TECHNOLOGY BRIEF

NEXT STEP FUSION

Passive Fast-Neutron Fluence Dosimeter

A graphene-on-silicon-carbide, radiation-hard passive dosimeter for next-generation magnetic confinement fusion (MCF) devices and future fusion pilot/power plants (FPPs).

THE CHALLENGE

In MCF devices, fast-neutron fluence drives material damage, and accurate knowledge of the dose at specific locations governs component lifetime and diagnostic reliability — so spatially resolved fluence measurement is essential for reactor qualification and safe operation.

THE TECHNOLOGY

The dosimeter uses a graphene-on-SiC platform as a miniature passive fast-neutron sensor — neutron-induced displacement defects accumulate mainly in the SiC substrate and are read out after irradiation by Raman spectroscopy. This combination brings five qualities that conventional metallic dosimeters do not offer together:

- **Millimeter-scale dimensions** — enabling dense placement in geometrically constrained locations.
- **Fully passive operation** — no power or cabling required during exposure.
- **Spatially localized readout** — measurement reflects the defect accumulation at the sensor's exact position.
- **Suitability for high fluence** — demonstrated up to 6.5×10^{18} n/cm², with calibration covering mainly 1–2 MeV neutrons and approximately 4% scatter around the fitted response curve [2].
- **Potentially lower activation than conventional metallic dosimeters** — easing post-irradiation handling.

HOW THE READOUT WORKS

The patterned **Al_2O_3/QFS-graphene/6H-SiC(0001)** platform stores the neutron fingerprint in its crystal lattice. After exposure, Raman spectroscopy of the SiC substrate quantifies the accumulated displacement damage and relates it to the integrated fast-neutron flux — a radiological-hazard-free, non-destructive protocol requiring no electrical connection to the sensor [2].

PARTNERSHIP & MATURITY

The dosimeter is being developed by **Next Step Fusion** (Luxembourg) and the **Łukasiewicz Institute of Microelectronics and Photonics** (Poland).

The next goal of this long-term partnership is to mature the platform from **TRL 4 to TRL 6** — from validation in a relevant laboratory environment to demonstration in a relevant operational environment — paving the way toward deployment in future FPPs.

COMPARISON WITH CONVENTIONAL FAST-NEUTRON FLUENCE DIAGNOSTICS

Active SiC, diamond, and fission detectors — real-time electrical readout for power control and spectroscopy, but need cabling and bias voltage and suffer degradation and pulse pile-up; graphene-on-SiC is unpowered and stores cumulative exposure in inaccessible locations.

Activation foils and wires — the better-validated absolute reference, with energy selectivity from threshold reactions, but require radioactive handling, cooling, transfer, and decay corrections, and offer no microscopic mapping.

Passive SiC temperature and damage monitors — match its radiation hardness via physical/electrical/Raman shifts, but lack its built-in reference region — the patterned platform provides readout both within the graphene mesa and outside it, enabling self-verified fluence estimation [2].

Helium-accumulation and transmutation monitors — ideal for high-fluence materials surveillance, but require destructive lab analysis with no spatial or shot-to-shot readout; graphene-on-SiC allows non-destructive Raman mapping.

REFERENCES

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