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PLASMA PHYSICS

Dedicated to Prof. Ioan Iovitz Popescu's 75th Aniversery

EVIDENCE OF NITROGEN IONS IN ORGANIC AND ANORGANIC POLYMER LAYERS GENERATED IN DISCHARGES AT ATMOSPHERIC PRESSURE

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Abstract. In this paper, we reveal that the positive nitrogen ions generated in a positive corona discharge at atmospheric pressure and room temperature do not attack the chemical structure af the polymers generated in these kind of discharges. They are only accumulated in the polymer layer increasing the compactness of these layers.

Key words: atmospheric pressure discharges, polymer layers

1. INTRODUCTION

It is well known that in air at atmospheric pressure, the negative and positive corona charge injection at the free surfaces of the different dielectric fluids introduced in the discharge attack their chemical structure inducing new polymers formation [1,2].

In this paper, we reveal that the positive nitrogen ions generated in a positive corona discharge at atmospheric pressure and room temperature do not attack the chemical structure of the polymers generated in these kind of discharges. They are only accumulated in the polymer layer increasing the compactness of these layers.

2. EXPERIMENTAL SET-UP

We have used the experimental set-up presented in Fig. 1.

The electrode discharge configuration is of wire-to-plane type. The copper wire electrode has a length of 40 mm and is situated in air at atmospheric pressure perpen-

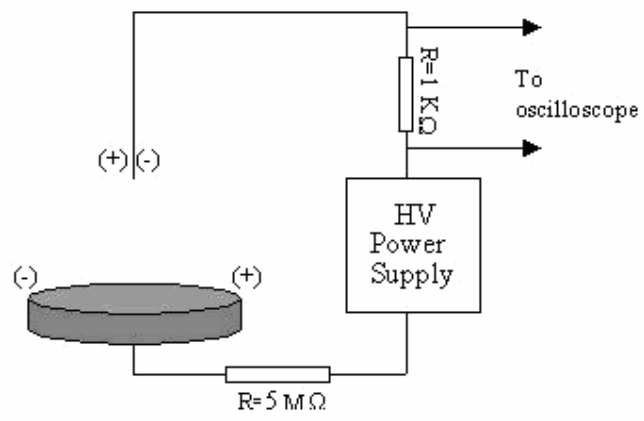

Figure 1: Experimental set-up.

dicular to the center of the germanium disk electrode, a disk with a diameter of 22 mm. In order to avoid any environmental air movement in the interelectrodic gap, the electrodes are introduced in a glass cage. The interelectrodic gap is varied between 8 - 30 mm. The DC high voltage was applied through a resistor of $R = 5$ MΩ.

The temporal evolution of the current discharge in positive corona discharge is measured using a Tektronics 320 oscilloscope. The current of the positive corona discharge consists only in a DC component having a value of about 10 μA.

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

A polydimetylsiloxane drop (1μl) with the IR spectrum presented in [1] is stretched in a thin layer on a germanium support under positive corona charge injection for an interelectrodic gap of about 10 mm and a high voltage of 10 kV.

In positive corona discharge, the positive ions (N_2^+, O_2^+) attack the polydimetylsiloxane chemical structure breaking C-H and Si-C bonds. The IR spectral mesurements performed on the organosilicon compound reveal the processes induced by the positive ions injection in the compound bulk, processes which lead to an amorphous SiO_2 cross-linked network formation. In Fig.2 is presented the IR spectrum of the compound obtained after 2 hours of positive charge injection. No Si-H, Si-OH and Si-C vibrational bands are observed. The spectrum is dominated by the vibrational band from 1100 – 1000 cm^{-1} assigned to Si-O-Si asymmetric streching mode. The band peak position at 1000 cm^{-1} frequency indicates a Si-O-Si bond angle of 123^0 ($\nu = 1134\ cm^{-1} \sin(\theta/2)$, where θ is Si-O-Si bond angle [1]). The broadening of the 1100 – 1000 cm^{-1} vibrational band, which can be also observed in the spectrum, demonstrates that rearangements

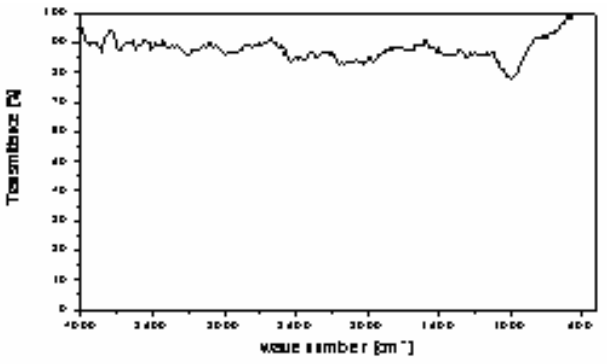

Figure 2: The IR spectrum of the SiO_2 layer.

and crosslinking occur in the compound bulk. [3] attributes the appearance in a Si-O based compound IR spectrum of a Si-O-Si vibrational band in 1200 - 900 cm^{-1} frequency range to an amorphous cross-linked SiO_2 network formation.

In the corona discharge glow regime (d = 30 mm, U = 20 kV, I = 5 μA) the positive ions N_2^+, O_2^+ injected in a linseed oil liquid bulk, the most rich oil in linolenic acids ($CH_3CH_2CH{=}CH\ CH_2\ CH{=}CH\ CH_2\ CH{=}CH\ (CH_2)_7COOH$), attack like a polar solvent the polarized carboxylic functional group –COOH and extra activate the α-methylene groups [2]. Thus, it is generated a chain reaction polymerization process.

Stretching a drop (10 μl) of linseed oil in a thin layer on a germanium support (the plane electrode) in positive corona discharges, solid polymers are obtained on the entire surface of the electrode after two hours. Compared to the linseed oil dried in air after ten days (fig.4b) the IR spectra of the polymers (Fig 3a) present an increase in the intensity of the polymeric band at 1050-1150 cm^{-1} ($\nu_{C\text{-}O\text{-}C}$) [4]. The band at 1650 cm^{-1} ($\nu_{C=C}$) are also strongly diminished. The absorption bands of the polymer (Fig.3a) are broader than those of the linseed oil dried in air (Fig.3b) demonstrating that the corona discharge charge injections induce chain reaction processes in the liquid bulk and consequently cross-linking (polymerization) of the linseed oil. The broadening of the absorption bands also indicates that the density of positive ions which reaches the linseed oil surface could affect the polymer compactness.

In order to investigate the composition of the polymers layers generated in positive corona discharge at atmospheric pressure, we perform an elemental analysis using a GD-OES system. The experimental results are presented in figures below, the layers being depose on a molybdenum support.

In Figs 4a, 4b can be observed that nitrogen atoms are identified in the polymer layers. The main advantage of this method is that the nitrogen is not involved in any

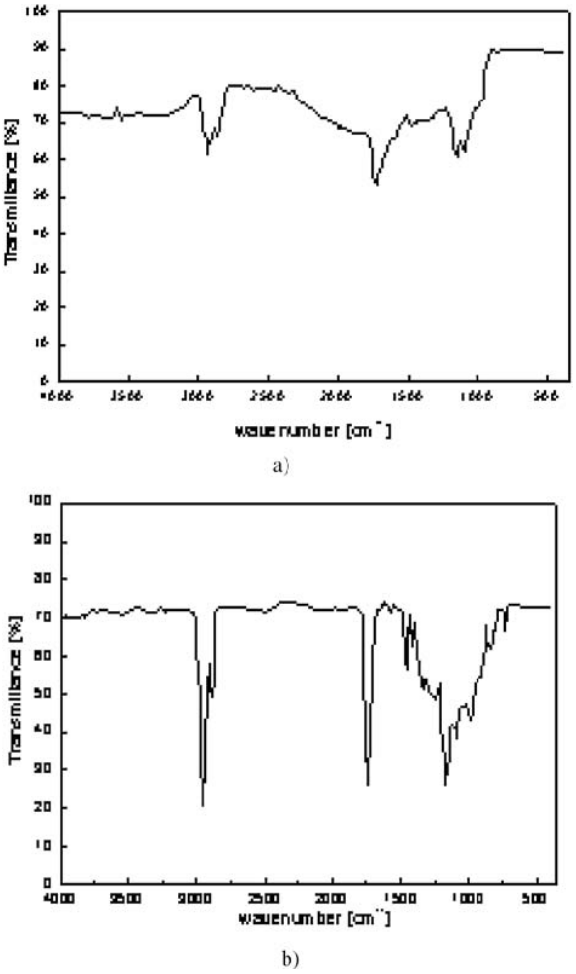

Fig. 3 - IR spectrum of linseed oil polymer layer obtained on a germanium support: a) after two hours of positive corona charge injection; b) after ten days in air.

bond generation of the polymer structure as it was observed in their IR spectra. The presence of the nitrogen in the depth profile elemental analysis diagram and it's absence in the polymer structure may indicate the increasing of the layer compactness.

4. CONCLUSIONS

In this paper it was demonstrated that the positive ions of nitrogen generated in the corona discharges do not influence the polymerization processes of the polydimetylsiloxane and linseed oil. They are only accumulated in the polymer layers increasing their compactness.

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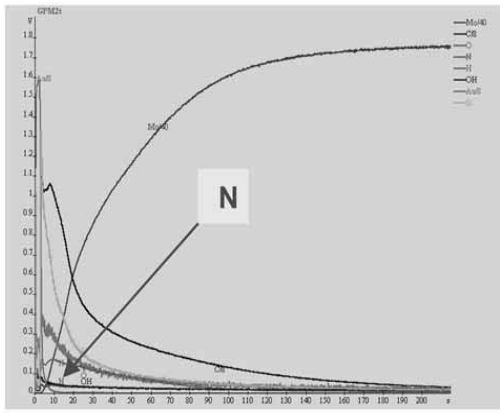

Fig.4 – Depth profile elemental analysis diagrams for: a) SiO_2 layer; b) linseed oil polymer layer

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