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Development of superconducting tunnel junction X-ray detector with high absorption yields utilizing silicon pixel absorber

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Superconducting tunnel junction (STJ) array detectors are routinely used for X-ray materials analysis, especially for fluorescence yield X-ray absorption spectroscopy, because of a high count rate of 500 kcps, a high energy resolution of 10 eV, and a high detection efficiency in a soft X-ray region. However, the applicable X-ray energy range is currently below 2 keV, because STJs are normally consist of thin metal films with thicknesses of a few 100 nm, which have low absorption efficiencies for high energy X-rays. In order to achieve both of a high detection efficiency and a high count rate, we are developing STJ array detectors with 400 μm thick silicon pixel absorber (SPA-STJ), which consists of silicon substrate with deep trench around each STJ pixel, to realize high detection efficiency for X-rays with energy more than 10 keV.

One hundred STJ pixels with a layer structure of Nb-Al / AlOX / Al-Nb are fabricated on a front side surface of a both side polished silicon substrate with 400 μm thick in CRAVITY (Clean Room for Analog & digital superconductiVITY) in AIST. The size of an STJ pixel is 100 μm square. The deep trench was fabricated from the back side of the substrate using the Bosch process in the NIMS Nanofabrication Platform. The trench depth is 350 μm, and the absorber size is 100 μm square. The detection efficiency is more than 95% at X-ray energy below 10 keV.

Subgap currents of the fabiricated STJs were lower than 100 nA in the 97 STJ pixels out of the 100 pixels. An SPA-STJ showed energy resolution of 150 eV FWHM for 5.9 keV Mn-K alpha line. The energy resolution can be improved by detector structure optimization in future. X-ray absorption fine structure (XAFS) spectroscopy in a range of 2 - 4 keV was performed at BL-11B in the photon factory, KEK (High Energy Accelerator Research Organization), and succeeded to acquire XAFS spectra of S-K and Cl-K edge with a concentration of less than 0.1 atomic % in a glass sample.