NOBLE-GAS-EXCIMER DETECTORS OF SLOW NEUTRONS

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of priority of U.S. Provisional Patent Application 61/429,207, filed Jan. 3, 2011, which is hereby incorporated by reference in its entirety.

STATEMENT OF FEDERAL RIGHTS

[0002] This work was funded by the National Institute of Standards and Technology (NIST) of the United States Department of Commerce.

FIELD OF THE INVENTION

[0003] The present invention generally relates to the detection of radiation and, more particularly, is concerned with detection and measurement of slow neutrons.

BACKGROUND OF THE INVENTION

[0004] Mechanisms for detecting neutrons in matter are generally based on indirect methods. Neutrons are generally detected by the signatures they produce through interactions with surrounding material. Such interactions include elastic scattering producing a recoiling nucleus, inelastic scattering producing an excited nucleus, or absorption with transmutation of the resulting nucleus. Most detection approaches rely on detecting the various reaction products of such interactions.

[0005] In one type of neutron interaction with matter, high-energy neutrons are scattered by a nucleus, transferring some of the kinetic energy of the neutrons to the nucleus. If enough energy is transferred, the recoiling nucleus ionizes the material surrounding the point of interaction. Since the maximum transfer of energy occurs when the mass of the atom with which the neutron collides is comparable to the neutron mass, hydrogenous materials are often the preferred medium for such detectors. In another type of neutron interaction with matter, low-energy ("slow") neutrons react with surrounding absorber materials to produce absorption products, such as protons, alpha particles, gamma rays, and fission fragments. Typical absorber materials used in this type of detection have high cross sections for absorption of neutrons, and include Helium-3 (^{3}He), Lithium-6 (^{6}Li), Boron-10 (^{10}B), and Uranium-235 (^{235}U). Each of these reacts with neutrons to produce high-energy ionized particles that can be detected by different means.

[0006] Detectors employing either target nuclei or nuclear reactions use solid, liquid, or gas-filled detection media. A majority of neutron detectors in use today are gas-filled proportional counters, and in particular, either $^{10}BF_3$ or ^{3}He gas proportional tubes.

[0007] Because slow neutrons have insufficient energy to ionize materials directly, a nucleus with high neutron absorption cross-section is added to gas-filled detectors to facilitate detection. Nuclei commonly used for this purpose are ^{10}B and ^{3}He. In gas-filled proportional neutron detectors using ^{3}He as the fill gas, the neutron reacts with the ^{3}He nucleus resulting in the production of a triton (the nucleus of tritium, ^{3}H) and a proton. The triton and the proton share the reaction energy of 765-keV (kilo-electron volts). These energetic particles generate electrons by ionizing collisions with fill-gas atoms. The electrons are accelerated by a high voltage (1300 to 2000 volts) maintained in the proportional counter, and this results in an electrical discharge that is detected as an electrical signal. In gas-filled proportional neutron detectors using BF_3 as the fill gas, absorption of a neutron by ^{10}B results in the production of ^{4}He and ^{7}Li, with 2310 keV shared between them. The ^{7}Li is left in an excited state with 93% probability from which it subsequently decays by emitting a 480-keV gamma ray. The energetic products of the neutron reaction generate an electrical discharge in the fill gas by a mechanism similar to that of the ^{3}He proportional counter.

[0008] Many instruments in the field use BF_3, but because BF_3 is toxic and corrosive, the use of ^{3}He has traditionally been preferred. ^{3}He proportional tube detectors have higher efficiencies, with none of the disadvantages of BF_3. All proportional detectors require high voltages to produce electrical discharges, are susceptible to microphonic noise, and have a dead time of approximately 1 microsecond that limits their maximum counting rate. The tubes also require an ultra-pure quench gas (usually CO_2) to achieve a sufficient signal-to-noise ratio, and suffer from wall effects when particle energy is lost by absorption at the tube walls.

[0009] Despite the above disadvantages, ^{3}He proportional tube detectors are effective and are the preferred choice in many types of operations, including oil well logging and medical applications such as diagnosis of chronic obstructive pulmonary diseases. The supply of ^{3}He is limited, and therefore, large-scale deployment of ^{3}He is not currently possible. Alternatives to ^{3}He-based neutron detection are necessary to meet the needs for highly sensitive neutron detectors having neutron/gamma discrimination similar to those of ^{3}He detectors. Such detectors are required for safeguarding nuclear materials and weapons, treaty verification, anti-proliferation, recovery of lost military payloads, surveillance at border and port facilities, transportation systems and other places through which large amounts of material pass on a regular basis.

[0010] Another class of conventional neutron detectors is scintillation-based detectors. Such detectors are based on photon emission resulting from the interaction of energetic charged nuclei released from collisions between incident neutrons and atomic nuclei with scintillation materials. Scintillation devices are typically coupled to a photon detector that generates an analog electrical signal based on the production of the light within the scintillation material. The photon detector analog signal is a measure of the incident neutron irradiation. To enhance the efficiencies of the scintillators, neutron sensitive materials are typically doped with ^{6}Li and ^{10}B. However, neutron/gamma ray discrimination remains an issue for scintillators, and must be resolved in order for scintillators to becoming practical for ^{3}He replacement.

[0011] Another class of neutron detectors includes solid state neutron detection devices based on thin films of ^{10}B or ^{6}Li coated onto silicon and other substrates. Losses in the substrate limit the ultimate efficiency of multi-layer detectors of this type.

[0012] A need exists for highly sensitive neutron detectors having neutron/gamma discrimination similar to ^{3}He detectors.

SUMMARY OF THE INVENTION

[0013] The present invention provides a highly sensitive neutron detectors having neutron/gamma discrimination