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Floating Potential of a Collector in a Plasma with two Species of Positive Ions and two Electron Populations with Different Temperatures

M. Čerček[1,2],T. Gyergyek[3,1], G. Filipič[1], C. Ionita[4], R. Schrittwieser[4]

[1]*Jožef Stefan Institute, Jamova 39, 1000 Ljubljana, Slovenia*

[2]*Faculty of civil engineering, University of Maribor, 2000 Maribor, Slovenia*

[3]*Faculty of electrical engineering, University of Ljubljana, 1000 Ljubljana, Slovenia*

[4]*Institute for Ion Physics and Applied Physics, University of Innsbruck, A-6020 Innsbruck, Austria*

Introduction

In this research we continue the series [1, 2, 3] of bounded plasma research. In [2, 3] effects of addition of energetic electrons to one electron-ion plasma were investigated. It was shown that presheath boundary potential and collector potential decrease with increasing hot to cold electron density ratio for small values of this ratio (≤ 0.4). For larger values of the ratio the values of presheath potential decreases less rapidly, while collector potential settles to more or less constant value. An important phenomenon is the formation of a double layer at the value of the hot to cold electron density ratio around 0.25. This time we have added another species of ions and we are interested in potential dependence on hot to cold electron density ratio at three ion density ratios, and in double layer formation. We approach the problem by computer simulations using the particle in cell code XPDP1 [4].

Simulations

Three series were simulated: $\alpha = 0.95$, $\alpha = 0.50$ and $\alpha = 0.05$. Here α is the ratio between the density of Ar^+ ions and total ion density with both Ar and He taken into account. In each series simulated potentials were obtained for β in range form 0 to 1. Here β is the ratio between the hot electron density and total electron density. The ratio α was set in the input file with injected ion current ratio, while ratio β was established by pre-simulation. First the system was completely empty, then we ran a simulation with injection of all 4 particle species. When the number of cold electrons in the system reached predetermined value the simulation was saved to a dump file. The input file was edited so that the injection of the cold electrons was set to zero and the influx of the hot electrons was set equal to the sum of both ion influxes. Then simulation continued from the dump file, but with the new input file. Simulation was over when number of particles reached a constant value. Length of the system was changed to get a stable simulation. For α 0.95 and 0.05 the length of the system was from 0.01 m for small values of

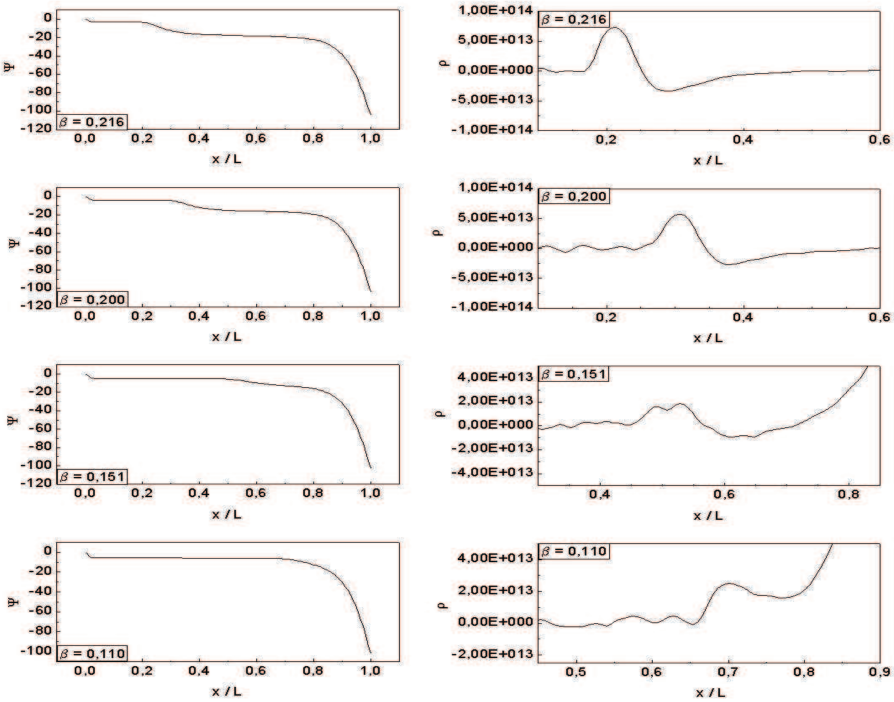

Figure 1: Potential and charge distributions of simulations for $\alpha = 0.95$ for different β, at which double layer is formed.

β to 0.08 m for larger β. For $\alpha = 0.50$ length interval was 0.05-0.4 m. In our analysis we used electrons with temperatures of 2 eV and 40 eV respectively for the cool and hot electrons and both ion species (He and Ar) had temperature 0.1 eV. As addition to previous simulations we made some changes in parameters to simulate plasma similar to plasma in our linear plasma machine. Discharge potential for accelerating electrons into our plasma system is of the order of 50 V, so we set lower and higher limit to electron velocity with cutoff velocity equal to 50 eV of kinetic energy. Again we were interested in presheath and collector potential. In the end we changed temperature of hot electrons to 12 eV and made simulations with and without cutoff velocity.

Results

Potentials Ψ_P and Ψ_C have similar behavior due to β as in [2, 3]. Both decrease, Ψ_P slowly at first, than faster and towards large β (≥ 0.4) the decrease is more gentle again. The collector potential Ψ_C falls rapidly for small β and at around $\beta = 0.4$ settles at almost constant value. Larger values of α bring lower values of the collector potential Ψ_C (normalized to the cool electron temperature) which is expected because of slower positively charged particles. Double layers are formed for all three α in intervals of β around 0.23, where at same β we had two values of the plasma potential at the inflection point normalized to the cool electron temperature Ψ_P. In Fig. 1 are shown potential profiles along the system (left column) and inserts of

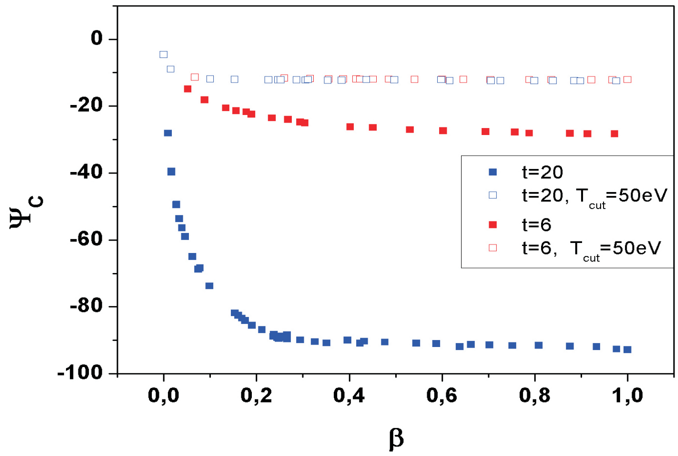

Figure 2: Collector potential for simulations with hot electrons temperature 40 eV and 6 eV, with and without cutoff velocity at 50 eV.

charge density profiles (right column). In first double layer is seen as sheath between two locally constant potentials and in later we see the rise of positive charge followed by an excess of negative charge. It is seen how double layer travels down the system with decreasing β and eventually gets assimilated into collector plasma sheath. Ions, which travel from the source to the collector, are accelerated in the double layer area and at the same time they are cooled down - velocity distribution is more narrow after double layer. In collector sheath they get accelerated once more to a final velocity with which they hit the collector. Velocity distribution for hot electrons before and after double layer does not change, while there is no more cold electrons after double layer because the collector potential is to strong and cold electrons get repelled. Some hot electrons reach the collector and thus they have truncated velocity distribution. Collector

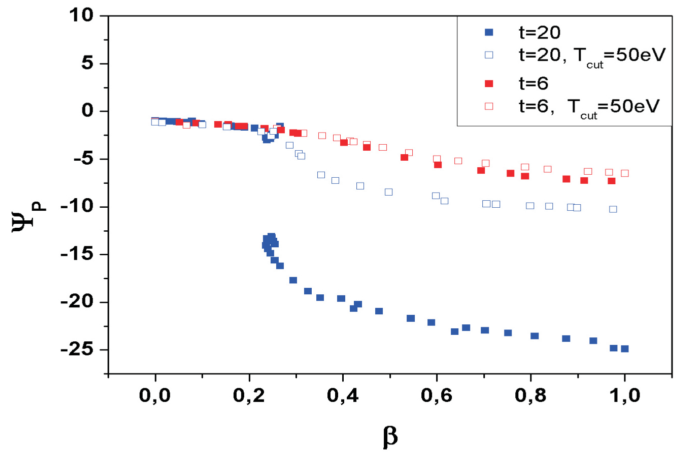

Figure 3: Presheath potential for simulations with hot electrons temperature 40 eV and 6 eV, with and without cutoff velocity at 50 eV.

potential is primarily determined by fastest of hot electrons which is seen in Fig. 2. Simulations with different hot electron temperatures but same cutoff velocity have almost identical collector potential. Collector potential determines whether the double layer is formed or not. If hot electrons are not fast enough, the potential is to high and barrier for cold electrons is to small and double layer can not exist. Simulations with cutoff velocity or with lower temperature of the hot electrons ($6eV$) do not have double layer as seen in Fig. 3.

Conclusion

We have shown that in collisionless double-ion plasma it is also possible to obtain double plasma layer, if temperature ratio of the electrons is sufficiently large. Double layer is formed in the same β range, regardless of α ratio. On the other hand the values of α do influence the collector potential. At constant electron temperature higher α means lower Ψ_C. At constant α ratio, Ψ_C rises with decrease in electron temperature. Thus heavy ion to hot electron particle current determines the Ψ_C. Cutoff velocity has similar effect as lowering the temperature of hot electrons. It can prevent double layer to form. Because of that we do not expect double layer to form in plasma in an experiment in a real machine.

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[4] The Plasma Theory and Simulation Group, http://ptsg.eecs.berkeley.edu/