Collisional and optical properties of the dense semiclassical plasma

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Elastic and non elastic scattering of the electrons are the elementary processes that continuously attract the attention of the researchers. For developing of the applications, where plasma is a working medium, one needs adequate data on physical properties of the system. Electron scattering strongly influences the transport, optical and other properties of plasmas. A large number of various theoretical and experimental studies is devoted to the scattering of the electrons on the noble gas atoms. Various theoretical methods are used for studying of the elementary processes and plasma properties.

In this work we consider the dense partially ionized plasma of the noble gases consisting of the electrons, ions and atoms. Particle densities are in the range of $n = 10^{20} \div 10^{23}\, cm^{-3}$ and the temperature range is from $2.5\times10^4 K$ up to $5\times10^4 K$.

In work [1] the effective potential of electron–atom interaction, taking into account both quantum-mechanical effect of diffraction and screening effects, is presented. The way to take into account the dynamic screening was proposed in work [2], where the statical Debye radius was replaced by the dynamic one:

$$r_o = r_D (1 + \frac{\upsilon^2}{\upsilon_{Th}^2})^{1/2}, \quad (1)$$

here υ is the relative velocity of the colliding particles, υ_{Th} is the thermal velocity of the particles in the system. Then the effective potential of electron-atom interaction with dynamic screening can be rewritten as [3]:

$$\Phi_{ea}(r) = -\frac{e^2\alpha}{2r^4(1-4\lambda_{ea}^2/r_o^2)}\left(e^{-Br}(1+Br) - e^{-Ar}(1+Ar)\right)^2, \quad (2)$$

where $A^2 = \frac{1}{2\lambda_{ea}^2}\left(1+\sqrt{1-4\lambda_{ea}^2/r_o^2}\right)$,

$$B^2 = \frac{1}{2\lambda_{ea}^2}\left(1-\sqrt{1-4\lambda_{ea}^2/r_o^2}\right).$$

In the framework of this pseudopotential mo-del for the particle interactions, the scattering phase shifts δ_l were calculated on the basis of the Calogero equation:

$$\frac{d\delta_l(k,r)}{dr} = -\frac{1}{k}U(r)\times \left[\cos\delta_l(k,r)\cdot J_l(kr) - \sin\delta_l(k,r)\cdot n_l(kr)\right]^2, \quad (3)$$
$$\delta_l(k,0) = 0 .$$

Here k is the magnitude of the wave vector of the incident particle, $U(r) = \frac{2m}{\hbar^2}\Phi_{ea}(r)$, $j_l(kr)$ and $n_l(kr)$ are the Ricatti - Bessel functions.

Phase shifts enable us to calculate the transport scattering cross section $Q_{ea}^T(k)$. The collision frequency of the electrons with atoms ν_{ea} can be obtained by the following expression:

$$\nu_{ea} = 4\sqrt{\frac{2}{\pi}}n_a\sqrt{\frac{k_BT}{\mu_{ea}}}\int_0^\infty Q_{ea}^T(g)g^3 Exp(-g^2)dg, \quad (4)$$

here $\mu_{ea} = m_e m_a/(m_e + m_a)$ is the reduced mass of the electron-atom pair, g is the reduced velocity.

Dielectric function due to the electron - atom interactions was calculated using the generalized Drude-Lorentz equation:

$$\varepsilon(\omega) = 1 - \frac{\omega_p^2}{\omega^2 - i\nu_{ea}\omega}. \quad (5)$$

From the dielectric function the reflectivity of the semiclassical electron plasma is calculated, using the Fresnel formula, and is compared with experimental results [4].

References

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