COMPUTER MODELING OF THE GAS DISCHARGE IN THE ELECTRODELESS LAMP

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The paper is devoted to computer modeling of gas discharge processes underlying working electrodeless light sources. Researches carried out for the analysis of the relationship of the radiation spectrum to the microwave lamps from the pressure in the bulb and the concentration of the substance which revealed that, when using the LTE model in the description of the plasma discharge, various pressure influence the spectral characteristics of the electrodeless lamps.

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INTRODUCTION

At present, the scientific community has devoted considerable attention to the electrodeless discharge of the vapor molecular compounds. One of these light sources can be driven microwaves discharge in the gas mixture whose main component is vaporized in the discharge of the sulfur [1].

The purpose of this research is to develop mathematical models and to create on its basis a numerical model based on gas discharge ignition in the microwave electrodeless sulfur lamp.

1. MATHEMATICAL DESCRIPTION OF THE STATES OF PLASMA AND ITS MODELS

Due to the diversity of processes occurring in spatially inhomogeneous plasma, an analytical description of the actual plasma is generally very difficult. Therefore, it is usually considered a simplified model of plasma, and then specifying how real plasma is close to the accepted model.

Condition of real plasma in an arbitrary pressure is determined by:

a) the concentration of particles of all kinds N (the number of particles in unit volume);

b) their velocity distribution function $N_i(n)$;

c) the population of the excited levels N_k (the number of particles per unit volume in the excited state);

d) the spatial distribution of these quantities.

Get information on all the above characteristics is extremely difficult, as the theoretical studies of the plasma state requires setting up and solving the system of equations connecting these quantities with the external conditions.

For a description of the gas-discharge plasma in the electrodeless sulfur lamp, formed under the influence of the electromagnetic field in the flask microwave lamp, it is advisable to use the LTE model. This model allows us to qualitatively and quantitatively describe the continuous spectrum of the lamp, as well as the distribution of basic physical quantities of sulfuric plasma.

According to the model of local thermodynamic equilibrium temperature in the different elements of the volume of the medium is different. There is a flow of radiation outside (radiation field is anisotropic), but in each volume element of the medium equitable distribution of Boltzmann and Maxwell, Saha equation, and in all of them for the amount of part one and the local temperature is the same for all types of particles.

LTE for most stationary plasmas received in the laboratory is typical. Under the conditions of LTE of plasma the detailed equilibrium for optical transitions it is broken, so it is advisable to consider radiation and absorption separately.

2. PHYSICAL PROCESSES IN THE TWO-COMPONENT MICROWAVE PLASMA

The principle of ionization of gases under the influence of microwave energy is the base for the plasma lamp. Microwaves emitted by the magnetron excites sulfur vapor in argon within the bulb. Highly ionized gas becomes a plasma state, which begins to emit light constantly, when a certain operating temperature is reached.

Trends in the development of the discharge lamp is sulfuric converting microwave energy into optical radiation. Therefore, for further improvement of the optical radiation source is necessary to study the physical processes occurring in the spherical quartz bulb filled with a gas mixture which main component is sulfur, when exposed to microwave radiation. The microwave field causes a glowing discharge in the buffer gas having a low breakdown threshold on a low initial pressure. At the same time heats the field – until evaporation – sulfur powder. The resulting gas mixture has a high pressure microwave field needs atoms (as well as dimers and etc.) of sulfur in the excited state. This applies channel direct atomic and molecular absorption and the mechanism of the collision. Finally, the re-emission from excited states forming the observed emission spectrum.

Characteristic lines in the spectrum of the sulfur atom is in the open portion of the optical spectrum of a molecule 867, 921 and 1045 nm. The ionization potential of each radiating state is less than 3 eV. To get some idea of the energetic interactions between dimers and sulfur atom, consider a simplified diagram of the energy levels of the two systems in Fig. 1.

The figure shows the level diagram of the molecule on the left and a sulfur atom in the right scale in relation to each other. Use the dissociation energy of the ground state of the dimer, and 4.4 eV – energy offset between the systems.

The ionization energy of the molecule is more attractive since the ionization potential of the molecular state is less than half of the ground state of the atom.

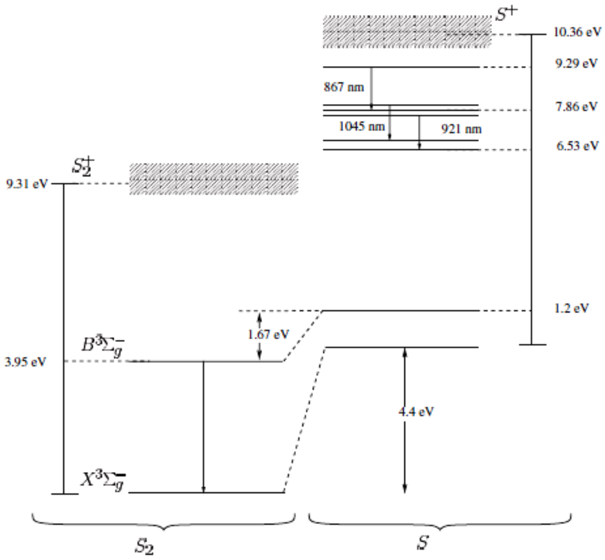

Fig. 1. The diagram of the energy levels of sulfur

Thus, if the degree of dissociation is relatively low, S_2^+ ions will be the dominant species. As the level of the emitting atoms is about 11 eV and higher molecular state, and their density is exponentially sensitive to temperature, they are ideal for study.

Studies show that the emission spectrum of sulfur lamp in the visible region is formed mainly by radiative transitions between the excited level $B^3\sum\overline{u}$ and the ground state $X^3\sum\overline{g}$ of diatomic sulfur molecules S_2.

3. DESCRIPTION OF THE SOFTWARE PRODUCT HID LAMPS V.2.0

A numerical model of the optical radiation source may be a spherical or cylindrical flask of transparent anhydrous quartz glass filled with metered amounts of sulfur (and possibly introduce contaminants, such as $CaBr_2$) or another substance (e.g. indium iodide InI) and buffer gas (argon, neon, krypton). Theoretical studies of output spectral characteristics of the optical radiation and their dependence on the microwave power to the pump wavelength from λ to $\lambda + d\lambda$ the temperature distribution inside the bulb, the electrical conductivity of the plasma, and others, can be carried out by changing the composition of filling the bulb.

The buffer gas (argon) is used to obtain the initial ionization and glow discharge (gas pressure is set at the initial stage). We get the dependence of the dynamics of change of pressure in the bulb temperature.

The interface developed software HID Lamps v.2.0 is shown in Fig. 2. All output parameters and characteristics of the charts have the opportunity to be saved in separate files for further analysis and comparison of the results with experimental data.

The simulation was performed for the study of electrodeless discharge lamps filled with indium and sulfur S iodide InI as active component with the buffer gas argon or neon. We studied the effect of the amount of filling in the luminous efficacy and color rendering index behavior. These results were tested and experimental studies. However, it was noticed that there are threshold values for the buffer gas below and above which can not be taken, since it is impossible to receive the gas discharge. For an easier ignition is necessary to take the pressure of the buffer gas is close to the lower boundary.

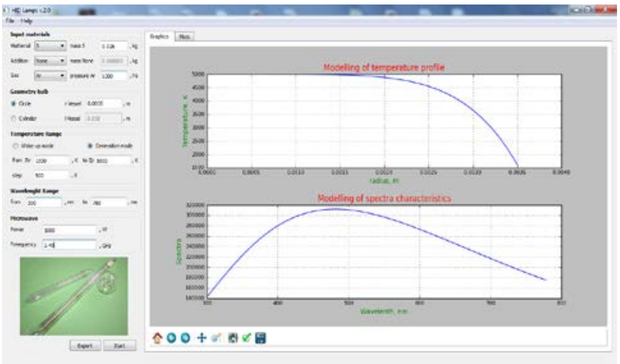

Fig. 2. Interface of the software HID Lamps v.2.0

There were also theoretical studies of the emission spectrum depending on the nature of microwave tubes on the pressure in the flask and the concentration of the substance, such an assumption can be made that, when using the LTE model to describe the gas-discharge plasma, the pressure change will primarily affect the spectral characteristics of the system. Therefore, the work was to study the behavior of the spectrum lamp for different values of the buffer gas pressure of argon.

CONCLUSIONS

The software HID Lamps v.2.0 has been developed based on the LTE model. HID Lamps v.2.0 allows to perform theoretical study of the optical characteristics of electrodeless microwave lamps at various input parameters (composition and weight of the substance, the buffer gas pressure, temperature, geometric dimensions of the bulb, and others). As of today, the program is still being perfected, and it will be possible to get more information about the physical processes in the plasma in future.

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КОМПЬЮТЕРНОЕ МОДЕЛИРОВАНИЕ ГАЗОВОГО РАЗРЯДА В БЕЗЭЛЕКТРОДНОЙ ЛАМПЕ

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Работа посвящена компьютерному моделированию газоразрядных процессов, лежащих в основе работы безэлектродных источников света. Исследования зависимости характера спектра излучения СВЧ-ламп от величины давления в колбе и концентрации вещества показали, что при использовании модели ЛТР в описании газоразрядной плазмы изменение давления влияет на спектральные характеристики ламп.

КОМП'ЮТЕРНЕ МОДЕЛЮВАННЯ ГАЗОВОГО РОЗРЯДУ В БЕЗЕЛЕКТРОДНІЙ ЛАМПІ

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Робота присвячена комп'ютерному моделюванню газорозрядних процесів, що лежать в основі роботи безелектродних джерел світла. Дослідження залежності характеру спектра випромінювання НВЧ-ламп від величини тиску в колбі і концентрації речовини показали, що при використанні моделі ЛТР в описі газорозрядної плазми зміна тиску впливає на спектральні характеристики ламп.