Recent improvements in the nuclear reactor dosimetry techniques for the epithermal neutron flux measurement

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Reactor dosimetry techniques are commonly used for the characterization of neutron spectra (both shape and level) encountered in nuclear reactors. One can derive neutron flux and fluences integrated on a specific energy domain such as thermal, epithermal or fast flux, from radioactivity measurements of a set of dedicated irradiated dosimeters. Neutron flux and fluences are calculated from activity measurements using Bateman equation, irradiation history and nuclear data (cross sections), neutron modelling codes and unfolding codes if necessary. For thermal and low epithermal energies (E<1keV) flux and fast flux (E>1MeV), nuclear reactions are numerous and well known as for example radiative captures (n,γ) and thermal fission for the first domain and inelastic (n,n'), (n,p) and (n,α) reactions for high energies. In addition, fission reactions can also give information, depending of the target isotope, either on the thermal and low energy epithermal neutrons, where resonance peaks of the cross section contribute significantly, or on the high energy epithermal and fast neutrons. Unfortunately there are no dominant reactions identified for the medium epithermal spectrum part (1keV-1MeV) that could give de-correlated information from thermal or fast energy contributions. The characterization of the intermediate energy region, in particular for neutron spectrum shape, relies then mainly on neutron modelling codes, such as TRIPOLI4®, and presents higher uncertainties than the other zones of the spectrum. This is an issue for reactor dosimetry, knowing that epithermal area constitutes the main neutron population in GEN-IV reactors and is also of first importance for material embrittlement evaluation of both internals and reactor vessel (displacement per atoms).

Therefore, several studies have been launched in the recent years at the Cadarache CEA center in order to enhance reactor dosimetry techniques for the epithermal neutron flux measurement in nuclear reactors. The first aspect explored concerns the upgrade of activity measurement techniques of the niobium and rhodium dosimeters which are X-ray emitters. Indeed, both of them have relevant (n,n') reactions for characterization of the upper part of the epithermal spectrum (E>700keV) but their activities measurement presents relatively high uncertainties. In parallel with the improvement of these measurement techniques, nuclear data are under study for lowering their associated uncertainties. The second aspect consists in searching new reactions or developing new irradiation and measurement techniques for having information integrated on the 1keV – 1MeV domain. The zirconium dosimeter has been identified as a good candidate for this purpose and a new measurement process has been developed.

Besides, studies have been performed concerning the ^{117}Sn(n,n')^{117m}Sn reaction for upper neutron energy domain (E>300keV) as well as the optimization of the neutron filter used during irradiation to de-correlate thermal neutrons from low energy epithermal neutrons.

After a synthetic review of the reactor dosimetry principle and issues concerning epithermal neutron spectrum, this paper will present the status of the different improvements listed above. Gains and limitations associated to these new techniques are then discussed and prospects about futures studies are listed.