

ANALYSIS OF COULOMB-CRYSTAL FORMATION PROCESS FOR APPLICATION TO TAILORED PARTICLE SYNTHESIS IN RF PLASMAS

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Particles can be suspended in the gas phase for long periods of time when they are negatively charged and trapped in the positive potential of a plasma. Dusty plasmas have been investigated mostly to get rid of them in processing plasmas since they cause severe problems in microelectronics manufacturing. On the other hand, particle plasmas which contain a substantial number of particles show interesting characteristics which differ from those of ordinary plasmas. One noticeable feature is the formation of Coulomb solids. It had been predicted by theoretical considerations [1], and last year three successful experimental results came out independently almost at the same time[2,3,4].

We have developed a new technique named as "Mie scattering ellipsometry", by which we can monitor particles in real time on the temporal changes of diameter, number density and optical index. Then, we tried to inject carbon soot of 50 nm nominal diameter into an RF methane plasma and observed the changes. After about 30 min in a typical plasma condition, it was observed that the diameter grew to $1\ \mu\text{m}$ and the loss rate of particle density decreased suddenly. At that time particles started to be arranged into a structure of hexagonal lattice as noticed by the video monitor. The shape of collected particles was almost perfectly spherical and the size was monodispersive as identified by the SEM observation, which was consistent with the Mie scattering ellipsometry results.

In order to analyze the solidification condition, we estimated the Coulomb coupling parameter Γ , which is defined as the ratio of Coulomb potential energy between particles to thermal kinetic energy. Based on speculated values of plasma parameters, the negative charge on a particle was estimated to reach $10^6 e$ at the time of solidification, and Γ became 200 to 300. This value is close to the theoretically predicted value of 170 for the phase transition.

Technologically, the application of Coulomb solidification process is expected to the synthesis of tailored particles, e.g., spherical particles with layered structures realized by switching the source gases. To perform the idea we are investigating the solidification conditions in more detail at various external conditions, i.e., choices of the source gases, the operating gas pressure, the RF frequency and the power.

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