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THE EFFECTIVE VIBRATIONAL TEMPERATURE ESTIMATION BY BAND HEAD INTENSITIES OF THE N_2 2^+ SYSTEM IN A CYLINDRICAL HOLLOW CATHODE EFFECT (H.C.E.) PLASMA

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Abstract. In a N_2 H.C.E. of nonthermodynamical equilibrium plasma, we have tested a local thermodynamical equilibrium (L.T.E.) of N_2 vibrational levels distribution and consequently we have estimated the effective vibrational temperature resulting from the relative band head intensities distribution of two progressions (in v'' = 2 and v'' = 3) from the N_2 second positive system (2^+), against the upper vibrational energy (G(v')), theoretically calculated.The estimated effective temperature (of 4000 – 10000 K) founded for different upper vibrational levels at different electric current intensities, correspond to a part of the small electron energies from the maxwellian distribution curve having an important cross section excitation for this vibration levels.

Key words: Spectral sources, hollow cathode discharge, plasma diagnosis.

1. INTRODUCTION

As we know from earlier published papers [1, 2], in a glow hollow cathode plasma at nonthermodynamical equilibrium can exist simultaneously two – three groups of electron energies able to interact inelasticaly with the atomic and molecular systems contained in the plasma cavity.

The aim of this paper is to prove the existence of a local thermodynamical equilibrium (L.T.E.) for the vibrational levels placed on in upper molecular electron state and consequently to estimate the effective vibrational temperature, corresponding to this levels.

In the equilibrium conditions the integrated intensity for a band arising from the transition between two vibrational states v' → v" placed on two dfferent electronic states, respectively, is:

$$I_{v'v''} = DN_{v'}h^4\upsilon^4_{v'v''}S_{v'v''} \tag{1}$$

where D is a constant depending on the geometric recording conditions, $N_{v'}$ the upper vibrational level population, h the Planck's constant, $\nu_{v'v''}$ the frequency of the considered radiation and $S_{v'v''}$ is the strength of the band given by:

$$S_{v'v''} = \mathrm{Re}^2\left(\bar{r}_{v'v''}\right)q_{v'v''} \tag{2}$$

where $Re\ (r_{v'v''})$ represents the electronic transition momentum, $q_{v'v''}$ the Franck – Condon factor [3].

From the equation (1) we can get the practical relation [4]:

$$\ln\left(\frac{I_v}{\upsilon^4 q}\right)_{v'v''} = const - \frac{G(v')}{0{,}6925T} \tag{3}$$

The experimentally obtained linear dependence $\ln\left(\frac{I_v}{\upsilon^4 q}\right)_{v'v''} = f\left[G(v')\right]$ atest a L.T.E. for the vibrational levels in the plasma.

From the slope of this straight line we determine the effective vibrational temperature $T_{eff.vibr.}$ More elevated precision is obtained when the intensity distribution is considered over the band progressis, having the common lower level.

2. EXPERIMENTAL

A similar experimental set – up like this used here was presented in a previous published paper [5]. Here we have a discharge cooper tube of a cylindrical geometry of a modular conception with quartz windows, connected to a standard vacuum system. The working nitrogen pressures were placed in the range 1 – 10 torr, the voltage in the range 200 – 400 V and the discharge currents between 0 – 250 mA.

The recording spectra system consist in a SPM – 2 Zeiss 650 tr/mm grating monocromator coupled with an EMI – 9558 QB photomultiplier and a data acquisition system.

The intensity measurements of the band head (representing the vibrational transition) were made on the top of the spectral line. The investigations were made by measuring two band heads progressions (v''= 2 and v" = 3) belonging to th e N_2 second positive ($C^3\Pi$ – $B^3\,\Pi_g$) system.

3. DISCUSSIONS

The transitions of interest are represented on the Fig. 1 (v'-v" = 0 – 2, 1 – 2, 3 – 2, 4 – 2 and v'-v" = 0 –3, 1 – 3, 2 – 3, 4 – 3).

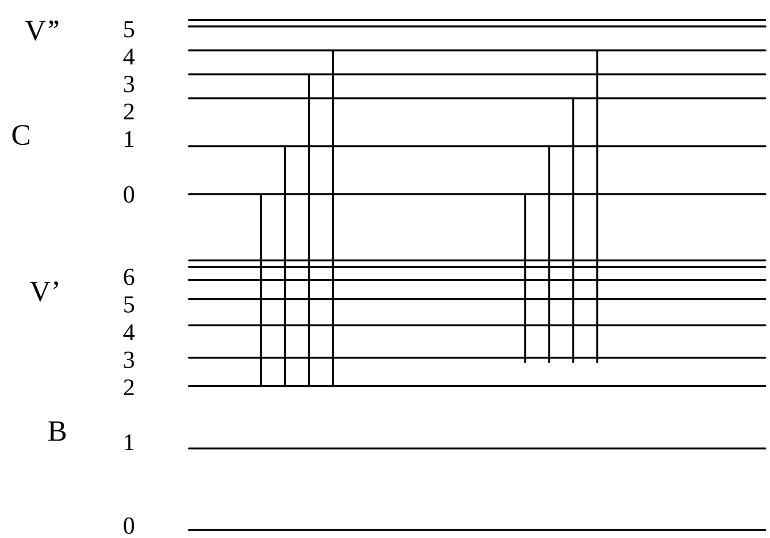

Fig. 1

The calculated spectral terms G (v’) for the two progresses are included in the Table 1 below:

Table 1

v'	G (v') [10^3cm^{-1}]
0	1.0135
1	3.0215
2	5.0146
3	7.0058
4	9.0080

On the Fig.2 we can see the experimental data representing the relation (3) for the whole transitions belonging to the progression in v’’ = 2 and for different current intensities.

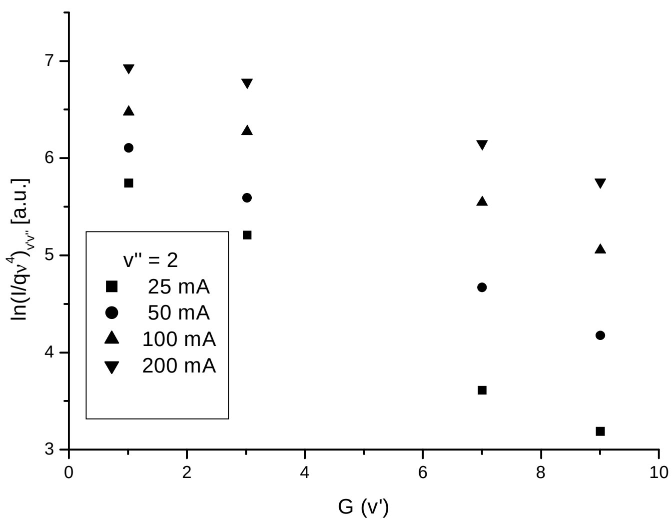

Fig. 2

For each current intensity is remarkable the distribution of the experimental points on a straight line. This fact certify the existents of a boltzmannian vibrational state distribution and, consequently, a local vibrational thermodynamical equilibrium.

So we are able to determine the effective vibrational temperature of the molecular plasma.

As we can see on the Fig.3, in the case of v” = 2 progression, the effective

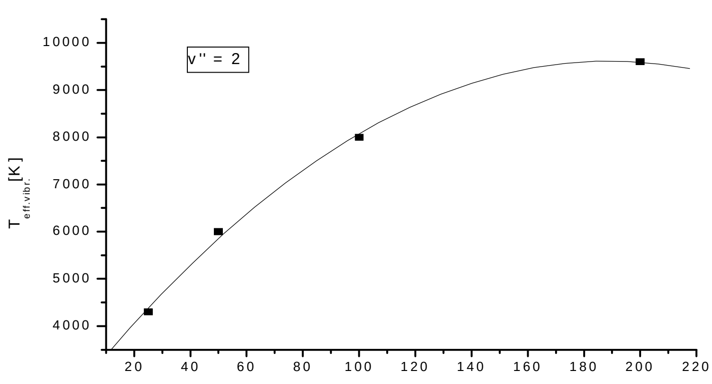

Fig. 3

vibrational temperature depends practically linearly on the current intensities.

As the potential across the tube was constant, independent of current this temperature behaviour suggests a correlation between the effective vibrational temperature and the possible power dissipated in the plasma source.

In the case of the v’’ = 2 progression the linearly dependence $\ln\left(\frac{I_v}{q\upsilon^4}\right)_{v'v''} = f\left[G(v')\right]$, for whole electrical currents, suggest the dominant role of the electrons in the collision processes of the molecular vibrational states. A same method in other physical conditions and with other results were reported in [6].

In the case of the v’’= 3 progressions, the linearity relation (3) is fulfilled only at a small electric current of 25 mA (as it is shown in Fig. 4).

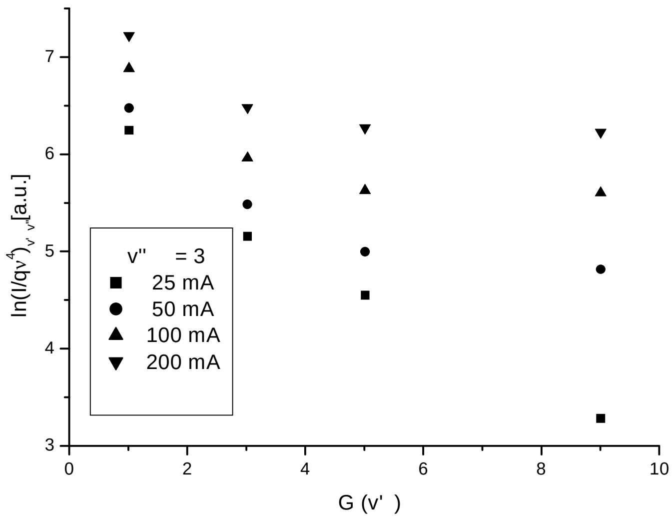

Fig. 4

That means that only at this electric current the whole upper vibrational levels are in local thermodynamical equilibrium.

At higher currents, the upper vibrational levels v’ = 3 and v’ = 4 become more populated compared with the linear laws.

This may be to the fact that at higher currents the upper levels become more sensible at the multiple collisional processes. Anyhow this effect requires a further study.

4. CONCLUSIONS

We have proved a selective local thermodynamical equilibrium of N_2 molecular vibrational states, by using the second positive band system, in a cylindrical, low pressure hollow cathode effect plasma. So we were able to determine a plausible effective temperature by using the v’’= 2 N_2 progression.

The v’’ = 3 nitrogen progression cannot be used in whole, for the effective temperature determinations, in such a plasma.

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