ABSTRACT

The global concern over zinc leaching into aquatic ecosystems has led researchers to seek ways to reduce zinc oxide (ZnO) content in rubber products. Conventional microsized ZnO, commonly used in the rubber industry, poses dispersion challenges due to its hydrophilic nature and micron size within the hydrophobic rubber matrix. Therefore, higher amounts of ZnO are added, elevating the risk to aquatic life. In this context we have explored various surface characteristic ZnO in natural rubber (NR), styrene butadiene rubber (SBR) and SBR-NR blend systems. It has shown that 1.5 phr of nano ZnO and 3 phr of active ZnO exhibit cure characteristics, dynamic, and mechanical properties equivalent to 5 phr of conventional ZnO in NR-carbon black matrix, reducing ZnO use in rubber compounding by 70 % and 40 %, respectively. In SBR matrix, 1.5 phr of nano ZnO, 2 phr of active ZnO, and 2 phr of functionalized ZnO exhibit cure characteristics, mechanical properties, and reduces ZnO amount by 70 %, 60 %, and 60 %. The study extends to give an insight into the impact of the various types of ZnO on the thermal stability of SBR/NR blends in the presence of carbon black and silica filler. Temperature scanning stress relaxation (TSSR) have been employed to understand the non-isothermal stress relaxation. Giving the insight on the influence of activators and reinforcing agents on rubber-filler interaction and the formation of various sulfur linkages. Active and nano ZnO formed mono and disulfide linkages exhibited higher thermal stability and lower activation energy for the blend, while functionalized ZnO formed polysulfides giving higher tensile strength in SBR-NR blends. Study further gives an insight in to the role of reactive surface Zn2+ ions on the ZnO surface in the in-situ formation of ZnO-anchored silica particles during mixing. The study also explores a green synthesis method, concluding that green-synthesized ZnO-loaded composites exhibit reduced Payne effect and improved mechanical properties, making strides toward achieving challenging tire properties. The low cytotoxicity of green-synthesized ZnO positions it as an environmentally friendly replacement for conventional ZnO in the rubber industry.

Keywords: Sustainability, Zinc oxide, Activator, Morphology, Structural characterization, Natural Rubber, Styrene-Butadiene Rubber, Blends, Dispersion, crosslink density, kinetics.