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Nanostructured tungsten as a first wall material for the future nuclear fusion reactors

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The lack of materials able to withstand the severe radiation conditions (high thermal loads and atomistic damage) expected in fusion reactors is the actual bottle neck for fusion to become a reality.

The main requisite for plasma facing materials (PFM) is to have excellent structural stability since severe cracking or mass loss would hamper their protection role which turns out to be unacceptable. Additional practical requirements for plasma facing materials are among others: (i) high thermal shock resistance, (ii) high thermal conductivity (iii) high melting point (iv) low physical and chemical sputtering, and (v) low tritium retention.

W has been proposed to be one of the best candidates for PFM for both laser (IC) and magnetic (MC) confinement fusion approaches. However, works carried out up to know have identified some limitations for W which have to be defeated in order to fulfill specifications [1, 2, 3]. Nowadays engineered 3D surfaces are being fabricated to reduce the thermal loads arriving to the PFM by increasing the surface area and thus, minimize the energy density deposited into the material [4]. On the other hand, ultrafine grain and nanostructured materials are being developed to facilitate the light species release and to improve the W mechanical properties [5].

We report on the growth of nanostructured W by using DC magnetron sputtering and high impulse power magnetron sputtering (HIPIMS) on different kind of substrates under different deposition conditions. X-ray diffraction (XRD) patterns illustrate that films are polycrystalline and preferentially oriented along the (110) axes. Transmission electron microscopy (TEM) and field emission gun-scanning electron microscopy (FEG-SEM) evidence that films consists of nanocolumns perpendicular to the substrate with a diameter in between 50 and 250 nm depending on the deposition conditions.
Some of the samples were annealed in an Ar atmosphere at temperatures in the range from RT to 1000ºC in order to study their thermal stability. Cross-sectional FEG-SEM images show no significant change in the nanocolumn shape but they point up the poor adhesion between film and substrate for those samples deposited on steels and heated at temperatures higher than 800ºC.

References

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