electron jellium in plasma fluid of metal vapors and noble gases

Khomkin A.L., Shumikhin A.S.

Joint Institute for High Temperatures of RAS, Moscow, Russia, alhomkin@mail.ru

Under shock-wave compression of condensed inert gases, an abrupt (depending on density) increase in conductivity was observed. It is experimentally demonstrated in Ar, Xe, Kr [1]. When compressing inert gases, initially in the gas state, a high conductivity is observed, but it is weakly depend on the density. The suggested “3+” model [2] described successfully the dense metal plasma, obtained in experiments on the electric explosion of wires and foils, with using the idea of electron jellium. The purpose of this paper is to apply the previously proposed "3+" model to the calculation of the conductivity of a dense rare gases plasma taking into account their specificity. Inert gases are fundamentally different from metal vapors. In the gas state, they are dielectrics and remain so during cooling and compression up to the liquid and solid states. According to the Lennard-Jones-Devonshire theory, the collective binding energy is formed due to the pairwise-additive interaction of the test atom with its nearest environment from the first coordination spheres. The use of the Lennard-Jones potential for the binding energy calculation leads to reasonable results in the framework of classical statistical physics [3]. The use of the proposed in [2] method of the jellium density calculation leads to its appearance in the compressed rare gases. However, the resulting jellium should be considered dielectric because it arises from a fully filled electron shell. The jellium electrons do not give direct contribution to the conductivity and the collective binding energy of atoms. The jellium arising in rare gases is formed from the tails of the electron density of the bound states and its position on the energy axis is directly adjacent to the ground level. The paper proposes to consider a new, unusual for plasma physics effect associated with the broadening of the ground level of the atom due to the formation of jellium in the equation of ionization equilibrium. The appearance of such broadening will facilitate thermal ionization, bringing the energy of the ground state of the bound electron to the continuum, acting as a kind of lowering of the ionization potential, but on the other side of the energy scale. Taking into account this effect, the composition and conductivity of dense, ionized rare gas vapors are calculated. It is found that the account of the broadening of the ground state caused by the appearance of jellium leads to a quantitative agreement with the experimental data. We can talk about the semiconductor nature of the electrical conductivity.

References

1. Fortov V.E., Ternovoi V.Ya., Zhernokletov M.V. et al., JETP, 2003, 97, 259.
2. Khomkin A.L., Shumikhin A.S., JETP, 2017, 125, 1189.
3. Fortov V.E., Khrapak A.G., Yakubov I.T. Physics of Nonideal Plasma (Fizmatlit, Moscow, 2010).