System Integration of Superconducting Tunnel Junction Detectors for Measurement of Unrevealed Material Information

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***Abstract*— The technology of superconducting tunnel junction (STJ) detectors has matured during past 20 years. Spectrometers with 100 pixels can be routinely used in analytical instruments for X-ray absorption fine structure (XAFS) spectroscopy, mass spectroscopy (MS), and scanning electron microscopy (SEM) [1, 2]. A 512-pixel system is under development for ion beam analysis of trace light elements. Scaling up to thousands is feasible with multilayer 3-dimensional structure with embedded leads. This is underway at an AIST facility called CRAVITY [3].**

Cryogenic engineering for system integration includes mounting an STJ array detector on a cryofinger that is cooled in an automated ^{3}He cryostat with twisted-pair cables connected to preamplifiers. Simultaneous parallel readout can be performed with Field-Programmable Gate Array (FPGA)-based digital signal processing. The Nb-based STJ spectrometers exhibit an energy resolution of 4-10 eV for a soft X-ray region less than 1 keV without any off-line processing. The best energy resolution is getting close to that of TES detectors. The real-time display of spectral data is often critical for material analysis. The natural linewidth of the characteristic X-rays from atoms in solids is in a range of ~15 eV, so that the STJ system can reveal X-ray emission line structure that is for nm-scale chemical state mapping.

One of the advantages of STJ is a high counting rate of ~5000 cps/pixel. This fast response is advantageous for detecting X-rays in synchrotron radiation and ion accelerator facilities; ions and neutral molecular fragments in mass spectrometry. The integrated STJ instruments have allowed us to analyze unrevealed material information such as the N dopant in SiC [1], the B additive element in heat resistant steels, the doubly charged diatomic molecular ions such as N_2^{2+}[4], and neutral molecular fragments [5]. The research fields are functional materials, structural materials, planetary science, interstellar prebiotic organic molecules, and neutrino mass.

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