X-Ray Detectors based on Superconducting Tunnel Junctions for Material Analysis

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Aluminum Superconducting Tunnel Junctions (Al-STJs) consist of two superconducting aluminum layers separated by a tunnel barrier. Energy deposition results in the breaking of cooper pairs, which leads to a measurable current across the barrier. To increase the quantum efficiency for X-rays, Al-STJ based detectors developed at the Technische Universität München are equipped with an additional layer of about 1.3 μm of lead, which is electrically isolated from the tunnel junction, leading to a quantum efficiency of about 50 % for an X-ray energy of 6 keV and more than 99.9 % for energies below 1 keV. The electrical isolation is required to avoid mutual influence of the superconducting band gaps of lead and aluminum. The high quantum efficiency together with the good energy resolution make these detectors interesting for material analysis.

Extensive tests have been carried out with these socalled SSP detectors (Superconducting tunnel junction and Superconducting absorber with Phononic coupling) to understand the details of the detector response. Of special importance was a measurement program performed at the Synchrotron BESSY (Berlin). The detector has been irradiated with X-rays of different energy (1 to 10 keV in steps of 1 keV), which allowed to study the linearity of the detector response and possible energy dependences of the pulse shape. A model, based on the physical processes in the different detector components, has been developed which explains the slightly energy dependent pulse shape and allows to linearize the detector response.

Most of the X-rays are absorbed in the lead absorber. However, a minor contamination from X-rays absorbed in the two electrodes or in the carrier substrate is observed. The detailed understanding of the detector helped to extract pulse shape parameters, which allow to identify these 'detector artifacts' event by event and thus remove them from the spectrum.

With this good understanding of the detector it became desirable to implement the detector into the Polaris system, an X-ray spectrometer operated at a scanning electron microscope at Infineon Technologies for material analysis.

First tests of the SSP detector in the Polaris system suffered from inadequate wirings leading to diturbances due to microphonics and unpleasantly high noise levels. However, it could be shown that this novel detector type can be used in industrial applications and provides an alternative to the TES based micro calorimeters presently used in the Polaris system. One main advantage of the SSP detectors is their capability to stand very high count rates, possibly shortening the times for material analysis substantially.