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Silicon carbide/graphene – the neutron-sensitive semiconductor technology of the future

Semiconductor detectors for ionizing radiation (X- and gamma-rays, electrons, protons, alpha particles, heavy ions) are employed extensively for spectrometry, dosimetry and imaging in many fields: from fundamental scientific research to medical applications, homeland security, material analysis and industrial applications. Many of these applications have increasingly demanding requirements on the detector devices, including high energy resolution, low power consumption, low-noise room temperature operation, structural stability, and radiation hardness to name only a few.

It is clear that the Si-based device technology of today cannot meet these criteria. This creates a desperate need for novel semiconductor materials, innovative device designs and advanced manufacturing processes across many applications.

A noticeable trend in functional materials is to turn towards 2D materials. A very promising concept are detectors based on silicon carbide/graphene. Compared to everyday silicon, silicon carbide (SiC) has lower noise levels at room temperature. Furthermore, it is intrinsically more resistant to radiation damage due to its stronger-bound cristal lattice. This physical strength of SiC also allows for ultra-thin membrane detectors that can be used in special applications such as living cell radiology and even intelligent vacuum windows. By depositing graphene layers into etched structures on the SiC, a monolithic material which combines the radiation resistance of SiC with the high electron conductivity of graphene may be created.

Further, SiC offers exciting possibilities in a field where the applications of semiconductor detectors are essentially unexplored: the detection of neutrons. Being uncharged, neutrons are detected only indirectly, e.g. via nuclear reactions in a converter material (for low-energy or "thermal" neutrons) or via recoil reactions (for high-energy or fast neutrons). In SiC, neutrons recoiling from the carbon nucleus yield a very distinct signature. By depositing moderator or converter materials such as polyethylene or 10B into structures on the SiC, this sensitivity can be increased and extended to thermal neutrons.

Thin, low-noise, radiation-hard, and mechanically stable semiconductor detectors capable of detecting a wide energy-range of neutrons as well as ionizing radiation are clearly invaluable for future scientific instruments, whether it is the final instrumentation suite of ESS or the next-generation of tracking detectors in particle physics experiments. With the existing experience and infrastructure for semiconductor development and neutron detection, and the established and ongoing collaboration with ESS and industrial partners of ACREO and Graphensic, the Physics Department at Lund University is the place where SiC can be established as the go-to semiconductor technology of 2025 in science.

Summary

Author: PERREY, Hanno (Lund University)

Presenter: PERREY, Hanno (Lund University)