Metastable Ar atoms in dusty plasmas

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1. Introduction

Dynamics of metastable argon atoms ($\text{Ar}^*$ ($^3\text{P}_2$) state) in pulsed and continuous-wave dusty plasma has been investigated by using Laser Absorption Spectroscopy (LAS). Four different gas mixtures have been used: a) pure Ar, b) Ar/C$_2$H$_2$, c) Ar/ C$_2$H$_2$/dust, and d) Ar/dust. Large increase (almost one order of magnitude) of Ar$^*$ has been detected in dust containing mixtures for the same discharge input power. The metastable dynamics in plasma afterglow has been strongly influenced by the presence of acetylene molecules. An increase of gas temperature in plasma containing dust has been measured.

2. Experiment

To generate dusty plasma we have used our standard CCP RF 13.56 MHz discharge (for more details on discharge set-up and procedure see [1] and references therein). The discharge was driven either in continuous – wave mode or in pulsed mode, with variable pulsing frequency between 100 Hz and 1 kHz. The Ar/ C$_2$H$_2$ mixture of 8:0.5 sccm flow ratio was continuously supplied to the discharge chamber and the gas pressure of 0.1 mbar has been kept constant throughout the measurements. The discharge input power ranged between 10 W and 80 W. The carbonaceous nano particles (dust) have been formed in the process of plasma polymerization of acetylene monomer. The Ar$^*$ density has been measured by LAS of 772.38 nm argon line (1s$_5$-2p$_7$ transition in Paschen notation) by using standard technique previously described in [2]. Gas temperature has been calculated from Doppler width of recorded line profiles.

3. Results

The time dependence of Ar$^*$ density for different gas mixtures is presented on Fig. 1. The pulsed frequency was 100 Hz and duty cycle 50%. The large differences between different gas mixtures could be seen in: a) Ar$^*$ density and b) metastable decay time in afterglow.

The metastable measurements have been started in pure argon (solid line on Fig.1). After adding the acetylene the metastable density sinks about seven times due to the increased quenching of Ar$^*$ with C$_2$H$_2$ molecules (triangles). The metastable decay constant in afterglow changes from 3.4 ms in pure argon to 0.4 ms in argon/acetylene mixture, again due to the additional quenching losses in Ar$^*$ - C$_2$H$_2$ collisions.

Appearance of dusts increases metastable density ten times compared to the Ar/C$_2$H$_2$ mixture. It is well known that the dust particles introduce additional losses of electrons in plasma, which has to be compensated by the increase of ionization in order to keep the discharge stable. This reflects in the Ar$^*$ production rate and Ar$^*$ density (Fig. 1, dashed line). The density of metastables is highest in the Ar/dust mixture, after stopping the C$_2$H$_2$ flow. In the absence of acetylene the metastable quenching is almost negligible, causing the density to increase further (circles, Fig. 1). On the other side, the dust – Ar$^*$ collisions are almost negligible, which could be seen by comparing the decay constants in pure argon and Ar/dust mixture. The decay time for Ar/dust mixture is 2 ms and the difference to pure argon comes probably from some acetylene impurities still present in the discharge.

4. Conclusion

The LAS measurements showed the significant increase of argon $^3\text{P}_2$ metastable state density, which is mostly populated by electron collisions from ground state. This reflects the increase of the mean electron energy to account for increased losses on dust particles ($\alpha – \gamma'$ transition [3])

Acknowledgment

This work has been supported through DFG project WI 1700/3.

References