PHYSICAL CHEMISTRY 2006

Proceedings

of the 8th International Conference on Fundamental and Applied Aspects of Physical Chemistry

September 26-29,
Belgrade, Serbia

ISBN	86-82139-26-X
Title:	Physical Chemistry 2006. (Proceedings)
Editors	Prof. dr A. Antić-Jovanović
Published by:	The Society of Physical Chemists of Serbia, Studentski trg 12-16, P.O.Box 137, 11001 Belgrade, Serbia
Publisher:	Society of Physical Chemists of Serbia
For publisher:	Prof. dr S. Anić, president of the Society of Physical Chemists of Serbia
Printed by:	"Jovan" Printing and Published Comp; 250 Copies; Number of Pages: x + 442; Format B5; Printing finished in September 2006.
Text and Layout:	Aleksandar Nikolić

250 – copy printing

AN EXPERIMENTAL STUDY OF RADIAL SYMMETRY DEVIATION IN DC ARGON ARC PLASMA BY CURRENT MODULATION TECHNIQUE

J. J. Savović[1], M. M. Kuzmanović[2], M. S. Pavlović[1], M. Stoiljković[1] and M. Marinković[1]

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

Abstract

A current square modulation technique is used to investigate radial asymmetry of plasma column of argon stabilized direct current U-shaped arc. By monitoring the temporal behavior of spectral line intensities (in a millisecond domain) for various elements, it was observed that nonhomogeneous emission was much more pronounced for current modulated arc plasma compared to the stationary regime plasma. The reason for such behavior, for this as well as for other arc sources, lies in a mode the stream of argon with aerosol is introduced into the arc plasma.

Introduction

For many applications, particularly in plasma diagnostics, detailed knowledge of symmetry in radial distribution of plasma parameters, especially in a direction perpendicular to viewing direction, is important. Radial plasma symmetry for one of the plasma parameters does not necessarily mean that the plasma is symmetric related to other plasma parameters. Also, different plasma parameters respond with different sensitivity to plasma asymmetry. It was shown in ICP that radial distribution of analyte emission intensity is not a sensitive tool for investigation of asymmetry [1]. On the other hand, instant responses to power modulation of spectral line intensities proved to be much more reliable tool for investigation of asymmetry distribution of important plasma parameters such as electron density and temperature.

The objective of this work was to investigate a radial symmetry of argon stabilized U-shaped dc arc, operating at atmospheric pressure [2]. For that purpose, we studied the temporal evolution of spectral line intensities for various elements with different ionization energies. Also, we investigated the influence of easily ionized elements (EIE) addition on the arc discharge symmetry. Because greatest influence of asymmetry is expected on transport processes in plasma (due to asymmetric analyte introduction) a special attention was paid to delayed responses, as they may give us a more detailed insight into these processes.

Experimental

A detailed description of the U-shaped arc device used in this work is given in previous publication [2]. The analyte water solutions were introduced into the plasma as aerosol obtained with glass concentric nebulizer and double-pass cloud chamber. Emission from a horizontal part of arc plasma was "end on" observed. Radial distributions of emission were monitored by moving the arc device perpendicular to the optical axis of the monochromator, taking care that it remained parallel to the arc axis.

The horizontal part of the arc column plasma was projected with acromatic lenses on the entrance slit of a Zeiss SPM-2 monochromator (dispersion 4 nm/mm in the first diffraction order). The argon stream carying the analyte particles was introduced into the central segment cavity of the arc device (diameter 68 mm, hight 8 mm) providing a gas vortex that additionaly stabilizes the arc column. In Figures 1 and 2, parts of distribution curves from the side where the aerosol is introduced are marked with (+) sign, and those from the oposite side are marked with (–) sign.

The arc current was square modulated between 9 and 3 A with the aid of electronic switch circuit based on fast MOS-FET transistors. The current transition time was better than 5 μs. The lower current period was 50 ms with a repetition period of 250 ms. In order to minimize a signal noise, photomultiplier current was first amplified by a factor of 50 with a fast preamplifier and then via coaxial connection carried to a digital storage oscilloscope. The oscilloscope was PC controlled via GPIB interface. The oscilloscope traces are 32 times averaged, and subsequently transferred to a PC.

Results and Discussion

The asymmetry in response of H_α spectral line intensity, on current jump, is seen in Figure 1. Similar effects are obtained for argon lines as well as for recombination continuum. The similarity between temporal responses for lines with high ionization energies and for recombination continuum is expected because in both cases intensity is a quadratic function of electron number density. Temporal responses presented in Figure 1. are hard to explain, but they certainly correspond to the plasma asymmetry which is a consequence of asymmetrical introduction of the argon stream carrying the aerosol.

Also, in stationary regime, asymmetrical radial distribution of spectral line intensities is obtained, but it is less pronounced than in Figure 1. Line intensities on a minus (-) side of plasma are a bit smaller and they show a steeper dependence of radial position.

Temporal responses of Mg I line, as a representative for elements with medium ionization energies, are presented in Figure 2. Temporal responses, of line intensities related to arc current drop and jump, show a pronounced asymmetry. The intensity increase during the arc current drop may be a consequence of a decreased barrier imposed by radial electric field [3]. Explanation of such behaviour by the increase of ground state atoms concentration due to recombination must be discarded because of a similar behaviour of ionic line intensities (e.g. Mg II, Ba II, Ca II...). Asymmetrical response at the arc current drop indicates a large asymmetry of radial electric field induced by ambipolar diffusion. The fact that the large addition of EIE reduces asymmetry in temporal responses of line intensities at arc current drop (since introduction of EIE decreases the radial electric field) is in accordance with the previous conclusion [3].

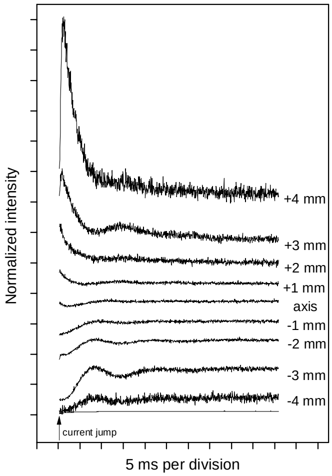

Fig. 1. Temporal responses for H_α 656.3 nm line intensity after the current jump, at different displacement from the arc axis.

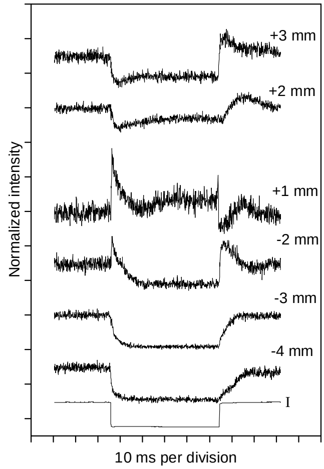

Fig. 2. Temporal responses of Mg I 285.21 nm line intensity in presence of 0.3% KCl, at different displacement from the arc axis.

Conclusion

By comparing the radial distribution of spectral line intensities and their temporal responses to arc power modulation, it was shown that delayed responses are more sensitive to asymmetry in plasma parameters compared to intensities in a stationary regime. Pronounced asymmetry in argon U-shaped arc is a consequence of asymmetry in the aerosol introduction in a discharge.

Acknowledgments

This work has been financially supported by Ministry of Science and Environmental Protection, Republic of Serbia, under Project No. 142065.

References

[1] L.E. Bydder and G. P. Miller, *Spectrochim. Acta* 1988, **43B**, 1431-42.
[2] M. S. Pavlović, N.Z. Pavlović and M. Marinković, *Spectrochim. Acta*, 1991, **46B**, 1487-1498.
[3] M. M. Kuzmanović, M. S. Pavlović, J. Savović, M. Marinković, *Spectrochim. Acta*, 2003, **58B**, 239-248.