CERMET ALLOYS FOR HYBRID FISSION-FUSION NUCLEAR REACTOR

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Among the innovative reactors for nuclear energy application, it is observed a worldwide interest in the concept fission-fusion hybrid reactors (FFHR), so there is a diversity of designs thereof. In essence, an FFHR consists of three parts [1]: a fusion device that acts as a source of neutrons, a system where the fissionable fuel is placed, and a tritium generating blanket that feeds the required fuel to the fusion reactor. Usually, all the system is also fitted with a neutron reflector. These parts are arranged concentrically forming a three-layer system to optimize the use of neutrons.

Achieving a reasonable neutron yield, in order to drive an FFHR, is difficult with current fusion devices, which is why the use of so-called multiplier cascades has been proposed. These cascades consist of concentric shells where the fissile material is placed, separated by a very large empty space. The dimensions, shape, and fuel of the shells and the size of the empty space between them, determine the multiplying capacity of the system. Figure 1 shows a model of FFHR following these principles, where two shells of 8% enriched Uranium are placed as fuel (this fuel has a metallic behavior), a Lithium silicate is used as TBB, and a Tungsten layer plays the role of reflector and shielding.

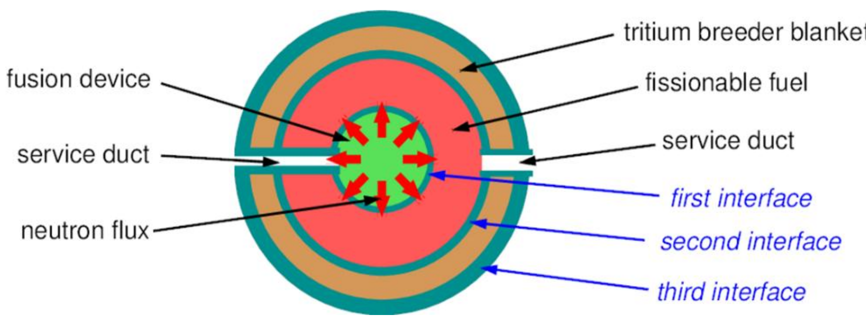

Figure 1: Scheme of a FFHR reactor

As we can see, each zone and interface described have different nuclear properties causing changes in the neutron flux spectra as it moves outwards.

The energy spectra of transmitted neutrons in Tungsten for the incident 14 MeV present reactions lead to a transmutation cycle which gives a net conversion of Tungsten into Osmium and Rhenium and traces of other metals, even Platinum and Gold. All these metals do not represent a problem for the structural properties of the material as was previously seen under fission spectra, as we show in ref. [2]

To improve the yield and retention of fission products, there is another model of hybrid reactor, based in the concept of concentric shells, forming with an specific alloy of W, the so-called Cermet, (Ceramic+Metal) allowing to reach near to 3000° K of temperature.

CerMets were developed to build reactors for air and space propulsion, as is described in [3]

With this conceptual reactor, composed of a nuclear fusion device that generates 14 MeV neutrons to propel a subcritical assembly, and using CerMet W/[U(50%)O2] in the two shells, we obtain its neutron spectra, shown in Figure 2. We reproduce a fast neutron spectrum equal to the fast spectra of fission reactors. Notice that for fast reactors, we cannot put water to cool them.

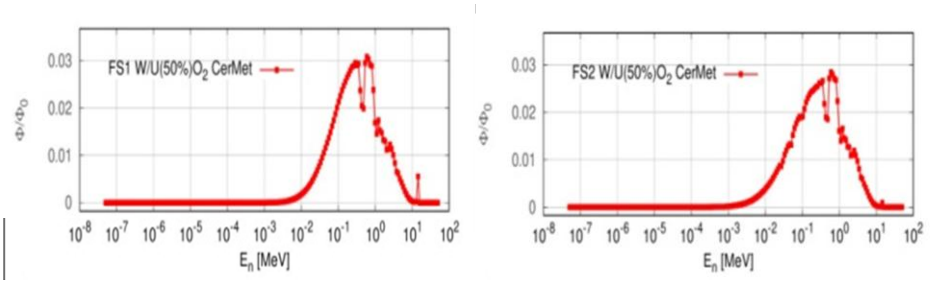

Figure 2: Neutron spectra for shell 1 and shell 2, using CerMet W/[U (50%) O2] in both.

Finally, analyzing the stability of Cermets, in Figure 3 we show a plot of the damage in the cermet, using the IMPC5 Montecarlo simulation; being the target a 30x30x40 nm^3 W prism (the 40 nm is in direction of the beam) with a 15 nm UO2 sphere centred at the centre of the prism. The incident beam is a 150 keV protons with a Gaussian distribution of impact angles, that is, on average there is normal incidence to the target surface but there are some protons that enter the cermet with a certain angle of entry. As we can see in the figure, at 150keV the protons are not capable of displacing W, the only displacements occur within the sphere. For bombarding with greater energies additional processes such as electronic sputtering contributes to surface erosion. A major part of the energy of incident ions is transferred to electrons along the ion track.

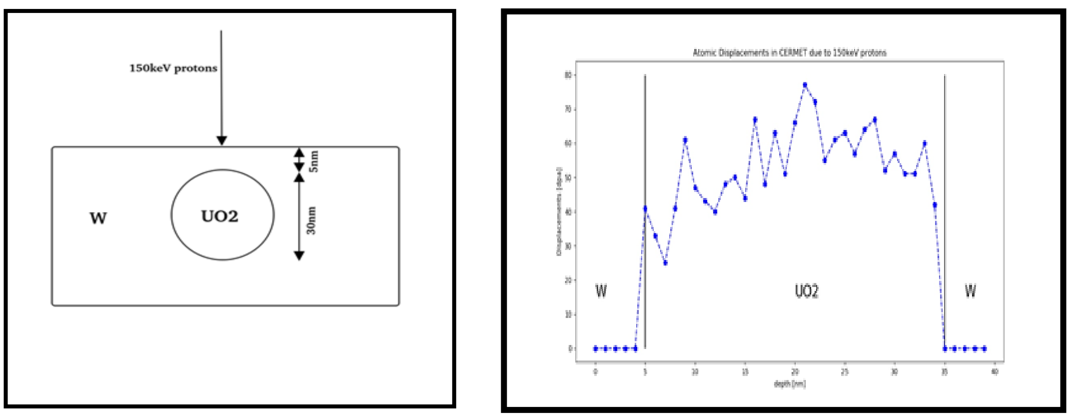

Figure 3: scheme (left) and damage in the Cermet (right), using IMPC5 simulation

The cermet alloys studied here, have reasonable thermophysical properties and, from irradiation experience in fast reactors to well over 100 dpa, a substantial resistance to swelling and high temperature embrittlement. From the point of view of its behavior with the gaseous coolant, we observe that for protons at the studied energies, there are not displacements of its atoms. Moreover, they have good compatibility with He coolants. But there are several difficulties open regarding the behavior of the coolant with the cermet. In particular, for these energies, we have to study the corrosion processes involve in this interaction. Further research would require the study of the temperature distribution around the fuel sphere, specially the properties of Tungsten as a function of T, for example, phonons, elastic constant, hardness, and so on.

References

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