

# Effects of Curing Accelerators on Cure Characteristics of Uncalcined Tin Dioxide Reinforced DPNR Nanocomposites

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**ABSTRACT** – Environmentally friendly materials have become the subject of interest for electrical insulation cable materials. This preliminary work investigated the potential of combining tin dioxide (SnO<sub>2</sub>) nanoparticles with deproteinized natural rubber (DPNR) for their potential as an excellent electrical insulation material. It is expected to combine the electrical properties of their parents. However, the curing system has a significant impact on processability. The effect of different accelerators and SnO<sub>2</sub> content on the cure characteristics of rubber nanocomposites was investigated. It was found that MBTS-cured compounds vulcanized too quickly regardless of SnO<sub>2</sub> loading. They also represented higher melt viscosity than the CBS-cured nanocomposite compounds. As a result, CBS-cured nanocomposites have acceptable process safety and processability.

## 1. INTRODUCTION

Natural rubber (NR) insulations for electrical wire have been used since the early days of the electrical industry. NR was the only polymeric material used as a wire and cable dielectric prior to the 1930s [1]. However, due to their unsaturated backbones, NR insulation materials are susceptible to thermal degradation and ozone damage. Furthermore, due to its lack of polarity, it has limited oil and chemical resistance [2]. For these reasons, various NR-based blends and composites with other elastomers like NR-CR, NR-EDPM, thermoplastics like NR-HDPE, and biodegradable polymers like NR-Chitosan and NR-PVA, and fillers have been examined by numerous researchers [2]. Filler materials, such as micro or nanofibers and particles, have significantly impacted the dielectric properties of NR-based materials. Some fillers have been discovered to improve surface and volume resistivity, as well as reduce leakage current and increase resistance to tracking and erosion [2]. These nanoparticles acted as a barrier to the passage of electrical charges. Nanofillers like silicon dioxide and titanium dioxide have been discovered to increase partial discharge (PD) activity. Meanwhile, electrical resistivity was reduced by iron oxide-carbon nanotubes and nickel-cobalt-zinc ferrite nanoparticles [2]. As a result, highly

conductive filler materials are expected to harm the dielectric properties of NR composites. Adding semiconductor fillers to the NR matrix would be a good way to improve the dielectric and mechanical properties. Nevertheless, rubber nanocomposites' mechanical properties and processability can be affected by the chemical reaction between constituents. It is primarily determined by the filler, and curing systems used [3]. Only a few studies have incorporated SnO<sub>2</sub> into NR for electrical insulation, and lesser studies have on curing accelerators' effect. As a result, this work investigated the feasibility of producing the SnO<sub>2</sub>-reinforced DPNR for an electrical insulator. The SnO<sub>2</sub> has a rutile structure, and the bandgap is 3.6 eV [4]. Its nanocrystalline structure has outstanding electrical properties due to its extremely high surface area. Regardless of the high electrical conductivity, the SnO<sub>2</sub> nanoparticles are expected to improve the heat stability of the material while producing good dielectric properties at the optimum level. The feasibility of producing uncalcined SnO<sub>2</sub> reinforced DPNR nanocomposites at 0.5, 1, 3, and 7 phr was investigated using various curing accelerator systems (2-2'-Dithiobis(benzothiazole), MBTS or N-cyclohexyl-2-benzothiazole sulfonamide, CBS). Fourier transform infrared (FTIR) analysis supported the findings.

## 2. METHODOLOGY

Two compounds with different curing accelerator systems were prepared through a melt compounding process. The formulations were based on 100 phr of DPNR and uncalcined SnO<sub>2</sub> nanoparticle loadings at 0.5, 1, 3, and 7 phr. 1.5 phr of sulphur (S) was used as a curing agent. The semi-EV system was assisted by adding 2 phr of stearic acid, 5 phr of zinc oxide (ZnO), 2 phr of 6PPD 0.3 phr and tetramethyl thiuram disulphate (TMTD). The compounds were cured with sulphur using either 1 phr MBTS or CBS accelerators. The DPNR/SnO<sub>2</sub> compounds were prepared through a melt compounding method per ASTM D-3182. The cure properties of the nanocomposites were evaluated using ASTM D2084 at 150°C within 5 minutes. The oscillating motorless rheometers were used in the experiment. The cure

characteristics consisting of minimum torque (ML), maximum torque (MH), maximum curing time ( $T_{90}$ ), and scorch time ( $T_2$ ), were determined. The compounds were then compressed in a hot press at 150°C and 150 kgf. FTIR analyses were performed on DPNR/SnO<sub>2</sub> nanocomposites and control samples using an FT/IR-6100typeA Spectrometer from JASCO at 400-4000 cm<sup>-1</sup>.

### 3. RESULTS & DISCUSSION

Figure 1 depicts the effect of MBTS and CBS accelerators on the cure characteristics of DPNR/SnO<sub>2</sub> nanocomposites. Figure 1(a) shows that nanocomposites cured by MBTS cure faster than the CBS system. Both systems' trends are similar when SnO<sub>2</sub> nanoparticles are added; SnO<sub>2</sub> loadings increased  $T_2$  and  $T_{90}$ . It denotes the ability of SnO<sub>2</sub> nanoparticles to delay curing. However, the CBS-cured nanocomposite compounds are suitable for safer processing.

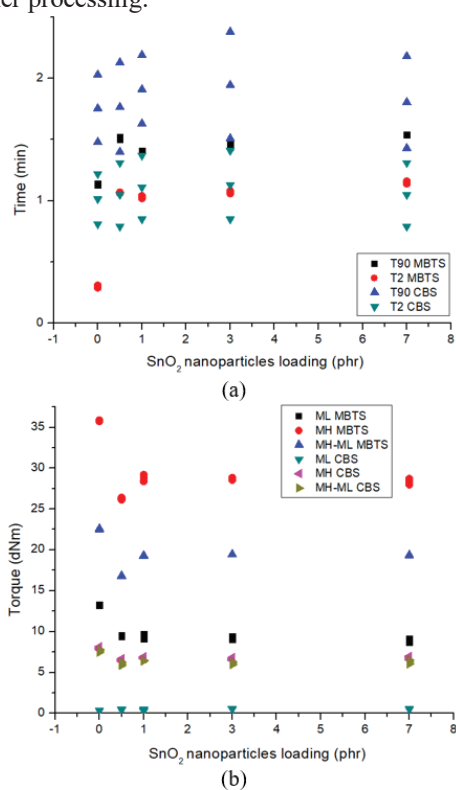


Figure 1 Cure characteristics of DPNR/SnO<sub>2</sub> nanocomposites, (a) time and (b) torque versus the SnO<sub>2</sub> nanoparticle loadings.

Increasing SnO<sub>2</sub> loadings observed decreasing patterns for torque values corresponding to the flow characteristics; MH-ML, ML, and MH. The ML values are primarily representing the viscosity of the compounds under heat. Therefore, it demonstrated SnO<sub>2</sub>'s ability to act as a plasticizer. Meanwhile, the workability of the melt was improved in the CBS-cured nanocomposite compounds. The viscosity of the CBS cured-nanocomposites was represented by ML values ranging from 0.3 to 0.6 dNm. In the meantime, the ML values for MBTS-cured systems ranged from 8.9 to 13.3 dNm. The findings were consistent with those reported by Indrajati and Dewi [5]. At the same concentration, MBTS-based systems showed more viscous compounds with higher ML values than CBS-based systems. The early

dominance of elastic elements during curing is associated with high Mooney viscosity [5]. Figures 1(a) and (b) show that SnO<sub>2</sub> plays an important role in delaying curing and lowering melt viscosity. It is consistent across both compounds and accelerator systems. Figure 2 shows how uncalcined SnO<sub>2</sub> nanoparticles altered the molecular makeup of the DPNR matrix. Sn-O-Sn and Sn-OH stretching modes were assigned to the 550-650 cm<sup>-1</sup> bands. Significant bands at 2922, 2841, and 1400 cm<sup>-1</sup> on uncalcined SnO<sub>2</sub> surfaces were attributed to C-H stretching and bending vibrations [6].

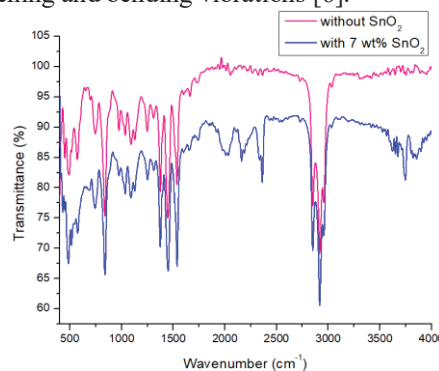


Figure 2 FTIR spectra of uncalcined SnO<sub>2</sub> nanoparticles reinforced DPNR nanocomposites.

### 4. CONCLUSIONS

The curing properties of DPNR nanocomposites were investigated concerning different accelerator systems and SnO<sub>2</sub> nanoparticle loading. CBS-cured nanocomposites outperformed the MBTS-cured system in terms of process safety and melt flow. SnO<sub>2</sub> played a similar role in both compounds, acting as a plasticizer and curing retarder in the SnO<sub>2</sub>-reinforced DPNR nanocomposites.

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