LONGITUDINAL DEMIXING IN A D.C. ARC DISCHARGE IN NEON-ARGON AND NEON-HELIUM ATMOSPHERE

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Introduction

Arc discharges at atmospheric pressure are widely used as excitation sources for atoms, ions and molecules. In such discharges, operated at steady state conditions plasmas close to Local Thermodynamic Equilibrium (LTE) or at least partial LTE may be easily produced, facilitating the interpretation of the detected spectra. Among various plasma sources of this kind, the wall-stabilized d.c. arc has been extensively applied in emission studies of atomic structure of many elements. It is usually assumed that at fixed distance from the axis of the arc column, the plasma is uniform along the direction cathode-anode, except for very small volumes close to the electrodes.

In our previous works [1, 2] we proved that such assumption is not fulfilled in plasmas containing helium as the main component. The strong non-homogeneity is caused mainly by large differences between the ionization potentials of the plasma constituents.

This departure from homogeneity may be very crucial for and interpretation of studies devoted to determination of transition probabilities of neon spectral lines by plasma spectroscopy method.

Experiment

The wall-stabilized arc consists of 11 copper plates, separated by insulators (teflon) rings. The most outer plates hold identical tungsten electrodes. The orifices (diameter 4 mm) bored in the centre of all remaining plates define – after assembling the device – the discharge channel. Each plate was water cooled. The central plate has a special construction with a small channel hollowed along its diameter which enables introduction of neon precisely in the geometrical centre of the arc. Slits cut in the insulator spacers allowed radiation of the plasma to be registered.

The radiation of the plasma emitted perpendicular to the arc axis (side-on) has been imaged on the entrance slit of the grating spectrometer (PGS-2) equipped with a two-dimensional CCD camera. By dividing the detector height into 64 tracks the spectra corresponding to the integrated light along different chords of the plasma column at given cross-section could be simultaneously registered. By shifting the arc in the direction perpendicular to the axis of the optical system, the plasma emission from different parts of the arc column was measured.

The working gas (argon or helium) were introduced uniformly at the whole length of the arc while neon was injected only at one point – at the geometrical centre of the arc as shown in Fig. 1. In case of the helium plasma, the regions close to the electrodes were supplied additionally with small amount of argon in order to obtain stable operation of the device.

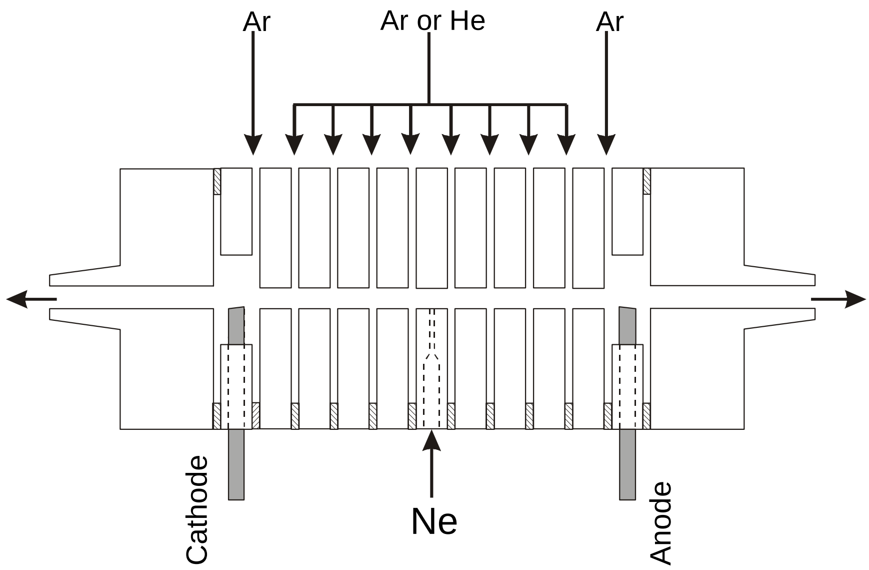

Figure 1. The scheme of the arc construction and the gas flow system is shown.

Results

The tracks corresponding to the integrated light along the diameter of the plasma column have been selected. After fitting Gauss profiles to the Ne I 692.9 nm line their intensities have been determined. All intensities have been normalized to “virtual” intensity corresponding to the position where neon was introduced (mean value of two adjacent measured intensities).

As one can see, in both cases the distribution is asymmetrical relatively to the centre of the arc. In the case of argon plasma the Ne I line intensities are evidently higher in the plasma regions closer to the anode. In case of the helium plasma one observes contrariwise phenomenon.

The intensities determined by integrating along the line of sight in case of side-on measurements (without performing Abel inversion) could only approximately describe the plasma properties and in some cases the distributions obtained this way can be completely misleading [3]. This “inconsistency” is caused by the fact that different cross-sections of the arc column can be characterized not only by different plasma composition and temperature but also by their different radial distributions.

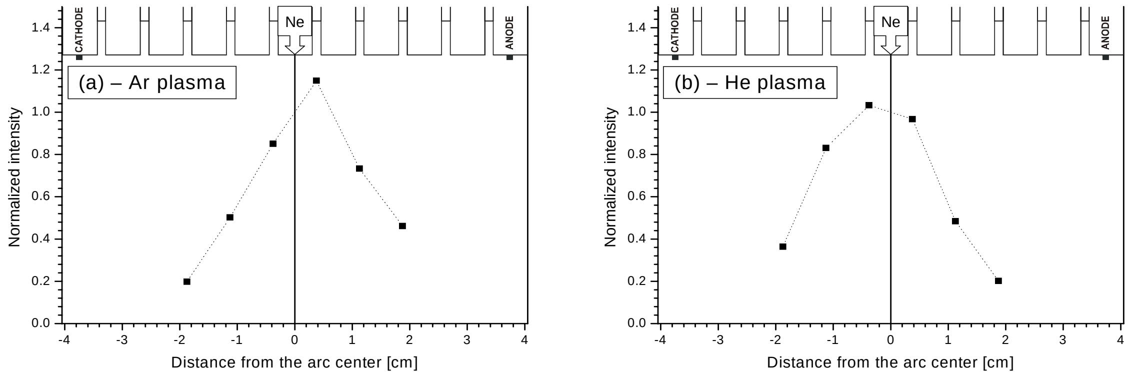

Fig.2. Axial distributions of Ne I 692.9 nm intensities, obtained by integration along the arc diameter. The values have been divided by the intensity corresponding to the position of neon injection.

In order to determine the plasma parameters on the arc axis the Abel inversion procedure for several spectral lines have been applied. The emissivities of these lines have been used, as input parameters in the equation set describing the plasma being in Local Thermal Equilibrium (LTE).

While argon plasma is in LTE at least very close to LTE conditions, the electron densities in the case of helium dominated plasma are too low to establish LTE. Because of the departure from LTE condition in the case of helium plasma one may expect that the obtained temperature values are systematically too low. However the shape of the temperature distribution nearly reflects the correct temperature profile.

In Fig.3 one can see that the admixture of neon introduced into the argon slightly increases the plasma temperature in cross-sections close to the place of neon injection. The axial temperature distribution reveals a very small asymmetry. In the case of helium dominated plasma the situation is definitely different. It is evident that the temperatures are higher in plasma volumes closer to the anode. This observation can be explained by the demixing effect. Diffusion of neon towards the cathode changes the plasma composition mainly in the left side of the arc shown in Fig. 3. Because helium is the element with the highest ionisation potential even a small admixture of neon may considerably influence the electron density. Since with increasing electron density the thermal and electrical conductivity increases the final effect is the observed drop of the temperature.

The most adequate parameter for describing the plasma composition is the mass fraction. The distributions of number densities as well as mole fractions are inadequate, because these parameters depend not only on the plasma composition but also on temperature. The axial distributions of neon mass fractions, presented in the Fig.4, clearly exhibit that the direction of diffusion of neon in argon plasma is reverse to the direction in helium plasmas.

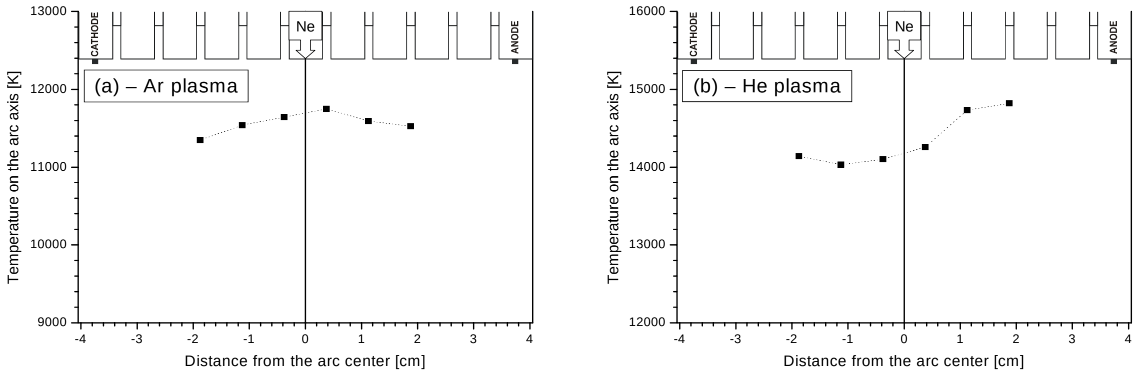

Fig.3. Axial distributions of temperature values on the arc axis are shown .

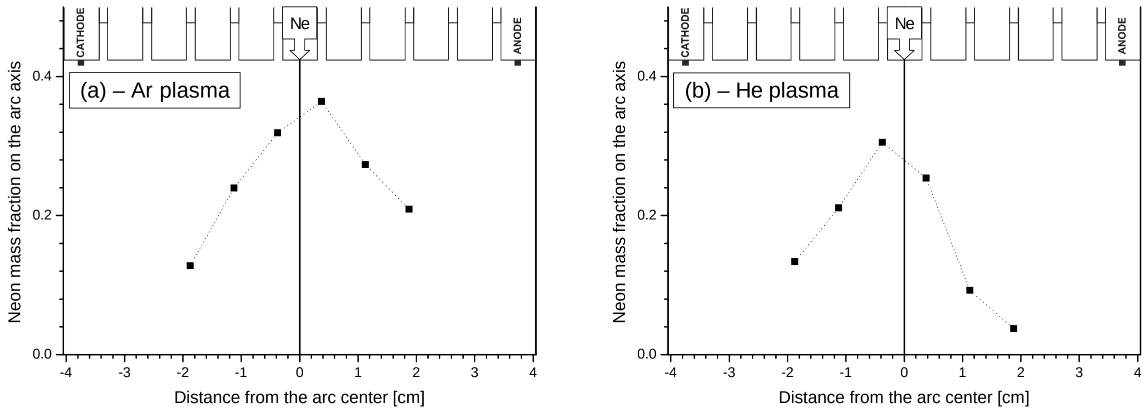

Fig.4. Axial distributions of neon mass fraction values on the arc axis are shown.

Conclusions

The results presented in this work confirm that the main quantity determining the direction of longitudinal diffusion in d.c. arcs is the degree of ionisation of the element. This diffusion has been quantitatively predicted and described by Frie [4] and Murphy [5]. The results of this contribution may be very important in planning experiments aiming toward determination of atomic constants by emission spectroscopy method.

References

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