Measurement of molecular argon ion density in an atmospheric pressure transient spark discharge by observation of ion acoustic waves

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1. Introduction

The method of observing ion acoustic waves is well known at low pressure plasma discharges and is a useful tool to access ion densities. The use of this technique at atmospheric pressure was until recently not believed to be applicable due to the high collision rates with the background gas. Nevertheless, our previous publication already reported on the observation of oscillations in a transient spark discharge that were discussed as ion acoustic waves [1]. In the present contribution, we will present results for a set of measurements to show the reproducibility of this measurement and we will show the solution of the dispersion relation for ion acoustic waves at the given conditions.

2. Methodology

The plasma source is self-pulsing, by applying a negative, high-impedance DC voltage onto a needle electrode. A metallic plate is used as the grounded electrode and a capillary surrounds the needle electrode and reaches into the discharge gap [2]. A transient spark discharge in argon at open atmosphere is created and investigated by means of a fast electric current probe (Tektronix CT-1, bandwidth 1 GHz) in combination with a fast oscilloscope (Tektronix DPO7104, bandwidth 1 GHz). The discharge shows fast current pulses with a duration of 10 ns (half width) and an amplitude variing from 100 mA up to 2 A.

3. Results

Recorded current signals show a fast oscillation signal in the pulse decay phase for a certain argon flow range (350 sccm - 500 sccm). These oscillations have characteristic frequencies of 50 MHz up to 250 MHz. As presented in [1], the frequencies are determined by the dominant ion density. Under the present conditions, the dominant ion is the argon molecular ion [3, 4] and the observed range of molecular argon ion density is presented in figure 1 for five acquisitions. The measurement does not average and therefore the set of data is slightly different for each discharge event with $n_{Ar_2^+} = (1{\cdot}10^{14} \;...\; 1{\cdot}10^{12})\ \mathrm{cm}^{-3}$.

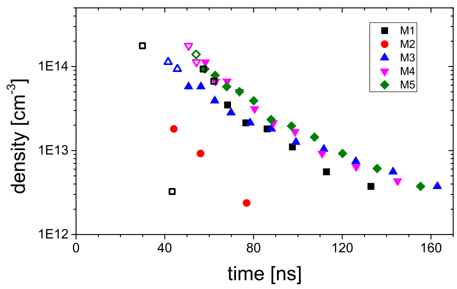

Fig. 1: *Density of molecular argon ions over time during the decay phase of the discharge current for five measurements. The maximum current value is at 0 ns. The hollow marks indicate the onset of the ion acoustic waves.*

From the solution of the dispersion relation for the ions under atmospheric pressure conditions, we found a strong dependence of the existence of such an ion acoustic wave on the ion density and the collision frequency. Therefore the lower limit of the observed ion density is related to the collision of the ions with the neutral gas background and the upper limit is related to the limitations of the experimental setup. First trials with a current probe of 2 GHz bandwidth and a 4 GHz oscilloscope showed frequencies up to 400 MHz.

4. Conclusions

The presented method is able to measure absolute ion densities in an atmospheric pressure plasma. The method is believed to be a promising diagnostic tool in the future for different discharge conditions. This method might possibly be extended to measure multiple ion oscillations simultaneously.

References

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