# Diagnostic Study of DC Gliding Arc Discharge

**Milan Simek and Martin Clupek**

**Institute of Plasma Physics, Academy of Sciences of the Czech Rep.**
**Za Slovankou 3, P.O. Box 17, 18200 Prague 8 , Czech Republic**

## ABSTRACT

New discharge chamber and movable electrode system configuration have been designed to study basic properties of the gliding arc discharge. Video camera with high shutter speed has been employed to record sequences of the discharge emission evolution. Preliminary spectroscopic study of the DC GlidArc discharge in the He-$N_2$ mixtures at atmospheric pressure was performed by means of multichannel emission spectroscopy. Time resolved emission spectroscopy together with voltage and current measurements were applied to follow dynamic behavior of the plasma filament.

## INTRODUCTION

New type of plasma generator producing reactive and relatively cold plasma at atmospheric pressure is so called gliding arc [1]. Essentially it consists of two electrodes diverging from each other placed in a fast gas flow. When powered with high voltage (several kV), the breakdown occurs in the point of a minimum distance between the electrodes and plasma filament is carried away in the direction of gas flow. As soon as the distance between the electrodes ( the length of plasma filament ) reaches certain value, the filament becomes broken, the current interrupted and the power supply voltage increases so long as new breakdown follows. Many successful applications of industrial as well as environmental interest of gliding arc discharge have been reported nevertheless up to now the physical mechanism of such discharge has not been well understood [1,2].

## EXPERIMENTAL

Experimental arrangement has been described in detail elsewhere [3]. The reactor consists of a stainless-steel chamber having an internal diameter of 150 mm equipped with input/output and diagnostic ports. Gas is injected into the discharge region through the bottom flange and the nozzle of 1 mm internal diameter. The distance of the nozzle orifice from the breakdown point can be adjusted from 0 to 10 mm. Movable electrode configuration system consists of a couple of electrode holders with positioning mechanics based on precision steel shafts and ball bushings allowing safe and smooth adjustment of both the interelectrode spacing ( max. 36 mm ) and angle ( max. 24° ) during the experiment. Both electrodes are water cooled to prevent overheating and electrode mount allows their easy and quick exchange. The discharge was powered by a home made 2kV/1A DC power source supply through the variable serial resistor (10-23 kΩ) with 8μF filter capacitor.

Emission spectra along the vertical axis of the discharge were collected by Jobin-Yvon HR-320 monochromator with PDA RY/1024 or with intensified IRY-512G/B/PAR multichannel detection heads. Video camera SONY CCD-TR808E with high shutter speed has been used to record emission evolution. Interesting frames can be grabbed, stored and processed in a computer. Plasma filament velocity measurement is realized by means of a 20-track fiber bundle with each single fiber having 200 μm in diameter. The plasma filament is imaged on a row of bundle fibers fixed at 5 mm in distance. The bundle is terminated in the input of a Hamamatsu R928 photomultiplier.

Resistive 3 stage 1000:1 voltage divider fixed outside on the lower flange of the chamber is used for voltage measurements during quasistationary phase of the discharge cycle. The discharge current is measured by low inductance 1Ω shunt coupled in ground of the divider circuit. Voltage and current wave forms are sampled and stored on HP 54542A digital oscilloscope using sampling rates up to 100 kSa.

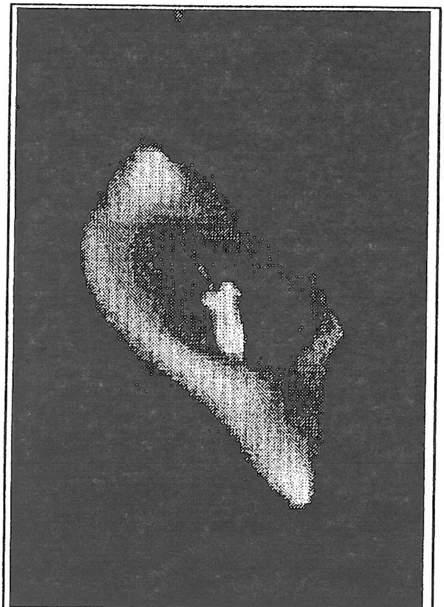


Fig. 1 : Head-on running frames in the "slow"regime.

## RESULTS AND DISCUSSION

. First experimental study pressure have been performed on low current DC GlidArc at atmospheric pressure in the $He+N_2$ mixture with low content of nitrogen and with 8 μF capacitor used in the RC circuit. As a consequence of low capacitor the " DC " voltage supplied is in fact 2kV DC with ~20% saw-tooth pulse modulation (100Hz). Three distinct regimes of the discharge have been recognized under these conditions:

**(a) "slow" regime** - plasma filament of few millimeters in diameter moves slowly (from few tenths of cm/s to several cm/s) between electrodes. Depending on the gas flow velocity plasma filament can be even trapped and sustained at the end of electro-de blades. Deacay phase of the discharge cycle, as it has been captured with a shutter speed 1/10000 [s] by video camera, is reproduced in Fig. 1.

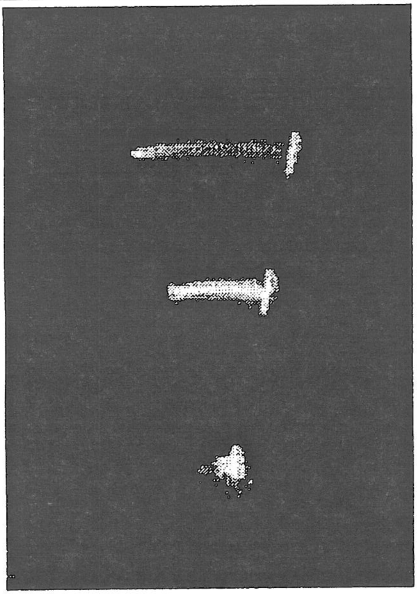
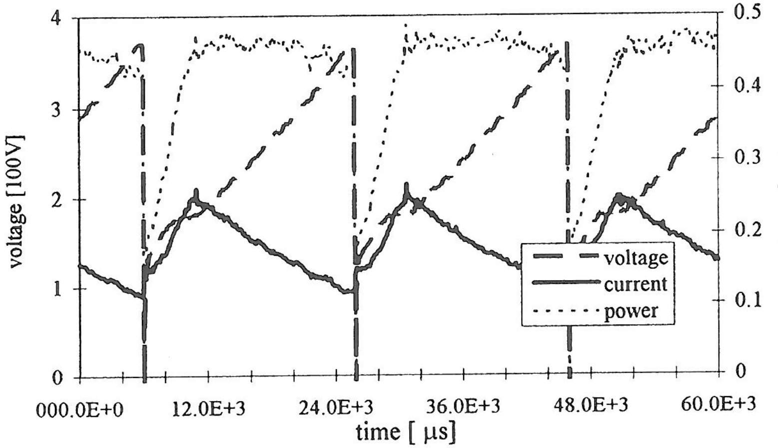


Fig. 2 : Side-on running frames in the “glow-like“ regime

**(b) “glow-like“ regime** - the area between electrodes looks like shining continuously without any apparent filament movement. In this case the discharge pulsing is very stable and reproducible and, in addition, it is in resonance with saw-tooth modulation of the power supply. The end of the discharge region is well defined and the geometrical length of the discharge area can be easily controlled by the interelectrode angle. Three phases of the discharge cycle ( the breakdown, intermediate and decay phase ) captured with a shutter speed 1/10000 s are shown on Fig. 2. Typical voltage, current and power characteristics corresponding to this regime are on Fig. 3.

**(c) “filamentary“ regime** - plasma filament increases its velocity and reduces its diameter significantly. In this regime we have several breakdowns during one saw-tooth modulation pulse. Discharge pulsing becomes rather chaotic in comparison with regimes (a) and (b), nevertheless still we can find some periodicity if the number of breakdowns during one saw-tooth pulse remains low ( ~ 3-5 ). For the stabilization of any of three regimes proper combination

Fig. 3 : Typical voltage, current and power behaviour in the "glow-like" regime, He-$N_2$ mixture.



of the interelectrode distance and angle, and gas velocity is required. Emission is mainly composed of nitrogen molecular bands and nitrogen and helium atomic lines. Time and space averaged emission in the “glow-like“ regime has been taken at low resolution in VIS-near IR range [4]. Part of the spectrum covering $\Delta v=0$ sequence of the 1.positive

Fig. 4 : Typical emission spectrum of the He-$N_2$ gliding arc discharge in the "glow-like" regime.

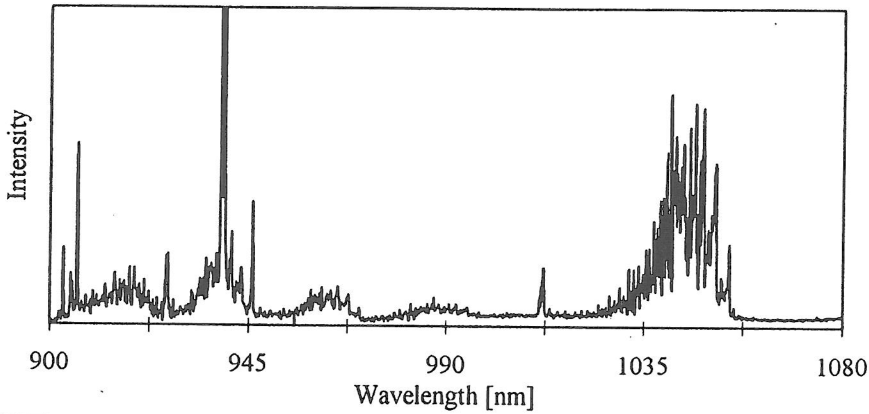
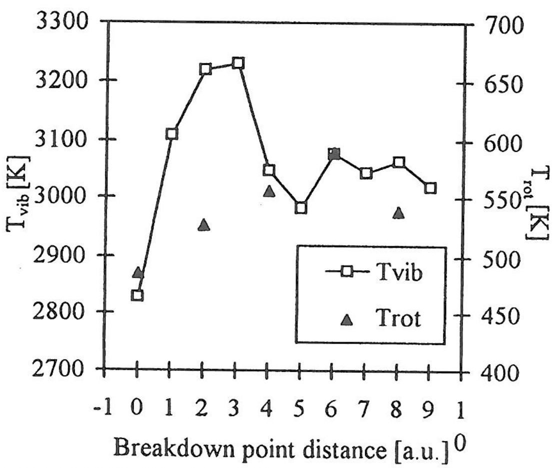



Fig.5 : Effective $C^3\Pi$–state vibrational and $B^3\Pi$–state rotational temperatures in the "glow-like" regime.




system ($B^3\Pi_g$-$A^3\Sigma^+_u$) of $N_2$ is shown on Fig. 4. Profile of the (0,0) band of 1. positive system at 1048 nm has been sampled along the vertical axes of the discharge. Rotational temperature has been estimated from partially resolved band profile (the details on the procedure can be found in [5]). At the same time we have sampled $\Delta v$=-2 sequence of the 2. positive system $N_2$ ($C^3\Pi_u$-$B^3\Pi_g$) emission and derived vibrational distribution with overpopulated $C^3\Pi$( v=1 ) level as a rule. Therefore we have omitted this level from calculation of characteristic vibrational temperature (Fig. 5).

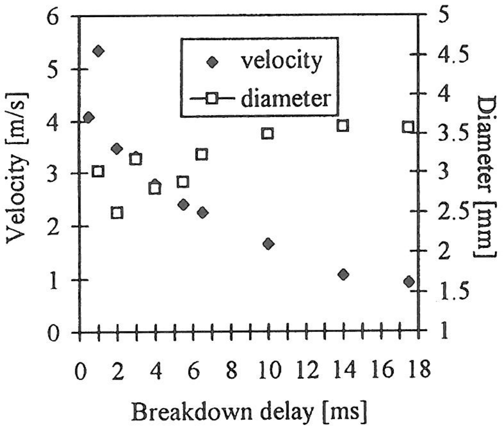



Fig. 6 : Plasma filament velocity and diameter.

Non-equilibrium state of gliding arc discharge as well as close to glow discharge characteristics of such plasma under these conditions seems to be quite evident, however our temperatures can be taken only as indicative and effective ones and for confirmation of departures from equilibrium state time resolved study has to be done. Result of plasma filament velocity measurement are on Fig.6. When the fiber diameter is negligible with respect to plasma filament, the PMT signal can be directly used to filament diameter and average current density estimation. Stabilization of a glow discharge at atmospheric pressure is an important problem in non-thermal environmental plasma chemistry and gliding arc may become an interesting alternative to corona or dielectric barrier discharges. Work on time resolved multichannel emission spectroscopy study as well as experiments with air-like mixtures are in progress.

## ACKNOWLEDGEMENTS

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