Stopping power and collisions for energetic ions in partially ionized plasmas

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Synopsis *Ab initio* stopping power for energetic ions in partially ionized plasmas has been studied which includes various collision processes. Comparison with experiments has been done and new experiments are suggested to test our model.

Stopping power of energetic ions in plasmas is important to the study of controlled fusion. So far the plasmas are usually partially ionized for experiments to measure the energy loss for ions in hot matters. As far as we know, the first relevant experiment was done more than 30 years ago [1], where the stopping of 1MeV deuterons in warm Al plasmas was measured and found enhanced compared with the cold targets. Last year [2] the energy loss of 15MeV protons in both cold and warm dense Be matters were measured in high accuracy, which showed an increasing relative to cold matter. The related theoretical investigation was started about 36 years ago [3] for fast protons in hot Au target. After that some phenomenal models [4-5] were suggested to estimate the stopping power for energetic ions in intermediate or high-Z plasmas. In recent time an *ab initio* model [6] was developed by us to study the problem based on the average atomic model [7], where some bound electrons may distribute at excited states in hot plasmas so that the excitation and ionization as well as their reverse processes have contribution to the inelastic stopping. In this model a non Maxwellian velocity distribution for free electrons is introduced due to the strong electrostatic field from the highly charged target ion. After that a series of works have been made by us to study the stopping power in hot plasmas, which includes the comparison with the relevant experiments and the influence of the mixing of heavy element material with the fusion DT plasmas upon alpha particle heating, etc.

In the present work we will introduce some of our recent progresses in the field mainly focusing on the influence of inelastic collision upon the stopping power as well as the nuclear stopping in partially ionized plasmas in three aspects. The method for the calculation of inelastic process is first-order relativistic plane wave Born approximation with all the possible transitions considered. It is found to work well for the projectile energy $E_p \geqslant 100$keV/u of deuterons by comparison of excitation cross sections of Al ions from solving the time-dependent Schrödinger equation.

First it is found that the inelastic stopping is considerably weakened due to the strong influence from the reverse processes of the excitation and ionization for deuterons in Al plasmas. Comparison with some other models indicates that our model is totally in better agreement with the experiment [1] and the main reason for this is that our results for the inelastic processes should be the most reliable**.** Basing on this a new experiment is suggested to test the contribution of inelastic stopping in different models.

Secondly a similar research with Al has been made in solid-density Be, where a new physical scenario is suggested to get the result at room temperature. Our results are found in good agreement with the recent experiment for both warm and cool matters. The comparison of our model with the local density approximation (LDA) model [5] is made and the reason for their difference is explored. The predictions of energy loss at smaller projectile energies are made by our model and LDA, which is helpful by future experiments to probe which model proves more reliable and judge whether the velocity distribution of free electrons quite different from Fermi-Dirac one exists in dense plasmas.

Thirdly the nuclear stopping for protons in hot Au plasmas is studied and reasonable results are obtained. It is found that the traditional model basing on Coulomb potential does not work in this case while it works well in DT plasmas and the reason for this is explored.

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