§17. Grain Charging/Coagulation Process in Dusty Plasmas

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The dust particles (grains) are found in planetary plasmas and play an important role in the formation of the structure, e.g., the rotating radial spokes of the Saturn's rings. They also become important in various plasma processing. In this study, we are investigating how such dust particles are charged and grow making coagulation, and how the structures are formed. Our final goal is to clarify the physical mechanism of the ordered structure formation from a viewpoint of the "Self-organization".

Generally, the grains have been considered to be charged negative because electrons of the background plasma attach to the grains more frequently than ions due to the difference of the thermal velocity. However, when the secondary electron emission effect from grains is taken into account, the electric potential of dust grains can change from negative to positive or positive to negative in the way of "flip-flop". We developed a new three dimensional particle code in which the dynamic charging process is taken into account such as the attachment of background electrons and ions to the grains, and the secondary electron emission from the grains when the high energy electron collides. Using this code, we have pursued the dynamics of the grains being charged up by the background plasma. We also considered the change of the charge, mass and size of the grain as a result of the coagulation between the grains of opposite charge.

We have already shown that the grains change their charges in the flip-flop way from -160e to +70e due to the secondary electron emission effect as the time passes by. The lowest (negative) limit of the charge is determined by the balance between the attachment of the electrons and ions, while the highest (positive) is determined by the balance between the electron attachment and the secondary electron emission. Such oppositely charged grains are making a coagulation.

There exists a suitable temperature of the background plasma for the growth of the grains. Namely, if the electron temperature of the background plasma is high, the grains can easily emit secondary electrons and hence, the charges of the grains stay positive. On the other hand, if the electron temperature is low, the electron attachment becomes dominant and the charges of the grains are kept negative. In either case, no coagulation occurs and the dust grains never grow. The spatial distributions of the dust grains at $t = 10^8 \omega_{pe}^{-1}$ are shown in Fig. 1 for the moderate electron temperature case in which the coagulation occurs (left panel), and for the low electron temperature case in which the dust grains are scattered due to the repulsive force (right panel).

It is also found that the flip-flop effect is outstanding when the radius of the grains is of the order of $10^{-2}\mu m$ under the typical plasma parameters. This is because the attachment of a single electron to the grain does not affect much on the surface potential of the grain when the radius of the grain is large enough, say, of the order of $1\mu m$. When the radius is small enough, the average probability of the electron attachment becomes small. This fact leads to the another interesting result, namely, the coagulation of a large number of grains, *e.g.*, 1000 grains, make the grain size 10 times larger, so that the flip-flop effect does not play a major role and the grain charge may stay negative. Then, the coagulation ceases and the growth of the grain may stop.

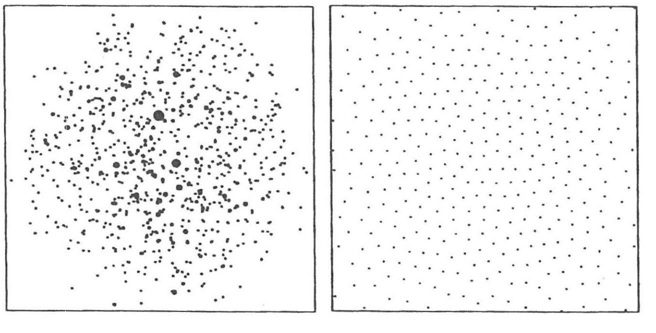

Fig. 1 : The grain distributions in space at $t = 10^8 \omega_{pe}^{-1}$ for the moderate (left panel) and low (right panel) electron temperature.