Physical properties of DC discharge generated in He, Ar, N_2 and Air bubbles in liquid

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DC excited discharge in liquid generated in bubbles (He, Ar, Air, N_2) has been investigated. V/C characteristics and emission spectra are recorded in the range of currents 10-30 mA. Gas temperature is determined by simulation of OH band with different T_{rot}, $T_{vib.}$ T_{rot} in He discharge is 1200 K at I=10 mA and linearly increase up to 1600 K with grows of the current. Similar increase of T_{rot} from 1100 K to 1700 K (30 mA) is observed in Ar discharge. In N_2 and Air gas temperature is higher and almost constant at different currents: N_2 discharge T_{rot}=2200 K (10 mA) and 2500 K (30 mA); Air discharge T_{rot}=2200 K (10-30 mA).

1. Introduction

Plasma physics and chemistry of underwater discharges or discharges in contact with liquid phase attract a lot of attention due to possible technological application for water purification and sterilization [1]. DC excited discharge in liquid generated in bubbles of different gases (He, Ar, Air, N_2) has been investigated in this paper. Voltage, current characteristics and optical emission spectra have been recorded in the range of discharge current from 10 up to 30 mA. Rotational temperature of OH radicals has been estimated by 2 temperatures fitting of experimentally measured OH band $A^2\Sigma^+(v=0) \rightarrow X^2\Pi(v=0)$.

2. Experimental set-up

On Figure 1 experimental set-up scheme is presented.

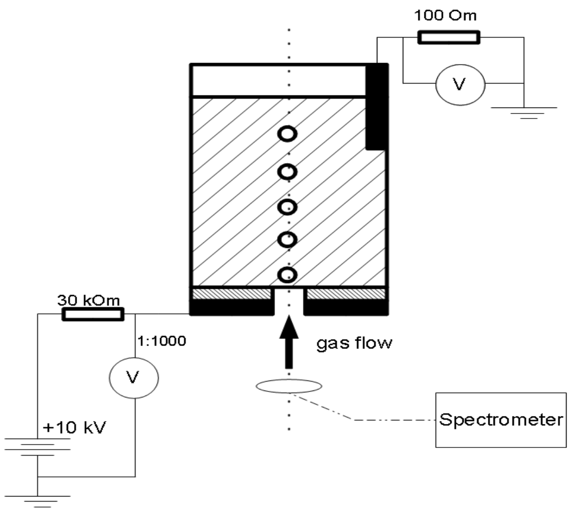

Fig. 1. Scheme of the experimental set-up.

Gas bubbles are introduced in chamber filled with solution (conductivity 5 or 50 μS/cm) at flow rate 50 sccm through pin-hole ∅ 0.4 mm in ceramic plate (thickness 1 mm). High voltage electrode is made of inox plate with pin hole of 0.4 mm placed underneath of the ceramic plate. Voltage/current waveforms has been recorded by TDS 1002 oscilloscope with HV probe and by voltage drop on 100 Om shunt resistor connected in series with the reactor. Optical emission spectra have been recorded by Avantes spectrometer (300-350 nm, resolution 0.05 nm) in axial direction.

3. Results and discussion

At low current mode with average I<10 mA the discharge is generated in unstable regime with fast oscillations of current and voltage in all gases – figure.2.

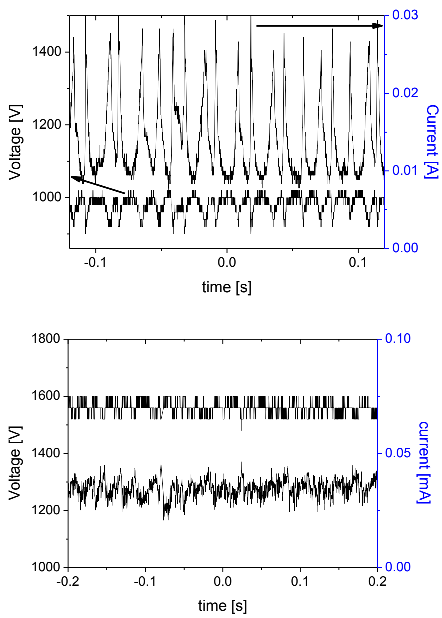

Fig. 2. V/I waveforms of unstable mode of He discharge (10 mA, 5 μS/cm) and stable mode (I=30 mA)

Increase of the voltage results to transformation of the discharge in stable regime. This regime is characterized by constant current (more than 10 mA in He and 15 mA in Air/N_2) and constant sustained voltage. Similar behavior of the plasma at different currents has been reported for bubble discharge in capillaries recently [2]. Visual view of the discharge by fast imaging technique shows that in both regimes plasma consists of narrow filaments propagated inside of bubbles in case of N_2 and Air. In case of He and Ar bubbles glow discharge is appeared in stable mode. Presence of intensive OH band in the discharge spectra allows us to estimate temperature of the plasma by simulation of rotational/vibrational structure of the OH band with different T_{rot} , $T_{vib.}$ This simulation has been performed in Lifbase software with instrumental function determined experimentally with Hg low pressure lamp. Fitting of experimental spectra has been carried out with two different rotational temperatures as it was suggested in [3]. First T_{rot}^1 is equivalent to gas temperature and T_{rot}^2=10000 K describes overpopulation of high rotational levels with J>13 due to different mechanisms of OH radicals production. The use of only T_{rot}^1 in the fitting procedure results to high overestimation of gas temperature. On figure 3 overall spectra of the discharge and results of best fitting for Ar bubble discharge are presented.

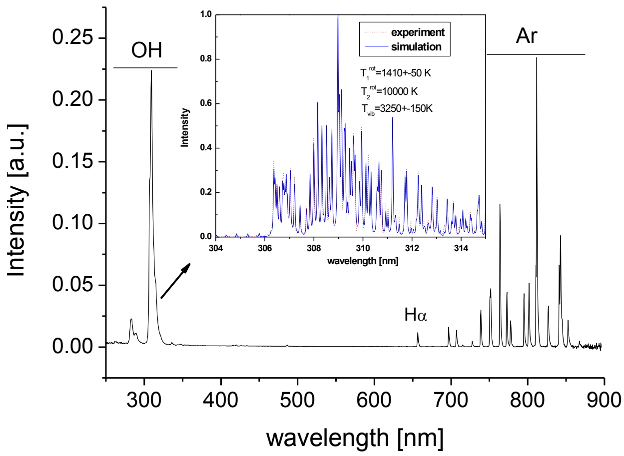

Fig. 3. Spectra of the discharge in Ar bubbles at range of 250-900 nm with low resolution and results of spectra fitting for Ar plasma, current 25 mA, conductivity 5 μS/cm.

Temperature of OH radicals has been measured at different current for both conductivities of the solution. It was revealed that for low conductivity T_{rot} in He discharge is about 1200 K at I=10 mA and linearly increase up to 1600 K with grows of the discharge current. Vibrational temperature of the radicals is much higher: 2250 K (10 mA) to 3700 K (30 mA). Similar increase of T_{rot} from 1100 K (10 mA) to 1700 K (30 mA) is observed in Ar bubble discharge. In N_2 and Air plasma gas temperature is higher and almost constant at different currents: N_2 discharge T_{rot}=2200 K (10 mA) and 2500 K (30 mA); Air discharge T_{rot}=2200 K (for current range 10-30 mA). Increase of conductivity does not influence on measured rotational temperature of the OH radicals at currents range 10-30 mA. Possible explanations of constant temperature of the gas at different discharge currents in N_2 and Air plasma can be due to filamentary nature of the discharge.

4.Conclusions

Underwater DC discharge in 4 different gases has been investigated. Two different modes of plasma have been determined –self-pulsing regime at low current up to 15 mA and stable glow discharge at higher currents. Gas temperature is estimated from OES by 2 rotational temperatures fitting method in order to take into account overpopulation of V/T distribution of OH radicals. It is shown that gas temperature is linearly increased from 1200 K to 1600 K in He plasma with increase of discharge current. The same behavior is observed in Ar discharge in contrast to N_2 and Air plasma where gas temperature only slightly depends on discharge current in the region of 10-30 mA.

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