# SPECTROSCOPIC STUDY OF POSITIVE COLUMN OF GLOW DISCHARGE IN BINARY MIXTURES OF OXYGEN WITH NEON AND ARGON

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**Abstract**

The positive column of the DC glow discharge has been studied in the binary mixtures of argon and neon with oxygen by means of emission spectroscopy. The total pressure of the mixtures was up to 6 Torr, discharge current was up to 30 mA. Assuming pressures higher than 4 Torr two forms (so-called the T and H form) of positive column have been investigated.

## 1. Introduction

Low-temperature plasma generated by discharges in pure atomic or molecular gases and its mixtures is employed in various applications. Pure oxygen and its mixtures containing rare gases or one or more molecular gases such as $N_2$, $Cl_2$, $CF_4$, $SF_6$ are often used. These mixtures are to be applied to plasma etching [1,2] and plasma oxidation [3]. Discharge plasma in mixtures of oxygen with rare gases (e.g. $O_2$ and Ne, $O_2$ and Ar) forms active medium in gaseous lasers[6].

## 2. Experimental

Measurements have been performed in the Pyrex glass tube of the U-shape with head-on plane windows filled with spectrally pure gases manufactured by Linde. The optical system collects radiation emitted in the direction of the axis of symmetry of the positive column. This device enables us to determine the mean values of intensities of the spectral lines and bands across positive column. The positive lens (f ” = 40 mm) whose axis of symmetry merges with the axis of symmetry of the positive column collects radiation on the entrance of the glass fibre pipe having circular profile (diameter 7.1 mm). The exit head of the cable has oblong profile (25x1.6 mm) and it is to be adjusted in front of the entrance slit of the monochromator SPM 2 using the X-Y shifter. Grating having groove density 651 grooves per mm is used. The auxiliary He-Ne laser is supplemented to the optical system in question. It enables us to set optical elements with required precision to such positions in which the axis of symmetry of the positive column and the optical axes of the positive lens and the fibre pipe merge. The intensity of transmitted monochromatic radiation is detected by photomultiplier tube Hamamatsu R 928. Assuming experimental conditions when only one form of the positive

column fills the central part of the discharge tube emission spectra have been investigated in the spectral range 350 - 850 nm (spectral resolution 0.8 nm).

Assuming conditions when two forms of the positive column occur simultaneously (i.e. total pressures higher than 4 Torr) it is necessary to detect radiation emitted in the direction perpendicular to the axis of the positive column. The circular head of the fibre pipe is mounted to the holder perpendicularly to the axis of the tube axis in such a case. The position is to be set in the direction parallel to the axis of the positive column keeping the distance of the front of the pipe from the axis of the positive column 50 mm. The other parts of the apparatus are the same as in preceeding arrangement. Spectral resolution 2.8 nm has been achieved.

## 3. Results

The most intensive lines 777.4 nm and 844.7 nm corresponding to transition between various states of neutral oxygen have been studied. Atmospheric A band [5] corresponding to transition between various rotational quantum states of the neutral molecule $O_2(b^1\Sigma_g^+, v = 0)$ - $O_2(X^3\Sigma_g^-, v = 0)$ was registered. There are two maxima which can be identified in spectra-the head of the A band (759.4 nm) and the origin of the A band (761.9 nm). The first negative system of the molecular ion $O_2^+(b^4\Sigma_g - a^4\Pi_u)$ [5] in the range of visible and near infrared spectrum was detectable. The lines of argon in the range 415 - 855 nm and the lines of neon in the range 585 - 725 nm have been investigated in binary mixtures.

### 3.1. Neon - oxygen mixtures

Considering mixtures of neon with oxygen in which the ratio of neon is 5, 20 and 50 % the oxygen line 777.4 nm is dominant at the pressure 1 and 2 Torr because the energy of this excited state is lower compared to neon [4]. The course of the relative intensity of the line is depicted in Figure 1 for total pressure 2 Torr.

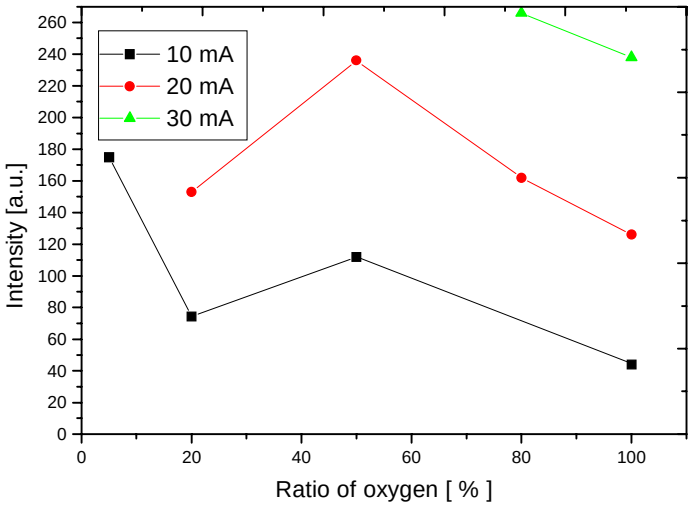


**Figure 1:** Dependence of relative intensity of the line 777.4 nm of the neutral oxygen atom (transition $3s^5S^0$ - $3p^5P$, energy of initial state 10.74 eV, energy of final state 9.14 eV, see e.g. [4]) on the ratio of oxygen in oxygen-neon mixture.

The transitions between excited states of neon atoms are not detectable in the mixtures containing 5 % neon. The

persistent line of the neutral neon atom 585.3 nm [5] is dominant for mixtures with 95 % neon.

### 3.2. Argon - oxygen mixtures

Neutral argon atoms play more important role compared to neon. The lines corresponding to argon are detectable in mixtures with low ratio of argon. This effect is caused by lower energy of the excited states of argon [4]. The line 751.5 nm of the neutral argon is dominant in the mixtures under these conditions. Considering total pressure 1 Torr (discharge current 30 mA) the intensity of the argon lines 826.5 nm, 840.8 nm, 842.5 nm and 852.1 nm is higher compared to pure argon in the mixtures containing 80 and 50 % argon. Assuming discharge current 20 mA the intensity of the lines 840.8 nm and 842.5 nm increases with decreasing ratio of the argon in the mixture while the intensity of the lines 826.5 nm and 852.1 nm is lowest in the mixture containing 80 % argon. Figure 2 presents comparison of mean values of intensity of argon line 852.1 nm in pure argon and mixtures containing 50 and 80 % argon (total pressure 1 Torr).

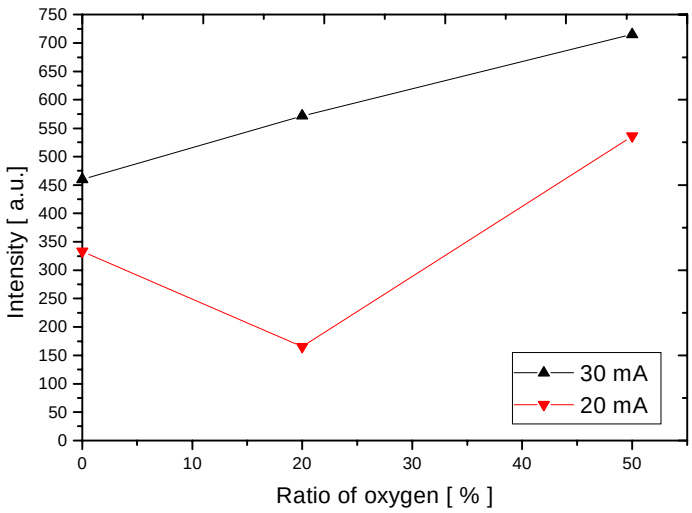


**Figure 2:** Mean values of intensity of argon line 852.1 nm (transition 4s'[$^1/_2$]$^0$ - 4p'[$1^1/_2$], energy of initial state 13.28 eV, energy of final state 11.83 eV, see e.g. [4]) for pure argon and binary mixtures containing 50 and 80 % argon.

### 3.3. Emission spectra of the T and H form of the positive column

Two forms of the positive column exist in mixtures containing 5, 20 and 50 % neon or argon for total pressure 6 Torr. Different forms have been detected in studied mixtures containing 5 and 20 % neon or argon at 4 Torr. Neon lines were not registered in the H form and their intensity was very low in the T form at both pressures. The intensity of the oxygen atomic lines 777.4 nm and 844.7 nm and the head of the atmospheric A band (759.4 nm) is lower in

the T form of the positive column, i.e. the ratio of the excited oxygen molecules $O_2(b^1\Sigma_g^+)$ and the excited oxygen atoms is lower in this form in oxygen-neon mixture (total pressure 6 Torr and 4 Torr). Considering argon-oxygen mixtures the persistent argon lines 696.5 nm and 706.7 nm were detectable in both forms. The density of the oxygen molecules $O_2(b^1\Sigma_g^+)$ is lower in the H form compared to pure oxygen (total pressure 6 Torr). This effect can be explained by dissociation of oxygen molecules by argon atoms. The intensity of the argon lines, atomic oxygen lines 777.4 nm and atmospheric A band were lower in the T form of the positive column. Figure 3 shows comparison of the relative intensities of the oxygen line 777.4 nm in both forms of the positive column for total pressure 6 Torr.

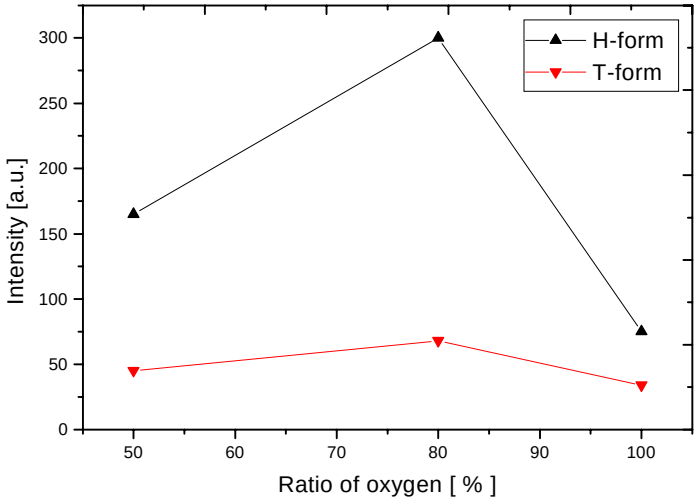


**Figure 3:** Dependence of relative intensity of the line 777.4 nm of neutral oxygen atom on the ratio of oxygen in argon-oxygen mixture for both forms of positive column (total pressure 6 Torr, discharge current 20 mA).


## Acknowledgements

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