

Effect of rubber ingredients on its dielectric properties

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(Received 20 November 1970)

Natural and synthetic rubbers, specially butyl rubber, are widely used in cable industry. It is worthy to study the effect of conventional rubber ingredients added stepwise to raw rubber on the dielectric constant ϵ' and dielectric loss ϵ'' .

Butyl rubber was chosen for this study as it is a non-polar copolymer with low degree of unsaturation (Clark 1962). Thus, it is heat, ozone and weather resisting rubber and has excellent insulating properties. Moreover, raw butyl rubber can be shaped easily into air-bubble-free discs needed for the measurements.

Five rubber formulations were prepared as shown in table 1, for this study ϵ' and ϵ'' were measured at frequencies between 60Hz/s and 10⁷Hz/s in the same way described before (Hanna & Ghoneim 1970). The results obtained are illustrated in figure 1. These results show that the addition of sulphur and accelerators MBT+TMTD (formula 2) decrease ϵ' slightly in the whole frequency region, which may be due to the cross linking by the curing system used. Also ϵ'' is much increased in the low frequency region and then decreased a little in the high frequency region (curve 2). The increase at low frequency region may be due to the interfacial polarization (Smyth 1955) arising from the existence of more than one phase. The addition of stearic acid (formula 3) increases ϵ' to some extent specially in the low frequency region, while ϵ'' is very much increased in the whole frequency regions (curve 3). This behaviour may

TABLE I

Formula no	1	2	3	4	5
Ingredients					
Butyl rubber	100	100	100	100	100
Sulphur	—	1.5	1.5	1.5	1.5
TMTD	—	1	1	1	1
MBT	—	0.5	0.5	0.5	0.5
Stearic acid	—	—	3	3	—
Zinc oxide	—	—	—	5	5

be attributed to the polarity of the carboxylic group in stearic acid. The addition of zinc oxide (formula 4) changes markedly the dielectric properties (curve 4). It is found that ϵ' is decreased to about the same value as samples 1 and 2. ϵ'' is also decreased to a value somewhat higher in the low frequency region but is lower in the high frequency region than that of raw rubber. This may be explained as due to the formation of zinc salt which is less polar than stearic acid itself. The addition of zinc oxide in the absence of stearic acid (formula 5) shows dielectric loss not much different from formula 4 in the low frequency region but are somewhat higher in the high frequency region, while ϵ' remains the same as formula 1. This may assist the suggestion that the polarity of the carboxylic group in stearic acid is the cause of the large increase in ϵ'' .

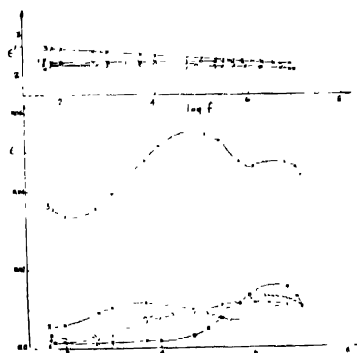


Figure 1. Dielectric constant ϵ' and dielectric loss ϵ'' for the 5 samples given in table I.

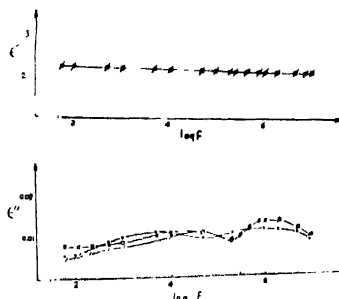


Fig. 2. ϵ' and ϵ'' for sample 2 using different cure time (\ominus - 10 min, \circ - 15 min, $-$ - 25 min)

The rubber vulcanizate obtained by formula 4 has good physico-mechanical properties, e.g. samples vulcanized at 160°C for 10 minutes give tensile strength 106 kg/cm², elongation 730%, modulus 300% elongation 9kg/cm² and permanent set 5%.

The effect of cure time on ϵ' and ϵ'' was also studied. Three cure times were used namely 10, 15 and 25 minutes. As shown in figure 2, ϵ' does not change with the cure time, while ϵ'' is changes slightly. Since the cure time affects mainly the physico-mechanical properties of vulcanizates, it is recommended to use the cure time which gives optimum physico-mechanical properties, as its effect on the dielectric properties is negligible.

This study leads to the conclusion that the ingredients which are normally added to improve the physical properties of raw rubber, specially in the described proportions, do not practically change the dielectric properties

We should like to thank Prof Dr. R. N. Sodra, Cairo University, for his kind interest in this work. The facilities offered to us by the Transport and Engineering Co. in preparing these samples are very much appreciated.

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Indian J. Phys. **44**, 516-518, (1970)

Comparison of experimental and theoretical pair cross-sections near the threshold

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It is well known that the experimental pair cross-sections of gamma rays very near the threshold are not in agreement with the predicted values from Bethe-Heitler theory (1934) or with the extrapolated values from Jaeger & Hulme (1936) calculations. Recently, however, more accurate theoretical pair cross-sections are reported by Overbo *et al* (1968) claiming a better agreement with the experimental values near the threshold. In the present communication a comparison is made of experimental cross-sections at 1.119 MeV reported by