. *Image Courtesy: Jihyun Baek, Prof. Xiaolin Zheng Group*

**Figure 2:** GIF showing gold (Au) particles coalescing under the electron beam. The small particle on the far left gets pulled in at the end and recrystalized on the larger particle facets. *Image courtesy: Andrew Barnum*
**Figure 3:** Atomic resolution energy dispersive x-ray spectroscopy map of Bismuth Ferrite (BiFeO3). The red and green colors represent Fe and Bi atoms respectively. The elemental maps are superimposed on the HAADF image to show the Z-contrast nature of the HAADF image. The bright dots of the HAADF image match with the position of Bi atoms. | *Image Courtesy: Kun Xu, Prof. Arun Majumdar Group*