§10. Design on New Type First Wall under High Temperature and Particles for Nuclear Fusion Reactor

Furukawa, H. (ILT, Osaka), Norimatsu, T., Kozaki, Y., Jozaki, T., Mima, K. (ILE, Osaka University)
Sagara, A.

Critical issue in designing an advanced fusion reactor with high output energy density is the ablation of the hot first wall exposed by energetic particles from plasma. In a case of a dry wall reactor for laser fusion operated with a 150 MJ yield target, the total thermal load on the surface is estimated to be 4.5 x 10^{18} W/cm^2, which heats the initially 500^{o}C tungsten surface to 3000^{o}C at the chamber radius of 6 m [1].

Before November 2001, we investigated ablation of tungsten and liquid lead under irradiation of x-rays, ions and α particles through computer simulation. The stopping power of plasma was calculated using dielectric response function of plasma and Bethe equations. We found that the stopping process in the ablated plasma is very important to discuss the ablation rate of the first wall.[2]

This year, we formulated the stopping power including influence of bound electrons to evaluate the vapor shielding effect. In this model, the ionization rate, the ionization energy of atoms and ions were involved to accurately evaluate the stopping process. A new model for hydrogen-like ions developed by Nishikawa of Okayama University[3] was used to calculate the number density of neutral particles, the ionization energy and the ionization rate.

The stopping power W of partially ionized gas was given by [4]

$$W = -\nabla \cdot E_k(x,t) = \frac{4\pi n_i Z_0{}^2 e^4}{m_e v^2} L \qquad (1)$$

$$L = Z^* L_f + (Z - Z^*) L_b \qquad (2)$$

$$L_b = ln\left(1 + \frac{2m_e v^2}{I}\right) \qquad (3)$$

where
L, the stopping number;
I, the ionization energy;
Z^*, average charge of partially ionized gas.

Here, $Z^*=0$ means it is neutral gas (vapor shielding). These equations indicate that accurate evaluation for the ionization rate and the ionization energy over a wide temperature range is very important to evaluate the vapor shielding effect.

Figure 1 shows the ionization rate of lead at temperature of 0.01 eV to 10 eV calculated over a wide density range from 10^8 to 10^{24} cm^{-3}. These results are very important for designing the first wall under a high thermal load such as the first wall of the laser fusion rector and a diverter of the magnetic confinement system.

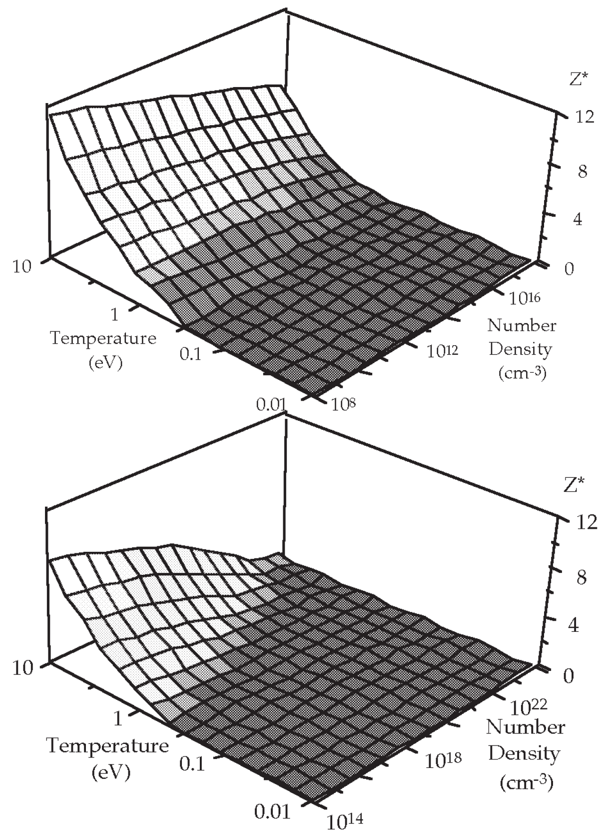

Fig. 1 Ionization rate of lead calculated over a wide density range from 10^8 to 10^{24} cm^{-3}.

References

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