Revista Brasileira de Aplicações de Vácuo, Vol. 11, n. 2, 1992.

SPACE CHARGE PRODUCED BY AN ENVIRONMENTAL IONIZER TYPE CORONA DISCHARGE

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RESUMO:

Os ionizadores de ambiente são dispositivos baseados em descargas corona e que são hoje amplamente aplicados para redução de contaminação em "salas limpas". Neste trabalho foram feitas medidas de carga espacial produzidas por descargas do tipo ionizador ambiental. Para esse fim utilizou-se uma configuração de eletrodos em forma de pontas -agulhas- as quais são polarizadas negativamente. Através de uma técnica de sonda eletrostática, sugerida por Tassicker[1] determinou-se a distribuição da densidade de carga espacial negativa à diversas distâncias do eletrodo. Adicionalmente alteramos a configuração do sistema fazendo-o consistir de dois ou mais eletrodos para determinar-se o efeito de incremento da densidade de carga,bem como modificação de sua distribuição espacial com respeito ao aumento do número de eletrodos. Finalizamos por constatar que a técnica utilizada,embora bastante simples, é capaz de fornecer bons resultados relativos à caracterização de dispositivos do tipo ionizador ambiental.

1. INTRODUCTION

An environmental ionizer is a device widely used to produce ionization in the ambient air and to reduce contamination levels in clean rooms. In the present work the corona discharge produced by a comercial ionizer consisting of a pair of point -electrodes,both at a negative voltage varying in the range (-6, -12)kV, is characterized to estimate the space charge density in the air at various distances from the electrodes.The measurements were made by using the principle of biased probe originally described by Tassicker[1]. The probe system consists of a circular plane probe of radius r_p, located complanarly and coaxially within a circular ring of radius r_a so that an annular gap of width $g = r_a - r_p$ is thus formed. A bias voltage is applied between the two parts to control the conduction current to the probe. From the current-voltage characteristic of the probe the magnitude of the external electric field at the probe surface can be deduced. The estimation of the space charge density can be made from the combined current density and field data, assuming the mobility of the carriers is known. The applicability of this probe technique was demonstrated by Selim and Waters[2].

2. SELIM'S PROBE TECHNIQUE

We consider a circular probe P of radius r_p, located centrally within a circular aperture of radius r_a so that the probe lies flush with the surface of an electrode E (Fig.1). An annular gap of width ($g = r_a - r_p$) is thus formed between the probe and the electrode.

Supposing that a uniform electric field E_o exists at the electrode surface in the region of the probe, when a bias voltage V_b is applied between the probe and the surrounding electrode, then a flux will appear in the vicinity of the probe, depending upon whether the bias field E_o apposes (Fig.2a) or aids (Fig.2b) the applied field E_o.

Tassicker's theory shows that the ratio of the probe current I in the presence of V_b to the current I_o, in the unbiased condition, is given as,

$$\frac{I}{I_o} = 1 + \frac{C_o}{\pi r^2_m \varepsilon_o E_o} V_b$$

where,

. $C_o = 4r_m \varepsilon_o [1.07944 + \frac{1}{2} \ln (1 + \frac{r_m}{2g})]$

(probe/electrode capacitance)

. $\varepsilon_o = 8.85.10^{-12}$ F/m

. $r_m = 1.4$mm

. $g = 1.4$mm

then, $C_o = 6.35.10^{-14}$ F

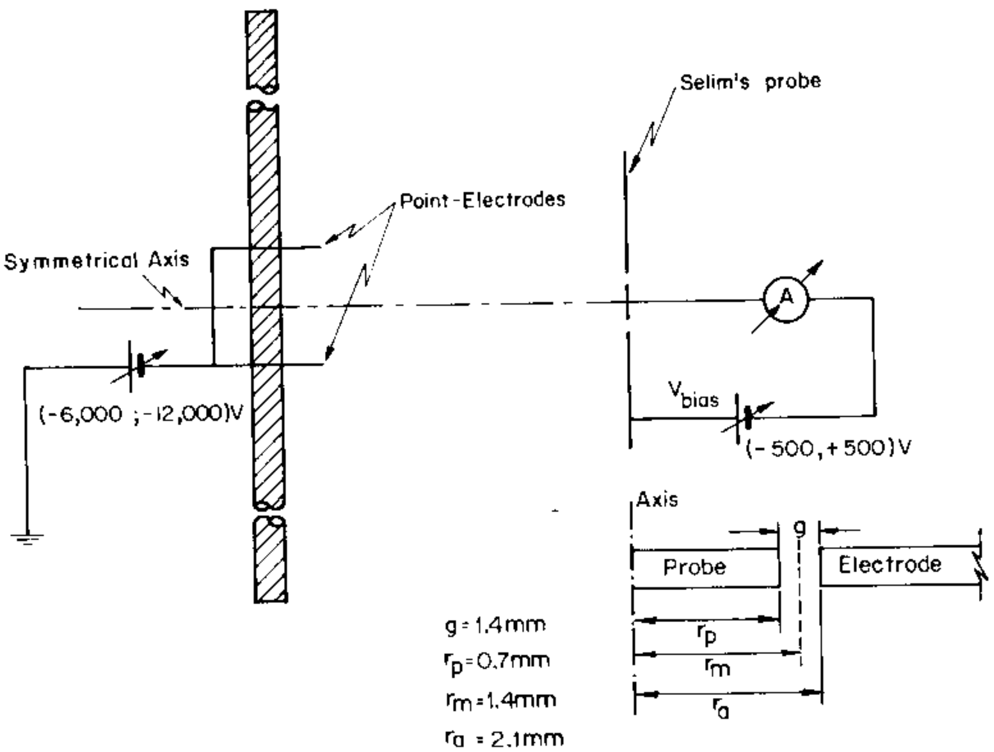

Figure 1: Experimental set-up

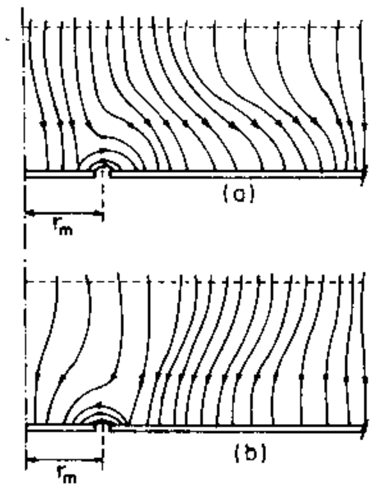

Figure 2: Flux pattern in vicinity of biased probe. a) Probe bias opposing applied field. b) Probe bias aiding applied field.

As an example, the plot below shows the current-voltage characteristic of our probe for a certain condition (figure3). From the curve, we can get the angular coeficient (K), and consequently the electric field E_O which drives the electric charges towards the electrode surface, producing then the current I_O. To measure this current a picoammeter was used. Measuring equipaments were isolated from ground in order to eliminate leaking currents.

$$\frac{I}{I_O} = 1 + \frac{1166.1}{E_O} V_b \rightarrow K = \frac{1166.1}{E_O}$$

$$\rightarrow E_O = \frac{1166.1}{K}$$

but,

$$J_O = \frac{I_O}{A} = \alpha E_O \rightarrow \frac{I_O}{A} = \rho_O \mu E_O$$

$$\rightarrow \rho_O = \frac{I_O}{\mu A E_O}$$

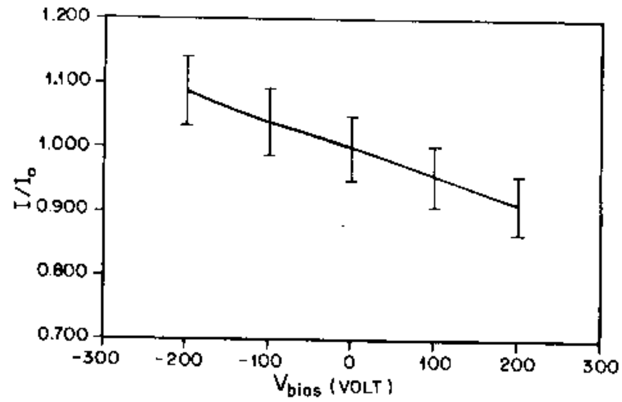

Figure 3: Current-voltage characteristic.

where,

- I_O is the current in the probe, when $V_{bias} = 0$,
- μ is the mobility of the negative ions in the air ($\mu_- = 2.21.10^{-4}$ m²/V.s[3])
- A is the area of the probe.

3. EXPERIMENTAL RESULTS AND CONCLUSIONS

The discharge was firstly produced in air with a single point electrode at a voltage of -10kV. In this condition we obtained the space charge density at several distances between the probe and the electrode. A twin point-electrode configuration was also assembled and similar measurements of space charge were made. Figure 4 shows the curves of the space charge density profiles obtained for both configurations. It can be observed that at low distances the twin-point electrode sistem provides slightly higher space charge density than the single-point sistem. At larger distances the curves were found to merge.

The transversal profile of space charge density was also measured and in both cases a symmetrical distribution was

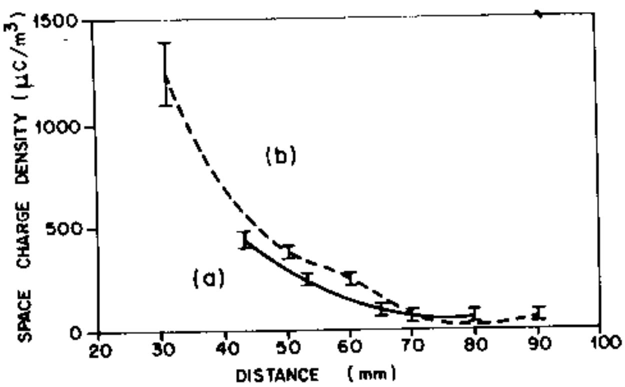

Figure 4: Axial Space charge density profile (point-electrode voltage = -10 kV). (a) 1 point-electrode. (b) 2 point-electrodes separeted by a distance of 50 mm.

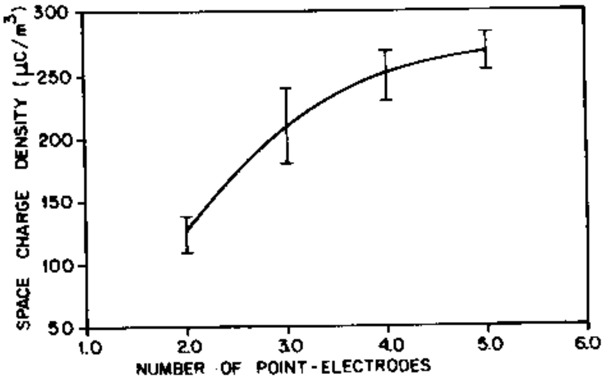

Figure 6: Variation of the space charge density as function of the number of point-electrodes at d = 60mm (point-electrode voltage = -10 kV).

obtained. In this case the distance between the probe surface and the plane of the electrodes was kept equal to 60 mm. Additional analysis considering a configuration of various point-electrodes from two up to five electrodes (Fig. 5) - was also performed. The results show that the space charge density increases with the number of point electrodes but at a decreasing rate (Fig. 6). We conclude that an additional electrode doesn't effectively affects the space charge when the number of electrodes is more than five.

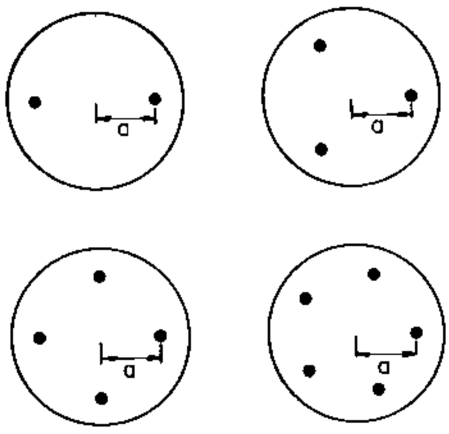

Figure 5: Position of the electrodes (a = 25mm)

Comparing the results of fig. 7 and 8 with those obtained by A.Boulloud [4] in a similar experimental set-up, we observe that in our case the partial profile of the space charge is more sharp probably because we used point-electrodes instead of semi-spherical ones. In spite of the different electrodes configurations the

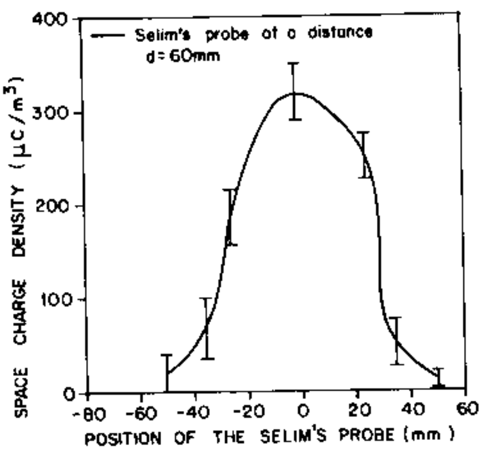

Figure 7: Transversal space charge density profile due to a single point-electrode. (point-electrode voltage = -10 kV).

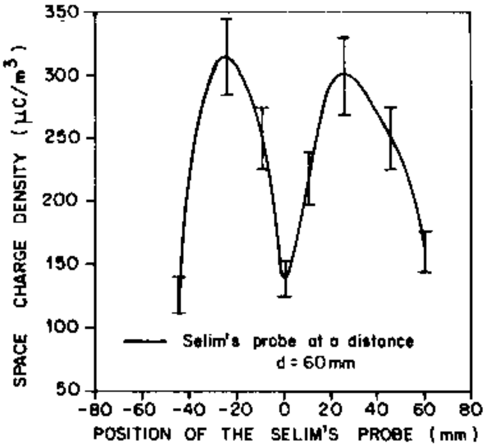

Figure 8: Transversal space charge density profile using two point-electrodes (point-electrode voltage = -10kV).

values of space charge density are comparable.

The results have shown that the biased probe is a valuable diagnostic tool to determine the properties of discharge in air such as those produced by environmental ionizers.

4. REFERENCES

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