Absorption spectroscopy in RF plasmas at atmospheric pressure: argon resonance and metastable densities.

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Non-equilibrium atmospheric pressure plasmas recently start to attract a lot of attention due to their potential application in materials treatment, biological and medical applications. Argon metastables and resonance species in *1s* states play an important role in sustaining of argon plasma jets and similar discharges. In this work, the number density of Ar *1s* levels and population distribution of Ar *2p* levels are obtained in 13.56 MHz plasma at sub- to atmospheric pressure range. The plasma source is a planar barrier discharge with electrodes area of 25 cm^2 having afterglow similar to RF plasma jets.

The absolute number density of non-radiative Ar *1s* states is determined by means of absorption spectroscopy using a low pressure spectral-lamp. It is shown that, the modified absorption theory of Mitchell and Zemanski [1] can be still applied at high pressure where pressure broadening of the lines start to be important.

Results of absorption spectroscopy shown that the increase of the metastable and resonance states density always accompanied by an increase of the input power. This agrees with a fact that electrons are important in the population mechanisms of Ar *1s* levels through electron impact excitation processes. However, the increase of pressure in the discharge leads to drop in absolute density of all the states, for example for $1s_4$ state at 70 W from 1.7×10^{18} m^{-3} at 500 mbar to 0.62×10^{18} m^{-3} at atmospheric pressure but this drop is not linear and much smaller for $1s_2$ and $1s_3$ states. Fig. 1 shows the non-monotonically change of Ar (*1s*) densities in function of pressure. The obtained results indicate that, some side reactions (other than the excitation by electron impact) are involved in population of *1s* Ar states. It is found that for the net production of *1s* states and their depopulation the recombination and two/three-body collision are of high importance. The two/three body collisions are also responsible for the depopulation of the excited *2p* levels and even start to be dominant mechanisms of depopulation of Ar *2p* states at high pressure. It agrees with emission spectroscopy data revealed strong non-equilibrium distribution of Ar *2p* levels.

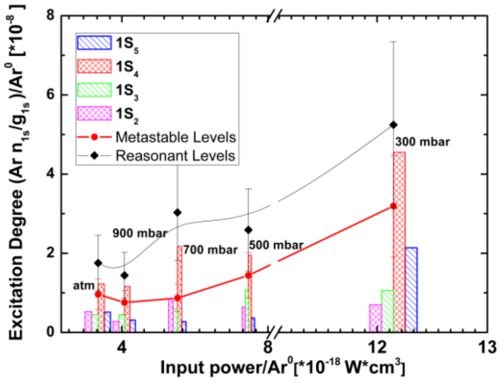

Fig. 1: *Number density of 1s levels in function of pressure at input power of 55 W. The n_{1s} is the absolute density of 1s levels and g_{1s} refers to the degree of degeneracy. Here the sum of two metastable states ($1s_5$ and $1s_3$) and two resonant states ($1s_4$ and $1s_2$) is also indicated by square-line symbol and circle-line symbol, respectively.*

Thus, a slight decrease of the metastables density with increase of the pressure to 700 mbar, observed in experiments, can be explain by a role of two- and three body collisions. Afterwards, the re-increase of Ar^m density with increase of pressure to 1100 mbar can be attributed to the dissociative recombination process:

$$Ar_2^+ + e \rightarrow Ar\,(1s, 2p) + 2e$$

The formation of Ar_2^+ by atom-assisted association ($Ar^+ + Ar + Ar \rightarrow Ar_2^+ + Ar$) become most important mechanism of positive ion production in Ar plasma.

It conclusion is shown that absorption spectroscopy can be power tool in diagnostic of high pressure plasmas. The developed RF source with 5 cm long gap can be a possible alternative to microplasma working in Ar at atmospheric pressure in terms of production of resonance and metastable states of Ar and so in formation of the afterglow.

References

[1] A. C. Mitchell, M. W. Zemansky, Resonance Radiation and Excited Atoms, Plenum, New York, 1971.