

Thermal diffusivity measurements on UO₂ fuels with the flash method

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Context and objectives

Thermal conductivity of the nuclear fuel :

- A key parameter to understand the performance of the fuel under irradiation
- **Highly dependent on microstructure, porosity and its distribution**
- Influences almost all important processes such as fission gas release, swelling

Knowledge of the nuclear fuel thermal conductivity (**derived from a thermal diffusivity measurement**):

- A fundamental data for a better prediction of fuel performance in reactor
- Must be measured accurately (including a reliable uncertainty assessment)

$$\lambda(T) = a(T) \cdot C_p(T) \cdot \rho(T)$$

a : thermal diffusivity

$C_p(T)$: heat capacity

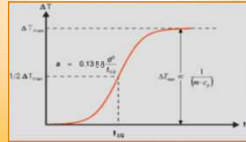
$\rho(T)$: density

Determination of thermal diffusivity with a LFA 467 HyperFlash® NETZSCH apparatus

Principle : heating of the front surface of a **plane-parallel sample** by a **short energy light pulse** and measurement of the **resulting temperature excursion** on the rear face

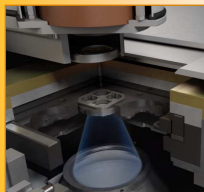
Thermal diffusivity identification

Fitting of experimental data to a calculated model (**Proteus® software**)
 Improved **Cape & Lehman model** (2-D axial-symmetric mode, radial and facial losses)



A transient heat flux technique

Heat pulse generation

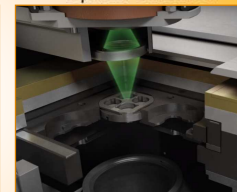


Xenon-pulse delivery source



From ambient to 500 °C with a gas control unit

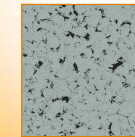
Optical detection



InSb IR detector
ZoomOptics system

Test specimens

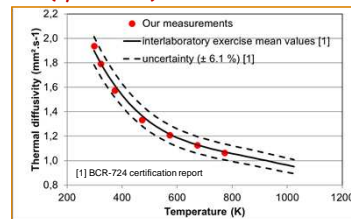
- **Thin UO_2 samples** (~ 2 mm thick), over a range of porosity
- **Steel supports**, loosely thermally coupled to the specimen



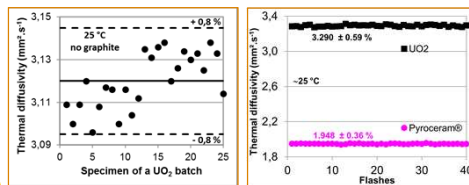
Experimental data

Verification

BCR-724 (Pyroceram®) certified thermal diffusivity



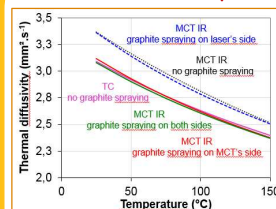
Repeatability



Within-batch repeatability better than 1%
Repeatability better than 1%

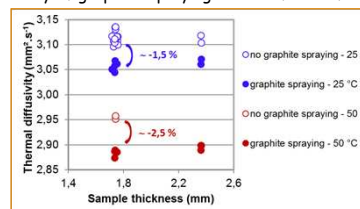
Effect of testing conditions

Graphite spraying to allow full absorption of the energy pulse



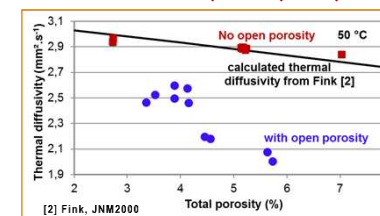
Study performed with a Laser Flash Apparatus with a MCT IR detector and a thermocouple (TC)
[D. Gosset, CEA Saclay]

semi-transparency to the wavelength of the IR detector
 ➢ Necessity of graphite spraying on both faces of the sample

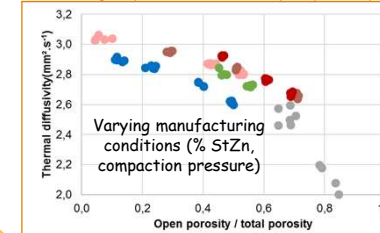


Effect of material characteristics

Effect of the specimen porosity



Strong dependence on the open porosity



Conclusions

- ✓ Flash method → **Appropriate to discriminate differences in the thermal diffusivity measurements of UO_2 samples** caused by a variation of the porosity
- ✓ **Recommendations for the operating conditions**: preparation of the samples (graphite spraying on both faces)

Perspectives

- ✓ Evaluation of the **effect of the fabrication process/material structure**
- ✓ Use of image analysis in order to **quantify the pore size morphology and distribution** and to correlate data with thermal diffusivity measurements