THE EMPIRICAL FORMULA OF DEPENDENCE OF FACTOR OF DISINTEGRATION OF NONIDEAL PLASMA FROM ELECTRONS CONCENTRATION

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Empirical formula of the coefficient decay dependence of strongly coupled plasma from the electron density in the range from 10^{17} to 10^{22} cm^{-3} is given. The dependence of the coefficients of the decay of NP from the temperature in the range from 7×10^3 to 45×10^3 K and the degree of nonideality of plasma Γ in the range from 0.2 to 3 was also experimentally studied.

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INTRODUCTION

Recombination processes in a nonideal plasma (NP) is studied too little. This is due to the complexity of the theoretical description of processes in nonideal plasmas [1-3]. Most theoretical models which are valid for an ideal plasma, in dense (nonideal) plasma does not work. In describing the dense plasma is also not true representations of solid state physics. Theory of NP is developed insufficiently, not only because of the complexity of calculations of such plasma, but also because of the lack of reliable experimental data from the properties of the NP and the relationship of its properties with the main parameters of the plasma. The experimental results obtained are also very difficult. Nonideal plasma, under laboratory conditions, exists a very short time – the nano- and micro- and milliseconds. No equipment to measure the basic parameters of the NP for such a short time. There are no methods for measuring the parameters of the NP. In the NP can only be measured the time variation the brightness temperature (T_{br}) of the surface layers of plasma. But with measuring the T_{br} at different wavelengths can be obtained by the difference in the values of T_{br} to 2 times [4]. This may indicate about the radiation no equilibrium NP. The electron concentration from the broadening of hydrogen lines H_α (656.3 nm) can be measured only below to values $N_e \le 10^{19}$ cm^{-3}. This requires the adjustment of the contour lines H_α [5]. In dense inhomogeneous plasma there is always the reabsorption which reduce the intensity contours reabsorbed lines. Correction of the reabsorbed contour lines H_α is very time-consuming and uncomfortable procedure. At higher concentrations ($N_e > 4\times10^{19}$ cm^{-3}) H_α line (656.3 nm) by the influence of microscopic fields of the plasma in the spectrum can not be realized [6]. In recent years, effort have been attempted to determine the concentration of electrons in the plasma on the effect of outage of lines under the influence of microscopic fields of the plasma, the so-called non-realization of the effect of lines, or on the effect of "gap" in NP [8].This made by the lines of hydrogen and tungsten. This can be done for other compositions of plasma where atoms and ions are sufficiently rich in line emission and absorption spectra. The results of theoretical work on recombination [1-3] – are contradictory. Experimental verification is required for theoretical work on recombination that has appeared in recent years. This paper studies the influence of various plasma parameters on the rate of decay of coupled plasma and obtaining an empirical formula for the dependence of the decay rate of NP on the electron density.

RESULTS AND DISCUSSION

In recent years have appeared several experimental studies on the decay of NP [7-9]. They presented the results of dependences of the decay of the NP from time. It is of interest to determine the dependences index of the decay from various parameters of the NP: temperature, electron density, the degree of nonideality of plasma pressure, the concentration of atoms in the NP, etc. In most theoretical work with the estimation of recombination coefficients use two basic parameters - electron density and temperature of the plasma [1, 2]. In [3] gives such a dependence from the nonideality parameter of plasma Γ. Γ (Ratio of potential to kinetic energy of the plasma) is written as

$$\Gamma = (4\pi N_e / 3)^{1/3} \cdot (e^2 / k \cdot T),$$

where T – plasma temperature, N_e – electron density, *k* – Boltzmann constant, *e* - electron charge.

In [10, 7] have mentioned that direct measuring the recombination coefficient of the plasma is very difficult because in addition to the recombination processes are processes thermal ionization. Experimentally, we can determine only the coefficient of plasma decay.

It can be seen in Fig. 1 that there is no unique dependence of the decay coefficients of the hydrogen-oxygen plasma from the temperature in the range $(20…50)\times10^3$ K. When the temperature of the plasma in the channel is reduced from 20×10^3 to 8×10^3 K, the decay coefficient increases from 3×10^{-16} to 10^{-12} cm^3/s. At the same chart for comparison is adduced the results taken from [10]. The decay coefficients value is given for the temperature 50×10^3 K, when the electron density is 2×10^{17} cm^{-3}, requisite value the decay coefficients is 10^{-12} cm^3/s. The decay coefficients value at the same temperature is received approximately 10^{-15} cm^3/s at concentrations of electrons $5\times10^{19}…10^{21}$ cm^{-3} by authors of this paper. The horizontal shape of the curve of the decay coefficient from temperature can apparently be explained by high values of ionization at high temperatures. Therefore, most likely, the temperature is not the most important parameter is the NP of which depend on the coefficients of decomposition. The dependence of the recombination coefficient from temperature in all theories of theoretical studies is the same, proportional to ~ $T^{-9/2}$. Experimentally, the strong dependence of the decay from temperature in the NP is not observed.

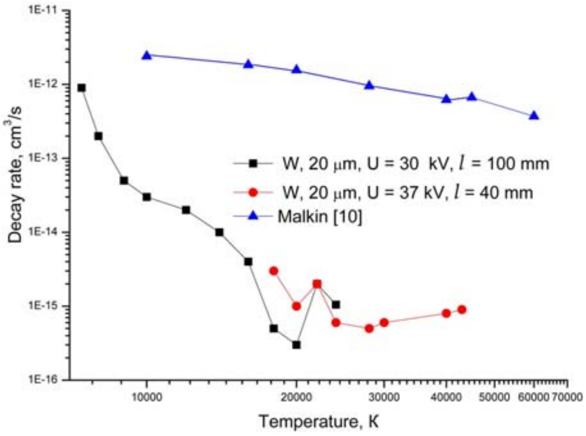

Fig.1. Dependence of the decay rate of strongly coupled plasma on the temperature

Fig. 2 shows the results of determining the coefficients of plasma decay in depending on the concentration of electrons. Chart based on a double logarithmic scale.

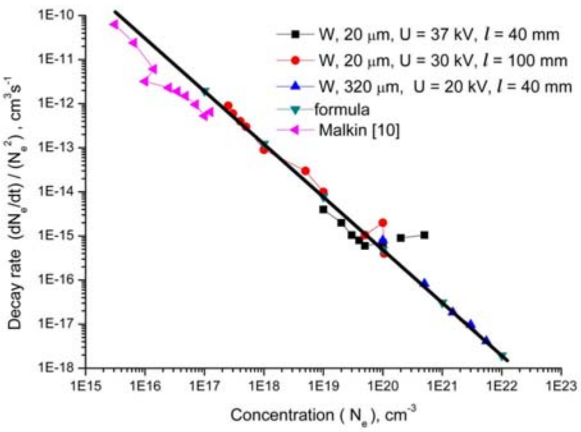

Fig. 2. Dependence of the decay rate of strongly coupled plasma on the concentration

It is seen that with decreasing concentration of electrons in the NP from 7×10^{21} to 2×10^{17} cm^{-3} the decay coefficient increases almost linearly from a value of 3×10^{-18} to 1×10^{-12} cm^3/s.

The plasma temperature was equal to $(8\ldots11)\times10^3$ K at an electron density $N_e = 7\times10^{21}\ldots10^{20}$ cm^{-3} for tungsten plasma and decreased from 50×10^3 to 7×10^3 K at concentrations of $N_e = 5\times10^{20}\ldots10^{17}$ cm^{-3} for the hydrogen-oxygen plasma.

Considering that the almost linear dependence of the decay coefficient from the electron density in the NP experimentally was obtained, an empirical formula for this dependence was picked up and has the form:

$$K = 4{,}9\cdot10^8 (N_e)^{-1{,}2} = 4{,}9\cdot10^8 N_e^{-6/5},$$

where $K = \left(\frac{dN_e}{dt}\right) \Big/ N_e^2$ cm^{-3} decay rate of NP, N_e (cm^{-3}) – electron concentration in the NP. This formula describes the experimentally obtained dependence of the decay coefficient of NP from the electron density in the range of 10^{17} $cm^{-3} \le N_e \le 10^{22}$ cm^{-3}. Temperature range $(7\ldots50)\times10^3$ K.

Data were obtained for the hydrogen-oxygen plasma in the range of electron densities $10^{17}\ldots10^{21}$ cm^{-3} for tungsten in the range of $10^{20}\ldots10^{22}$ cm^{-3}.

The charges value of ions and temperature were not considered. The experimental data of the decay coefficients was obtained of the three modes of discharges. In plasma tungsten is possible second ionization, but it was not considered in the empirical formula.

Some variation in the coefficients of the decay in the concentration range of electrons $5\cdot10^{19}\ldots10^{21}$ cm^{-3} can be attributed to a significant ionization of neutral atoms at high temperature hydrogen-oxygen plasma ($T \approx (40\ldots50)\times10^3$ K).

A comparison of experimental results with theoretical calculations of [1-3] is given.

At comparing the experimental values of the decay coefficients with theoretical work [1] in which is supposed to triple-recombination mechanism (electron - electron - ion), a big difference at high concentrations of electrons were received

With decreasing the concentration of electrons occurs convergence of experimental and theoretical results.

In a theoretical paper [2] predicted a reduction in the decay coefficients with increasing electron concentration. Qualitatively this is consistent with experimental results. But it is assumed binary recombination (electron-ion), but not triple.

In [3] shows the dependence of the recombination coefficient (decay) in depending on the degree of the plasma nonideality Γ. According to this work should exhibit a maximum in the ratio of recombination $\Gamma \approx 0{,}6\ldots1{,}2$.

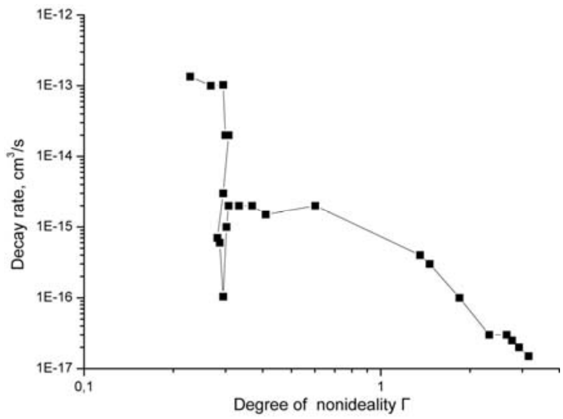

Fig. 3. Dependence of the decay rate of strongly coupled plasma on degree of nonideality

Fig. 3 shows the experimental results of the dependences of the decay coefficient in depending on the degree of the plasma nonideality Γ. The experimental values of the decay coefficients from the degree of plasma nonideality have really a small peak in the region Γ = 0,4…2. The region with the degree of nonideality Γ = 0,6…1,5 yet we have not been investigated. From this dependence follows that nature of the decay process change at Γ ≈ 0,3. Perhaps, the binary recombination at large N_e with a decrease in N_e ($N_e \le 5\times10^{18}$ cm^{-3}) is transformed into a triple.

CONCLUSIONS

Almost linear relationship (on a double logarithmic scale) the plasma decay coefficient from the electron density for the NP was discovered. An empirical formula for this dependence was obtained. A small maximum the decay coefficients for the degree of nonideality of plasma Γ ~ 0,6…1,5 experimentally observed that agrees qualitatively with the results of [3].

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ЭМПИРИЧЕСКАЯ ФОРМУЛА ЗАВИСИМОСТИ КОЭФФИЦИЕНТОВ РАСПАДА НЕИДЕАЛЬНОЙ ПЛАЗМЫ ОТ КОНЦЕНТРАЦИИ ЭЛЕКТРОНОВ

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Приводится эмпирическая формула зависимости коэффициентов распада неидеальной плазмы (НП) от концентрации электронов в диапазоне от 10^{17} до 10^{22} $см^{-3}$. Исследованы также экспериментальные зависимости коэффициентов распада НП от температуры в диапазоне (7×10^3)...(45×10^3) K и степени неидеальности плазмы Г в диапазоне от 0.2 до 3.

ЕМПІРИЧНА ФОРМУЛА ЗАЛЕЖНОСТІ КОЕФІЦІЄНТІВ РОЗПАДУ НЕІДЕАЛЬНОЇ ПЛАЗМИ ВІД КОНЦЕНТРАЦІЇ ЕЛЕКТРОНІВ

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Наводиться емпірична формула залежності коефіцієнтів розпаду неідеальної плазми (НП) від концентрації електронів в діапазоні від 10^{17} до 10^{22} $см^{-3}$. Досліджено також експериментальні залежності коефіцієнтів розпаду НП від температури у діапазоні (7×10^3) ...(45×10^3) K та ступеню неідеальності плазми Г в діапазоні від 0.2 до 3.