Possibilities for Thick, Simple-Structure X-Ray Detectors Operated by Peltier Cooling and One High Voltage Bias

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Abstract

To detect a trace of hazardous elements or radioactive elements in foods, soil, and human bodies, the energies and counts of X-ray fluorescence photons emitted from those elements in them are measured by X-ray detectors with high energy resolution. In commercial silicon drift detectors (SDD) with Si thickness of approximately 300 or 500 μm, however, the absorption of cadmium X-ray fluorescence (energy: 23.1 keV) is approximately 19% or 30%. On the other hand, its absorption becomes approximately 65% or 76% in 1500- or 2000-μm-thick Si. In order for a lot of people to easily use X-ray fluorescence spectrometers on site, the cost of X-ray detectors should be low and the detectors should be transportable. Therefore, we have proposed simple-structure Si X-ray detectors with thicker high-resistivity Si substrates, which are able to be operated at reasonably low negative bias and cooled by Peltier cooling. Since the device structures are much simpler compared with commercial SDD and the detectors require only one high voltage, the cost of the X-ray detection system can be reduced very much. We have simulated the electric potential distribution within the proposed detectors and carried out fundamental experiments towards the realization of the detectors. In the early stages of experiments, an energy resolution of 145 eV at 5.9 keV is measured from the ^{55}Fe source at a peaking time of 5 μs and temperature of -35 ^{o}C with the proposed structure using a 625-μm-thick and 10-kΩ·cm Si substrate. Using a 100-μm-diameter pinhole and moving the detector in 100-μm increments, the active area is mapped out, and is found to be approximately 18 mm^2.

Biography

Hideharu Matsuura received his BS, MS, and Dr. Degrees in electronic engineering from Kyoto University, Japan, in 1980, 1982, and 1994, respectively. In 1979-82, he studied the electrical properties of metal-insulator-semiconductor solar cells using Mg and p-type Si. In 1982, he joined Electrotechnical Laboratory in Tsukuba, Japan, where he engaged in the field of hydrogenated amorphous silicon, with emphasis on the electrical properties of amorphous/crystalline heterojunctions. He proposed a current-transport mechanism (MTCE: Multistep Tunneling Capture-Emission model) of a-Si:H/c-Si heterojunctions, and developed a method (HMCS: Heterojunction-Monitored Capacitance Spectroscopy) to determine the energy distribution of localized states in the energy bandgap for highly resistive amorphous semiconductors such as undoped a-Si:H, from the transient capacitance of the amorphous/crystalline heterojunctions. In 1995, he joined Osaka Electro-Communication University, and has been engaged in the developments of methods to determine the energy levels and densities of impurities or defects in semiconductors. He proposed and has been developing two types of graphical peak analysis methods, i.e., FCCS (Free Carrier Concentration Spectroscopy) and DCTS (Discharge Current Transient Spectroscopy). Using DCTS, especially, he has investigated the energy levels and densities of defects in high-resistivity and semi-insulating semiconductors that are used as a substrate of X-ray detectors operating at room temperatures. Since 1997, furthermore, he has engaged in the development of X-ray detectors for X-ray fluorescence spectrometers, especially, the development of low-cost and transportable X-ray detectors. He has proposed verious simple-structure X-ray detectors operated by Peltier cooling and one high voltage bias, which were applied for Japan and US patents on.