Topic number: 7

Influence of dust formation in Ar/C_2H_2 plasma on spatial distribution of Ar* metastables atoms, studied by Laser Induced Fluorescence

Ilija Stefanović(1,*), Brankica Sikimić(1), Nader Sadeghi(2), and Jörg Winter(1)

(1) Institute of Experimental Physics II, Ruhr-University Bochum, 44780 Bochum, Germany
(2) Lab. de Spectrometrie Physique, Universite J. Fourier & CNRS, Grenoble, France
(*)ilija.stefanovic@rub.de

Dusty or complex plasmas differ from usual non-equilibrium plasmas through a presence of small solid particles with the radius ranging between a few nanometers and hundreds of micrometers. Such solid particles are usually negatively charged and can significantly influence the plasma properties, especially if their charge density is equal or larger than the free electron density [1-3]. The additional loss term for electrons is compensated through the increase of electron mean energy, enhancing the excitation, ionization and dissociation reactions.

To inspect changes in argon plasma parameters due to the dust particle growth, we applied the well known Laser Induced Fluorescence (LIF) technique on Ar*($^3P_2$) metastable atoms [4]. To follow the time and space variation of these metastable atoms, we have employed an external cavity diode laser to excite the Ar* atoms at 772.38 nm and to observe the LIF signal at 810.38 nm. The laser beam was launched perpendicular to the electrodes, 10 cm off - axes, and the LIF signal was recorded with a CCD camera equipped in front of it with an interference filter centred at 810 nm (see Fig. 1). The spatial and temporal distribution of Ar* metastables is proportional to the monitored LIF signal. Dust particles were grown in argon/acetylene plasma at pressure p = 0.1 mbar, input power P = 15 W and 8 sccm / 0.5 sccm flow rates of argon and acetylene, respectively (sccm = standard cubic centimetre per minute).

In Fig. 2 the spatially resolved distribution of Ar* metastables in pure Ar plasma, deduced from the LIF signal, is presented. Positions of the upper and lower electrodes are shown to allow the estimate of the plasma sheath width. Under our experimental conditions, the main production mechanism of metastable atoms is the direct electron-impact excitation from the ground state of argon atom. The steady-state density results therefore from an equilibrium between production and loss frequencies of Ar* atoms [5]. The spatial distribution of Ar* atoms is characteristic for a rf glow discharge in α regime [6], where the excitation zone is localized near the electrodes.

About one minute after, acetylene is added and due to the efficient quenching of Ar* by C_2H_2, the maximum value of Ar* metastable density decreases about tree times (Fig. 3). At the discharge centre, the density decrease is even larger - about seven times compared to the pure argon case. This change of spatial distribution reflects the predominance of quenching of Ar* by acetylene relative to the diffusion loss. The discharge still burns in α regime, in which Ar* atoms are produced in the negative glow, near the electrodes. But opposite to the pure argon discharge, Ar* atoms are now efficiently quenched by C_2H_2, before their diffusion to the discharge centre [7].

Four minutes and twenty seconds after starting the discharge (or three minutes and fifteen seconds after adding the C_2H_2) the dust particles are developed and reached the size of about 60 nm in diameter. The metastable density increased about two times but the most striking change is in the metastable distribution (Fig. 4). The maximum of the density shifts to the discharge centre and the discharge switches to the spatially homogeneous excitation of Ar* atoms in γ' regime. The increase of metastable density in the plasma centre is twenty times. This change reflects the increase of electron mean energy, which compensates the increase of electron losses on the growing dust particles.

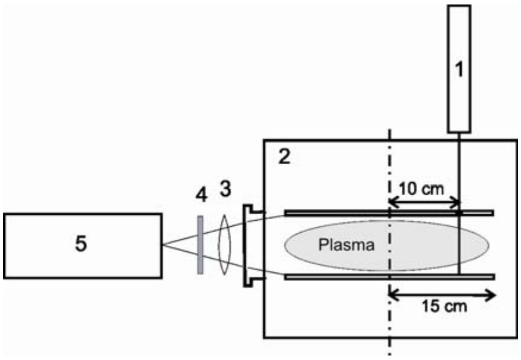

Fig. 1. Experimental set-up, side view: 1- Laser diode 772.38 nm; 2 - plasma chamber; 3 - objective; 4. interference filter at 810 nm; 5- CCD camera.

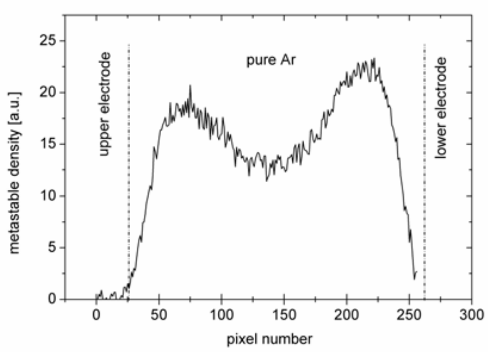

Fig. 2. Spatial Ar* density distribution in a pure argon discharge.

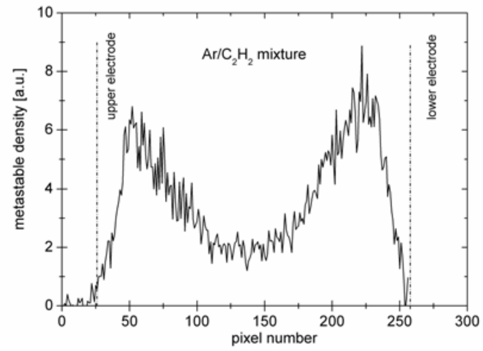

Fig. 3. Ar* metastable density distribution in Ar/C_2H_2 discharge, before dust particles formation.

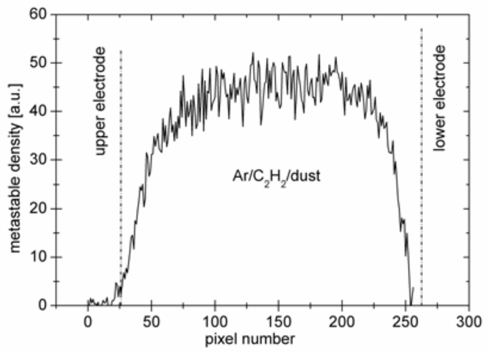

Fig. 3. Ar* metastable density distribution in Ar/C_2H_2 discharge after dust particles formation.

Acknowledgements

This work was supported by the DFG within the framework of the DFG- grant WI 1700/3-1, DFG – FOR1123, and Research Department “Plasmas with Complex Interactions”.

References

[1] Bouchoule A and Boufendi L 1994 *Plasma Sources Sci. Technol.* **3** 292

[2] Stefanović I, Kovačević E, Berndt J and Winter J 2003 *NJP* 5 39

[3] Denysenko I, Berndt J, Kovačević E, Stefanović I, Selenin V and Winter J 2006 *Phys. of Plasmas* **13** 073507

[4] Sadeghi N 2005 *Journal of Plasma and Fusion Research*, 80 767

[5] Latrasse L, Sadeghi N, Lacoste A, Bes A and Pelletier J 2007 *J. Phys. D: Appl. Phys.* **40** 5177

[6] Denysenko I, Yu M Y, Ostrikov K, Azarenkov N A, and Stenflo L 2004 *Phys. Plasmas* **11** 4959

[7] Stefanović I, Sadeghi N and Winter J 2010 *J. Phys. D: Appl. Phys.* **43** in press