DIELECTRIC FUNCTION AND REFLECTIVITY OF DENSE XENON PLASMA

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In this work the dielectric function and reflectivity of dense xenon plasma were investigated on the basis of effective potentials taking into account the quantum-mechanical effect of diffraction and screening effects. The Drude-Lorentz and Fresnel formulas were applied to calculate the dielectric function and reflectivity.

The investigation of optical properties of the dense xenon plasma is important for the realization of different technological applications [1-4].

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

In work [5] the effective potential of electron–atom interaction, taking into account both quantum-mechanical effect of diffraction and screening effects, was presented. The way to take into account the dynamic screening was proposed in work [6], where the statical Debye radius was replaced by a dynamic one:

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

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 [7]:

$$\Phi_{ea}^{dyn}(r) = -\frac{e^2\alpha}{2r^4(1-4\lambda\!\!\!^-_{ea}{}^2/r_o^2)}\left(e^{-Br}(1+Br) - e^{-Ar}(1+Ar)\right)^2, \tag{2}$$

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 these pseudopotential models for the particle interactions, the scattering phase shifts were calculated on the basis of the Calogero equation [8].

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

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

here $\mu_{ea} = m_e m_a / m_e + m_a$ is the reduced mass of the electron-atom pair, g is dimensionless reduced velocity. The results will be compared with earlier results which were based on experiments for the transport cross section [9].

After that the dielectric function due to the electron atom interactions was calculated using the generalized Drude-Lorentz [10] equation:

$$\varepsilon(\omega) = 1 - \frac{\omega_p^2}{\omega^2 - i\nu_{ea}\omega}. \quad (4)$$

However, for the total electronic dielectric functions contributions due to electron-ion and electron-electron interactions will also be considered [10,11]. From the dielectric function, the reflectivity of the semiclassical electron plasma using the Fresnel formula is calculated and compared with experimental results [12].

References

[1] L. Martinu and D. Poitras, “Plasma deposition of optical films and coatings: a review,” *J. Vac. Sci. Technol. A* **18** (2000) 2619 –2645.
[2] S. Pongratz and A. Zöller, “Plasma ion assisted deposition: a promising technique for optical coatings,” *J. Vac. Sci. Technol. A* **10** (1992) 1897–1904.
[3] D. Bohling, M. Coda, R. Blacker, and R. Gove, *43rd Annual Technical Conference Proceedings of the Society of Vacuum Coaters*, (Society of Vacuum Coaters, 2000), p. 222–229.
[4] L. Gerenser, “Surface chemistry of plasma-treated polymers,” in *Handbook of Thin Film Process Technology*, D.A. Glocker and S.I. Shah, eds. (Institute of Physics, 1998), p. 1–21.
[5] T.S. Ramazanov, K.N. Dzhumagulova and Y.A. Omarbakiyeva, Effective polarization interaction potential “charge-atom” for partially ionized dense plasma, *Phys.Plasmas* **12** (2005) 092702.
[6] D. Kremp, M. Schlanges, W. D. Kraeft, Quantum Statistics of Nonideal Plasmas, *Springer* (2005), p. 326.
[7] K.N. Dzhumagulova, E.O. Shalenov, T.S. Ramazanov, G.L. Gabdullina, Phase shifts and scattering cross sections of the particles of nonideal semiclassical plasmas based on the dynamic interaction potential, *Contr. Plasma Phys* **55** (2014) 230-235.
[8] L.D. Landau and E.M. Lifschitz, “Quantum mechanics (nonrelativistic theory)”, *Nauka, Moscow* (1989), p. 691.
[9] J. R. Adams, H. Reinholz, R.Redmer, Electrical conductivity of nobel gases at high pressure, *Phys. Rev. E* **76** (2007) 035405.
[10] H. Reinholz, Dielectric and optical properties of dense plasmas, *Ann. Phys. Fr.* **30** (2005) 1.
[11] H. Reinholz, G. Röpke, *Phys. Rev. E* **85** (2012) 036401.
[12] Yu.B. Zaporoghets, Y.A. Omarbakiyeva, H. Reinholz, G. Röpke, V.B. Mintsev, V.K. Gryaznov, Optical reflectivity of Xenon plasma revisited, *Contr. Plasma Phys.* in press (2016).