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# Microstructured silicon neutron detectors for security applications

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**Neutron detection and the REWARD Project**

Neutron detection is essential to intercept and find out the location of radiological threats like radioactive sources or special nuclear materials (SNM) that could be used to build improvised nuclear weapons or dirty bombs.
To enhance nuclear security, the FP7 European project Real Time Wide Area Radiation Surveillance System (REWARD) has been developed. This project proposes a novel mobile system for wide-area radiation surveillance in real-time. The system is based on the integration of new miniaturized solid-state radiation sensors: a (Cd,Zn)Te detector for gamma radiation and a high efficiency neutron detector based on perforated neutron silicon detectors.

**High efficiency silicon neutron detector**

Neutrons do not interact in matter by ionization, so they are not easily detected by silicon detectors, whose working principle is based in the creation of electron-hole pairs. However, a silicon diode covered with a neutron-sensitive conversion layer can be used as an active neutron detector. If the reaction products, photons or charged particles, reach the silicon sensitive volume with enough energy and create a signal over the minimum threshold they will be detected.
The REWARD project uses a novel 3D silicon detector as the base detector. The device is fabricated on a wafer with active thickness of 300 μm. High efficiency is achieved with sinusoidal or hexagonal channels (150 μm deep and 25 μm wide), etched in the silicon and filled with converter material, increasing the surface area of the converter in contact with the sensitive semiconductor volume.
The converter material used in these sensors is powdered $^{6}$LiF who has a cross section of 942 barns for the capture of thermal neutrons (0.025 eV) and give the following reaction:

$$n +^{6} LiF \rightarrow \alpha(2.05MeV) +^{3} H(2.73MeV)$$

The sensors were designed at IMB-CNM and fully fabricated at the Institute's clean room. Their active area is 1.0 cm$^2$ and the operating voltage is only 3 V.

**Geant4 simulations**

The Monte-Carlo code Geant4 v.9.6.1 was used to simulate both sinusoidal and hexagonal geometries with various $^{6}$LiF densities. The simulations consists in a monoenergetic broad thermal (0.025 eV) neutron beam normally incident on the surface of the detector with a total of $10^6$ neutrons per run. The statistical relative uncertainties were less than 0.1%. The simulations allow us to study the dependence of the neutron detection efficiency with the geometrical parameters.

**Thermal neutron tests at IST/ITN**

In order to study the response to neutrons of the detectors, it is necessary to test them with a neutron beam as monoenergetic and well-known as possible. The nuclear reactor of the Instituto Tecnológico e Nuclear in Lisbon was used for such aim. The intrinsic detection efficiency of the detectors for thermal neutrons and their gamma sensitivity as a function of the energy threshold were measured.

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