Optical Emission Spectroscopy of Plasma of Electric Spark Discharge between Metal Granules in Liquid

Murmantsev O.O., Veklich A.M., Boretskij V.F.

Faculty of Radio Physics, Electronics and Computer Systems, Taras Shevchenko National University of Kyiv, 64/13, Volodymyrska str., Kyiv, 01601, Ukraine

E-mail: murmantsev.aleksandr@gmail.com

Introduction. Currently, the electric discharges burning in the liquid are of great interest. Among the numerous applications of such discharges, the synthesis of nanoparticles is most relevant and demanded issue among scientists. This is caused by widespread use of nanoparticles in various branches. In particular, the colloidal solutions with nanoparticles of different metal (in particular, copper, silver, molybdenum, etc.) have excellent bactericidal, antiviral, antifungal and antiseptic effects, what makes them essential biocide products.

The investigation of plasma of discharge in liquid between metal granules is carried out directly in the discharge chamber of the installation, specially developed for the synthesis of colloidal substance with metal nanoparticles. The influence of different energy input on the main plasma parameters was understudy.

It is nature that to improve the characteristics and properties of solutions with nanoparticle it is necessary to investigate directly the process, which occurs during nanoparticles formation. Namely, the plasma of discharges, which burns between granules used as a source of metal particles in the obtained solutions, should be understudy. The most suitable approach to such investigation is optical emission spectroscopy. On the one hand, this method enables to obtain with sufficient accuracy the main plasma parameters, such as temperature and electron density, which characterise the processes of nanoparticles formation. On the other hand, such technique does not perturb the plasma and cannot affect the properties of the resulting product.

Therefore, optical emission spectroscopy methods are used to determine main plasma parameters. Namely, the excitation temperature is determined by the Boltzmann plots technique. The electron density is obtained from width of certain spectral lines, the dominant broadening mechanism of which is Stark effect. So, it is possible to determine the most optimal mode of nanoparticles generation from the point of view of energy dissipation in the discharge.

Methods. The investigation of underwater discharge plasma between iron granules is carried out directly in the discharge chamber of the installation, specially developed for the synthesis of colloidal substance with metal nanoparticles (see Fig. 1).

The discharges are ignited by pulses of the generator, which is powered by a single-phase voltage 220 V, between iron granules, immersed into water inside the chamber. The composition of power diodes VD1 and VD2, thyristors VD3 and VD4 and capacity C1 (adjustable from 25 to 650 μF) is used as a controlled phase rectifier. Randomly switching of microdischarges between various pairs of granules is realized due to pulse voltage in output of thyristor VD5. Registration of electrical parameters can be performed by the voltage divider, Rogowski coil and oscilloscope.

Investigations are carried out in four modes of nanoparticles generation (modes 1, 2, 3, 4), where mode 1 corresponds to the minimal input energy, and mode 4 corresponds to maximal energy, respectively.

The registration of emission spectra of underwater discharge plasma at current pulse up to 150 A is provided by Solar LS SDH-IV spectrometer in the spectral range from 440 to 910 nm.

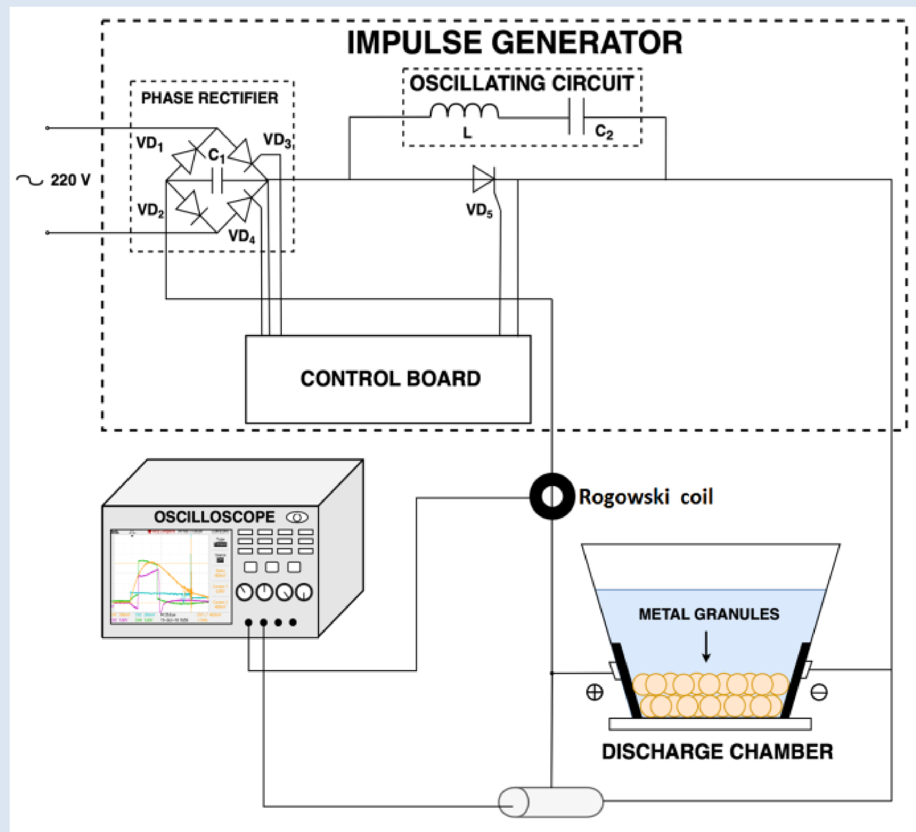

Fig. 1. Experimental arrangement for pulsed underwater electrical discharge investigation [1]

Results. Some samples of emission spectra were registered and treated to obtain the electron density and excitation temperature (see Fig. 2). The ratio of electron density and excitation temperature are used as a parameter in estimation of optimal efficiency of energy dissipation in the discharge in nanoparticle generation process. It was found that the most preferable aforementioned parameter corresponds to mode 3 for underwater discharges between iron or molybdenum granules (see table).

Mode	N_e/T of Mo	N_e/T of Fe
1	3.91E+19	3.11E+19
2	4.11E+19	3.86E+19
3	7.29E+19	5.67E+19
4	4.62E+19	2.77E+19

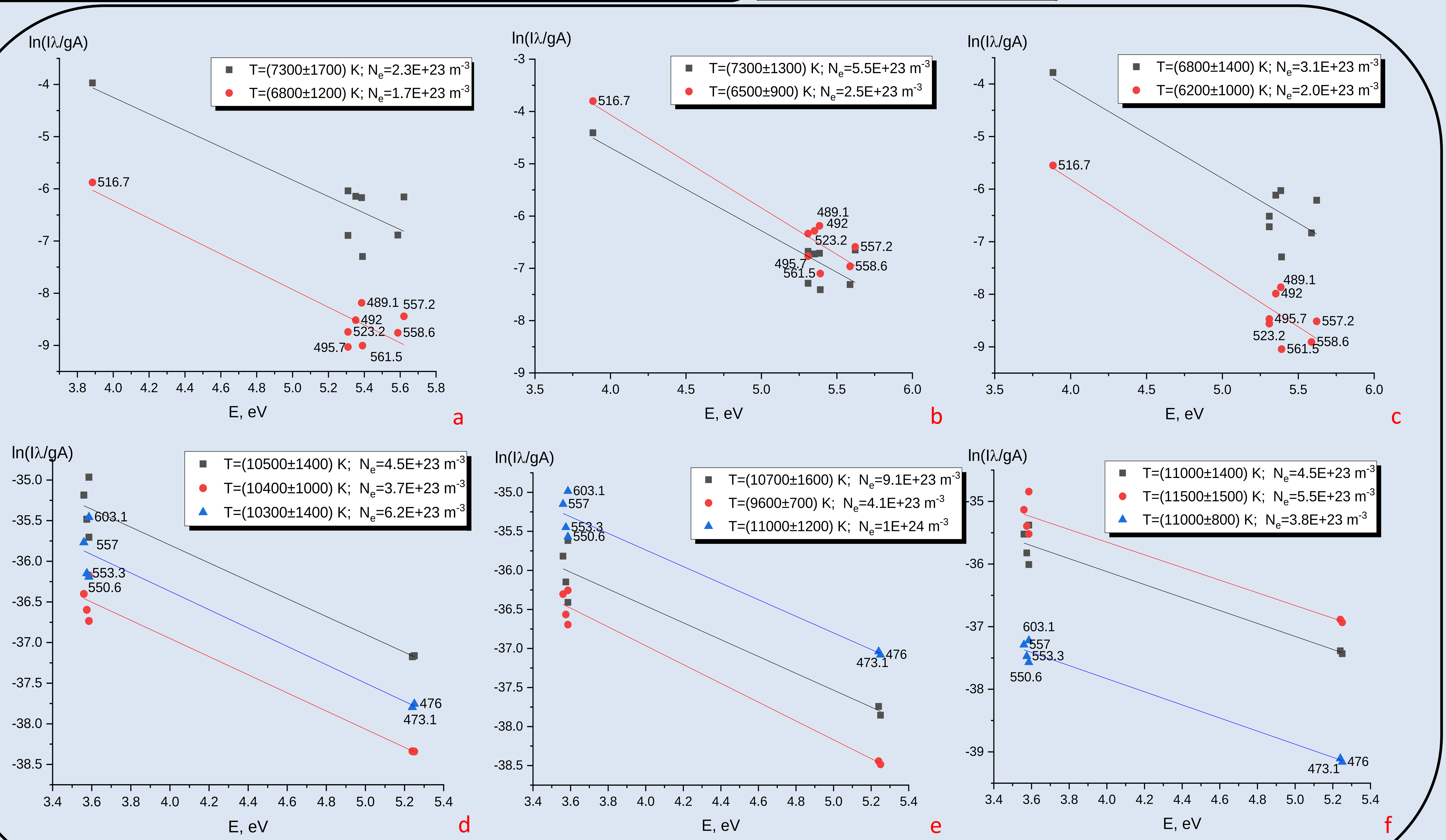

Fig. 2. Typical Boltzmann plots on the base of Fe I (a, b, c) and Mo I (d, e, f) spectral lines for the mode 2 (a, d), 3 (b, e) and 4 (c, f)

Conclusions. The optical emission spectroscopy methods are used to determine the main plasma parameters. Namely, the excitation temperature is determined by the Boltzmann plots technique. The electron density is obtained from width of H_α spectral line. The ratio of this parameters is considered as a parameter in estimation of optimal efficiency of energy dissipation in the discharge in nanoparticle generation process. It was found that the most preferable parameter corresponds to mode 3 for underwater discharges between iron or molybdenum granules.

The obtained results will be used to found the interrelation between the main plasma parameters and size distribution of the generated nanoparticles.

Reference.

1. T. Tmenova, "Etude expérimentale de la décharge électrique pulsée dans l'eau (Thesis)", Toulouse (France), 2019.