One-Dimensional Nanostructures for Neutron Detection

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ABSTRACT

Neutrons represent the fundamental radiation signal that may be used as the observable in controlling various nuclear science and engineering applications. For example, this includes power monitoring and control in nuclear reactors, safeguards and illicit materials detection, process monitoring during nuclear fuel manufacturing and waste processing, and the general dosimetry of a neutron field. Frequently, the species to detect are thermal neutrons. In this case, the detection process proceeds by converting the neuron (through a nuclear reaction) into a charged particle that is stopped within the volume of a given material. The most prevalent of neutron detectors has so far been dependent on using gas detection media. This proposal aims at the development of advanced and novel solid state detector technology that is capable of providing a solution to the technical problem of detecting neutrons compactly, accurately and efficiently.

Basically there are two types of semiconductor neutron detectors based on: 1) indirect conversion (i.e., thin-film coated or conversion layer) and 2) direct conversion (i.e., solid form). For indirect conversion scheme, a thin film of a neutron-capture agent (converter) is placed in intimate contact with a semiconductor (accumulator) so that the scattering or reaction capture product(s) (i.e., moderate-energy ions) may create electron-hole (e–h) pairs in the adjacent semiconductor. In contrast, for direct conversion scheme, the neutron-capture agent and semiconductor are the same, so that nearly all of the energy of the charged particle reaction products may be or is available for transduction. Advancing both direct- and indirect-conversion techniques, in the context of improving spatial, temporal and/or energy resolution, requires simultaneously maximizing neutron stopping, e–h pair production, and e–h pair separation and sweepout, while suppressing nonsignal carriers and trapping/recombination.

In this proposal, we propose to develop a novel direct-conversion neutron detector based on $B_xC_yN_z$ nanotubes. The research program is divided into four interrelated tasks: • Detector materials optimization using electronic structure simulations. • Fabrication and characterization of high-efficiency neutron detectors based on $B_xC_yN_z$ nanotubes; • Evaluation of detector performance at the NCSU PULSTAR reactor;• Multiscale modeling of electric properties of $B_xC_yN_z$ nanotube as functions of its chemical composition, and optimization of detector performance using a combination of experiments and simulations.

The proposed research spans nanomaterial synthesis and characterization, instrumentation, advanced modeling/simulation and nuclear testing. This state-of-the-art program will create opportunities for students in these diverse fields to link their skills to a key Nuclear Engineering challenge, and thereby increase the pool of talented scientists and engineers that enter the nuclear industry. Finally, the makeup of this team includes two junior faculty members. As such, this program will engage early career researchers and actively address the need to mentor a new and sustainable generation of Nuclear Engineering educators and researchers.