From plasma facing components to airborne radioactive dust: A study on the behavior of tritiated dust in fusion reactors

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Nuclear fusion reactors based on plasma magnetic confinement and tokamak technology produce toxic and/or radioactive metal (beryllium and tungsten) dust as a result of plasma/wall interactions within the vacuum vessel (VV). In addition to being a factor of pollution of the plasma, these dusts also involve safety issues in case of opening of the machine, maintenance or accidental situation like a break of the confinement barrier. Thus, it appears necessary to assess the adhesion and resuspension properties of these dusts during the lifetime of the reactors.

To answer these safety issues, we adopted complementary approaches based on experimental and numerical works that we present in this paper. First of all, collection of particles inside the WEST tokamak operated by CEA/IRFM has been realized thanks to a new *in-situ* particle collection system called DUSTER BOX. This method is innovative and allowed to identify various types of tungsten particles among them spherical shaped micro-particles in the micrometer range. Based on these results, a surrogate tungsten powder has been provided by means of spheroidization process. Moreover, the possibility to work with tritium is a unique asset of our team and provided direct information regarding the powder tritium retention capacity. Thanks to its simplicity and small dimensions, the DUSTER BOX device has also been used for resuspension experiments in a nuclear glove box with tritiated particles. The feasibility of such experiments has been demonstrated and the protocol is operational. At the micro-scale, adhesion forces of such particles onto relevant tokamak surfaces remains ignored while it is a key element for particle removal and mobilization understanding. Thus, a parametric study using Atomic Force Microscopy (AFM) was completed. Adhesion force distributions were obtained for spherical tungsten particles with diameters between 2 µm and 20 µm lying on tungsten substrates with *rms* roughness between 10 nm and 700 nm, the latter representing usual roughness of tokamak surfaces in contact with plasma. This technique made it possible to identify an adhesion force model that has been successfully integrated in a resuspension numerical code.

The results of these experiments combined with the implementation of particle removal models provide robust data for the determination of the tritium source term which is mandatory for the definition of workers radioprotection plans. Moreover, such data are essential when assessing the dispersion of toxic/radioactive material in the environment that could follow a loss of containment.