고전계와 저전계에서 천연고무의 전기전도기구

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Natural Rubber Electrical Conduction Mechanism in High and Low Electric Fields

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Abstract : This work shows the experimental results obtained from ageing at a temperature of 100 C for 48, 70 and 312 h, although the application of AC electrical tension in samples and the measuring ofcurrent leakage are presented. The measurements in samples were carried out with samples prepared from the deformulated commercial materials and respectively reformulated into thin films. The obtained results showed the mechanisms of conduction of samples in low and high electric fields. It was also identified an electric tension transition showing that in low fields it prevails the Ohm's law conduction, and in high electric fields it prevails the conduction of space charge limited current (SCLC). These results can support the natural rubber formulation process having as their main objective the reducing of the mechanisms that occur under high conduction current in high electric fields, which leads the material to a dielectric breakdown. Raw Natural rubber in Brazil is extracted from rubber trees (Hevea brasiliensis) in farms in So Paulo State by using some new plantation technology in smaller spaces, with trees placed a few meters from each other. In the Amazon rain forest the rubber trees are found naturally and their spacing may be of hundreds of meters or even kilometers between them. It is necessary to research this raw material from different internationally standard clones to characterize dielectric and electric properties for industrial applications. Moreover, this natural material has a low commercial price when compared to the synthetic ones.

Key Words : Natural Rubber, AC electrical tension, SCLC

1. Introduction

The service in live lines becomes more important because it avoids interruptions in the electric power supply to consumers and it reduces the loss for electric companies. Good execution for such a service depends highly on the worker of these live lines, and this only will be safe if the worker is protected by good quality tools. Gloves, sleeves and insulating blankets made out of natural rubber are part of this set of tools. It could be said that many tools made of natural rubber have a reduced lifespan.

This fact led COPEL and LACTEC to establish a joint venture to investigate the quality of the tools used in live line work. Starting from commercial material, sleeves, blankets and insulating gloves were deformulated and then reformulated into the shape of thin films to accomplish the necessary studies. The films were made by using the thermal-pressing method and led to a temperature of 150 C [1], with a thickness of 600 m.

The samples were aged at a temperature of 100 C for 312 h, as well as aged in AC electric field of 6MV/m of intensity for 6, 24 and 168 h. Other times and aging temperatures were used, although only the most significant results were shown.

2. Experimental

In general, insulating material has electrical conduction mechanisms in low and high fields. In low fields the ohmic conduction prevails with species of charge carriers that can be of electronic or ionic nature [2, 3]. The materials that present this kind of behavior in low fields follow Ohm's law, as far as the tension or the electric field transition where the material starts to suffer the action of the high electric field, where the conduction mechanisms prevail and depend on the kind of carrier injected by the contacts. This phenomenon will occur if the electric field is sufficiently high to overcome the barriers of potential among contacts and the polymers. The models for high field conduction are: i) Electrode Limited: Schottky's and Thermal Injection; ii) Bulk Limited: Poole-Frenkel's Effect, Hopping Conduction and Space Charge Limited Current (SCLC), among others [4]. In low fields there is a linearity between current density and the field applied upon the sample, and in high fields it prevails the non-linearity between current density and the applied electric field. Usually, one may write that the current density that flows through the sample as a function of the applied electric field is as follows [2,3]:

$$J = \sigma E + A.E^2 \qquad (1)$$

where the first term is the ohmic conduction in low field , is the electric conductivity of the sample and the second term is the high field conduction where in this present case is SCLC with $A = \frac{9\epsilon_0\epsilon_r\mu}{8d}$, where μ represents mobility, ε_0 the permittivity of free space, ε_r the dielectric permittivity and d represents the thickness of the sample. The equipment used in the experiment consists of a high tension AC source, Mark Haffley Multi Test Set 272 model and Mark Tektronix Digital multi-meters TX3 model. The sample is placed between two metallic electrodes with a constant pressure applied upon it. During the experiment the sample remains immersed in insulating silicone oil having as the main goal to avoid flashover or superficial discharges.

3. Results and Discusion

As it can be seen in the graph of the Figure 1, there is an increase in the current density for the same electric field in function of aging time, which indicates an alteration in the conduction mechanisms of the samples. The results obtained with the fitting throughout equation 1 are showed along with the respective transition voltages. This fact can be explained by the dissociation of chains and the natural rubber bonds, which increase the numbers of electric carriers in the ionic conduction. This can also be justified because of the larger interaction between the molecular chains, which increases the electronic conduction. The coefficient A shows a tendency in the increase along aging time, one possible indicating that there is an increase in the number or mobility of carrier in the SCLC process [4], also indicating that a larger number of traps appear in the material in function of its aging time. According to these results, it is more probable that a breakage of the chain is occurring as well as its dissociation and so increasing the ohmic conduction. It also can be realized that the voltage transition has a poor tendency to increase along aging time, which elevates the region of low electric field (low field).

4. Conclusions

The obtained results clearly show that the natural rubber shows two mechanisms of predominant conduction in AC: the ohmic conduction in low field and the SCLC process in high field. It also shows that the breakdown of the natural rubber used in tools of live lines occurs through the SCLC processes. This result becomes important because by using it, the formulation of natural rubber can be changed having as the objective the reducing of the number of traps for spatial charges.

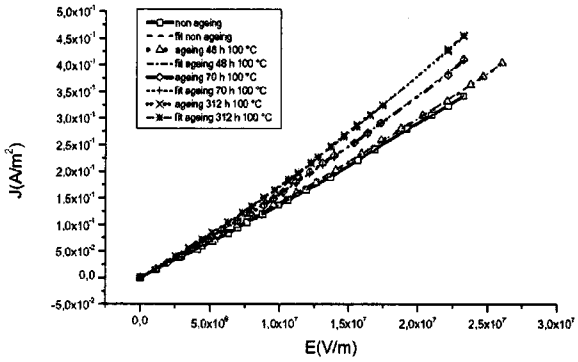

Fig. 1. J versus E plot of samples of non-aging and aging natural rubber at a temperature of 100 C for 48, 70 and 312 h, with respective fitting throughout equation 1.

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References

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