Contribution ID: **417** Type: **Oral**

Thermomechanical properties of nanostructured W based coatings under ITER-relevant thermal loads

Monday 5 June 2017 16:20 (20 minutes)

The full tungsten (W) divertor of ITER will suffer from extreme thermal loads during both steady and transient operating conditions. These thermal loads, together with energetic species bombardment from the plasma, induce W surface erosion, melting and recrystallization. The sputtered particles could migrate and form micrometric thick co/re-deposits on the peripheral regions of the divertor. These layers, together with recrystallized and solidified W, show different thermophysical properties from bulk W and must be opportunely characterized.

Since we actually are not able to recreate the full ITER environment, it is mandatory to study at the lab-scale how W based components behaves in ITER-like operating conditions. In order to study the behavior of co/re-deposits expected in ITER, in previous works we exploited the versatility of Pulsed Laser Deposition (PLD) to deposit W based coatings, namely pure W coatings with tuned nanostructure and morphology and W-oxide coatings with different oxygen contents. These coatings, chosen as proxy of co/re-deposited W, have been exposed to ITER-relevant plasmas, and their deuterium retention properties, as well as their structural and morphological modifications after exposure, have been assessed [1, 2].

In this work we characterize the mechanical properties (i.e. stiffness and ductility) of these PLD W coatings by Brillouin spectroscopy (BS), as function of nanostructure (e.g. crystallite size) and oxygen content. Thermal properties, i.e. coefficient of thermal expansion, are also assessed by an ad-hoc developed experimental setup based on substrate curvature measurement. In addition, we investigate their thermomechanical behavior under two different scenarios that mimic steady and transient ITER operating conditions. For the former case, we perform standard thermal annealing treatments at 200–1000℃ on nanocrystalline-W (nano-W) samples, in order to study their behavior at ITER-relevant steady operating temperatures. We focus on the mechanical, structural and morphological properties modifications upon heating. BS is exploited to derive the mechanical properties, while samples structure is assessed by SEM and XRD analysis. We find that nano-W starts to crystallize at around 600 ℃, which is well below the bulk W recrystallization temperature (i.e.1400℃); at this temperature, comparing to as-deposited nano-W, an increase by 60% of material stiffness with a corresponding loss of ductility by 30% is observed [4]. In addition, we expose the as-deposited coatings to nanoseconds laser irradiation. Nanoseconds lasers have been already exploited for mimicking thermal effects induced by ITER-like transient events (e.g. disruptions, ELMs)[3]. Here, exploiting the same Nd:YAG laser system we used for PLD, we look for thermal effects (e.g. cracks formation, melting) as function of laser energy fluence. The characterization is assessed by SEM morphological analysis. The fluence thresholds for the thermal effects are then compared with the ones obtained by the irradiation of bulk W plates, selected with different surface finishes. The measured experimental thresholds are compared to the ones obtained by numerical simulations using a 2D thermo-elastic code developed to this purpose.

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[2] A.Pezzoli et al., J.Nucl.Mater 463, 1041(2015)

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Eligible for student paper award?

No

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Session Classification: M.OP2: Materials I

Track Classification: Materials and fabrication