



Computation of Potential and Electron Concentration Distributions in Dust-Electron Thermal Plasmas with Axial Geometry Particles

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Abstract:

The distribution of potential and electron density in an equilibrium dust-electron plasma considering the parameters of the electron gas inside the axial geometry dust particles. These parameters are included on the basis of the model of "solid-state plasma", which considers a condensed particle system as an ion core and free electron gas.

Keywords: Dust-Electrons, Thermal Plasma

Introduction:

A system of dust particles, free electrons and neutral gas atoms at temperatures of 1000-3000 K at atmospheric or high pressure is called a dust-electron thermal plasma. Under these conditions, the system is an isothermal result of intense collisional heating, i.e. statistical equilibrium is established. Such plasma is produced in the combustion of solid and liquid fuels, in thermal spray coating processes, in MHD generator channels, in plasma chemical reactors, in the synthesis of nano- and micro-sized particles, and in magnetic fusion devices. The typical size of dust particles is in the range of 0.01 to 100 microns. Dust grains heated by the emission process are the source of free electrons. As a result, dust particles become positively charged. If such plasma does not contain readily ionizable alkali metal impurities, the presence of ions can be neglected.

The most important characteristics of dust-electron thermal plasmas are potential and electron density distributions. The "jelly" model, which was previously widely used in

the description of the electrical properties of atomic clusters, was used to determine these features of the data used in this study. According to this model, the dust particle is represented as a two-component system. The first component is the ion core, which creates a uniform positive background throughout the volume of the dust particle. Another element is the electron gas. The density of this gas is distributed in the area due to the balance of internal gas pressure and electrostatic forces. Thus, in this model, a dust particle can be regarded as a solid state plasma field. From the above it can be seen that the distribution of potential and electron density within and around dust particles depends on temperature, type of material, size and concentration of particles.

Consider the system of equations describing the potential distribution and electron density in the solid-state plasma and its surroundings in statistical equilibrium when the temperature is low and ionization of the gas can be neglected. The distribution of the potential ϕ of the electrostatic field is described by the Poisson equation.

$$\Delta\phi = \frac{n_e - n_1}{\epsilon_0\epsilon_1}q,$$

Equation 1

Where ϵ_1 relative permittivity, ϵ_0 - electrical constant - concentration of positive charge of ion core (density of positive background), q absolute value of electron charge. From the Boltzmann formula

$$n_e = n_{e0}e^{\frac{q\phi}{\theta}}$$

Equation 2

Where n_{e0} is the electron density at the origin of the potential, i.e. when $\varphi = 0$ we get the Poisson-Boltzmann equation

$$\Delta\varphi = \frac{n_{e0}e^{\frac{q\varphi}{\theta}} - n_i}{\varepsilon_0\varepsilon_1} q,$$

Equation 3

The solution of equations (2) and (3) determines the electron density distribution. Consider a simple function when the dust particles are uniform cylinders and this

concentration is constant in space. In case of axial symmetry, equation (3) can be written in following format

$$\frac{\varepsilon_0\varepsilon_1}{r} \cdot \frac{d}{dr} \left(r \cdot \frac{d\varphi}{dr} \right) = \left(n_{e0}e^{\frac{q\varphi}{\theta}} - n_i \right) q$$

Equation 4

As a result of the introduction of dimensionless quantities:

$$\frac{r}{R} = x, \frac{q\varphi}{kT} = \phi, \frac{n_i}{n_{e0}} = \bar{n}_i$$

We can obtain the following

$$\frac{1}{x} \cdot \frac{d}{dx} \left(x \cdot \frac{d\phi}{dx} \right) = b^2 (e^\phi - \bar{n}_i), b^2 = \frac{q^2 R^2 n_{e0}}{kT \varepsilon_0 \varepsilon_1}$$

Equation 5

Here R is the dust particle radius, n_{e0} is the electron density at the centre of the cylinder, \bar{n}_i is the constant in the field of $0 \leq x \leq 1$ and $\bar{n}_i = 0$ in the field of $x > 1$.

Some electrons are ejected from the dust particles and so the $n_i > n_{e0}$ equation will be solved according to the conditions.

$$\phi(0) = 0, \phi'(0) = 0, \quad \phi'(1) = 0$$

The distance between the centres of two neighbouring dust particles. The last boundary condition indicates the total electric charge vanishing in a volume bounded by a sphere of radius l and is used to determine the value of n_i .

Electric potential distribution along the radius for different values of absolute temperature. As can be seen in dust particles with increasing x potential, first decreases slowly and then decreases rapidly approaching the particle surface. This is due to the emergence of a large electron density gradient near the surface. Accordingly, there is a large electric field. With increasing temperature, the potential drop over the entire distance from 0 to 1 decreases as the electron yield of the particles increases.

Since the potential and electron density are directly related by the Boltzmann formula, x increases in magnitude $x \approx 1$ and decreases exponentially. Removal of the particle reduces and the rate of change at the point of position $\frac{dn_e}{dx} = 0$.

At higher temperatures, the electron density decreases rapidly as x in the particle

increases. However, outside the particle, the electron density increases with increasing temperature.

Conclusion:

with equation 4, which describes the potential and electron density distribution in an equilibrium dust-electron plasma, taking into account the parameters of the electron gas inside the axial geometry dust particles. These parameters are included based on the model of "solid-state plasma", considering the condensed particle system as an ion core and free electron gas. Solving Equation 4 we obtain the potential distribution and electron density in the thermal equilibrium dust-electron plasma. We found that there is a large gradient of electrical potential near the surface of the particles and, as a result, the concentration of free electrons, that is, the electrons in the dust particles are located in the potential well. The obtained expressions allow to calculate the effect of several parameters such as temperature, concentration and size of dust particles, type of material of particles on the properties of equilibrium dust electron plasma.

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