Seminar

Institute for Plasma Research

Title : Computational modeling of tritium release from porous Lithium ceramic pebbles

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Date : 27th March 2019 (Wednesday)

Time : 02.00 PM

Venue : Committee Room 1, IPR

Abstract :

Deuterium-Tritium (D-T) plasma based Tokamak fusion reactors are considered to be the future source of energy. Deuterium is available in abundance, but Tritium is radio-active and it is not available naturally. Tritium has to be bred in the fusion reactor by utilizing the neutrons generated by D-T reactions in plasma. Lithium based materials (solid or liquid form) are kept in the breeding blanket around the plasma for producing tritium through the Lithium-neutron interactions. The candidate materials are Lithium based ceramics such as Li_2TiO_3, Li_4SiO_4, $LiAlO_2$, etc. Tritium bred in the solid breeding blanket is released in a purge gas, extracted from purge gas and refueled in the plasma for the operation of the reactor. Tritium produced in the grains of porous Lithium ceramic pebbles undergoes several mass transfer processes before it is released in the purge gas. Apart from this, the neutron induced damage to Lithium ceramics affects the tritium migration in grains. For a given reactor blanket operating condition this leads to a certain tritium inventory and residence time in the blanket. Tritium inventory and residence time are very important and crucial for the design of the reactor fuel-cycle, reactor doubling time, reactor safety, manufacturing of the solid breeder pebbles etc. Therefore tritium release study is a very important R & D area for the development of fusion reactors. Several experiments (in-situ and out of pile) have been carried out to study the tritium release behavior of porous Lithium ceramics. However the tritium diffusivity reported by the experiments vary over several order of magnitude and the reasons for these differences are not clearly understood.

In this thesis work, important aspects of tritium release have been studied. This includes generation of tritium in solid breeder blanket of fusion reactor and ITER TBM, development of a multi-model framework for systematic evaluation of defects in lithium ceramics, Kinetic Monte Carlo simulations of intragrain and inter-grain tritium diffusion in ceramic pebble, Nishikawa's model for tritium inventory and residence time. Radiation transport analyses have been performed to evaluate tritium breeding ratio (TBR) for Indian solid breeder blanket in SST-2 and tritium production rate in Indian Lead Lithium Ceramic Breeder (LLCB) Test Blanket Module (TBM) in ITER. In SST-2, with breeding blanket only at inboard side, the TBR is 0.94 and for fusion power of 300 MW this corresponds to tritium generation of 3.95E-03 grams/s. A multi-model frame-work has been developed in which sequential evaluations starting from the neutron spectra, Primary Knock-on Atom spectra and collision cascades have been carried out for obtaining the radiation damage to the Lithium ceramic pebbles. Using this frame-work the defects production in Lithium Titanate in LLCB TBM, under ITER irradiation conditions, have been analyzed. An existing KMC model of diffusion in porous media has been modified to simulate the intra-grain and inter-grain migration of tritium. This KMC model has been used to analyze the experimental results on various intra-grain and inter-grain diffusion to understand the physics of tritium migration in Lithium ceramics. We observed that porosity impacts the tritium diffusivity in Lithium ceramics. Tritium release characteristics such as tritium inventory and residence time for SST-2 solid breeder blanket have been analyzed using Nishikawa's model. A study has been done to investigate the impact of temperature, grain size, purge gas composition etc. on the residence time and inventory in SST-2 solid breeder blanket. It shows that Li $2TiO_3$ pebbles with grain sizes 2-5 μm exhibits better tritium release behavior. In this presentation several of the above mentioned results, issues and possible future work will be discussed.