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ELECTRON AND GAS TEMPERATURE DIFFERENCE IN LOW CURRENT ARGON D.C. ARC STUDIED BY POWER INTERRUPTION TECHNIQUE

M.M. Kuzmanović[1], M.S. Pavlović[2], J.J. Savović[2], M. Stoiljković[2] and A. Antić-Jovanović[2]

[1]*Faculty of Physical Chemistry, University of Belgrade, P.O. Box 137, 11000 Belgrade,*
[2]*Laboratory of Physical Chemistry, The Vinča Institute, P.O. Box 522, 11001 Belgrade, Serbia and Montenegro*

Abstract

Atmospheric pure argon plasma without analyte water solution injection has been exposed to power interruption experiments in order to study the difference between electron and gas temperature. The arc plasma was studied in low currents range, between 3 and 10 A. Obtained temperature difference ranges from 3000 to 1500 K, from low to high current. A comparison with previous results, for argon plasma with water aerosol supply, have shown that introduction of water reduces temperature difference.

Introduction

In plasmas with lower electron number densities deviations from local thermodynamical equilibrium occurs. The deviations become more pronounced as the concentration of electrons decreases. The disturbance of plasma equilibrium is especially reflected in electron (T_e) and heavy particle (T_h) temperature difference. In arc plasmas that difference increases when current decrease.

Power interruption technique is convenient diagnostic method for investigation of thermal disequilibrium in low electron density plasmas [1]. At the moment of power interruption T_e becomes equal to the T_h while electron-ion recombination requires longer time. If the population of the level is determined by the electron-ion interaction electron temperature drop will cause increase of excited atoms concentration (in contrast to recombination ionization strongly depends on temperature). As a consequence the line intensity sharply increases at the moment of a sudden current interruption. This intensity increase is related to T_e-T_h.

The object of this work was U-shaped d.c. argon stabilized arc which is suitable for spectrochemical analysis of water solutions [2]. In literature there is a lack of precision data for temperature equilibrium in low current argon plasmas. This arc device is very stable for low current burning and thus convenient for this kind of measurements. The aim of this work was to get more insight into analyte excitation conditions by comparing with previously obtained results [3,4] for the same device but with introduction of aerosol.

Experimental

The U-shaped arc column is burning in a channel of 16 mm diameter formed by water-cooled electrically insulated brass segments. The argon gas was introduced into the cavity of the central segment providing additional vortex stabilization. Geometrical features of the plasma make possible "end-on" observation without the use of Abel inversion.

The power interruption was accomplished by fast electronic switch circuit. On the trigger signal, the switch short-circuits the arc column that extinguishes discharge. The anode current of the photomultiplier tube was amplified 50 times with a wide band d.c. amplifier and than recorded by a digital storage oscilloscope. The oscilloscope and switch circuit was controlled by external trigger signal. Data acquisition was controlled by a PC computer.

Results and Discussion

In order to use power interruption technique to obtain T_e-T_h difference it is necessary to measure electron temperature first. In this work electron temperature was approximated with excitation temperature, which was determined from absolute integral emissivities of the argon line at 430.01 nm. Absolute emissivities of the argon line were determined with a carbon arc anode as a radiation standard. A value of $0.00394 \cdot 10^{-8}$ s^{-1} was taken as the probability of the transition of this spectral line.

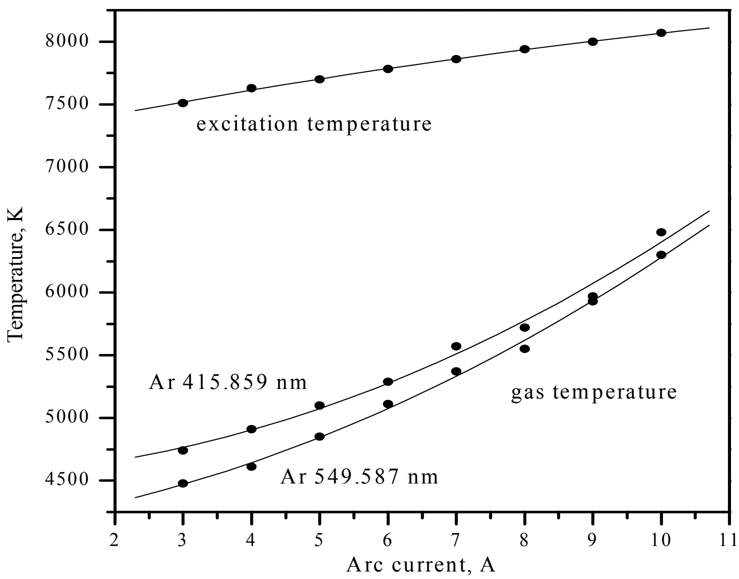

Figure 1. Dependence of excitation and gas temperature on arc current.

Intensity jumps were measured as the difference between intensity at maximum and in stationary state. In order to determine the intensity jump accurately the continuum evolution beside the line was taken into account. The time needed for spectral line intensity to reach the maximum is around 5 μs. Two argon lines with different first ionization energies (14.53 and 15.33 eV) were used for evaluation of gas temperature. Results for the line with lower ionization energy are more reliable because of smaller deviation from partial local thermodynamic equilibrium (p-LTE) but the intensity jump is larger for the line with higher ionization energy and the measurements are more precise. With current increase intensity jump of a spectral line decrease. Also intensity jumps exponentially decrease with the increase of line excitation energy.

For higher arc currents results obtained for two different spectral lines come close to each other because lower excited level approach p-LTE, as it can be seen from Figure 1. In the measured current range (3-10 A) obtained temperature difference ranges from 3000 to 1500 K with the tendency for equalization at higher currents.

Conclusion

Argon d.c. arc plasma burning at atmospheric pressure is two temperature plasma where electron temperature determines excitation and ionization processes, i.e. the plasma is in p-LTE. The obtained temperature difference reaches as much as 30%. Previous results [4] for the same plasma device, but with water aerosol introduction, have shown smaller temperature difference. In other words introduction of water causes more efficient electron energy transfer to heavy particles.

Acknowledgments

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