A Cryogen-Free Microcalorimeter Spectrometer for Ultrahigh-Resolution X-ray Microanalysis

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X-ray detectors based on superconducting microcalorimeters currently represent the most attractive technology capable of <5 eV resolution for energy dispersive spectroscopy and microanalysis applications. The superior energy resolution as compared with conventional solid-state X-ray detectors enables the analysis of nanometer-scale device features, as well as quantitative analysis for the inspection, characterization, and compositional analysis of nanometer-scale contaminant particles and defects. To analyze features at this length scale, the X-ray generation volume in the sample must be nanometer scale as well. With current-generation field emission scanning electron microscopes it is possible to reduce the X-ray generation volume to a depth under 10 nanometers for high spatial resolution imaging by operating at reduced electron beam energies. At these low energies, however, the electron beam excites only low-energy elemental X-ray lines, which conventional solid-state detectors are unable to resolve owing to severe peak overlaps at these low energies.

Cryogenic microcalorimeter X-ray detectors based on superconducting transition edge sensors (TES) offer up to a roughly 60-fold improvement in energy resolution as compared with conventional detectors for energy-dispersive spectrometry. The energy resolution of state-of-the-art microcalorimeter detectors rivals the resolution of spectrometers for wavelength-dispersive spectrometry (WDS), yet microcalorimeters offer all the advantages of EDS detectors - ease of use, long-term stability, and the ability to quickly provide qualitative as well as quantitative chemical analysis.

Microcalorimeter detectors have been used to develop our MICA-1600 EDS spectrometer, based on a pulse tube cryocooler and adiabatic demagnetization refrigerator (ADR), that does not require any liquid cryogens. In this presentation, we describe the cryogenic system and automated controls that simplify the operation of the spectrometer and recent application data including qualitative/quantitative analysis and X-ray mapping/line analysis data.