Silicon carbide detector testing with DT neutrons and at high temperatures

Axel Klix, Dora Szalkai, and the ISMART collaborators
## Work Group Neutronics and Nuclear Data

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Breeding blanket: Important nuclear responses to neutrons

- Tritium production rate → Fuel (self-sufficiency)
- Shielding → Life time of components (field coils etc.)
- Heat generation → Energy conversion, cooling requirements
- Gas production → Material damage
- Material activation → Radiation safety (licensing, operation regime maintenance, decommissioning)

To large extent determined by the neutron flux and material distribution

Experimental proof of suitability and applicability of available transport codes, nuclear data and method for predicting such responses:

**Calculation +/- Uncertainty**

_to be compared with_

**Experiment +/- Uncertainty**
Environmental conditions for TBM instrumentation

Conditions in the TBM bad for detectors / diagnostics

- **Neutron flux** $10^9 \sim 10^{14}$ cm$^{-2}$s$^{-1}$
- $300..550$ °C (could be higher in breeding layers of HCPB TBM)
- Magnetic fields $\sim$4 T
- difficult access
- little space

**Possible candidates:**

- Neutron activation system, miniatur fission chambers,
  diamond detectors, **silicon carbide detectors**, 
  self-powered neutron detectors

R&D work mostly funded by F4E grants so far
Silicon carbide (fast) neutron detector

- Large band gap semiconductor detectors
- Better radiation hardness than Si
- SiC electronics proven to operate at temperatures of several hundred °C
- R&D on SiC detectors has been done since many years
Silicon carbide (fast) detector

Typical signal from a commercial Schottky diode irradiated with 14 MeV neutrons and corresponding pulse height spectrum
Collaboration between CEA, KIT, SCK*CEN, AMU, Univ. of Oslo, KTH, AGH funded by KIC InnoEnergy with the aim to develop a SiC detector system.

SiC diode with boron conversion layer for thermal neutrons.

Plain SiC diode
Response of the ISMART diodes to thermal and fast neutrons

With boron implantation in thermal neutron field of BR1 (SCK*CEN Mol) at room temperature

In DT neutron field (TUD-NG, HZDR Rossendorf) at room temperature
Neutron laboratory of Technical University of Dresden
 DT neutron irradiations

**TUD-NG**: 300 kV, 10 mA deuterium beam on solid tritium/deuterium targets

- up to $10^{12}$ n / s
- continuous or pulsed operation
  (accelerator prepared for ns pulsing)
- fixed and rotating T-Target

**Targets:**
Tritium: 3, 30, 250 Ci
Deuterium
Setup for high temperature tests at TUD-NG

Experimental setup for high temperature tests under DT neutron irradiation

Diode encapsulation with stainless steel coaxial „cable“
Response of the ISMART diodes to DT neutrons at high temperatures

Measured and modeled (GEANT-4) pulse height spectrum under irradiation with 14 MeV neutrons

Measured pulse height spectra under irradiation with 14 MeV neutrons and at temperatures relevant for the ITER TBM
Response of the ISMART diodes to DT neutrons at high temperatures

Measured and modeled (GEANT-4) pulse height spectrum under irradiation with 14 MeV neutrons

Measured pulse height spectra under irradiation with 14 MeV neutrons and at temperatures relevant for the ITER TBM

Even at 500 °C spectroscopic behaviour is retained to some extend.
Response of the ISMART diodes to fast neutrons at high temperatures

Stability tests at elevated temperatures under DT neutron irradiation: 10 × 10 minutes, 1-3 hours interruption, 3 × 10 minutes
Response of the ISMART diodes to fast neutrons in high magnetic fields

- DT neutrons from TUD-NG
- Room temperature
- Permanent magnets

No significant changes in pulse height spectrum
Response of the ISMART diodes to fast neutrons in high magnetic fields

- Epithermal neutrons from D3 facility at ILL Grenoble
- Room temperature
- Magnetic field up to 8 T

No significant changes in pulse height spectrum
Main results

- Stable operation up to 300°C with 4H-SiC detector at high bias voltages
- Beyond 300°C up to 500°C operation at reduced bias voltages
- Stable count rate over several hours at several steps from room temperature up to 500 °C.
- Operation at high magnetic fields did not show significant count rate changes