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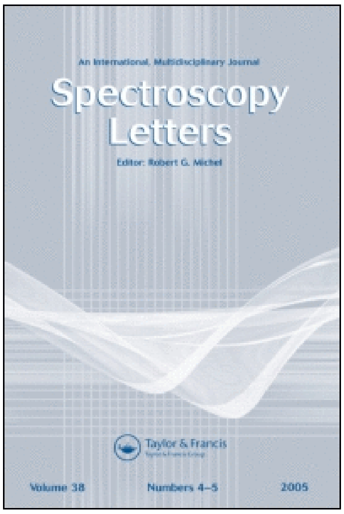

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Rotational Temperatures Determined from C_2 Molecular Band Spectra in a Thermal Argon Plasma Interacting with Insulating Materials

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ROTATIONAL TEMPERATURES DETERMINED FROM C_2 MOLECULAR BAND SPECTRA IN A THERMAL ARGON PLASMA INTERACTING WITH INSULATING MATERIALS

KEY WORDS: Argon plasma, insulator, molecular spectra, rotational temperature, Bolzmann equilibrium.

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ABSTRACT

The interaction between argon plasma and an insulating material is studied in an arc chamber. Argon plasma is put in contact with insulator by means of a magnetic field produced by Helmoltz coils. Arc spectrum is analysed by means of an optical multichannel analyser (O.M.A) connected to a monochromator and a Personal Computer.

The spectral analysis shows, for each insulator, the molecular spectrum of C_2 Swan system ($d^3 P_g$,ν ' = 0 --> a ^3P_u ,ν " = 0) with head band at 516,52 nm.

The rotational temperature is determined from the slope calculation of the Boltzmann plot.

INTRODUCTION

This paper follows up theoretical and experimental studies made in our laboratory concerning the interaction of plasma and insulating materials [1, 2]. The aim of these

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studies is to observe the behaviour of these materials in breakers, and particularly the modifications that they bring in plasma characteristics. This study is focused on the rotational temperature of C_2 molecules , Swan band system (0, 0) [3] for the following insulators:

- Plexiglas PMMA
- Nylon PA 6 - 6
- Polyethylene PE
- Polyoxymethylene POM

The experimental conditions are: direct arc current of 18 A and 22 A at atmospheric pressure. In order to control the reproducibility of the events, ten tests have been made for each insulating material.

EXPERIMENTAL SET-UP

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The aim of the experiment is to move the arc under magnetic field effect, in order to put it in contact with an insulator and to interact with it. The interaction duration is fixed at 25 ms to limit the insulator attack by the arc.

The arc set-up [4] described in Fig. 1 is composed of a chamber; its principal part is a cupel cooled by water with in its center a semicircular groove which limits the arc column to a diameter of 3 mm without the magnetic field. Cylindrical electrodes of 3 mm of diameter are made of tungsten alloyed with 2% of thorium. An argon flow of 0. 7 l / mn protects the electrodes. The magnetic field moving the arc is created by two Helmoltz coils; the magnetic field value is 2.7 mTesla.

To obtain the chosen duration of 25 ms, a generator supplies the coils with a rectangular signal whose length can be changed.

Two holes perpendicular to the arc motion plane allow observation and arc analysis without or with magnetic field and when it is interacting with insulating material.

The light emitted is focused on the entrance slit of the monochromator. The optical set-up is shown in Fig. 2.

The monochromator is a THR 1500 Jobin -Yvon with a 1500 mm focus ; it consists in a holographic grating of 2400 lines per mm operating on the whole of the visible spectrum and achieving a dispersion of 0.19 nm/mm for a 600 nm wavelength.

The spectrum analysis is performed by an optical multichannel analyser (OMA). The detector is an intensified CCD matrix of 512 x 512 pixels. Data acquisition and recording

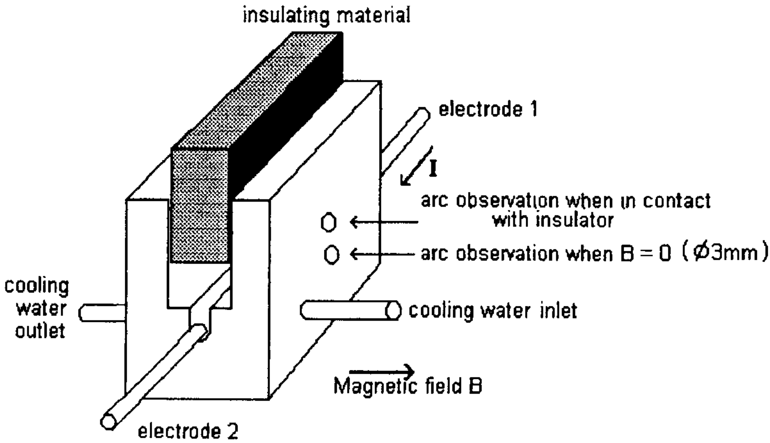

Fig. 1. Schematic arc chamber set - up.

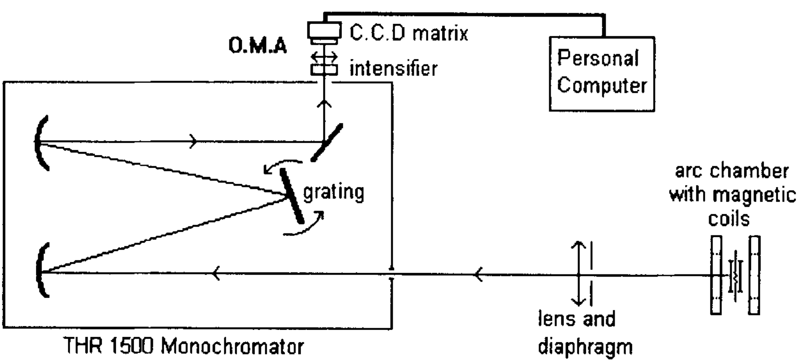

Fig. 2. Experimental set - up.

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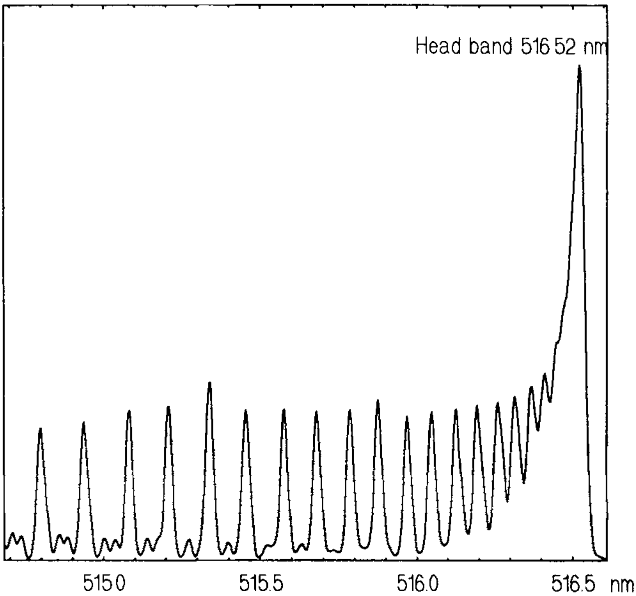

Fig. 3. Observed C_2 Swan band for PMMA insulator.

are made by a Personal Computer. A specific program allows spectrum visualisation and analysis.

SPECTROSCOPIC DATA ANALYSIS

Fig. 3 shows a molecular spectrum observed for Plexiglas. Fig. 4 presents the part of the spectrum used to determine rotational temperature T_r of C_2 molecules. The most intense lines represent P branch, the coefficients are obtained by comparison with a spectrum given by Nieuwport [5].

The results presented on TABLE. 1 correspond to mean values calculated for 10 measurements.

The statistic incertitude on these measurements is about 50 K except for POM for which it is of about 150 K for I = 22 A. Other incertitudes due to the apparatus (line intensity) or to calculations (precision on coefficients) have to be added. We have evaluated the total incertitude at about 300 K.

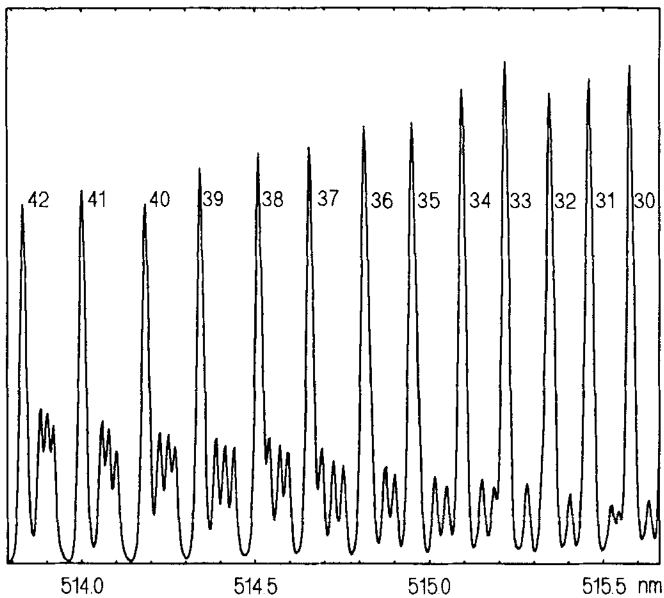

Fig. 4. Spectrum lines used to calculate T_r.

TABLE 1.

Rotational temperatures evaluated for different insulating materials.

Insulator	Tr (K) for I = 18 A	Tr (K) for I = 22 A
PMMA	2870	3390
PA 6-6	2920	3380
PE	2940	3420
POM	3030	3970

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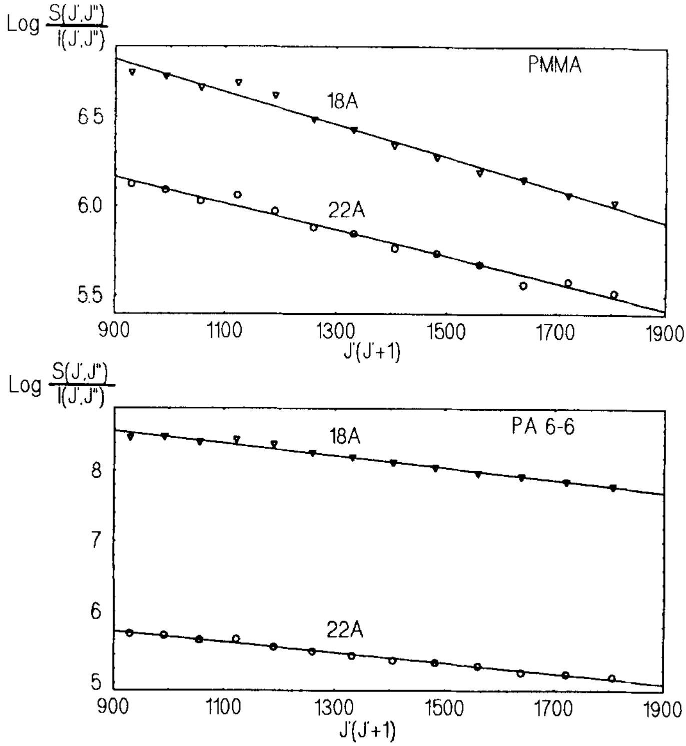

Fig. 5a. Boltzmann graphs for PMMA and PA 6 - 6.

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The numerical calculation of T_r is obtained by drawing the curve corresponding to the following equations:

$$Log[I(J',J'')\ /\ S(J',J'')] = f(J',J'+1) \qquad (1)$$

avec $f(J',J'+1) = -B'J'(J'+1)hc\ /\ kTr,$ (2)

than gives a slope of $-B'hc\ /\ kTr$

In these formulas B' is the rotational constant of J' level, tabulated in [7]; S (J', J") is the Hönl - London factor for J' --> J" transition [8]; I (J', J") is the line intensity. This determination supposes that the rotational levels of C_2 are in Boltzmann equilibrium. We present the graphics for all insulators in Fig. 5 a and in Fig. 5 b .

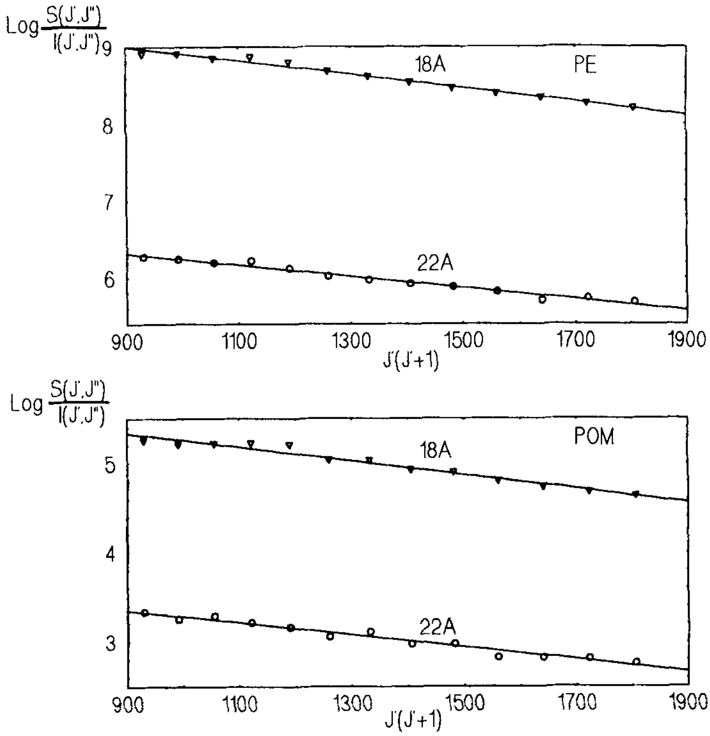

Fig. 5b. Boltzmann graphs for PE and POM.

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RESULTS AND DISCUSSIONS

The results show a good reproducibility of the measurements . The increase in T_r with current I seems consistent because the arc energy also increases. We notice that three of the insulators have similar rotational temperatures; only POM has a different temperature especially for I = 22 A. This result can be explained by the fact that the interaction of this material with the arc gives hardly any carbon deposit after several arc attacks unlike the other three insulators; the weak intensities of lines for POM also lead to a higher incertitude on T_r evaluation. For these materials too, the carbon percentage is lower (25 %, whereas it is of 31. 58 % for PA 6-6 and 33. 3 % for PE and PMMA). Finally, a good alignment of the experimental points on Bolzmann lines confirms the validity of Boltzmann's equilibrium hypothesis. In order to widen this discussion, we have done other complementary measurements on atomic hydrogen ray (H_{α}, λ = 656. 28 nm) and atomic carbon rays (λ_1 = 477. 175 nm, λ_2 = 538. 93 nm). For I = 22 A they give temperatures of about 7000 K for the hydrogen atom and 4900 K for carbon .

These results lead us to the hypothesis that the arc presents a complex structure due either to the absence of a thermodynamical equilibrium state or to a non-homogeneous state of the observed region, the peripheral regions of arc in contact with the room air or with the insulator being cooler than the discharge heart.

CONCLUSION

We have observed, in original experimental conditions, the C_2 molecular spectrum of Swan band (0 - 0) of an arc interacting with insulating materials and evaluated rotational temperatures of C_2 molecules. The complex structure of this interaction has been revealed.

Among the studied insulators , we have seen that rotational temperatures are higher for POM than for other insulators, which shows a stronger interaction plasma - insulator in the other three cases confirming a better efficiency already observed by breaker manufacturers in particular for Plexiglas.

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