Cryogenic High-Resolution X-ray Spectrometer Development for Synchrotron Science

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We are developing superconducting high-resolution energy-dispersive X-ray detectors for fluorescence-detected X-ray absorption spectroscopy. These detectors are based on superconducting Nb-Al-AlOx-Al-Nb tunnel junctions (STJ). X-rays absorbed in the top Nb film create excess charges in proportion to their energy, which diffuse into the Al trapping layer and produce a measurable current pulse as they tunnel through the AlOx barrier. Since the energy gap in superconductors is ~1000 times smaller than in semiconductors, STJ detectors can have v1000 ˜ 30 times better energy resolution than conventional Ge or Si(Li) detectors. Our STJ detectors have achieved an energy resolution below 10 eV FWHM for soft X-rays below 1 keV, and maximum count rate capabilities above 10,000 counts per second for a single pixel [1].

For STJ operation at the synchrotron, we have built a two-stage adiabatic demagnetization refrigerator (ADR) with a 40 cm long cold finger that holds the STJ at a temperature of ~0.1 K within ~15 mm of a room temperature sample in a UHV chamber (figure 1a) [2]. The ADR has a hold time of 20 hours between demagnetization cycles, and does not require pumping on the liquid helium bath. We currently use a 3 ? 3 array of 200 µm ? 200 µm STJs that covers a solid angle ? /4? ˜ 10^{-4}, and can be operated above 100,000 counts/s.

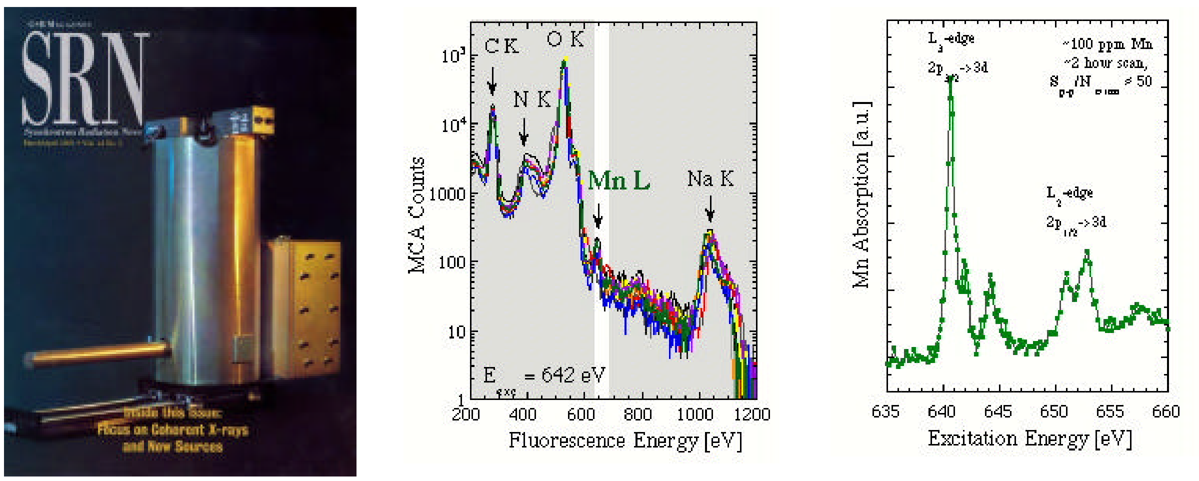

Figure 1a: Cryogenic STJ spectrometer with detector cold finger. Figure 1b: 9-Channel STJ fluorescence spectrum from a (biologically inactive) photosystem II protein (~100 ppm Mn). Figure 1c: Fluorescence-detected L-edge absorption spectrum from photosystem II

We will discuss spectrometer performance at beam line 4.0.2 at the ALS synchrotron (figure 1b) and future directions of detector development. We will also show sample applications of fluorescence-detected soft X-ray absorption spectroscopy from material science and biophysics (figure 1c).

References

[1] – M. Frank et al., Rev. Sci. Inst **69**, 25, (1998)
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