ABOUT THE INFLUENCE OF THE PLASMAS NONIDEALITY DEGREE ON THE PLASMA DECAY COEFFICIENTS

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The comparison of experimental results, the dependency of the coefficients on the degree of decomposition of NP strongly coupled plasma with the calculated for various theoretical models. None of the existing theoretical models do not fully describe the experimental results in the range of the degree nonideality of 0.1...5.

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INTRODUCTION

The recombination processes of dense nonideal plasma (NP) are poorly understood. This is the subject of theoretical work [1-6]. Experimentally, we can determine only the coefficient of decay (K_d). At a pressure of 100...10 000 at and temperatures $(7...50)\cdot10^3$ K. ionization processes are comparable to the recombination. Therefore, only the difference of their decay rate can be determined, and from it calculate the recombination coefficient. In [7] were determined decay rates and recombination of hydrogen plasma at concentrations of $2\cdot10^{17} \geq N_e \geq 3\cdot10^{15}$ см$^{-3}$ and temperatures $(3.7…64)\cdot10^3$ K. In [8-11] shows the results of experimental studies of K_d of NP, depending on the temperature, electron density and the degree of nonideality. But it is not a comparison with various theoretical models.In the theoretical works [1, 4, 5] were given the corrections to classical formula for coefficient of triple recombination Pitaevskii-Gurevich [12].

In [2] were given the formula for K_r in the NP obtained in the approximation of nearest neighbor and the cell model. It is assumed binary recombination mechanism. The formula in various models differs only in the coefficient near the Coulomb logarithm – Λ. In [3] examines the impact of microscopic fields on the recombination coefficient in the NP, as in [1]. In [1] considered the ratio K_r of the NP to K_r in ideal plasma and its dependence on concentration n_e at different temperatures under the condition "non-realization of levels." According to the results of this work, reduction of K_r can be up to two orders of magnitude. In the experiment [8, 9] is observed a difference of up to 6 orders of magnitude. Therefore, the study of the experimental dependence of K_d were continued and their result are presented in this paper. We also give the comparison of experimental with calculated K_d NP for various models.

RESULTS AND THEIR DISCUSSIONS

Studies of K_d of NP were conducted in the decay of the plasma of pulse discharge in water (RWI). Capacitance of the capacitor bank 14.5 μF, inductance discharge circuit 0.47 μH. Battery voltages was varied from 3 to 37 kV. The maximum currents reached 200 kA discharges with a rise time of 4 μs. The length of the discharge gap was 10…100 mm. The discharge was initiated by an exploding wire diameter of 20…500 microns. The brightness temperature was measured experimentally and was $(5…50)\cdot10^3$ K. The electron concentration in the NP was varied from $2\cdot10^{17}$ to 10^{22} cm^{-3}. The electron density was measured by different methods and calculated by the pressure and temperature in the channel. As noted by RWI than recombination is intense ionization and must be taken into account when calculating the coefficient of recombination.

Decay coefficient determined by the formula:

$$\frac{dn_e}{dt\cdot n_e^2} = \frac{n_a}{n_e}\cdot b - \alpha\cdot n_i\cdot \quad (1)$$

If we neglect the ionization, the K_d coincides with the K_r.= $\alpha\cdot n_i$. Experimentally, the decay rate can be determined by the formula

$$K_d = \frac{dn_e}{dt\cdot n_e^2} \quad (2)$$

where n_e – the concentration of electrons; d – ionization coefficient; n_i – ion concentration; n_a – the concentration of atoms; $\alpha\cdot n_i = K_r$ recombination coefficient. If no additional input of energy in the plasma channel, and the electron concentration decreases with time, then calculating the concentration of electrons in the course of time, determine K_d. Let us consider the dependence of K_d of different plasma parameters. Fig. 1 shows the dependence of K_d. the temperature obtained by the authors for several modes of the discharge and taken from [7].

Regardless of the temperature the same values coefficients of decay obtained for the same values of the electron density n_e. In this case the temperature varies from 7000 to 64000 K, which is almost an order of magnitude. According to the classical K_d should decrease for the same values n_e, and this change of temperature in $\approx 3\cdot10^4$ times. But, as seen in Fig. 1, this does not happen. Consequently, such a parameter as the temperature is not critical for the recombination processes in the NP. It should be noted that at the beginning of the decay rate increase is consistent allocation of lines H_α, H_β, H_γ of the continuous spectrum of radiation.

Consequently, there are new levels that possible recombination of electrons. Another factor favoring an increase in the recombination process is the reduction of the optical thickness of the continuous spectrum; therefore, the radiation from the plasma channel is beginning to emerge not only from the surface, but also from the volume, which leads to an increase in the rate of cooling of the plasma channel. Both of these factors contribute to an increase in the rate of decay of the plasma channel. In Fig. 2 shows the experimental dependence of K_d on the time and the comparison with classical and formulas for the NP [2].

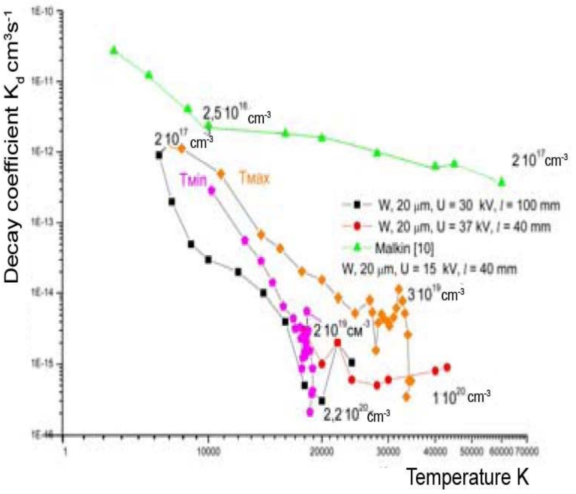

Fig. 1. The dependence of T the K_d decay coefficients

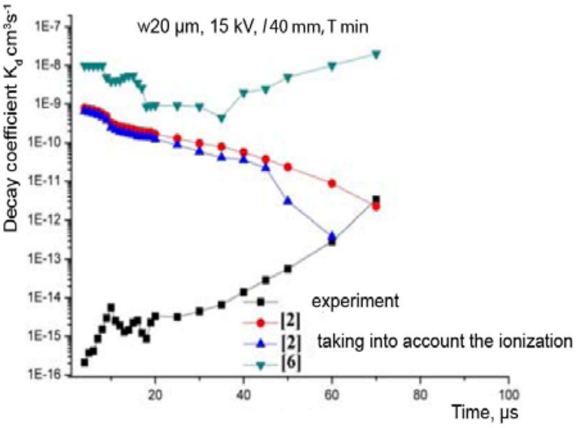

Fig. 2. Progress in time K_d decay coefficients

In [2] takes into account nonideality of plasma, and the recombination process is a binary (only the collision of electrons and ions). In [6] it is assumed that three-body recombination occurs, and then there is a electron-electron-ion collision. At the same time also takes into account ionization processes. A good agreement with [2] obtained only with a decrease in the electron density n_e to values of 10^{17} cm^{-3} (ionization taken into account in the calculations of [6]). At high values n_e of the electron density n_e, the difference amounted to 5…6 orders of magnitude. In [6] first time takes into account the ionization processes and the opacity of the emission lines of hydrogen in the Lyman series.

The experimental dependence of K_d on the degree of nonideality of the plasma at Γ = 0.2…4.5 (Fig. 3).

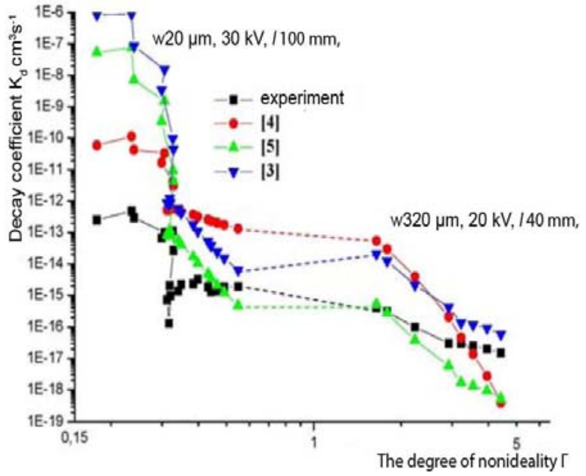

Fig. 3. The dependence of the decay coefficient of the plasmas nonideality degree

First K_d values decrease sharply with increasing Γ from 0.1 to 0.3 on the three orders, and then start to increase almost an order of magnitude, are the maximum and an increase in Γ from 2 to 4.5 has been a slow decrease of the decay the order. Qualitatively, the experimental results agree with those calculated theoretically in [4]. But there are quantitative differences. For $\Gamma < 1$, the experimental values of K_d by 2 orders of magnitude lower than the theoretical, and at $\Gamma = 4$ are the same. At $\Gamma > 4$ theoretical values of the recombination rate becomes smaller than the experimental.

The values of the recombination coefficients obtained by the formulas given in [3], were several orders of magnitude higher than the experimental values. But the calculated values are parallel to the experimental one. In this paper we considered only the effect of electric micro field NP.

Comparison with the calculated values of [5] shows that the well described the experimental results on the decay of NP with values of $\Gamma \geq 0.5$. It should be noted that in [5] the calculation was performed for ultra cold plasma. For small values of r there is a greater discrepancy than estimated by theory [4]. It should be noted that the degree of nonideality parameter Γ is ambiguous; it depends not only on the n_e, but also on the plasma temperature T. Experimentally, the unique dependence of K_d was obtained only on the electron concentration in the NP [11]. None of the known theoretical work does not describe the experimental dependence of K_d on the plasma nonideality degree Γ. Apparently, Γ is not unique parameter to describe its effect on the rate of plasma decay.

Some theoretical calculations do not take into account the effects of "non-realization of" levels of atoms in strong micro fields NP. Accordingly, there is no level to which it would be possible recombination of electrons. The experimentally observed sharp increase in the rate of decay of the hydrogen-oxygen plasma with the advent of the hydrogen emission lines H_α, H_β, H_γ.

CONCLUSIONS

The temperature is not unambiguous parameter to describe the K_d NP. Theoretical dependences of the plasma decay coefficient of the degree of nonideality published in [3-5] satisfactorily describe dependence the K_d for the plasma nonideality degree, if it is greater than unity. At low the plasma nonideality degree is not an acceptable theoretical description of such dependences. Unambiguous experimental dependence of K_d is the only on the electron concentration n_e [11].

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О ВЛИЯНИИ СТЕПЕНИ НЕИДЕАЛЬНОСТИ ПЛАЗМЫ НА КОЭФФИЦИЕНТЫ РАСПАДА

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Приведено сравнение экспериментальных результатов зависимостей коэффициентов распада неидеальной плазмы (НП) от степени неидеальности плазмы с расчетными по разным теоретическим моделям. Ни одна из существующих теоретических моделей не описывает полностью экспериментальные результаты в диапазоне степени неидеальности 0.1...5.

ПРО ВПЛИВ СТУПЕНЯ НЕІДЕАЛЬНОСТІ ПЛАЗМИ НА КОЕФІЦІЄНТИ РОЗПАДУ

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Приведено порівняння експериментальних результатів залежностей коефіцієнтів розпаду неідеальної плазми (НП) від ступеня неідеальності плазми з розрахунковими за різними теоретичними моделями. Жодна з існуючих теоретичних моделей не описує повністю експериментальні результати в діапазоні ступеня неідеальності 0.1...5.