Set-up for post-irradiation determination of temperature during nuclear reactor exposure with 3C-SiC

G. Cornelis [1], J. Vande Pitte [1,2], I. Uytdenhouwen [1], A. Gusarov [1], C. Detavernier [2], J. Lauwaert [2,3]

[1] Nuclear Materials Science Institute, SCK•CEN, Boeretang 200, 2400 Mol, Belgium

[2] Department of Solid State Sciences, Ghent University, Krijgslaan 281-S1, 9000 Gent, Belgium

[3] Department of Electronics and Information Systems, Ghent University, Technologiepark-Zwijnaarde 126, 9052 Gent, Belgium

E-mail: guy.cornelis@sckcen.be

INTRODUCTION

Research reactors such as Belgian Reactor 2 (BR2) currently rely on thermocouples for accurate temperature measurements. However, a lot of irradiations are carried out in lower cost un-instrumented capsules where thermocouples are not a viable option. Here reactor operators rely on calculations or melt wires to determine the irradiation temperature. These methods do not suffice for state-of-the-art irradiations where temperature needs to be accurately known.

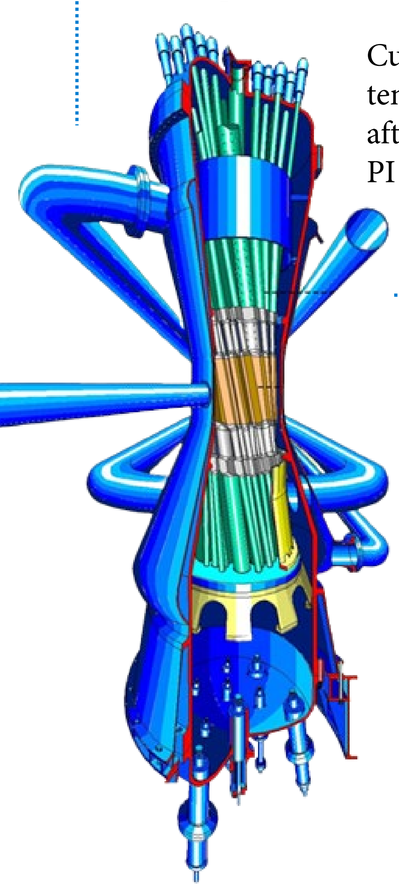

Figure 1: Belgian Reactor 2

Cubic Silicon Carbide (3C-SiC) is a potential material to use as post-irradiation (PI) temperature monitor which allows the determination of the irradiation temperature using PI annealing. Recent developments at Idaho National Laboratory and Oak Ridge National Laboratory show changes in electrical resistivity after isochronal annealing are an accurate method to measure irradiation temperature. Based on this work we are currently developing a set-up for automated PI temperature measurements to improve measurements conditions in the BR2 reactor.

GOAL

Improve the current procedure of isochronal annealing treatments with an automated process which **continuously measures resistivity during the annealing treatment.**

The set-up can be used to monitor resistivity *in-situ* during annealing in a controlled environment.

CHALLENGES

electrical insulation:
Sensitive electrical measurements should be properly isolated with ceramics.

radiation protection:
Impurities in SiC can activate so the design should pay attention to glove box and possible hot cell work.

high contact resistances:
SiC has an high intrinsic resistivity complicating measurements.

large temperature range:
Oxidation should be controlled and the resistivity measurements should be able to cover several orders of magnitude.

Figure 2: SiC samples

small scale:
SiC samples are discs (Ø 5 mm – 1 mm) and bars (12 mm – 1 mm – 1 mm)

SET-UP

Electrical measurements will be performed with the *four-point probe technique* to minimize contact resistances and possible effects of long electrical leads to a hot cell.

For these measurements a source-measurement unit is selected as these devices are capable of simultaneous applying a current to the SiC and measure the accompanying voltage drop with high precision.

PBN ceramic heater:
- up to 1000 °C
- electrical insulation
- gas cooling
- vacuum 1e-5 mbar
- differentiate for 2 geometries

SiC discs
- four spring loaded pins
- tantalum wires
- custom ceramics to keep pins in place

SiC bars
- four tantalum wires running through ceramic base plate
- wires are pressed against sample with custom ceramic part

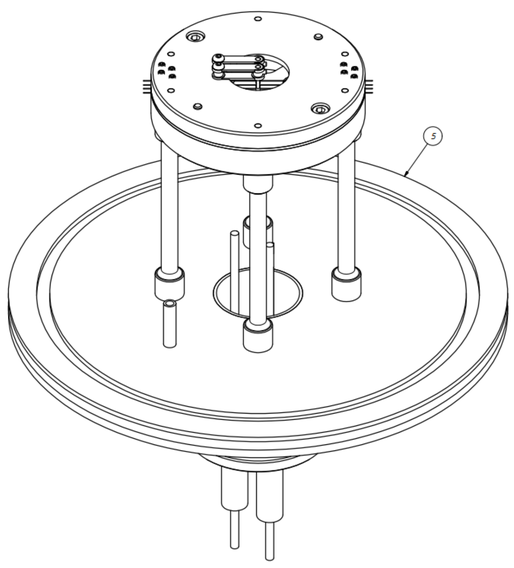

Figure 3: 3D drawing of the base plate of the vacuum chamber with the heating plate and a measure probe holder for 12 mm SiC rods placed on top

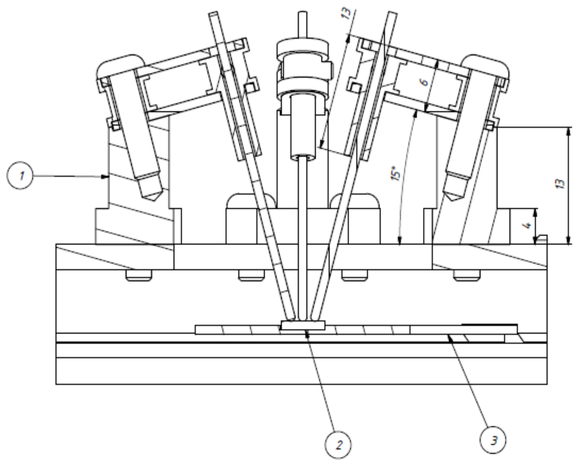

Figure 4: A section of the heating plate with a measurement probe holder for 5 mm SiC discs

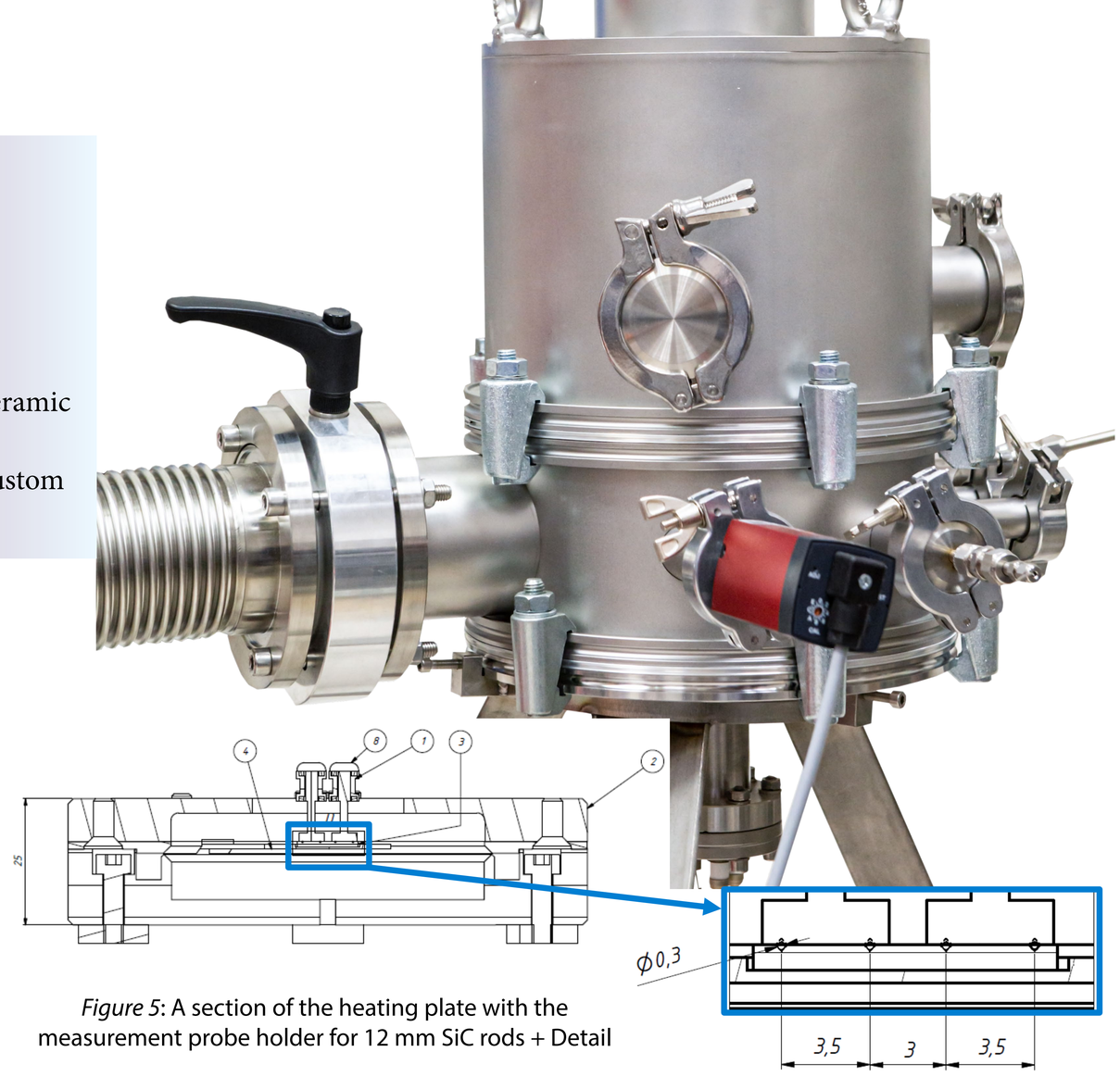

Figure 5: A section of the heating plate with the measurement probe holder for 12 mm SiC rods + Detail

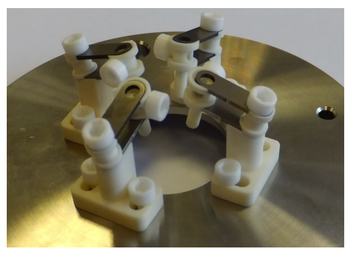

Figure 6: A picture of the probe holder for 5 mm SiC discs

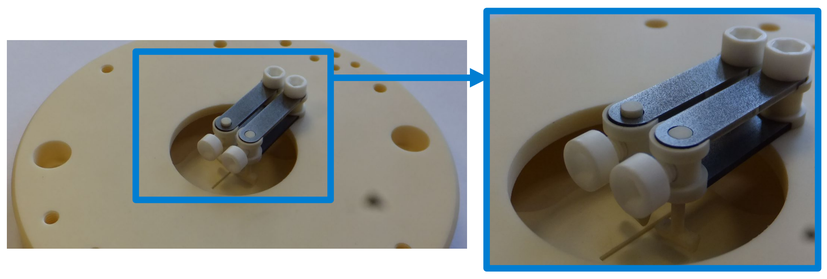

Figure 7: A picture of the probe holder for 12 mm SiC rods + Detail

FUTURE PROSPECTS

Based on previous research SCK-CEN started construction on a set-up for PI temperature monitoring to improve experimental data from un-instrumented capsules in the BR2 reactor.

First tests are planned at the end of 2019, early 2020.

Acknowledgements: Daniel Penneman for his technical support with vacuum components, Dirk Delnooz and Stefan Dekelver for their support on the electrical part and Johan Schuurmans for his help with software and the measurement process.