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Review

Conductivity mechanism of mica powders inlaid elastomer based materials

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ABSTRACT

In this study, electrical properties of mica powder inlaid NR/SBR type elastomer based rubber material have been investigated by dielectric spectroscopy. Electrical modulus of this sample showed dispersion in the frequency range investigated, especially in the lower frequency region of the dispersion curve showing long distance conductivity for the charge carriers. DC conductivity curve exhibits that glass transition temperature is around 350 K. AC conductivity behavior supports the Correlated Barrier Hopping mechanism.

Contents

1. Introduction

Natural rubber (NR) and synthetic rubber (SBR) elastomer materials are referred to as broad range of application due to their interesting properties. These materials, including primarily in the automotive industry, aerospace, machinery manufacturing, construction, manufacturing appliances are used in packaging and shoemaking [1–3].

In the process obtaining the desired properties in these type of materials one needs to add various filling and additive materials in to the structure [4]. Carbon black is the best one to reach to the desired physical and chemical properties as a filler material in the investigated elastomer based sample. However, due to recent increases in oil prices, mineral fillers have taken great importance to be used in elastomer based samples [5,6]. For this purpose; glass spheres, rice husk, wood ash, flue dust of high temperature furnaces, reclaimed rubber, phosphate, nanoclays, silica, calcite and wollastonite are being used in rubber materials as filling material [1–7]. Generally, mechanical properties of these types of samples are studied in some experimental works [8,9]. Many research groups nanocomposite materials obtained from pure natural rubber and influence of the microstructure of vulcanized polybutadiene rubber have been investigated by dielectric spectroscopy and analyzed using the Havriliak-Negami model [10,11]. The mechanical ageing of filled silicone rubbers as a static pre-stretching had been investigated for dielectric elastomer applications [12]. In this study, the mica powder as a filler material is chosen and electrical properties are analyzed by impedance spectroscopy.

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2. Experimental

In this study, NR/RSS3 natural rubber and SBR 1502 styrene butadiene rubber, laurel rubber, carbon black and mica powders are obtained from Petkim and Kaultun mining company. Other additives used in the study were obtained from the Bayer chemical company. Some physical properties of the materials used are given in Table 1.

In the production of test specimens in the first stage, NR and SBR were stirred until they became homogeneous in the two-cylinder open mixer. Then NR/SBR weight ratio of 5.14% mica powders was added to the rubber mixture. Finally, plasticizers, activators, vulcanization accelerators, and sulfur additive materials have been added and stirred for a further 5 min and the mixing process is completed. Compounds in an open mixer (80 °C) stirred at a total of 12 min and they were introduced into the flat plate. The properties of fillers and dopants used in experiments are given in Table 2. Rubber compounds formed into the flat plate were placed in a mold of 180 × 180 × 6 mm in size in which they can be compressed. They were put into furnace of 160 °C then pressed for 6 min at 16 MPa and they were vulcanized.

For all samples the processes conditions are fixed in all stages. After cutting the samples a suitable measure and standards, they were placed in an environment of a temperature 25 ± 2 °C and 50% relative humidity for 24 h. Before doing the electrical measurements, the surface area and thickness were measured by using a digital caliper and all surfaces roughness was eliminated. The silver paste was applied to the electrodes for ohmic contact. The electrical parameters of the sample were measured by HP4194 Impedance Analyzer within the frequency interval of $1 \times 10^2 - 40 \times 10^6$ Hz for 19 different frequencies in the range of 298–373 K.

3. Results and discussion

The frequency dependence of the real part of the electrical modulus for different temperatures is shown in Fig. 1 and it shows a clear dispersion. Dispersive behavior of the dielectric constant or electrical modulus is attributed to a polarized structure or mobile charge carriers and sometimes even the both in the material studied. It is very clear from the figure that the modulus doesn't reach to the zero and has not a frequency independent constant value at low frequencies for all temperatures. This behavior is a result of the electrode polarization that is still active [13]. However, it is believed that the continuous part of the dispersion curve remains outside the scanning range of the LCR meter. The long range conductivity of charge carriers remains in unseen lower frequencies tail in figure [13].

The imaginary parts of the electrical modulus versus the frequency at different temperatures are depicted in Fig. 2. The imaginary parts of the electrical modulus are increased in all temperatures by increasing the frequency. The antisymmetric behavior for this modulus refers to extra-ordinariness to the sample being tested since this behavior is not observed for the sample. The curve part in between 10^4–10^5 Hz is thought to be the main reason for this abnormality. Crimp points don't shift at frequency

Table 2
Composition of rubber compounds.

Compounds	% Composition
Natural rubber (NR)	11.2
Styrene butadiene rubber (SBR)	33.4
Carbon black (HAF N330)	29.7
Silica	10
Mica powder	5.15
Sulfur	1.35
Zinc active	1.5
Stearic acid	0.9
Process oil	5.9
Others	0.9

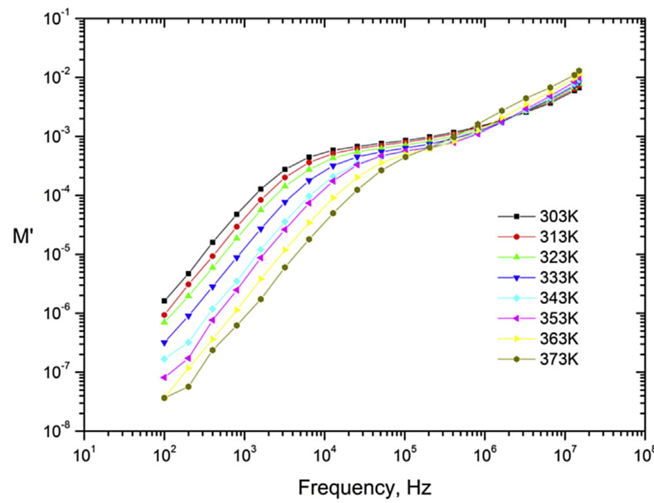

Fig. 1. Frequency dependency of the real modulus at different temperatures.

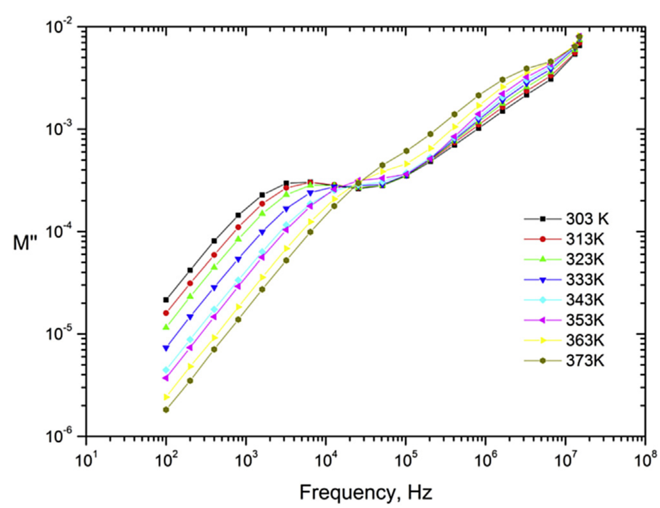

Fig. 2. Frequency dependency of the imaginary modulus at different temperatures.

Table 1
Technical properties of the filler material.

Materials	Trade names	Density (g/mm^3)	Particle size (m)
Natural rubber	RSS 3	0.93	–
Styrene butadiene rubber	SBR 1502	0.94	–
Carbon black	(HAF N330)	1.8	28 (nm)
Silica	Egesil BS 20 A	2	20 (μm)
Mica powder	Mica SMW 375	2.7	50 (μm)