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#4-165 A step-by-step approach to validate a new thin-film deposited heating element integrated into a calorimeter from laboratory to irradiation conditions in the JSI TRIGA reactor

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The intense mixed neutron and photon fluxes found in nuclear environments, such as research reactors, lead to energy deposition within the material. This energy deposition is called absorbed dose rate or nuclear heating rate in the case of extreme conditions. This latter quantity is a key parameter for the design and interpretation of the experiments, conducted using major facilities such as Material Testing Reactor (MTR), for safety and security reactor operation, optimization of fuel and radioactive waste as well as testing new concepts of reactor.

Due to the aging of the major research facilities, particularly the MTRs, the Jules Horowitz Reactor is currently under construction at the CEA Cadarache center in the south of France. It will produce extreme and harsh conditions: high fast neutron flux of 5.5x1014 n/(cm^2.s) (from 1 MeV) leading to a high accelerated aging (up to 16 dpa/year) and a high absorbed dose rate (up to 20 W/g in aluminum). These unequalled conditions in Europe, launched new collaborative research topics in 2009 between Aix-Marseille University and the CEA thanks to the joint laboratory LIMMEX - Laboratory for Instrumentation and Measurement in Extreme Environments) and its IN-CORE program (Instrumentation for Nuclear Radiations and Calorimetry online in REactor).

One of the objectives is to develop and design innovative sensors and measurement methods dedicated to the on-line nuclear heating rate quantification using non-adiabatic calorimeters. The associated challenge is to increase the measurement range (from very low to high nuclear heating rate values), while working on the miniaturization of the calorimeters, the optimization of the metrological performances (sensitivity, linearity, response time, etc.), the development of new calibration and measurement methods and the measurement of the associated thermal properties as a function of the temperature.

Consequently, a new research program within the framework of the LIMMEX laboratory, called MICRO-CALOR, began in 2020 to design and study miniaturized single-cell calorimeter integrating new thin-film heating element (patented by AMU and the CEA), under laboratory and real conditions.

This paper will present a step-by-step approach to study a new thin-film deposited heating element integrated in a CALORRE single-cell calorimeter. This approach is realized from the design of this thin-film heating element to its characterization under laboratory conditions and under irradiation conditions in the dry Triangular Irradiation Channel (TIC) of the JSI TRIGA reactor.

The first part of the paper will briefly present the CALORRE single-cell calorimeter.

The second part will focus on the new thin-film heating element. This part will describe its design and fabrication achieved using the serigraphy technique. Then, its chemical, dimensional, electrical, and thermal characterizations out-of-calorimeter will be presented. Finally, the metrological characteristics of the calorimeter integrating this new heating element will be detailed in the case of the calorimeter calibration by Joule effect under laboratory conditions (sensitivity, linearity, range, reproducibility, response time, and maximum temperature obtained).

The last part will present the irradiation inside the dry Triangular Irradiation Channel (TIC) of the JSI TRIGA reactor at the median plane of the fuel. Firstly, the JSI TRIGA reactor core conditions and the TIC channel as well as the nuclear-hardened CALORRE integrating the new heating element will be detailed. Secondly,

the out-of-flux calibration curves obtained by using this heating element before and after irradiation will be presented to confirm the stability of the sensor. Finally, the qualification and the validation of the new heating element under real conditions and the nuclear heating rate measurement as a function of the reactor power (from 12.5 kW to 250 kW) thanks to two measurement methods (one based on out-of-flux calibration curves and the other one using the heating element during the reactor operation) will be shown and discussed.

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