MICROCALORIMETER SPECTROMETERS FOR HIGH RESOLUTION SPECTROSCOPY BETWEEN 30 AND 400 KEV

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Microcalorimeter spectrometers combine the attractive features of energy-dispersive and wavelength dispersive instruments. They are broad-band, efficient, large area, and have excellent spectral resolution. For example, we have recently developed a 256 pixel microcalorimeter spectrometer with an active area of 5 cm^2 and an average energy resolution of 53 eV FWHM at 97 keV. This collecting area is similar to a planar germanium sensor, but the resolution is more than five times better than germanium.

Transition-edge sensor (TES) microcalorimeters consist of a thin superconducting film electrically biased in the resistive transition. The absorption of a photon increases the device temperature and resistance and decreases the bias current. This current change is proportional to the deposited energy and can be detected with a Superconducting Quantum Interference Device (SQUID) ammeter. The remarkable energy sensitivity of microcalorimeters is derived from their low operating temperatures near 100 mK. In order to make these temperatures accessible to spectroscopists, we have developed a mechanically cooled adiabatic demagnetization refrigerator that operates without liquid cryogens; the only consumable is electricity.

Microcalorimeter design varies with the intended energy range of interest. The spectrometer above is optimized for the detection of X- and gamma-rays between 30 and 400 keV. To increase efficiency, photons are absorbed in a layer of 380 micron thick polycrystalline tin that is hybridized to the TES films. Using similar but smaller devices, we have obtained energy resolutions as good as 22 eV FWHM at 97 keV.

We briefly describe the application of a microcalorimeter spectrometer to the assay of nuclear materials. The spectral resolution of the instrument resolves important line overlaps that presently complicate the determination of isotopic ratios in complex mixtures of actinides encountered in the nuclear fuel cycle.

The broad-band response, simple efficiency curve, and excellent spectral resolution of microcalorimeter spectrometers also make them an attractive technology for the determination of fundamental parameters such as line positions and X-ray line widths. We illustrate this capability using a data set from a gamma-ray reference source. We also discuss complexities in the energy calibration of microcalorimeters and techniques to address this complexity.