Dielectric Properties of Butyl Rubber Mixtures at 10^6–10^{10} Hz

INTRODUCTION

Butyl rubber is known to have good weathering properties and also electrical properties due to its paraffinic nonpolar character.[1] Butyl rubber is superior to natural rubber especially in radiation and aging effects.[2,3] Few investigations have been carried out to study the mechanical and electrical properties of this type of rubber. The effect of the stepwise addition of conventional rubber ingredients to raw butyl rubber on its dielectric properties was previously carried out at low frequency region.[4,5] Systematic studies of the dielectric properties of butyl rubber is not yet available over a wide range of frequency. In this note, the dielectric properties are studied at a wide range of frequencies extending from 10^6 to 10^{10} Hz.

EXPERIMENTAL

The dielectric permittivity ϵ' and dielectric loss ϵ'' are measured for butyl rubber loaded with 30 and 50 parts of one of the six fillers per hundred parts rubber (phr) at room temperature (27°C).

The fillers used are local talc, calcium carbonate, barytes, dolomite, kaolin, and Hi-Sil. Hi-Sil is precipitated silica of average particle diameter 25 μm. It was obtained from Degussa Co. The measurements were carried out in the frequency range from 10^6 to 10^{10} Hz.

From 1 to 12 MHz, a multidekameter type DK06 from Wissenschaftlich Technische Werkstätten, (West Germany) based on the superheterodyne principle was used. The samples were discs of 59-mm diameter and 3–4 mm thickness. A guard-ring capacitor type NFM5/T was used. The accuracy of the measurements was better than 1% in ϵ' and 3% in ϵ''.

For frequencies of 100, 200 and 400 MHz, an apparatus based on Drude's second method was constructed in the laboratory. It consists of two parallel wires shorted by two bridges one is fixed and the other is movable. The sample under investigation, which is a plate of dimensions 15 × 15 cm and 8-mm thickness, is placed across the wires (lecher system). A signal generator type "SMDU" from Rhode and Schwarz is coupled to the system. Its frequency ranges from 0.14 to 525 MHz. The apparatus and the theoretical investigations have been previously reported.[5-7] The accuracy of the measurements was better than 2% in ϵ' and 5% in ϵ''.

At 10^{10} Hz, a voltage standing wave method in a rectangular waveguide was used. The construction and details of this apparatus is given elsewhere.[8] The specimens are in the form of rectangular blocks 3 cm long and 2.4 × 1 cm cross section to fill a rectangular waveguide of the same dimensions. The accuracy of the measurements was ±3%.

The formula used for preparing the rubber samples is given in Table I. The optimum cure time was 10 min for the filler-free sample and the Hi-Sil sample and 8 min for the other fillers.

TABLE I
Formula for Butyl Rubber Samples

Ingredients	Weight (g)
Butyl rubber	100
Zinc oxide	5
Stearic acid	1.5
MBTS[a]	0.5
TMTD[b]	1.0
Sulpher	1.5
Filler	30 or 50

[a] Mercaptobenzothiazol disulfide.
[b] Tetramethylthiuram disulfide.

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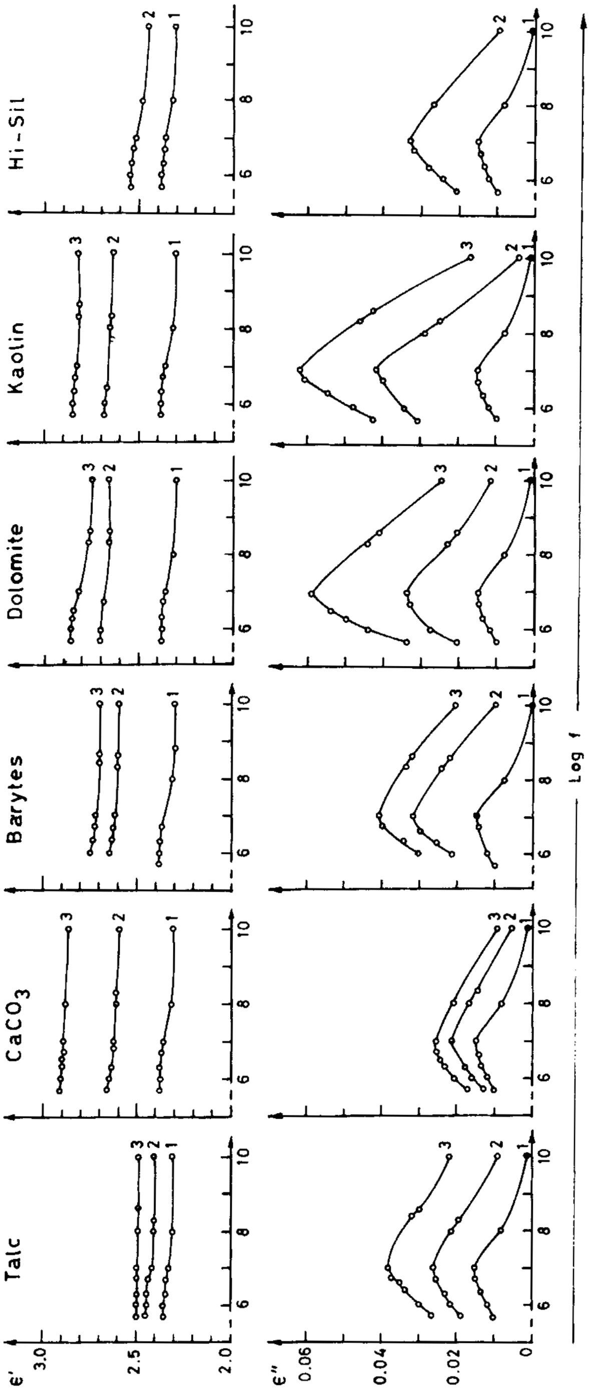

Fig. 1. The permittivity ε′ and dielectric loss ε″ versus log frequency at room temperature for butyl rubber loaded with talc, calcium carbonate, barytes, dolomite, kaolin, and Hi-Sil: (1) unloaded; (2) loaded with 30 phr; (3) loaded with 50 phr.

RESULTS AND DISCUSSION

The values obtained for ϵ' and ϵ'' for the different samples are shown graphically in Figure 1. The values of ϵ' and ϵ'' increase with increase of filler content. From these figures it is clear that there is a region of anomalous absorption with a maximum at about 10^7 Hz, which corresponds to pure Debye losses. The position of the maximum is nearly the same for the filler-free sample and the filled ones, indicating that there is no chemical interaction between any of the fillers and butyl rubber. Also it can be noted that samples of butyl rubber loaded with $CaCO_3$ have the lowest losses and highest permittivity while those loaded with dolomite and kaolin have the highest losses.

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