고밀도 폴리에틸렌의 전계 세기의 영향

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Pigment Influence of High Density Polyethylene Electrical Strength

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Abstract : In this work, the TiO_2 pigment influence in HDPE dielectric strength was analyzed. Chemical and structural characterizations were made to identify changes during the processing and your influence in the electrical properties. Formulations containing 0, 0.5, 1, 2.5, 4 and 6 of titanium dioxide were processed by extrusion and injection molding with stabilization -antioxidants, ultraviolet stabilizers and plasticizers. The electrical strength tests were analyzed by the statistical distribution of Weibull, and the maximum likelihood method. The high concentrations present lower values to electrical strength. The β parameter could be using to insulator particles dispersion. The TiO_2 concentration variation shows that these incorporations implicate strength values increase has a maximum (5,35MV/cm). High pigment concentration induces a little falls in property values. Observing the β parameter, minimum experiment electric field (Ebmin) and electric strength value, found that the best electric perform formulation was the formulation with 2.5% TiO_2 weight.

Key Words : Pigment influence, HDPE, Dielectric strength, Ultraviolet stabilizer

1. Introduction

Polymeric materials will be using like electrical insulations, mainly in the substitution of the ceramic materials either electrical energy distribution. The insulators need to be good electrical, chemical and mechanic performance. It is necessary that use agents to auxiliary the material life increasing - antioxidants, ultraviolet stabilizers and plasticizers. The most important property that characterizes the electrical performance is the electrical strength that means maximum voltage per thin unity without fail. This property is influenced by chemical composition, structure and microstructure, experimental conditions like temperature, tension application time, and sample and electrode geometry, ambient, etc. [1-2]

Following the literature [1-4] the physics and morphological factors are that contributes to the polymers dielectrical rupture but these are influenced by chemical factors. The combination these factors implicate in the studies to understand the polyethylene electrical characteristics. In the literature have contradictions information about the material additivation the titanium dioxide. For LDPE, KHALIL and co-workers [5] showed that the TiO2 induce a decrease to dielectrical strength. Others works [5-10] show that this pigment auxiliate in the increase to electrical strength. UEKI [3] showed that the pigment dispersion is a factor that has an influence in the electrical strength.

2. Experimentals

The high-density polyethylene, HDPE, in form of powder without pre-stabilizers was supplied. It has a melt flow of 0.01g/min and density of 0.952 g/cm3. Several HDPE formulations were prepared at 150ºC with different percentages -from 0 to 6%, of titanium dioxide, TiO_2, the antioxidant, the UV stabilizer (UV) TINUVIUM and the plasticizer magnesium stearate (MgEst). The formulations were incorporated into pure HDPE by a twin-screw extruder and after that chopped. The formulation above described is usually employed for the use of polyethylene in electrical applications. Samples with thickness of about 50 μm were molded by pressing the polymeric material between hot plates (180 ºC) under 25 kN of applied force (2.5 ton). The formulations are showed in the Table 1.

Table 1. Formulations studied in this work.

Formulation	AO	UV	TiO_2	MgEst
F1	0	0	0	0
F2	0,2	0	0	0
F3	0,2	0,2	0	0
F4	0,2	0,2	0,5	0,02
F5	0,2	0,2	1	0,02
F6	0,2	0,2	2,5	0,02
F7	0,2	0,2	4	0,02
F8	0,2	0,2	6	0,02
F9	0,2	0,2	2,5	0

Differential Scanning Calorimetry (DSC) measurements indicated that the crystallinity of the samples were about 60% and independent of the percentage of TiO_2. Infrared spectra of the samples were also obtained in order to evaluate the carbonil index and the induced oxidative time was measured. The measurements were done in hot compressed samples with thickness to 50 from 70 μm. The dielectric breakdown test was carried out in a self-developed system. The system is interfaced with a microcomputer that controls a power supply, whose function is to apply the voltage in the electrodes. This system allows the control of the voltage ramp rate, interruption and selection of the voltage waveform automatically. For this study, the type of electric stress was a positive ramp with rate of 500 V/s, applied among sphere-plane electrodes immersed in silicone oil in a controlled environment. The results were evaluated with two Weibull model parameters (β and E_γ).

3. Results and Discussion

The OIT results, in the Table 2, show that the oxidation resistance increase this the additive addition. The lower time is from the pure HDPE (F1). The best formulations are the TiO2 additive samples. The samples F4, F5 and F8 don't oxide during the test (50 minutes). The tests are made with high reproducibility, which means that the additives are good homogenized in the samples.

Table 2. Oxidation Inducided Time for the formulations.

Formulação	OIT (min)
F1	5,06
F2	7,07
F3	10,97
F4	>50
F5	>50
F6	23,28
F7	23,79
F8	>50
F9	21,37

It is possible to observe that above the 2.5% TiO_2 in weight the Ebmin decrease. So is possible to think that the formulation F6 (2.5% de TiO_2 weight) has the best electric performance. Doing a most detail analysis from the Weibull Statistical Distribution, How much lesser they will be these data, greater will be the reability of the final measure. So, low E value is the best results to be a good formulation. So, this analysis suggests that the best formulation is the F6 and the worst is the F1.

Doing a most detail analysis from the Weibull Statistical Distribution, the Table 3 shows the form parameter β determinated by the maximum likelihood method and linear regression methods. The table 4 shoes the E (log Eɣ- log Ebmin) values, which represent the data experimental dispersion in relation a data measured. How much lesser they will be these data, greater will be the reability of the final measure. So, low E value is the best results to be a good formulation. So, this analysis suggests that the best formulation is the F6 and the worst is the F1.

Table 4. The β parameter determinate by maximum likelihood method and regression linear method.

Formulation	Maximum Likelihood		Graphic Method	
	β	ΔE	β	ΔE
F1	5,87	0,40	6,00	0,41
F2	7,18	0,26	8,39	0,27
F3	6,01	0,37	6,45	0,39
F4	7,39	0,30	8,93	0,31
F5	6,09	0,37	5,61	0,33
F6	9,49	0,15	9,49	0,16
F7	6,23	0,16	7,00	0,17
F8	6,71	0,27	6,78	0,27
F9	8,31	0,17	9,02	0,18

The Figure 1 shows the β relation with .E in the studied formulations. When the β value is analyzed is possible identify that the formulations F4, F6 e F9 have the highest β value. It is possible observe in the Figure 1 that both methods, the β value has a tendency to increase with E decrease. This doesn't happen with the formulation F7 that is out of this tendency for both methods. The difference in the β and .E behavior can be understood because the rupture mechanisms are different when comparated with formulations with carbon black (conductor) instead of titanium dioxide (insulator). From result of Figure 4 can be affirm that, independent of the method, the β value can be used to measure the TiO_2 dispersion in the polymeric matrix. Comparing the β value with OIT results is possible to observe that high β value has a good additive dispersion and this fact is confirmed by the oxidation high time (20 minutes).

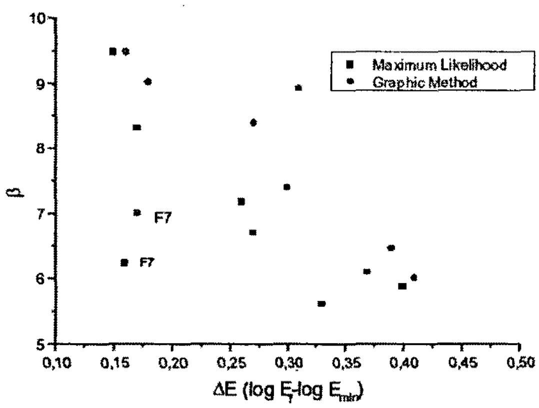

Fig. 1. Relation between β and (log Eɣ-log Ebmin) for the formulations.

The TiO_2 influence analysis used the samples F4 from F9. In the Table 4 is possible to observe the highest Ev value for the samples with TiO_2. Analyzing only this value, the best formulation is the formulation F5. It is necessary analyze the points about minimum rupture value. So, the formulation F5 is not the best one, instead of the sample F6 has the highest Ebmin value that F5. The formulation

F6 has the lowest data dispersion. So, it is possible to conclude that the formulation with the best electric performance is the F6, because it has the best value for the β, Ebmin, e E that contribute for the good reability.

4. Conclusion

This paper introduce the tested samples showed good dielectric strength value, producing results for the maximum likelihood method and linear regression method. The value didn't change significatively with the different additive incorporation and the highest value was to 1% TiO_2 in weight. The β parameter, showed coherent values and it can be used to describe the particulate dispersion in the polymer. It was observed a tendency in the decreasing β value with an increasing E value. The Ebmin value increased with the TiO2 additive in the formulations. So the reability was increased until 4% in weight. Analyzing the data, it is possible to determinate that the formulation F6 was the best electric performance because it has a high Ebmin value and the β value showed that the particulate dispersion is good and this sample has a low dispersion experimental data.

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