Joint seminar of the NPI of the CAS

Dr. Olga Ogorodnikova, Department of Nuclear Reactions, NPI:

Materials under extreme conditions

In many areas of energy production and application, materials with superb neutron irradiation resistance, thermal and mechanical properties are required. In particular in fusion devices, first wall materials are exposed to extreme heat, neutron and particle fluxes, leading to material degradation (erosion, melting, embrittlement, cracking, etc.), as well as accumulation of radioactive tritium fuel inside wall materials. In solar tower power plants the exposure to highly concentrated and alternating solar fluxes, leading to cyclic thermal loads, and operating in humid air environment combined with high operational temperatures of above 1000°C required for commercially competitive electricity production imposes comparably challenging requirements on materials for solar receivers. New production methods, material combinations and complex materials concepts are investigated to develop new materials with improved properties, reduced production costs and larger flexibility with respect to manufacturing of final components, as well as increasing the overall efficiency of energy systems.

The final application of fusion energy mainly depends on the development of key materials in a thermonuclear reactor "Tokamak", in which the choice of materials in contact with plasma is one of the most important issues both from the point of view of reactor safety due to tritium radioactivity and changes in material properties during operation, and for calculating the fuel balance in plasma. The application of materials in extreme environmental conditions cannot be avoided in thermonuclear reactors due to exposure to energetic particles of hydrogen isotopes and helium (He), high heat flux, and neutrons.

Tungsten and dense nano-structured tungsten (W) coatings are used as plasma-facing materials in current tokamaks. Pure W and advanced W-based materials are suggested to be used for the future fusion devices, ITER and DEMO. Power injection molding is a cost-effective fabrication route that allows shaping of complex components. Tungsten oxidation is suppressed in smart alloys where e.g. chromium and yttrium are added to tungsten as alloying elements. Tungsten-fiber reinforced tungsten composites and micro-structured tungsten surfaces demonstrate improved mechanical properties under transient heat loads. Such advanced materials will also meet the requirements for solar receivers in the new generation of solar tower power plants. New high entropy materials are under development and testing for an application in extreme environment of neutron irradiation, corrosion and high heat flux.

Low-activated ferritic-martensitic steels (RAFM), together with a new generation oxide dispersion strengthening (ODS) steels by the addition of Y_2O_3 particles, are considered as promising materials for fast neutron fuel cladding and priority structural materials for a thermonuclear reactor. These structural steels have high thermal conductivity, good resistance to radiation swelling, as well as low thermal expansion.

Radiation-induced damage is one of the key issues often defining the lifetime of materials used in fission and fusion reactors. In this report, new knowledge on primary defect formation in pure bcc metals (W, Mo and Fe) irradiated by high-energy self-ions, protons and neutrons with different spectrum at near-room temperature is presented. The formation of clusters of alloying elements under irradiation of the promising material alloys is shown. Finally, interaction of deuterium with radiation-induced damage is discussed.

The seminar will take place on Wednesday, June 14, 2023 at 10:00 a.m. in the NPI conference room.