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# Thermal Diffusivity of $UO_2$ up to the Melting Point

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**Abstract**

The thermal diffusivity of uranium dioxide was measured from 500 to 3060 K with two different set-ups, both based on the laser-flash technique. Above 1600 K the measurements were performed with an advanced laser-flash technique, which was slightly improved in comparison with a former work. In the temperature range 500 to 2000 K the thermal diffusivity is decreasing, then relatively constant up to 2700 K, and tends to increase by approaching the melting point. The measurements of the thermal diffusivity in the vicinity of the melting point are possible under certain conditions, and are discussed in this paper.

**Keywords**: Uranium dioxide, Laser heating, Thermal diffusivity, Laser-Flash, Nuclear Fuel

## 1. Introduction

Uranium dioxide is certainly one of the most studied nuclear materials because it is the fuel for almost all nuclear reactors worldwide. Consequently the investigation of its thermophysical properties in a wide range of conditions from normal operation to off-normal and severe accidents is of prime importance for the nuclear industry. Particularly the study under extreme temperature conditions occurring during incidental and accidental conditions became necessary at the earliest after the Three Mile Island and Chernobyl accidents, and has been brought back to attention by the Fukushima accident.

A key property is the thermal conductivity, which describes the capability of a material to transport the heat. Direct measurements of the thermal conductivity at high temperatures are very difficult. One of the direct methods is the radial heat flow technique used by some research groups [1, 2], which is unfortunately very difficult to implement for temperatures higher than 2500 K. Another possibility is to obtain the thermal conductivity from the product of the specific heat, $C_p$, the thermal diffusivity, $\alpha$, and the density, $\rho$. The so-called flash method is the most used technique for thermal diffusivity measurements. That technique developed by Parker et al. [3] in the early 1960s is quite old and was improved in the course of the time significantly [4]. One of the biggest improvements is the use of a laser beam to produce the flash.

In our laboratory the laser flash method has been employed in order to measure the thermal diffusivity and specific heat of irradiated nuclear fuels [5] with the so-called LAF (laser-flash) apparatus, and on non-irradiated samples at very high temperatures [6] with the CLASH (continuous wave laser-heating) apparatus. The LAF device is placed in an $\alpha$[1]-tight glove-box surrounded by a lead shielding for protection against gamma radiations. In this equipment the sample is heated in a high-frequency furnace and thermal diffusivity measurements are possible up to 1600 K. A Nd:YAG laser applies the pulse on the lower side of the sample (front face), which is placed at mid-height inside the sample holder. The emitted thermal radiation from the centre of the upper side of the sample (rear face) is focused in an optical fibre and transmitted to a photodetector (Si or InGaAs). The amplified signal is recorded by a fast transient recorder, and converted in temperature for the determination of the thermal diffusivity and conditioning temperature. The CLASH device allows measurements on $\alpha$-active samples up to melting point, which is possible due to the following features:

- The time taken to bring the sample to the required measurement temperature is fast and kept as short as possible. The sample is not heated in a typical HF-Furnace, but by two opposite laser beams. In fact, the heating ramp depends of the capacity of the studied material to withstand fast thermal transients.
- The sample holder, a three-pin mounting, minimizes the contact surfaces with the sample and while the centre of the specimen reaches temperatures higher than 3000 K, the holder stays at lower temperature, usually lower than 1000 K. The use of three zirconia pins to hold the sample minimizes the chemical reactions, and the heat conduction losses between the holder and the sample,
- The numerical code for the analysis of the thermograms allows experiments with laser spots smaller than the sample diameter. This contributes keeping the sample holder at a lower temperature and minimising the heating of the vessel.

1) $\alpha$ means alpha-type radioactivity emitter