DIAGNOSTICS OF **E**×**B**-DRIVEN GLIDING DISCHARGES

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Abstract

The concept of magnetic stabilization is investigated as a means to obtain non-thermal plasmas at elevated pressures. Electrical and optical diagnostics are deployed to measure the magnetic drift velocity and the plasma column width.

1 Introduction

Plasmas that are used in technical applications are called “thermal” or “non-thermal”, depending on the equilibrium between light (electrons) and heavy particles (ions, molecules). Non-thermal plasmas typically operate at high electrical fields and low electron densities. They offer a high selectivity and efficiency in chemical processes, but operate at limited power levels and are difficult to stabilize at high pressures. Thermal plasmas, on the other hand, operate at low electrical fields and high electron densities and can deliver high power at high pressures. To some extent, the advantages of both types of plasma are combined in non-equilibrium gliding arc discharges. These energy-efficient plasma sources have found many practical applications in today’s technology, for example in flue gas cleaning [1,2].

In this paper we explore the possibility to use crossed electrical and magnetic fields to generate a gliding discharge with non-equilibrium properties at high pressure. The velocity of the discharge in the **E**×**B** direction is measured as a function of pressure, current and magnetic field. From the optical emission signal the shape of the moving plasma is reconstructed in order to determine the plasma column width.

2 Experimental setup

The gliding discharge reactor consists of two diverging copper rods as electrodes, fixed between dielectric (glass or ceramic) plates to form a trapezoidal slab volume. Permanent magnets generate a magnetic field that is perpendicular to the plane of the slab. Both the length of the electrodes and the spacing between the dielectric plates is varied in the experiments. The discharge is powered with a 40kV/100mA DC power supply. The reactor is mounted in a vacuum chamber allowing measurements at reduced gas pressures and in different gas mixtures. The reported measurements are performed in air.

To measure the velocity of the discharge in the **E**×**B** direction the light emission that exits from a 1mm circular diaphragm, placed on top of one of the dielectric (glass) plates, is captured with a photomultiplier, connected to a digital oscilloscope. The recorded waveforms are transferred to a personal computer.

3 Experimental results and discussion

In crossed electric and magnetic fields, the Lorentz force induces an ambipolar drift of the charged particles in the **E**×**B** direction [3]. The magnetically induced drift velocity is given by

$$v_L = \frac{(\mu_e + \mu_i)\mu_e \mu_i EB}{\mu_e(1+\mu_i^2 B^2) + \mu_i(1+\mu_e^2 B^2)} \approx \mu_e \mu_i EB$$

where $\mu_{i,e}$ are the electron and ion mobilities, E and B are the electrical and magnetic field strengths. Given the pressure and temperature dependencies of the mobilities, and assuming that E is proportional to the gas density N, it follows from the above expression that the magnetic drift velocity scales with B/N. This scaling is confirmed at least qualitatively by the experimental results of fig.1. Moreover, the ratio of the slope of the two curves, 166 mbar.m/s and 397 mbar.m/s, matches with the ratio of the magnetic fields. The increase of the velocity with increasing current (fig.2) is ascribed to the concomitant temperature increase.

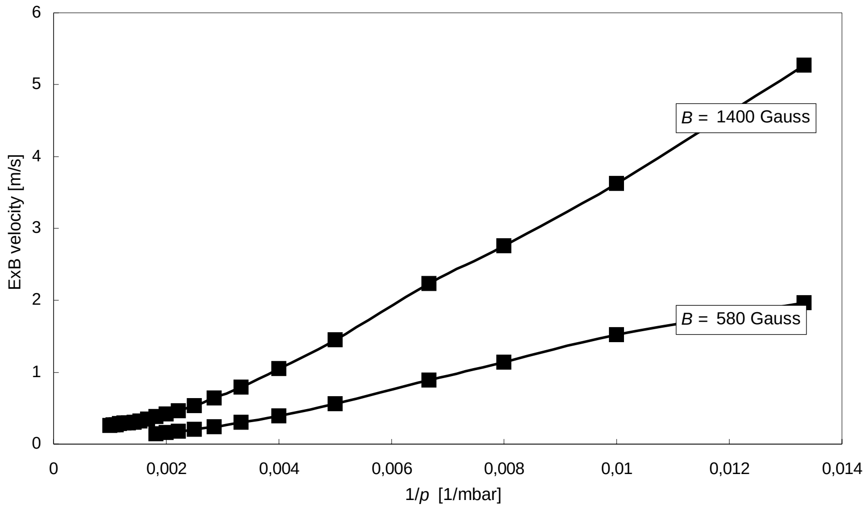

Figure 1: Magnetic drift velocity versus inverse pressure (I = 18,8 mA)

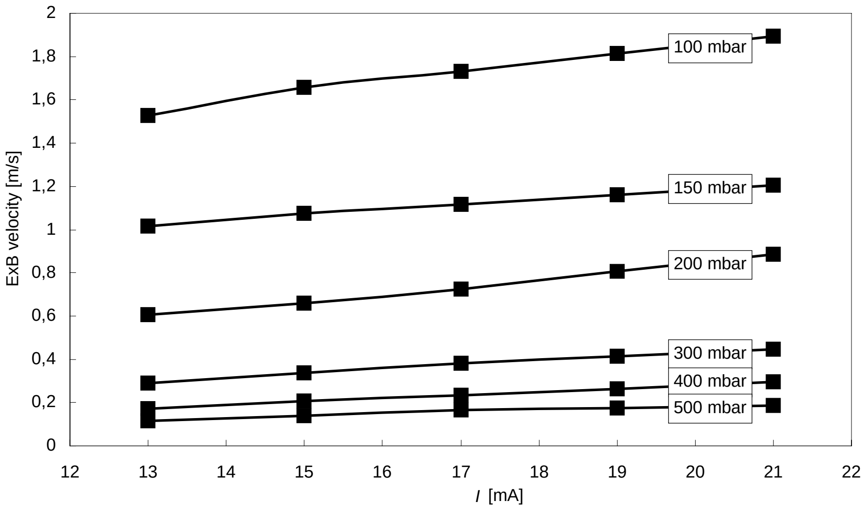

Figure 2: Drift velocity versus discharge current

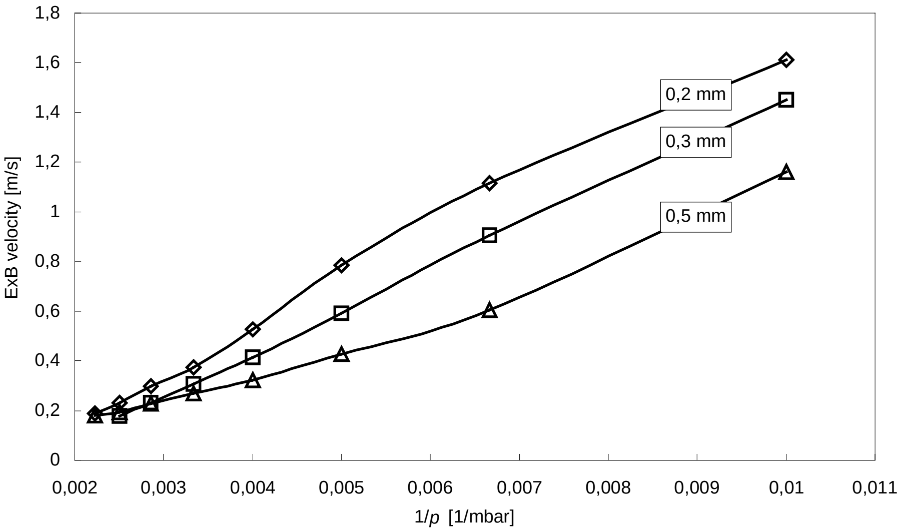

Figure 3: Magnetic drift velocity versus slab height (I = 18,8 mA)

In fig.3 the influence of the slab height, i.e. the distance between the dielectric plates, is shown. A plausible scenario that explains the fact that at lower pressures the velocity increases with decreasing slab height is that when the pressure is sufficiently low the plasma column width is dominated by diffusion to the walls. In this regime the current density increases with decreasing pressure, the total current being kept constant. The increase in velocity is then again a temperature effect. It follows that the dependence of the magnetic drift velocity on the slab height provides information on the plasma column width.

Once the plasma velocity is known, a more direct way to determine the plasma width in the **E**×**B** direction is to reconstruct the plasma shape from the light pulse emitted by the drifting plasma when it passes a diaphragm. In practice, a specific spatial intensity profile is a priori chosen or eventually calculated by solving a simplified electron diffusion equation,

$$-D_{ae}\frac{d^2 n_e}{dz^2}+v_L\frac{dn_e}{dz}=\frac{n_e}{\tau_g}$$

where the *z*-coordinate is in the **E**×**B**-direction, D_{ae} is the ambipolar diffusion coefficient, n_e is the electron density and $\tau_g \sim (jE)^{1/2}$ is a typical growth time for thermal instabilities. The full-width-at-half-maximum (FWHM) of the spatial profile is then used as a fitting parameter to obtain the best fit between the recorded and the calculated time signal (fig.4). In the case shown it is assumed that the spatial intensity profile is a cosine function. With this choice, a good fit can be obtained in the central part of the pulse. However, the experimental signal features broader wings and even a slight asymmetry.

The pressure dependence of the fitted plasma column widths is displayed in fig.5. After an initial drop with increasing pressure, the plasma width reaches a constant value. The fact that this constant value lies close to the slab height, is indicative of the beneficial effect of diffusion to the wall on the plasma stability.

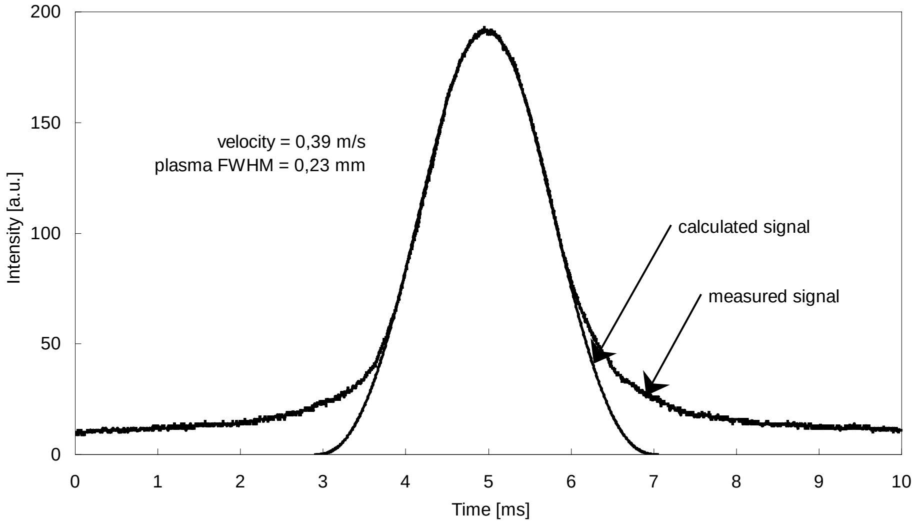

Figure 4: Recorded and simulated light emission pulse
(*I* = 18,8 mA, *p* = 250 mbar, slab height = 0,3 mm)

4 Conclusion

The reported experimental study of a magnetically driven gliding discharge focussed on the **E**×**B** plasma velocity and the plasma column width. The plasma velocity is inversely proportional to the pressure and increases both with magnetic field strength and discharge current.

Ongoing research is aimed at determining the degree of non-equilibrium in the plasma and at finding the optimal electrode geometry and magnetic field configuration to obtain a non-thermal plasma at atmospheric pressure.

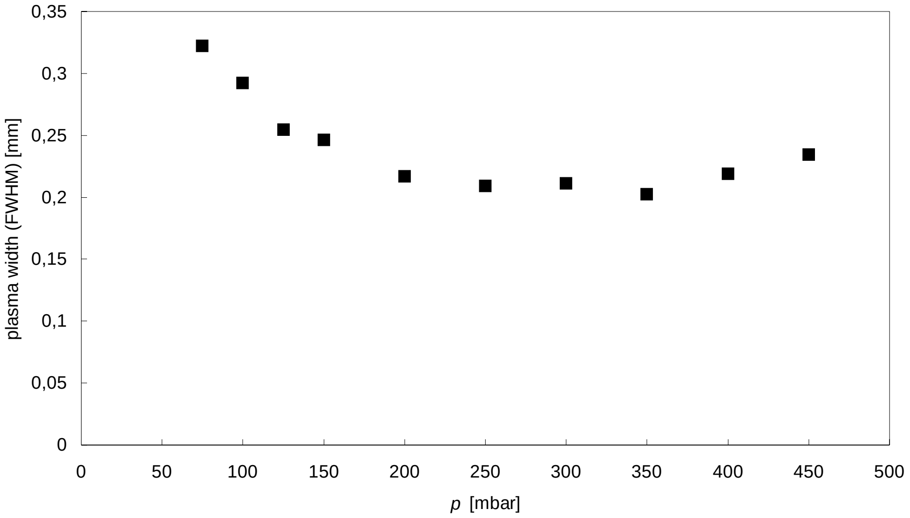

Figure 5: Plasma column width versus pressure
(*I* = 18,8 mA, *p* = 250 mbar, slab height = 0,3 mm)

References

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