§55. Physics of the Plasma-wall Boundaries in Inertial Fusion

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Since two applications (2014NIFS14KUGK083 & 2014NIFS14KUGK084) in NIFS collaboration research program have been combined as a single budget the theme of the combined proposals has been changed to have a new title.

Interactions of intense energetic particles with matter in inertial fusion reactors are discussed. A hydrodynamics simulation code coupled to the calculations of the energy deposition from the particles has been developed to study the interactions. It has been found that the ionization processes of the ablated matter are important to determine the energy deposition of the incoming particles. Similar effects of ionization on particle interactions have been found in laboratory scale experiments of laser-ablated plasma-plasma interactions.

In inertial fusion reactors, the reactor wall is exposed to high-energy particles such as fusion products, unburned fuel, and ions contained in the fuel pellet as well as high energy x-rays. The particle intensity can be above the ablation threshold of the first wall. Ways to avoid the wall ablation can be increase the chamber size or reduce the fusion power, however, these solutions could reduce fusion efficiency. Another approach to minimize the effects of energetic particle irradiation to the walls uses a buffer gas. The buffer gas works as an energy absorber of the energetic particles. However, the gas density is limited to avoid the optical breakdown that prevents the irradiation of the implosion laser to the fuel target.

We propose a new concept that could reduce the material ablation caused by intense, energetic particle beam irradiations. In the concept, the first part of the beam ablates the matter, and then, the ablated matter itself behaves as a shield, which is similar to the "vapor shielding" around the divertor in the magnetic confinement fusion[1].
Here, the common key of the concepts is heating of ablated matter due to the incoming energy flux. Energy deposition efficiencies of the energetic ions in matter are determined as a stopping power.
We have calculated the stopping power of matter as a function of its temperature (i.e. ionization level). For the study of shielding effect in the ablated matter from energetic particle irradiations, a 1D hydrodynamics simulation code has been developed that is coupled to the energy deposition calculation due to energetic particle injection to the matter using the temperature dependent stopping power.

We estimate the temperature increase by irradiation of charged particles form the calculation of the particle energy deposition and thermal conduction. We couple the calculation of the particle energy deposition to hydrodynamics in order to describe the variation of density, velocity and temperature as shown in Fig.1. The details of the calculation has been shown in Ref.[2].

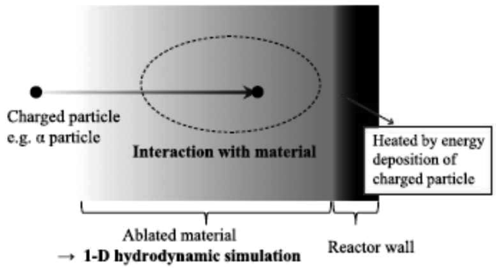

Fig. 1 Energetic particle comes onto wall material.

Figure 2 shows the energy deposition from 100 keV alpha particle onto vapor and solid carbon. The solid phase last until 0.5 nsec where most of the alpha energy is deposited. The phase changes clearly from solid to liquid at 0.5 nsec. Alpha particle energy starts being absorbed in the vapor phase instead of in the solid region. Actually after the vapor region develops the alpha particle energy is 100% absorbed in the vapor. This state of condition represents the function of vapor shielding.

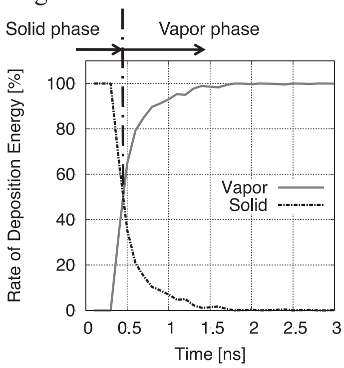

Fig.2 Energy depositon of 100 keV aspha particle onto vapor and solid carbon.

[1] Hassanein,A, et al.,Fus.Eng.Des.60, 527 (2002)
[2] Takaki, K, et al., J. Nucl. Mat., 459, 77(2015).