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INDet: Lessons Learnt from Boron-coated 3-D Silicon Detector Production

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Due to their lack of charge, low-energy neutrons are not detectable in typical semiconductors often applied to radiation detection, and instead detectors use expensive or dangerous gases (e.g., 3He, BF3) in bulky, immobile devices. Using a neutron-sensitive material however, silicon can be used to indirectly observe neutrons via detection of decay products. The INDet (Improved efficiency for Neutron DETection) project used deep reactive ion etching to produce a 3-D surface on silicon which was subsequently coated with boron carbide via chemical vapour deposition (CVD). By making use of the ^{10}B(n, ^{11}B*) capture reaction, the spontaneous fission of the excited 11B nucleus into two charged decay products (α and ^{7}Li) can be used as a signature for a neutron event by detecting either product in the silicon.

3-D neutron detectors have been created previously, but performance has been limited due to lack of optimisation in the microstructures, thick inactive layers at the silicon-converter interface, and non-conformal deposition of the neutron converter. INDet aimed to overcome these issues using atomic layer deposition of an aluminium oxide passivation layer, a new CVD process, and shape optimisation. Various geometries, with different structure shape, size, depth and pitch, were produced and tested, with these dimensions optimised using the NCrystal library with the Geant4 framework.

Several challenges have been uncovered during the production phase of the INDet project. In particular, the CVD process takes place at a high temperature of over 400˚C in a relatively dirty environment, affecting the properties of the silicon and charge collection. Simulations have attempted to reproduce the observed spectra from PSI, Switzerland, which lack clear peaks from heavy particles.

Initial tests at PSI led to some changes in production, with several sensors created using sputtered B_4C deposition. These were tested in-beam at BNC, Hungary, and show promising early results seen in figure 1. Multiple angle measurements have been taken at this facility, and the effect of incident angle on neutron detection will be shown.

This presentation will discuss the neutron detection efficiency and results from characterisation. This will focus on the outcome of tests at neutron facilities, lessons learnt from the manufacture process, and prospects for future development with these devices, within the context of existing work done using coated silicon sensors for neutron detection. These outcomes will be contrasted with the expected performance, presented at the 23^{rd} International Workshop on Radiation Imaging Detectors.

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