Measurement of hydrogen isotopes retention in tungsten: bulk, thin films, and nanoparticles.

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In the magnetic confinement fusion devices like ITER tokamak, the interactions between the intense plasma and the tungsten wall might lead to the creation of fine dust particles, with sizes from few nano to several tens of micrometers [1]. These particles may contaminate the hot plasma and also to absorb and retain the tritium gas from the fusion environment. Due to safety reasons, tritium retention in ITER shall be limited to 1kg in-vessel, therefore being important to evaluate the relative importance of the different possible T retention mechanisms [2]. In addition, tritium retention will negatively impact the efficiency of the fuel cycle and so the efficiency of the reactor. For these reasons it is important to understand the characteristics of the dust particles produced inside fusion machines in respect with fuel retention, this subject being nowadays a hot topic in the field of fusion research. Still, the total amount of tungsten dust produced in existing tokamaks is actually insufficient to carry out such studies, resulting the necessity to use alternative production routes for fusion like tungsten dust (nanoparticles): pulsed laser ablation technique [3], ball-milling, reactive ball-milling, self-propagating high temperature synthesis (SHS) and mechanically activated SHS (MASHS) techniques [4], sole magnetron sputtering (MS) [5] or combined with inert gas aggregation (MSGA) [6,7].

The last one (MSGA) was proven by the authors of this proposal to produce tungsten nanoparticles (WNPs) in the range of 80-100 nm, having pure metallic chemical phase and different morphologies (dendritic nanoflowers [6] and concave hexapodes [7], and also monocrystalline faceted cube octahedral [7]). The experimental setup is presented in Fig. 1.a while Fig.1b, c, d present WNPs with mentioned morphologies.

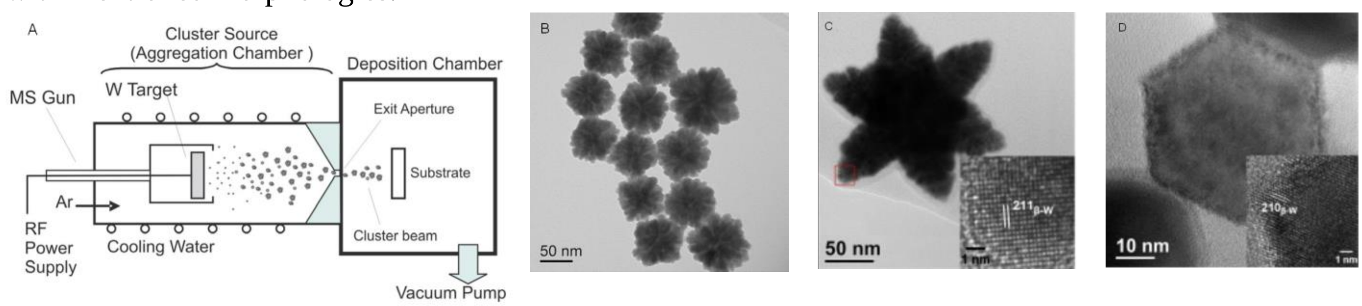

Fig.1: a) Schematic of the nanoparticle synthesis system; and TEM images of tungsten nanoparticles with different morphologies: nanoflowers (b), concave hexapodes (c) and faceted ones (d).

The nanoparticles produced in the cluster source are ejected through the exit aperture in the deposition chamber and are deposited on different type of substrates (Si is preferred) where they slightly adhere. The deposition rate of is a few mg/hour and they can be uniformly distributed on small substrates (like 1cmx1cm).

Here we propose to test the retention of nuclear fuel of these types of W nanoparticles in comparison with thin films of W and bulk W. Deuterium will be used as a replacement for tritium. For this purpose, the samples holding W nanoparticles will be exposed to a radiofrequency deuterium plasma for different duration. After deposition the amount of deuterium retained in the samples will be evaluated by ion beam analysis (IBA) techniques, well known for quantification of low mass elements with high sensitivity and in a straightforward manner. Among several ion-beam technique for detection and depth profiling of hydrogen isotopes, Elastic Recoil Detection Analysis (ERDA) technique using a low energy 4He beam proposed by Doyle and Peercy [8] is particularly advantageous; all hydrogen isotopes can be profiled simultaneously with a sensitivity as high 0.1 at.%, the measurements can be performed using a relatively low energy accelerator and the samples undergoes less damage as compared with the use of high-Z analysis [8,9].

For comparison, thin films of W deposited by magnetron sputtering and also samples of bulk W will be exposed to deuterium plasma (simultaneously with WNPs samples) and will be also evaluated for their fuel retention by IBA.

Due to the variety of the samples, the proposed experiment will bring clarification over the influence of different W material characteristic (like bulk, thin film, dust with different morphologies and microstructure) over the retention of nuclear fuel.

Beam request:

5 days (15 shifts) at the 3 MV Tandem

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