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#07-108 UO2 thermal diffusivity measurement with laser techniques

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The knowledge of the thermal conductivity of nuclear fuel and its evolution as a function of temperature and burn up is a major challenge in the context of the evaluation and understanding of irradiated fuel performances in current reactors. It is also the case for the development and qualification of fuel for future reactors. Indeed, numerical simulations of the fuel behaviour under various conditions require the accurate knowledge of thermal conductivity over a wide range of temperature (from 293 K to melting point temperature) but also at the scale of few tens of micrometers to take into account the microstructural effects on the thermomechanical evolution of the fuel in normal or incidental irradiation conditions. For example, the decrease of thermal conductivity involves an increase of the fuel pellet temperature, which can generate thermal expansions as well as cracking of the fuel due to internal stresses resulting from the radial thermal gradient. Thermochemical equilibria within the pellet, and hence fission product release, may also be affected.

The laboratory reference method can deduce the thermal conductivity from a thermal diffusivity measurement. One of the most common and non-intrusive method is the laser flash method. This technique is based on a laser-flash excitation and infrared thermography non-contact measurement of the thermal response of a studied sample. The sample can be heated to different temperatures (for instance with lasers) to determine the dependence of thermal conductivity on temperature. The thermal diffusivity measurements obtained with this technique present typically millimeter spatial resolution. Another method is the photoreflectance microscopy, based on the measurement and analysis of the periodic temperature increase induced by the absorption of an intensity modulated laser beam ("pump"beam). By detecting the thermally induced reflection coefficient variations with the help of a secondary continuous laser beam ("probe"beam), the temperature increase at the sample surface is measured as a function of time. Unlike laser flash method, this technique has a micrometric spatial resolution. A laser method with intermediate spatial resolution (few tens of microns) is the Infrared Microscopy technique, based on the detection, by means of infrared thermography, of the surface sample temperature rise distribution induced by the absorption of an intensity-modulated focused laser beam. All of these approaches, using laser, allow reaching thermal diffusivity measurements for temperatures up to at least 3000 K.

The potential of each of these techniques in the context of the determination of the fuel thermal conductivity will be discussed. Furthermore, the experimental bench being developed at CEA Cadarache, implementing laser techniques to obtain thermal conductivity, from thermal diffusivity measurements, at different scales of interest and for different range of temperature will be presented. The aims of the development of this new experimental set-up in a "test"glove box and the associated methodology are to assess the potential of these techniques by applying them first on non-irradiated UO2 or model materials before its transposition in a hot cell for measurements on irradiated fuels.

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