

SPECTRAL DIAGNOSTICS OF GLIDING DISCHARGES AT AN EXCITING FREQUENCY OF (0.05 - 25) kHz AND A PRESSURE OF (0.1 - 1.2) MPa

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Abstract

Spectral methods allow to determine the vibrational, rotational and electron temperatures of high-pressure gliding discharges excited at different experimental conditions. AC glow discharges were excited in streaming air at a pressure of (0.1 – 1.2) MPa, with flow rates of (8 – 50) l/min. Discharges were excited at frequencies of (0.05 – 25) kHz on horn-shaped Cu electrodes with a minimum distance of electrodes of (0.2 – 0.8) mm. The vibrational and rotational structures of N₂ and OH radicals were observed up to pressures of (0.3 ~ 0.4) MPa only. The vibrational and rotational temperatures T_{VC} and T_{R1} were determined from the 2nd positive system of N₂. The rotational temperature T_{R2} was determined from the rotational structure of OH (branch Q₁, vibrational band 0 – 0, 306.4 nm). The electron excitation temperature T_e was measured by means of the relative intensities of Cu atomic lines.

1. Introduction

Spectral analysis of gliding low frequency glow discharges in air as the effective gas, under atmospheric and increased pressures up to 1.2 MPa, may demonstrate the utilisability of this kind of discharges for ignition of various flammable organic mixtures, [1]. The application of the standard spectral diagnostics methods depends on the working gas used in which a given type of discharge is excited. When exciting discharges in air, we may preferably make use of the spectral methods elaborated for molecular nitrogen N₂ and OH radicals. The abrasion of the electrode material permits, under specific physical conditions, to employ also atomic spectra for the determination of the electron temperature.

The temperature-related spectral diagnostic of a nonisothermic discharge plasma is basically the finding of a relationship between the electron temperature T_e , the vibrational temperature T_V , the rotational temperature T_R , and the temperature of neutral gas in the plasma T_N .

The temperatures are the kinetic temperatures of a nonisothermic discharge plasma. The virtually measured temperatures may be within the relations $T_N \leq T_R \leq T_V \leq T_e$. These differences are even more markedly expressed in the flowing discharge plasma [2], [3].

The vibrational temperature T_{VX} of the ground electron state $X'\Sigma_g^+$ of the N_2 molecule was determined by means of the effective vibrational temperature T_{VC} and measured from the transition $C^3\Pi_u - B^3\Pi_g$, [2], [5].

The rotational temperature T_{R1} of the molecule N_2 was determined from the relative intensities of rotational lines of the R -branch of the vibrational band $0-0$ of the N_2 molecule. The relation of rotational line intensity factors published in [6], [7] was applied in our calculations.

The rotational temperature T_{R2} of the OH radical was determined from the relative intensities of the first five rotational lines of branch Q_1 , of the vibrational band $0-0$ of the transition $A^2\Sigma^+ \rightarrow X^2\Pi$ of a system of $306.4nm$, [8].

This rotational temperature T_{R2} was corrected according to paper [9] to a temperature T_{RN} .

The electron temperature T_e was determined by means of the relative intensity of the atomic lines of Cu of wavelengths $\lambda = (578.21, 521.82, 515.32, 510.55) nm$, [11].

2. Experimental

Gliding discharges were excited in a pressure vessel between horn-shaped Cu electrodes (Fig. 1). The minimum distance of electrodes was $(0.2 - 0.8)mm$. This discharge was blown out by air of a temperature of $20^\circ C$ from a tube of $4mm$ in diameter and the stream rates of $(8 - 50)l/min$. The pressure in vessel was increased from $(0.1 - 1.2)MPa$. In accord with it also the air stream rate at $0.1MPa$ at the output from in the vessel was increased.

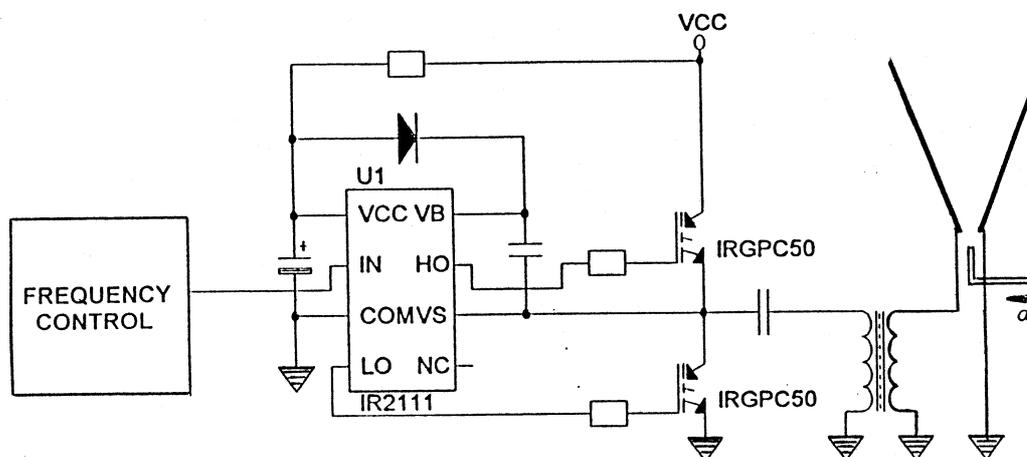


Fig. 1. Electric and electronic circuit for the excitation of gliding discharges of $(0.3 - 25) kHz$ and the horn-shaped Cu electrodes.

The blowing-out of the ionised plasma of the arc upwards between the extending horns caused the short arc to change into a spark discharge. The plasma of the spark discharge then faded out in a vague form of coronal discharge. We called this type of discharge in flowing air the high-pressure glow discharge [HPGD].

The thin and flat discharge area between the horn-shaped electrodes is thus filled out with two types of discharges. In the narrowest part and immediately over it is the region of spark discharges with a high intensity of the electric field in the spark channel at a high current density.

Sparks are excited in each half-period of the alternating voltage at a frequency of $(0.1 - 50)kHz$. In the extended part of horn-shaped electrodes there prevails the plasma of sparks disintegrating into coronal discharge.

The principal electrical scheme of the high-voltage power supply is shown in Fig. 1. The half-bridge inverter (IGBT or MOS FET devices) is controlled by means of the IR 2111 intergrated circuit. The power control was effectuated by changig the DC power supply voltage.

For the frequency range of $8 kHz$ to $25 kHz$ an HV transformer with ferrite core was used; for the frequency below $8 kHz$ use was made of an inductive automotive coil (which in fact is an autotransformer with a high N_2/N_1 ratio).

The voltage of the electrode system was measured by means of a Tektronix DTS 210 digital oscilloscope and a compensated high-voltage probe. The maximal peak to peak voltage was about $30 kV$ in the case of the ferrite transformer, and about $25 kV$ in the case of the inductive coil.

The electrical discharges of $0.05 kHz$ were performed by the method used in [2].

The spectral analysis of the individual parts of a discharge under various physical conditions was performed by means of the monochromator Jobin-Yvon HR 640.

3. Results

The molecular spectra of N_2 , N_2^+ , and OH were recorded only up to the pressure of $(0.3 \sim 0.4) MPa$ with varying intensity in different parts of the discharge.

air			OH	N_2	N_2	Cu
$pressure$	$flow$	v_{air}	T_{RN}	T_{R1}	T_{VX}	T_e
[MPa]	[$lmin^{-1}$]	[ms^{-1}]	[K]	[K]	[K]	[K]
0.1	10	13.25	680	3270	3800	6570
0.2	20	"	620	3470	4450	6600
0.3	30	"	630	3690	4870	6400
0.5	50	"	-	-	-	6050
0.7	70	"	-	-	-	6170
0.9	50	7.36	-	-	-	9950
1.2	50	3.31	-	-	-	11000

Tab. 1. The rotational temperatures T_{RN} , T_{R1} , vibrational temperatures T_{VX} and electron temperatures T_e at the constant stream speed air in the region of the gliding discharge $v_{air} = 13.25ms^{-1}$, the exciting frequency $(0.05) kHz$.

For pressures of $(0.4 \sim 1.2) MPa$ the intensities of N_2 and OH molecular spectra were very weak in the preserved form of the discharge, and thus Cu atomic lines may be used for the T_e determination only. The temperatures presented in Table 1 were measured in the position where the light irradiation in the plasma is maximal. The measured values of the T_e , T_{VX} , T_{R1} , T_{RN}

air		<i>OH</i>	<i>N₂</i>	<i>N₂</i>	<i>N₂</i>	<i>Cu</i>
<i>frequency</i>	<i>flow</i>	<i>T_{RN}</i>	<i>T_{R1}</i>	<i>T_{VC}</i>	<i>T_{VX}</i>	<i>T_e</i>
[kHz]	[lmin ⁻¹]	[K]	[K]	[K]	[K]	[K]
0.05	10	680	3270	4600	3800	6570
0.60	10	710	2960	4470	3690	6110
1.00	10	730	3350	4820	3980	5980
2.00	10	650	3230	4480	3700	5950
4.60	10	740	2940	4470	3690	6430
8.00	10	910	2680	4060	3360	6350
12.0	10	760	2380	4410	3640	5560
16.0	10	850	2800	4080	3370	6160
20.0	10	930	3010	4900	4050	6010
25.0	10	820	2700	4660	3850	5850

Tab. 2. The rotational temperatures T_{RN} , T_{R1} , vibrational temperatures T_{VC} , T_{VX} and electron temperatures T_e for discharge frequencies of (0.05 – 25)kHz in the region of the gliding discharge (pressure ~ 0.1 MPa).

temperatures show that the gliding plasma is nonisothermic in the whole interval of investigated pressures and frequencies.

Acknowledgment

This work was performed under the auspices of the Grant Agency of the Czech Republic, contract 202/96/0139.

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