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Characterisation of the spectroscopic properties of p-type Si sensors for X-ray spectroscopy

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To meet the requirements of next-generation light sources, STFC has begun work on a new generation of detector technology, capable of operating at MHz frame rates. Although readout electronics are key components of these systems, the choice of sensor material is critical, with high-density semiconductors such as CdZnTe (CZT) required for higher-energy operation. Whilst high-Z materials are commonly used to measure radiation >20keV, the lower electron-hole-pair-generation energy of Si (3.62eV cf. 4.67eV for CZT) offers the potential of improved spectral resolution at lower energies. However, unlike most Si sensors, these compound semiconductors are predominately electron-readout materials. The advantage of p-type-Si sensors is that they are electron readout, meaning a single electron-sensitive readout chip may be used in the measurement of both low- and high-energy X-rays; previously, detector groups were required to design separate versions of an application-specific integrated circuit (ASIC) or operate at sub-optimal performance. Crucially, this will enable a single ASIC technology to have applications across multiple instruments at these light sources.

In this paper, results relating to the characterisation of p-type-Si sensors, each pixelated on a 76×80 array of 300- or 500μm-thick material, and bonded to the STFC HEXITEC ASIC (Veale et al. 2018), are presented. Current-voltage measurements show low <165 pA mm^{-2} leakage currents up to an applied bias of -120V for 500μm-thick devices, and alongside excellent charge-transport properties this results in high-resolution spectroscopic performance. Results demonstrate highly-uniform room-temperature spectroscopic resolution can be obtained across the investigated energy range with average FWHM of <0.8keV measured at 13.81keV. Results are presented alongside studies into the temporal and temperature-based stability of such devices, and the effect of applied bias on energy resolution and charge sharing.

The results presented are highly promising and suggest p-type Si may be used alongside high-Z sensors for X-ray Imaging at future light sources.

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