

#### Spectroscopic study of the neutral gas temperature of silicon based DC MHCD in various gases close to atmospheric pressure

Sylvain Iséni, Ronan Michaud, Philippe Lefaucheux, Volker Schulz-von Der Gathen, Goran B Sretenovic, R. Dussart

#### ▶ To cite this version:

Sylvain Iséni, Ronan Michaud, Philippe Lefaucheux, Volker Schulz-von Der Gathen, Goran B Sretenovic, et al.. Spectroscopic study of the neutral gas temperature of silicon based DC MHCD in various gases close to atmospheric pressure. 13th Frontiers in Low-Temperature Plasma Diagnostics, May 2019, Baf Honnef, Germany. 2019. hal-02131666

#### HAL Id: hal-02131666 https://hal.science/hal-02131666

Submitted on 24 May 2019

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers. L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Spectroscopic study of the neutral gas temperature of silicon based DC MHCD in various gases close to atmospheric pressure UNIVERSITE D'ORLEANS

<u>S. Iseni<sup>1</sup></u>, R. Michaud<sup>1</sup>, P. Lefaucheux<sup>1</sup>, G. B. Sretenović<sup>2</sup>, V. Schulz-von der Gathen<sup>3</sup> et R. Dussart<sup>1</sup>

<sup>1</sup>GREMI–UMR 7344, CNRS/Université d'Orléans, FRANCE.

<sup>2</sup>Faculty of Physics, University of Belgrade, SERBIE.

<sup>3</sup>Department of Experimental Physics II, Ruhr-Universität Bochum, ALLEMAGNE.

### **Motivation**

Micro hollow gas discharges (MHCD) have been on high interest to produce highly ionized gas while keeping the gas temperature close to room temperature. This study focuses on the accurate measurement of the gas temperature in and out the cavity, operated in different regimes, by means of space resolved optical emission spectroscopy. Two approaches are applied depending on the gas mixture (He, Ar,  $N_2$ ):

analysis of the profile of resonant atomic lines taking in to account the Van

## Temperatures inside/outside the MHCD – $T_{\rm g}$ vs $T_{\rm rot}$





RUB



- der Waals broadening,
- $\blacktriangleright$  analysis of the relative population distribution of ro-vibrational N<sub>2</sub>(C-B) bands.

Limitations of the latter approach will be discussed specifically. Heat transfer and temperature gradient will be discussed with regard to the geometry and the material properties of the present MHCD design.

# **Source plasma – micro-cavity plasma (MHCD)**



- Experimental conditions:
- ► Powered in DC,
- ► Polarity: positive ou negative, ▶ 0.2 µA à 600 µA,

⊳ 2 mW à 150 mW.

- ► Gas pressure 0.26 atm à 1.2 atm,
- $\blacktriangleright$  Gas: He / Ar / N<sub>2</sub>,
- $\blacktriangleright$  MHCD arrays, e.g. 32  $\times$  32 micro-cavities.

# Imaging optical emission spectroscopy





 $T_{\rm g}$  measured with line profile analysis. (0.66 atm).



Temperatures inside/outside of the MHCD in He gas at 0.66 atm.

- Significant thermal differences between He and Ar,
- ▶ Discrepancies between  $T_{\rm g}$  and  $T_{\rm rot} \Rightarrow$  is N<sub>2</sub>(C-B) in equilibrium in He...?

### Focus on the temperature gradient...







# **Resonance broadening and rotational temperature of N<sub>2</sub>(C-B)**

The pressure broadening contributes to the Lorentzian full width at half maximum (FWHM) of the line,  $w_{
m L}$ . At atmospheric pressure,  $w_{
m L}$  is dominated by the resonance broadening with a minor contribution due to the van der Waals interactions. Thus,  $w_{
m L}pprox w_{
m R}+w_{
m vdw}$ , with,

$$w_{\mathrm{R}} = K(0,1) rac{r_{\mathrm{e}}}{\pi} \sqrt{rac{g_{\mathrm{G}}}{g_{\mathrm{R}}}} \lambda_{0}^{2} \lambda_{\mathrm{R}} f_{\mathrm{R}} N,$$
 (1)

$$u_{
m vdw} = 8.18 \cdot 10^{12} \lambda_0^2 \left( \bar{\alpha} \bar{R}^2 \right)^{2/5} \left( \frac{T_{
m g}}{\mu} \right)^{3/10} \cdot N.$$
 (2)



- 100 150 200 250 300 350 400  $I_{MHCD} / \mu A$  $T_{
  m g}$  in Ar (0.66 atm).
- $ightarrow T_{
  m g}$  front corresponds to the light from the negative glow (the brightest ionized volume) above the cathode sheath,
- $\blacktriangleright$  Si substrate acts as a heat sink while the SiO<sub>2</sub> plays the role of a thermal isolation with the anode surface.

# Comparison $T_{rot} N_2(C-B)$ in MHCD and in guided ionization waves



# A detailed analysis of the line profile is used to determine $T_{ m g}$ .

With reasonable assumptions,  $T_{
m g}$  is often considered to be equal to the rotational temperature  $(T_{\rm rot})$  of diatomic molecules, e.g. N<sub>2</sub>. The relative spectral intensity  $(I_{I''}^{J'})$  of transitions from two different vibrational states (J' 
ightarrow J'') reads,



- $\triangleright$  Spectral simulation based on molecular constants of  $N_2(C^3\Pi_u)$ determined for  $oldsymbol{J} \lesssim 25.$
- Fitting routine using only four parameters and two optimization passes; computed confidence interval of 95 %, e.g. uncertainties.

 $T_{\rm rot}$  in pure N<sub>2</sub> MHCD.

 $T_{
m rot}$  in He guided ionization waves at atmospheric pressure (APPJ).

 $ightarrow T_{
m rot}$  in pure DC MHCD and in guided ionization waves. . .  $T_{
m rot} pprox T_{
m g}$ ?

### **Concluding remarks**

- $\blacktriangleright$  Higher  $T_{\rm g}$  and  $T_{\rm rot}$  outside the cavity than inside  $\Rightarrow$  heat flux disturbed by SiO<sub>2</sub> layer,
- $\triangleright$  Closer to atmospheric pressure, is  $T_{\rm rot}$  of N<sub>2</sub>(C-B) in equilibrium in He discharge...?
- ▶ Iseni S, et. al., 2019 On the validity of neutral gas temperature by emission spectroscopy in micro-discharges close to atmospheric pressure, PSST, 2019, in press.

#### sylvain.iseni@univ-orleans.fr