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SYNERGISTIC EFFECT OF CARBON NANOFIBER AND NON-IONIC SURFACTANT FOR IMPROVED ELECTRICAL CONDUCTIVITY OF NATURAL RUBBER COMPOSITES

A.D.K. DESHAN[a1], N.M.S. SIRIMUTHU[b], L. KARUNANAYAKE[c], A. SARANGI[d] AND R.R.M.S.K. RANATUNGA[e]

[abcd]Department of Chemistry, Faculty of Applied Science, University of Sri Jayewardenepura, Sri Lanka
[e]Elastomeric Engineering (Co) LTD, Horana, Sri Lanka

ABSTRACT

Synergistic effect of carbon nanofiber and non-ionic surfactant for electrical, cure and mechanical properties of natural rubber composites were studied. Electrical properties of the natural rubber vulcanizates were measured, according to ISO standard 2878. Cure characteristics and mechanical properties were also evaluated in the cured natural rubber vulcanizates. The results indicated that, electrical resistance was drastically decreased when incorporating carbon nanofiber and non-ionic surfactant together and the percolation threshold value was 8 phr (parts per 100 g rubber). Considering the cure characteristics, it was found that natural rubber vulcanizate with 2 phr of carbon nanofiber and non-ionic surfactant together, showed low values of optimum cure time (t_{90}) compared with carbon nanofiber and non-ionic surfactant alone. Natural rubber vulcanizates were achieved better mechanical properties with low loading of combination of carbon nanofiber and non-ionic surfactant. This study will lead to the manufacturing of electrically conductive natural rubber composites with low amount of carbon nanofiber, with better cure and mechanical properties.

KEYWORDS: Carbon Nanofiber, Cure Characteristics, Electrical Conductivity, Mechanical Properties, Non-Ionic Surfactant, Percolation Threshold.

Electrically conductive polymer composites are used in electro-magnetic shielding materials, self-regulated heaters, pressure sensors etc. [1] Different carbon materials have been used to make electrically conductive natural rubber composites; such as carbon black, carbon nanotubes and graphene [2]. Large quantities of carbon black have to be used to make the electrically conductive natural rubber composites [3]. Costly methods have to be used to synthesize carbon nanotubes and graphene [4]. Metal particles like nickel, aluminium and iron have been used to make electrically conductive polymers [5]. Wear and tear problems of the machines have been caused when compounding metal particles into the polymer matrix.

Carbon fiber has been mainly used as an electrical conductive material in different rubber matrices; such as, silicon [6] and chloroprene [7] rubber. Electrical and mechanical properties of NBR, EPDM and their blends were studied by incorporating acetylene black and short carbon fiber [8]. Carbon fiber/natural rubber and carbon fiber/ ethylene vinyl acetate (EVA) composites used for electromagnetic shielding has been reported by Das et al. [9] where percolation value was 15 phr (parts per 100 g rubber) for carbon fiber/ natural rubber composites.

Non-ionic surfactants have been used as an antistatic agent in rubber composites, because of its electrical conductive property. Non-ionic surfactants have also been used to improve the dispersion of reduced graphene oxide in rubber latex [10].

Large amount of carbon fiber gives dark color to the rubber composite and it could be adversely affect for the application of the conductive rubber. When non-ionic surfactants are used in large quantities it could be caused the blooming phenomenon on the rubber surface. Therefore, synergistic effect of carbon nano fiber and non-ionic surfactant was studied to improve the electrical conductive property of natural rubber composites without causing color effect and blooming phenomenon.

METHODOLOGY

Materials

The NR, SVR 3L of Mooney viscosity ML (1+4) at 100 ^{0}C equal to 85 was received from Viet Phu Thinh Rubber Company, Vietnam. ZnO was obtained from P.T.Indolysaght Co: LTD, Malaysia. Silica was obtained from Hisil CO: Chemical Industries Co. LTD, China. Silane (Si 69) was supplied by Huangyan Zhedong Rubber Co: LTD, China. Stearic acid and Antilux-654 was supplied by Palm-Oleo Sdn.Bhd, Malaysia and Hayles Industrial Solution (Pvt) LTD, Sri Lanka. Sulphur and Polyethylene glycol was obtained from Miwon Chemical Co:LTD, Korea. The accelerator, TBBS (N-tert-butyl-2-benzothiazyl sulphonamide) was supplied by DailanRichon Chemical Co:LTD, China.

[1]**Corresponding author**

Carbon nano fibre was received from SGL carbon fibers Ltd, UK. Non-ionic surfactant, AE 315W was received from Lankem surfactants, UK.

Sample Preparation

Base rubber compound was made by melt mixing method in in an internal (banbary) mixer. Dry NR (353.3 g) was masticated in banbary mixer, followed by 423.2 g Silica, 13.02 g Si 69, 26.04 g ZnO, 13.02 g stearic acid and 32.55 g PEG-4000 were added and again masticated. Masticating was continued by the addition of the accelerator TBBS (16.27 g) and the vulcanizing agent sulfur (6.51 g). Further mixing was done in the two-roll mixer.

Carbon nano fiber and non-ionic surfactant were added separately into the base rubber composite by varying the phr from 2, 4, 8 and 12.

To study the synergistic effect, 90% of non-ionic surfactant and 10% of carbon fiber were added into the base compound according to the 2, 4, 8 and 12 phr amounts.

Testing Electrical Conductivity (ISO 2878)

Insulation tester was used to measure the electrical resistance and all the samples were measured at room temperature. Test specimens were clamped between two electrodes and the resistance was measured by applying 250 V.

Measuring Of Cure Characteristics

The cure characteristics of the mixes were studied using a Monsanto Moving Die Rheometer (MDR 2000) according to ISO 3417 at 150 ^{0}C. The respective cure times as measured by t_{90}, scorch times, t_{10}, maximum torque, minimum torque, etc., were determined from the rheograph. The compounds were then compression molded at 150 ^{0}C using the respective cure times, t_{90}.

Mechanical Properties

Dumb-bell shaped samples were cut from the moulded sheets and tensile tests were performed at a cross-head speed of 500 mm/min using a Monsanto Tensometer M500 according to ISO 37.

RESULTS AND DISCUSSION

Electrical conductivity measurements of the base composite and carbon nano fiber, non-ionic surfactant filled composites are mentioned in the following table 1.

Table 1: Electrical resistant values of natural rubber composites at different conductive filler loadings.

Type of material	Electrical Resistance/ MΩ			
	2 phr	4 phr	8 phr	12 phr
Carbon nano fiber	90	78	48	10
Non-ionic surfactant	92	80	50	15
Carbon nano fiber/non-ionic surfactant	80	68	35	3

Carbon nano fiber and non-ionic surfactant showed the percolation threshold value at 8 phr, and when both are combined together percolation threshold value is 8 phr. Therefore, electrical resistance of the natural rubber composite has been drastically decreased due to the synergistic effect of carbon nano fiber and non-ionic surfactant.

The measurement of cure characteristics, optimum cure time (t_{90}) and scorch time (t_{10}) values of the conductive fillers (2 phr) added rubber composites are mentioned in the table 2.

Table 2: Cure characteristics of the conductive filler (2phr) added rubber composites.

Conductive material	t_{90} /min	t_{10} / min
Carbon nanofiber	2.1967	0.38167
Non-ionic surfactant	2.2200	0.38500
Carbon nanofiber(10%) /non-ionic surfactant (90%)	2.1267	0.37600

Base rubber compound has shown, 2.3367 min as the optimum cure time (t_{90}) and 0.38754 min as the scorch time (t_{10}). When adding carbon nano fiber and non-ionic surfactants separately, t_{90} and t_{10} values of the base compound have been decreased. Therefore, it is observed that carbon nano fiber and non-ionic surfactants have been improved the cure properties of the natural rubber composites when they are adding separately and together.

Tensile strength was 20.32 MPa when 2 phr of carbon nano fiber was added and 19.20 MPa, when non-ionic surfactant added. When carbon nano fiber and non-ionic surfactant combined together, tensile strength value was 19.32 MPa. It was observed that, tensile strength was reduced when adding non-ionic surfactant to the carbon nano fiber reinforced composite.

Elongation of carbon nano fiber added composite was 510% while it was 543% for the non-ionic surfactant added rubber composite. When carbon nano fiber and non-ionic surfactant combined together, elongation was 532%. It was observed that, elongation was increased when non-ionic surfactant was added into the carbon nano fiber natural rubber composite.

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