On the Thermal Properties of HAF Black-loaded Butyl Rubber Vulcanizates

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ABSTRACT

The flash method is used to determine the effect of HAF carbon-black concentration of the thermal properties of butyl rubber vulcanizates in the temperature range (30–150°C). It was found that the thermal conductivity, thermal diffusivity and specific heat increase with carbon black loading. The thermal conductivity of such composites is analyzed in terms of contributions from the carbon black and the pure rubber. A slight discrepancy was detected between the experimental results and the theoretical calculations.

KEY WORDS: Butyl rubber, carbon-black, thermal conductivity.

INTRODUCTION

Carbon black-loaded rubbers represent a great interest from both the scientific as well as the technological points of view.

Many theories have been developed to describe the origin of thermal conductivity in polymeric glasses[1–5] that tend to be based on either liquid, or solid state model; the difference being that the former assumes energy transfer to occur as uncorrelated events while the latter consider the collective motions of repeating units. Moreover, some workers[6,7] studied the effect of pressure on the thermal conductivity of polymers in its glass state.

Another area of common interest is the investigation of the termperature dependence of the thermal conductivity of polymers[8–11]. Following this interest the present work is aiming to study the thermal properties of butyl rubber vulcanizates and how they are affected by the presence of different concentrations of HAF carbon black in the rubber matrix.

EXPERIMENTAL

The preparation of the rubber sample (as illustrated in Table 1) was carried out on a two-roll mill 170 mm diameter and 300 mm long; and gear ration 1.4. After preparation, the rubber mixture was left at least 24 h before vulcanization. The vulcanization process was conducted at 143 ± 2°C for 20 min under a pressure of 40 kg/cm^2.

TABLE 1. Formulations of Butyl Rubber Containing Different Concentrations of HAF Black.

Ingredients in (phr)[a]	CH4	CH5	CH6	CH7	CH8
Butyl rubber	100	100	100	100	100
Stearic acid	2	2	2	2	2
ZnO	5	5	5	5	5
$BaTiO_3$	20	20	20	20	20
Processing oil	10	10	10	10	10
HAF	40	50	60	70	80
MBTS[b]	1.5	1.5	1.5	1.5	1.5
Sulfur	3	3	3	3	3

[a] part per hundred parts of rubber by weight.
[b] Dibenzthiazyl disulphide.

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ductivity of the two-phase assembly. This leads to a value for the conductivity of the assembly given by:

$$\frac{\lambda^*}{\lambda_2} = 1/4 \,[\, (3\,\phi - 1)\, x + 2 - 3\,\phi + \{[(3\,\phi - 1)\, x^2 + 2 - 3\,\phi\,]^2 + 8x\}^{1/2}] \quad (3)$$

As can be seen from figure (1), equation (3) is in better agreement with the experimental results than equation (1), but in neither cases the fitting is satisfactory.

The dependence of λ^* for different samples on the temperature is clearly observed in Fig (2). The addition of c.b. (< 70 phr) slightly affected the λ^* versus T curves. The further addition of carbon black >70 phr), appreciably affected the thermal conductivity which may be interpreted as follows:

The magnitude of the mean free path of the phonon is markedly affected by both the type and amount of the filler[17]. Taking into account the high value of the thermal expansion coefficient of rubber[18] α(200×10^{-6} deg^{-1}) with respect to that of carbon black[19] α(1×10^{-6} deg^{-1}), the increase of λ^* with temperature is due to the increase of the magnitude of the mean free path of the phonon.

Both the thermal diffusivity, a, and specific heat capacity, c_p, and their dependence on temperature for these composites were examined as shown in Figures (3, 4) respectively. One may conclude that the diffusivity, like electrical conductivity (for these samples) increases with the increase of carbon black loading and also with the increase in the degree of structure of the carbon black[20] (as was detected by our group[21] when we used another carbon black (FEF) instead of HAF black).

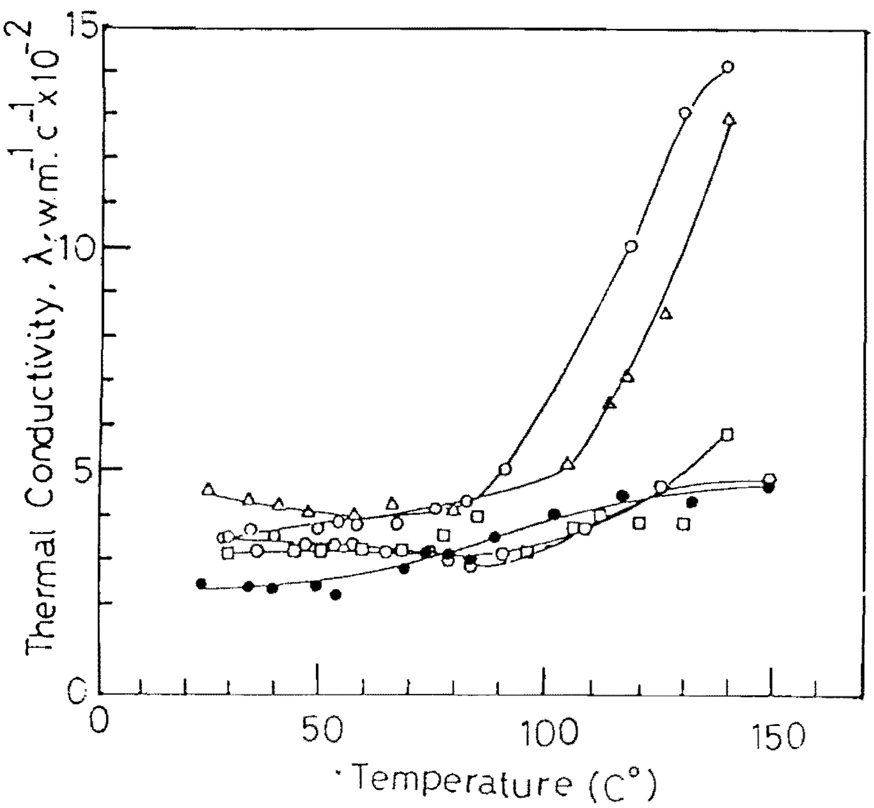

Fig. 2. Temperature dependence of, λ^*, for conductive butyl rubber-loaded with different concentrations of HAF black; ● CH4; ◯ CH5; □ CH6; △ CH7; O CH8

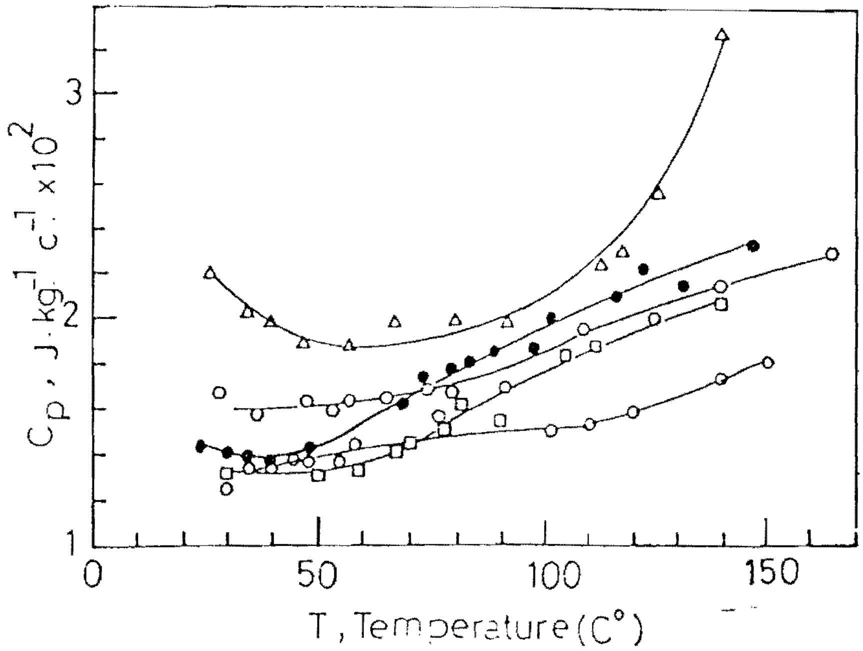

Fig. 3. Temperature dependence of, a, for conductive butyl rubber-loaded with different concentrations of HAF black. ● CH4; ○ CH5; □ CH6; △ CH7; O CH8

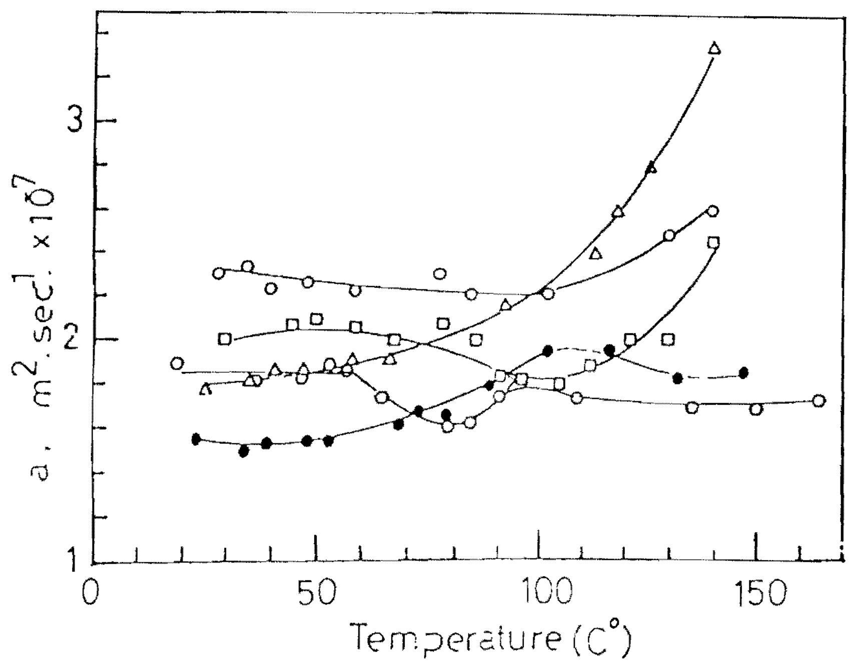

Fig. 4. Temperature dependence of, c_p, for conductive butyl rubber-loaded with different concentrations of HAF black. ● CH4; ○ CH5; □ CH6; △ CH7; O CH8

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