Associazione EURATOM ENEA sulla Fusione

National Agency for New Technology, Energy and Sustainable Economic Development

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New Sorgentina Fusion Source (NSFS) Experimental Facility Supporting Materials Research

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ABSTRACT

Within the framework of fusion technology research and development, a neutron source has long been considered a key facility to perform irradiation tests aiming at populating materials engineering database – supporting DEMO reactor design and licensing. New Sorgentina Fusion Source (NSFS) has been proposed taking advantage of well-established D-T neutron generators technology, scaled in order to attain a bright source of about 10^{15} n/sec. Actual 14 MeV neutron spectrum is a relevant feature. Ion beams of 30 A are produced and accelerated up to some 200 keV energy. Present design considers ion generators and extraction grid technology employed in neutral injectors currently utilized at large experimental tokamaks. Then deuterium and tritium ion beams are delivered to the target - impinging on a hydride thin layer which is on-line D-T reloaded via ion implantation. Metal hydride is continuously re-deposited preventing layer from being sputtered, increasing installation load factor. Large and fast rotating target is conceived to enhance heat removal - coping with thermal transients and mechanical loads. Design is aimed at achieving challenging performances regarding elevated heat flux of 60 kW/cm² and thermal fatigue concerns. Main facility characteristics are provided, as well as target thermal and mechanical issues.

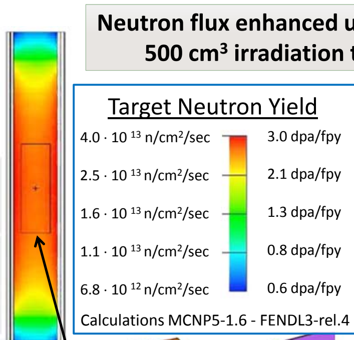
Continuous on-line layer deposition for long irradiations

D-T fusion reactions generating 14 MeV neutrons for material irradiation

D^+ - T^+ Ion Beams Impinging Metal hydride layer as D-T enriched target

Rotating wheel target to manage high heat flux

Neutron flux enhanced up to 3 DPA/fpy in 500 cm³ irradiation test chamber



Rotating Target System

High heat flux to target
Thermal-mechanical issues managed by rotation

- Large wheel 4 m radius – 800 rpm rotation
- 0.3 msec pulse-width heating and 75 msec period
- Material selection and multi-layer strategy

Metal hydride layer (2 micron)

Susbtrate resistant to heat shocks
Thermal-mechanical fatigue

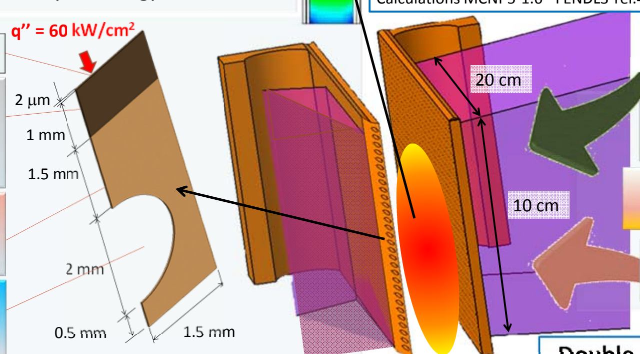
Highly Oriented Pyrolytic Graphite HOPG or CFC (ongoing evaluations)

Structural resistant to centrifugal hydro pressure and heat removal

Copper alloy CuCrZr

Cooling water

$T_{bulk(inlet)}$ = 50°C , $p_{(top)}$ = 660 bar
Htc = 60,000 W/m²/K



Double rotating target Neutron surface sources

Ion Beam

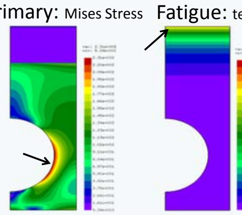
High current ion sources and accelerators
Positive Ion Neutral Injectors at tokamaks (JET)

- Double beam 30 A D+ and 30 A T+ ions is utilized
- 200 keV to match fusion cross-section resonances
- 200 cm² beam size (20cm x 10 cm)
- RF source: higher monoatomic yield (fusion probability)
- 20 sec (up to quasi-continuous) pulse duration

PINI NBI at JET tokamak

Target Thermal and Mechanical Analysis

Primary: Mises Stress Fatigue: temperature



CuCrZr tubing plate

σ_{max} = 230 MPa

σ_y (100 °C) ≈ 380 MPa

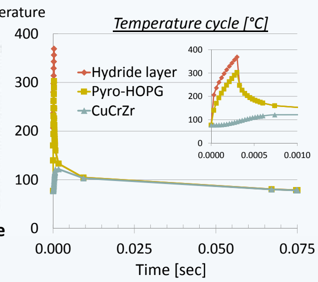
Pyro-graphite substrate

σ_{min} = 4 MPa

σ_{max} =17 MPa

$\sigma_a = \Delta\sigma/2$ = 6.5 MPa

σ_a limit ~ 9 MPa

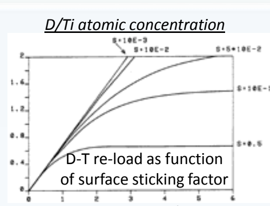


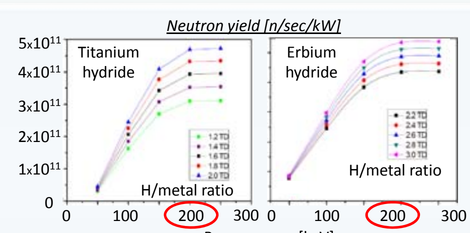
$T_{max\ hydride}$ = 370 °C

Hydride Target Layer

Deuterium-tritium stocked in metal hydride form target surface
D-T ions Continuous re-load through ion beam implantation

- Titanium – Erbium metal hydride: sputtering restored by on-line deposition
- D-T storage in vacuum - high temperature (up to 400 °C)
- 2 micron layer for D^+/T^+ 200 keV ions





Design Strategy | **Early irradiation objectives matching proven technology Assets**

- Neutral beam injector systems (NBI) utilized as large area high current D^+/T^+ ion sources
- D-T ions stored in hydride metal layer on target – D-T reload via ions implantation
- High total current beam sputtering solved through on-line metal deposition
- High power density delivered to target managed by rotating wheel structure
- Thermal-mechanical issues approached by multi-layer design (thermal shock & substrate)

References

- M. Pillon et al., Feasibility study of an intense D-T fusion source: «The New Sorgentina», Fusion Eng. and Des. (2014)
- M. Martone et al., High flux high energy deuterium ions implantation in high temperature titanium, ENEA Internal Report (1992)
- M. Martone, Feasibility Study of a 14 MeV Neutron Source (Sorgentina), ENEA Internal Report (1990)