*36th EPS Conference on Plasma Phys. Sofia, June 29 - July 3, 2009 ECA Vol.**33E**, P-2.109 (2009)*

THE BASIC CHARACTERISTICS OF THE PULSE HELIUM MICROPLASMA SOURCE FOR ANALYSIS OF GASES BY THE METHOD OF COLLISION ELECTRON SPECTROSCOPY (CES)

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Traditional electron spectroscopy methods provide an opportunity to analyze an energy of electrons released during ionization of atomic or molecular impurities A by particles B^* with definite energy E_p. It is presumed that A become ionized to produce free electrons $\bar{e}$, if the B^* particles (metastable atoms or VUV photons) energy E_p is high enough:

$$A + B^* \rightarrow A^+ + B + \bar{e} \qquad (1)$$

The electrons released in this process gain kinetic energy E_e:

$$E_e = E_p - E_i \qquad (2)$$

where E_i is the ionization potential of an impurity atom or a molecule under analysis. Measuring electrons energy spectra provides a very powerful method of a substance analysis. In this way any kind of atoms and molecules in a gas phase can be detected and its concentration can be measured.

Fundamental equations (1) and (2) and their implementation seems very simple, but for a decades traditional electron spectroscopy methods did not widely enter into analytical practice. It is due to a high vacuum requirements inside of conventional electron energy analyzers, common known problems of a gas sampling and transportation from high pressure atmosphere to ionization chamber and, therefore, significant dimensions and complexity of the analytic device.

To traverse above mentioned shortcomings we have developed a new concept called Collisional Electron Spectroscopy (CES) for gaseous media analysis and ionization detectors for its implementation [1-3]. The method CES allows to analyze energy of electrons generated during ionization of atomic or molecular impurities at a high pressure because dimensions of ionization cell L and a gas mixture pressure p are chosen so that the energy distribution of the electrons reaching analyzing electrode is formed in a non-local regime [4]. If the electron energy relaxation length $\lambda_\varepsilon >> L$, the electrons would reach analyzing electrode faster then they lost a predetermined level of their initial energy. Really, when characteristic

electron is scattered elastically with a buffer gas atom, it loses a portion of its kinetic energy equal to $\delta = 2m/M << 1$, where m is the electron mass and M is the mass of the buffer gas atom. So, the characteristic electron may suffer a number of elastic collisions losing only a negligible part of its characteristic kinetic energy. In this way the gap size between anode and cathode must be chosen so that

$$L << \lambda_\varepsilon = \lambda/\sqrt{\delta} \geq 100\lambda \qquad (3)$$

where λ - electron mean free path.

In this way the characteristic electrons randomly move, suffering a "controlled quenching" on the electrodes or the walls, and reach analyzing electrode (cathode), losing only a predetermined portion of their initial kinetic energy. I.e., they are permitted for a limited "walking" not to degrade in energy too much. To work at atmospheric pressure interelectrode gap L is of the order 0.1 mm.

In present report the results of a full-scale modeling of a pulsed micro-plasma source for CES are presented. The interelectrode gap $L = 0.1$ *mm* is filled with a buffer helium at the pressure $p=760$ *Torr*. The current density in the active phase of the discharge is j = 8485 *mA/cm*^{2}, with applied voltage U = 209.5 *V*. In 1D geometry the self-consistent system of equations for density of charged and excited particles was solved. The plasmachemical model used includes five atomic and two molecular excited levels of helium and more than 80 reactions between them. The rates of reactions with participation of electrons and their transport coefficients were determined by solving the kinetic Boltzmann equation. The self-consistent electric field was calculated using Poisson equation.

Spatial profiles of discharge parameters including charged particles and excited states of helium atoms and molecules at the end of the active phase are presented on the figures 1. As shown in the pictures, the micro-discharge consists of the cathode layer with high electric field and 20 microns thickness and of the negative glow plasma with low electric field and electron temperature.

Temporal decay of electron temperature, charged and excited particles density in the afterglow are presented on the figures 2.

Thus, the results demonstrate that the micro-plasma source makes it possible to obtain relatively high densities of metastable and charged particles necessary for CES implementation.

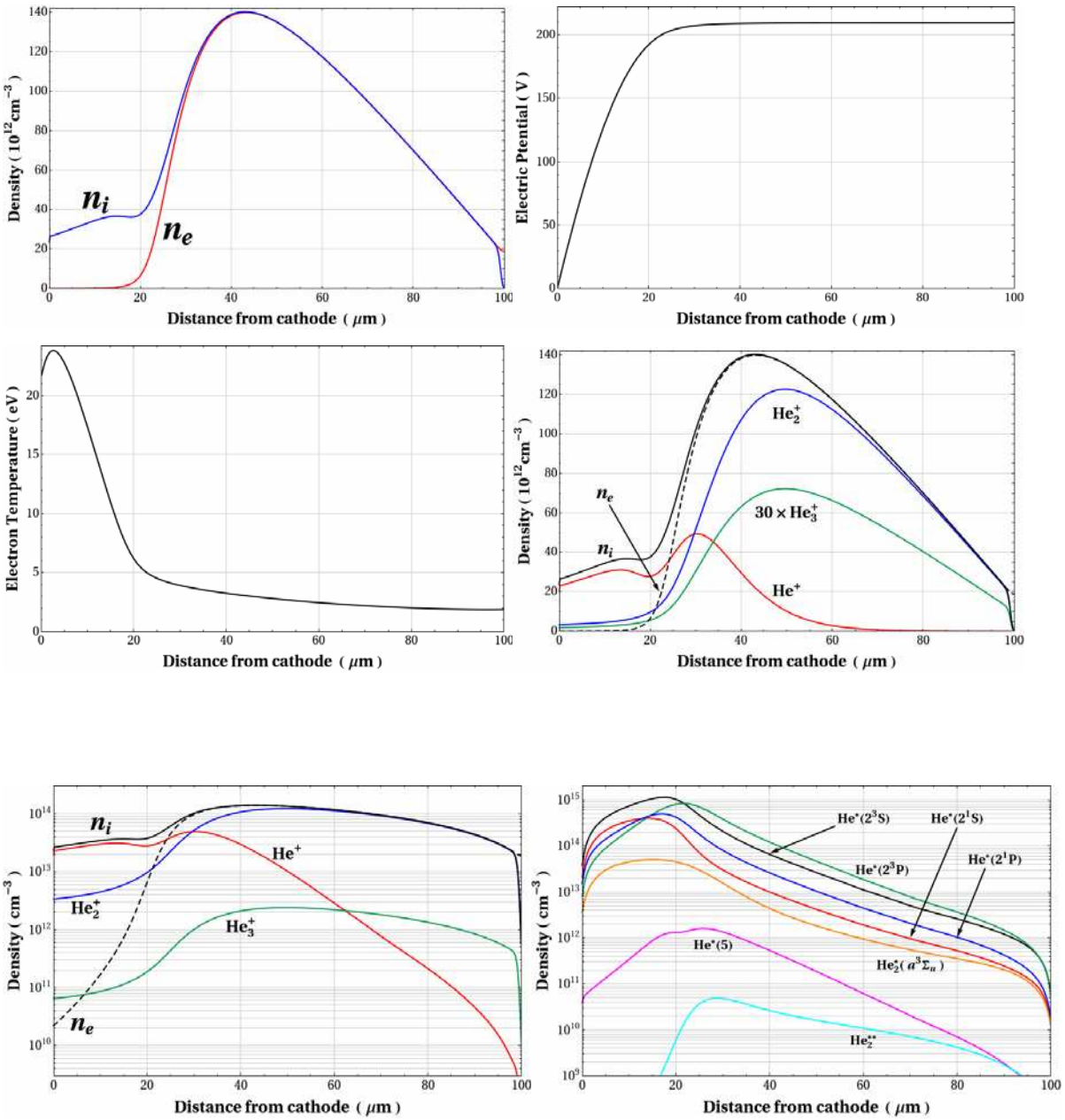
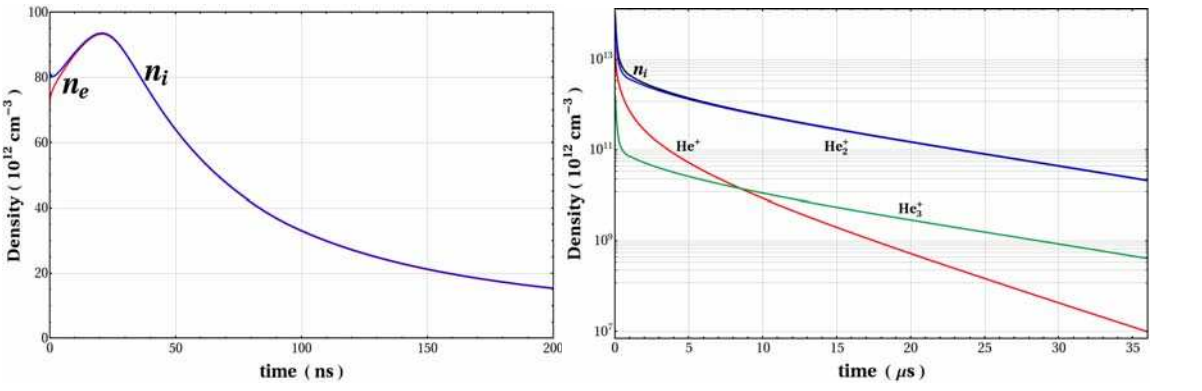


Fig.1. Axial profiles of discharge parameters in the end of the active phase.



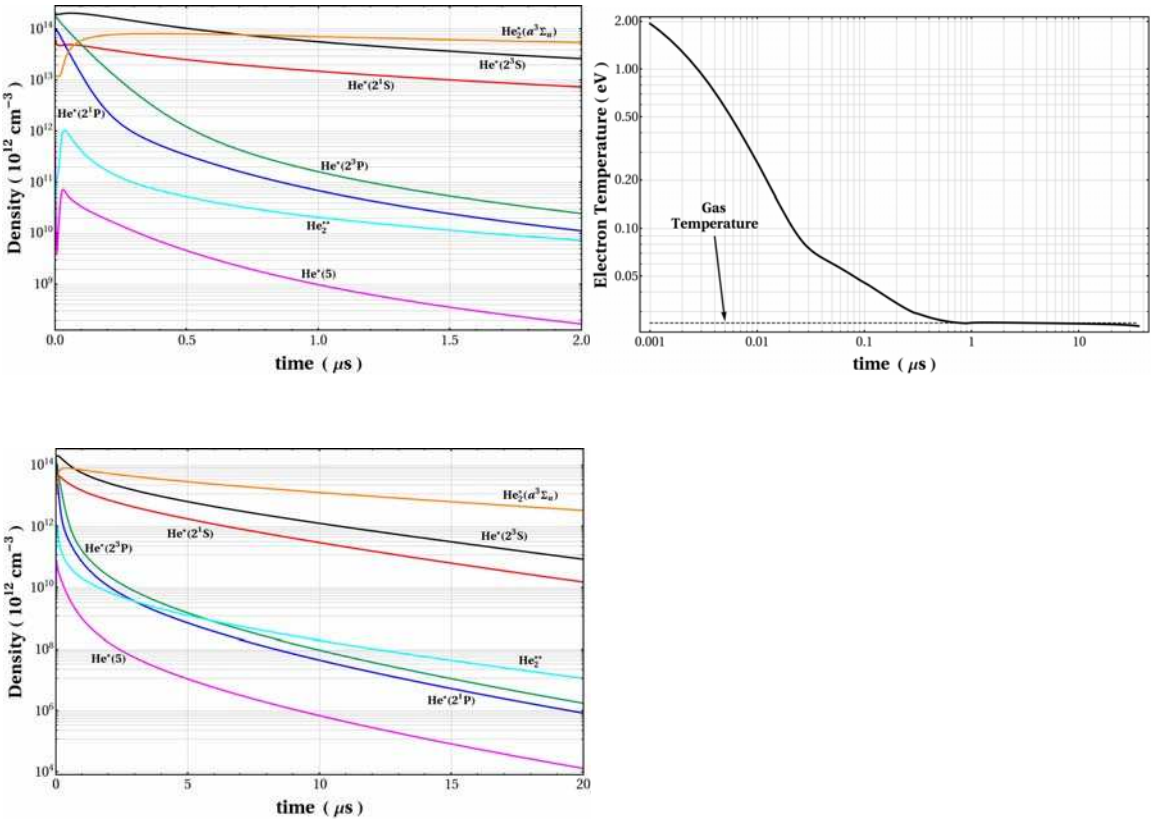


Fig.2. Temporal decay of the plasma parameters in the afterglow.

References

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