Conception et modélisation de collectrons innovants pour la mesure de la composante rapide des flux de neutrons en réacteur

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Abstract

Selective on-line measurement of fast neutron flux in a water-pool type reactor environment remains a challenge for in-core measurements. Self-powered neutron or gamma detectors (SPDs) are detectors used for on-line monitoring of thermal neutron and/or gamma ray fluxes. Operating without high voltage, their use is suitable for high flux levels and thus for in-core measurements. SPDs are mainly coaxial and consist of three main components: an emitter, an insulator and a sheath. Provided a wise choice of these three materials, the SPD could focus on interactions with particles of interest (neutrons or gamma). To meet the need for on-line fast neutron measurements in material testing reactors (MTR), this thesis aims to develop a new Self-Powered Neutron Detector (SPND) selective to fast neutrons flux. The design of such a detector with significant fast neutron contribution to the signal means reducing thermal neutron and gamma contributions to a minimum level in radiation environments where fast neutrons are the least flux. Prototype development and reactor tests of this new selective self-powered neutron detector are the main objectives of this PhD thesis work. Despite several publications in literature, some theoretical aspects of signal generation in SPDs remain incomplete, especially when it comes to small contributions. Also within the framework of this PhD thesis, and with the aim of a better understanding of SPNDs operation, all mechanisms affecting the current generation are studied by means of an electron beam experiment, helping for a better understanding of the behavior for insulation part of the sensor. Solving continuity equation systems and applying the Shockley-Ramo theorem to the SPD case is also part of this study. A complete understanding of the SPD signal generation is required in the development of new detectors. The main effort in designing a SPND sensitive and selective to fast neutrons lies in the choice of materials. In fact, thermal neutron cross-sections for common materials are much larger than fast neutron cross-sections. In reactor environment, gamma rays are also present in significant proportions. Gamma ray interactions with detector materials can also produce a significant signal compared to fast neutron interactions. Consequently, the SPND materials must maximize the fast neutron contribution. Fast neutron interactions have to be predominant in the emitter to induce a sufficiently large signal for measurement, meanwhile insulator and sheath materials shall produce a very limited signal. The estimation of the SPND current contributions is possible by means of numerical modelling and calculations. This led to the definition of a prototype of a fast neutron selective SPND. Prototypes of this innovative detector have been manufactured and tested at the Slovenian TRIGA Mark II research reactor (Jožef Stefan Institute), providing a proof of concept for the proposed specific emitter material.