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Reactor Structural Materials

Fusion Reactor Materials

Fusion research in Europe is co-ordinated by the European Commission (DG XII, Fusion Office). At SCK•CEN, the fusion activities focus on environmental tolerance of opto-electronic components (see "Advanced Instrumentation and Teleoperation," on page 107), materials characterization, and neutron irradiation services.

Objective

- to contribute to the knowledge on the behaviour, during and after neutron irradiation, of fusion-reactor materials and components.

Programme Our programmes foresees

- to study the fracture mechanics of neutron-irradiated beryllium, based on tensile and compact tension tests and on microstructural evaluation;
- to describe the helium behaviour in irradiated beryllium at atomic scale;
- to define the kinetics of beryllium reacting with air or steam;
- to perform a feasibility study for the testing of integrated blanket modules under neutron irradiation.

Fracture mechanics of neutron-irradiated beryllium Brush Wellman, USA, fabricated compact tension and tensile specimens from four species of beryllium differing in both beryllium-oxide content and powder-consolidation method. These specimens were irradiated at 200, 400, and 600°C up to neutron fluences ranging from 0.8 to $2.1 \times 10^{21}\,n\cdot cm^{-2}$ ($E > 1$ MeV) or 250 to 750 appm helium. The same number and kind of specimens, called thermal-control specimens, were aged under the same time-temperature profile as the irradiated specimens.

The tensile and fracture-toughness tests on the irradiated material lead to the following conclusions:

- irradiation results in classical effects on tensile properties: loss of ductility and strengthening of the material;
- the four beryllium grades cannot be clearly distinguished, except S200 VHP, which behaves differently. The Hot Isostatic Pressed (HIP) material shows higher strength than the Vacuum Hot Pressed (VHP) one;
- irradiation drastically reduces the fracture toughness, in particular in the 400 to 500°C temperature range. In this range, unirradiated samples failed by stable crack growth and irradiated ones by unstable fracture.

Modelling the helium behaviour in irradiated beryllium at atomic scale The Igarashi-Vitek-Kantha (IVK) potential, on which the current cohesion model is based, incorrectly describes the vacancy migration energy and the surface energy in the case of beryllium. In close co-operation with ULB, SCK•CEN therefore concentrated on improving the IVK potential. An analytical and an empirical approach applied on three different cases gave consistent results.

In the first case, the elastic constants, the cohesive energy, the c/a ratio, and the equilibrium atomic volume are matched to experimentally measured values. However, the inhomogeneous contribution to the elastic constants vanished and the calculated vacancy migration energy was still unphysically high.

In the second case, in addition to the previous constraints, consistency with the measured Raman frequency was imposed on the inhomogeneous contribution to the elastic constants. Although the set of parameters for the IVK potential was more realistic, the vacancy migration energy was still too high.

In the third case, in addition to the previous constraints, the IVK potential function was modified to provide a more realistic description of the close atomic interactions. The first attempts gave reasonable results on migration energy.

However, further development is required to ensure reasonable excess energies associated with extended defects and interfaces.

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Kinetics of beryllium reacting with air or steam We have acquired, installed in a controlled zone, and calibrated a thermogravimetric/differential temperature analyser (TGA/DTA). The first tests on unirradiated and irradiated dense beryllium show linear kinetics at 600 and 700°C and a parabolic law at 800°C and above. Tests are continuing on irradiated porous material and in steam at 1 bar.

Integrated blanket modules under irradiation Which type of tritium-breeder blanket to use in the future thermonuclear fusion reactors is still an open issue. Two concepts are currently in competition for ITER and DEMO. The first is based on beryllium and lithium orthosilicate pebble beds, cooled by helium. In the second, tritium is generated in liquid lithium-lead, cooled by pressurized water. Feasibility studies are performed for the irradiation of integrated blanket modules in the BR2 materials testing reactor, relevant for both concepts. The study leads to a preliminary technical concept of the experimental facilities. It includes a budget for the whole project (construction, operation, and dismantling of the facilities in BR2) and extends until mid-1998.

The module should include representative segments of the actual breeding material, of the neutron multiplier, and of the first wall, operated with the actual coolants at relevant process pressure and temperature. Such integral experiments aim at confirming the general behaviour of the system and, in particular, the tritium production, release, permeation, and recovery rates in an environment as close as possible to the designed blanket operation conditions.

Partners, sponsors, and customers

Scientific partners Forschungszentrum Karlsruhe (FZK) — EC Joint Research Centre (JRC) — Commissariat à l'énergie atomique (CEA) — Université Libre de Bruxelles (ULB)

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Scientific output

Presentations delivered in 1997

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