ED2-1-INV

Energy-Resolved Neutron Imaging using a Delay Line Current-Biased Kinetic-Inductance Detector

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Superconducting detectors are one of the most successful superconducting applications [1]. It has an advantage in high sensitivity and fast response, and has been applied to the detection of cosmic rays and single photons [2]. We have been developing a unique superconducting neutron detector, called current-biased kinetic-inductance-detector (CBKID) [3,4]. Our detector comprises *X* and *Y* superconducting Nb meander lines with Nb ground plane and a ^{10}B neutron conversion layer, which converts a neutron into two charged particles. High-energy charged particles (α particle or ^{7}Li particle) are able to create hot spots simultaneously in the *X* and *Y* meander lines, and thus, the local Cooper pair density in meander lines are reduced temporary. When a DC-bias currents are fed into the meander lines, pairs of voltage pulses are generated at hot spots and propagate toward both ends of the meander lines as electromagnetic waves. The position of the original hot spot is determined by a difference in arrival times of the two pulses at the two ends with a spatial resolution of the order of the meander repetition length for *X* and *Y* meander lines, independently. This is so-called the delay-line method, and allows us to reconstruct the two-dimensional neutron transmission image of test patterns with four signal readout lines.

CBKIDs can handle multi-hit events, and the typical signal width was a fen tens ns. Hence, we estimate the detection-rate tolerance to be as high as a few tens MHz. Therefore, energy resolved-neutron imaging is available with the combination of the time-of-flight technique in pulsed neutron sources.

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Keywords: Superconducting detector, Kinetic inductance, Neutron imaging

ED2-2-INV

Development of SEM-EDS analyzer utilizing 100-pixel superconducting-tunnel-junction array X-ray detector toward nanometer-scale elemental mapping

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An energy-dispersive X-ray spectroscopy (EDS) analyser combined with a scanning electron microscope (SEM) is suitable to obtain spatial and quantitative information on the elemental composition of a sample non-destructively. In particular, low-acceleration-voltage SEMs (LVSEMs) theoretically allow evaluating those informations of a sample with a nanometer lateral resolution [1]. However, it isn't suitable to use conventional EDS analysers such as silicon drift detectors (SDDs) for obtaining X-ray spectra from samples in LVSEMs, because emitted X-ray from samples in LVSEMs are only soft X-ray and the energy-resolving power of conventional energy-dispersive X-ray detectors is insufficient to clearly resolve such soft X-rays. On the other hand, wavelength-dispersive X-ray spectrometer (WDS) can be resolved the soft X-rays because its energy resolution is less than 10 eV. However throughput of the WDSs is very low.
In contrast, energy-dispersive X-ray detectors based on superconducting-tunnel-junctions (STJs) have simultaneously exhibited excellent energy resolution of <10 eV, relatively large detection area of >1 mm^2, and high counting rate capability of >200 kcps for soft X-rays less than 1 keV [2]. We have developed the SEM utilizing STJ array as an EDS analyzer [3], which is abbreviate as SC-SEM hereafter, in order to realize nanometer-scale elemental mapping.
Fig. shows a picture of the SC-SEM. The SC-SEM consisted of a field emission SEM and a 100-pixel STJ array X-ray detector. X-rays emitted from the sample by the electron beam were detected by the STJ array via the polycapillary X-ray lens and two X-ray windows. The enegry resolution for N-Kα of the STJ (12 eV) was about 5 times higher than that of the SDD (60 eV). The throughput for N-Kα of the STJ was about 50 times smaller than that of the SDD. In the future, by improving the X-ray optics, the throughput is expected to be increased about 10 times. The SC-SEM can perform nanometer-scale elemental mapping because the SC-SEM realizes both the high throughputs of SDDs and the excellent energy resolution of WDSs.

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Fig. Picture of the SC-SEM

Keywords: SEM-EDS, Superconducting tunnel junction, X-ray, nanometer-scale

ED2-3-INV

HTS-SQUID module with high tolerance to magnetic field and its application

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We developed an HTS-SQUID module applicable to various systems [1]. The SQUID module was designed to connect an external pickup coil suitable for each application. The hermetically encapsulated SQUID module includes an HTS planar gradiometer and an HTS multi-turn input coil, which are fabricated on separate substrates and stacked together. Since the SQUID module can be magnetically shielded to avoid exposure to external magnetic field, a stable feedback operation is possible under severe conditions such as strong excitation field and/or motion in the Earth's field. The SQUID modules have been used in a bioassay system based on ac magnetic susceptibility measurement [2], moisture content measurements of rice kernels and soil utilizing diamagnetic characteristics of water [3], magnetic particle imaging [4, 5] and so on. Recently, we have developed a three-channel SQUID eddy current testing (ECT) system on a hand cart for detection of a fatigue crack in a steel deck plate under an asphalt pavement used in an expressway bridge [6]. We could demonstrate a stable long-time operation of the ECT system on an expressway bridge in an urban area during the daytime and acquisition of correct data corresponding to some structural features of the expressway bridge.

A part of this work was supported by the "Cross-ministerial Strategic Innovation Promotion Program" funded by JST.

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Keywords: SQUID, Nondestructive evaluation, Biological diagnosis , Eddy current testing

ED2-4

Development of scanning SQUID microscope system and its applications on geological samples: A case study on marine ferromanganese crust

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We present developments and applications of a high-resolution scanning superconducting quantum interference device (SQUID) microscope for imaging the magnetic field of geological samples at room temperature. The scanning SQUID microscope (SSM) uses a hollow-structured cryostat. A directly coupled low-temperature SQUID with a 200 μm × 200 μm pickup loop, which is mounted on a sapphire conical rod, is separated from room temperature and atmospheric pressure by a thin sapphire window. Precise and repeatable adjustment of the vacuum gap between the SQUID and the sapphire window is performed by rotating a micrometer spindle connected to the sapphire rod through the hollow portion of the cryostat. When the SQUID was operated in superconductive shield with the low-drift FLL, we obtained a field noise of 1.1 pT/√Hz at 1 Hz. While the typical environmental noise of the system operated within the two layered PC permalloy is about 50 pT. Environmental noise is reduced by subtracting a signal from a reference SQUID that is placed inside a cryostat. A geological thin section is placed on top of a non-magnetic sample holder with an XYZ stage that enables scanning of an area of 100 mm × 100 mm. The minimum achievable sensor-to-sample distance is measured as ~200 μm. The new instrument is a powerful tool that could be used in various geological applications.

A successful application of the SSM to a marine ferromanganese crust will be shown. Marine ferromanganese crusts are marine ore deposits rich in rare earth elements. They grow slowly and record long-term deep-sea environmental changes. We conducted magnetic field mapping with the SSM on a crust sample from northwestern Pacific and found beautiful stripes in the magnetic field images. It is known that the Earth's magnetic field experienced polarity changes in the past. Because the major polarity changes were studied well and the ages were determined with the other methods, we could make use of the boundaries of magnetic field changes to estimate an age of a deposition (a technique known as "magnetostratigraphy"). By correlating the obtained profiles with a standard geomagnetic polarity timescale, we obtained an average growth rate of several mm/Ma, which is consistent with that obtained by radiometric dating.

Keywords: Scanning SQUID microscope, magnetic field imaging, geological applications, marine ferromangense crust