ABLATION OF HIGH-Z MATERIAL DUST GRAINS IN EDGE PLASMAS

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Nowadays it is well recognized that dust particles can play an important role in fusion plasma performance and material transport [1]. Therefore, it is important to have a good understanding of the most important processes dust grains encounter in the course of the interactions with fusion grade plasmas. Many fundamentals of grain-plasma interactions were developed by dusty-plasma community. However, grain-plasma interactions in fusion devices have some important distinctions. In particular, in hot and dense fusion plasma environment dust grains ablate rather quickly. The effect of the vapor on grain-plasma interactions can only be neglected for relatively small grains (below ~10 microns). Meanwhile, it is important to know how the vapor "shielding" alters grain-plasma interactions for larger (~100 microns) grains, which may pose significant threat for plasma performance and even result in disruption, especially for the case where these are high-Z material grains.

There are several numerical codes developed for modeling of the dust transport: DUSTT, DTOKS, MIGRAIN etc. However, the models employed in these codes do not account for plasma interaction with vaporized grain material. Usually it is supposed that for large grains one can use shielding model developed for hydrogen pellet ablation [2]. In this model heating of the dust grain by fast electrons causes the grain evaporation. The vapor is responsible for energy loss of ambient plasma electrons, reducing the total heat flux coming to the grain surface. Description of the loss mechanism is a key ingredient for any shielding model. For pellet ablation the loss is defined in free streaming electron approximation. This approximation is indeed justified for the grains with small atomic number Z, but can be violated for heavier grains. One can see that if the mean free pass length for electrons in the vapor cloud is larger than the cloud typical size, the free streaming approach is valid. However, for large Z material, such as tungsten (W), this assumption is wrong and shielding should be described by electron thermal conductivity, rather than just stopping of an electron beam.

In the present work we develop such a model. We use thermal conductivity equation to describe electrons loss in both neutral vapor and secondary plasma. To make our model reasonably simple we use a number of simplifications. The coronal model is used for secondary W plasma and Saha equilibrium is supposed in the W vapor. The validity of these assumptions will be checked in our future works.

Using our model, we show that the thermal conductivity effect leads to a notable decrease in the grain ablation rate, compared to the free-streaming model. A set of variables responsible for applicability of our model is defined and impose restrictions on the problem parameters: the grain size, temperature and pressure of the ambient plasma. Analysis of these conditions shows that the thermal conductivity effects are valuable for large enough grains, several micrometers in diameter, in tokamak edge plasmas.

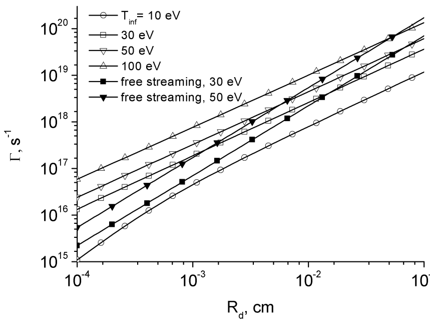

Fig. 1. The grain ablation rate vs the grain radius.

An example of calculated ablation rate values, Γ, versus the grain radius, R_d, is shown in fig. 1. The rates are presented for several different ambient plasma temperatures T_{inf}. Our results are marked by hollow markers, while filled markers represent the ablation rate calculated in free streaming approach, taken from [1]. One sees that the rate values as well as their scaling with Rd are different for both models. We notice that wrong estimate of the ablation rate can have a critical impact on plasma-dust interactions, since it defines the depth of the dust penetration in the core plasma.

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