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ORIGINAL PAPER

Properties of natural rubber/recycled ethylene–propylene–diene rubber blends prepared using various vulcanizing systems

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Abstract The role of various vulcanizing systems on the curing characteristics, mechanical properties, morphology and dynamic mechanical analysis of natural rubber and recycled ethylene–propylene–diene rubber blends was investigated. Accelerated sulfur-vulcanizing systems (semi-EV and EV), peroxide, and mixed sulfur/peroxide-vulcanizing systems (semi-EV/peroxide and EV/peroxide) were observed and compared. The blends were processed on a two-roll mill, and a fixed amount of carbon black was also incorporated. Amongst the blends, accelerated sulfur-vulcanizing systems exhibited higher torques, state of cure, tensile strength and elongation-at-break, in comparison with the peroxide-vulcanizing system, whereas the tensile modulus, hardness and cross-link density showed lower trend. In the mixed sulfur/peroxide-vulcanizing systems, it showed intermediate behavior to the individual sulfur- or peroxide-vulcanizing systems. This was associated to the interference of peroxide during the cross-linking formation. SEM micrographs of semi-EV-vulcanizing system exhibited more roughness and cracking path indicating that higher energy was required towards the fractured surface. The high cross-link density observed from the swelling study could be verified from the storage modulus (E') where peroxide vulcanized blends provided a predominant degree of cross-linking followed by semi-EV, semi-EV/peroxide, EV and EV/peroxide-vulcanizing systems, respectively. The glass transition temperature (T_g) depicted at maximum peak of mechanical loss factor ($\tan\delta_{max}$), indicating that semi-EV-vulcanizing system showed highest T_g value. The T_g values can be ordered as semi-EV > peroxide > semi-EV/peroxide > EV > EV/peroxide-vulcanizing systems. The T_g of rubber vulcanizates can be increased due to the restriction of molecular movement such as cross-link density.

Keywords Natural rubber · Recycled ethylene–propylene–diene rubber · Vulcanizing systems · Tensile strength · Dynamic mechanical analysis

Introduction

Blending is an easy and cost-effective way to produce new combination properties. The purpose of blending the rubber is to improve the physico-mechanical properties as well as modifying the processing characteristics and reducing the manufacturing cost [1–3]. Ethylene–propylene–diene rubber (EPDM) has been the fastest growing elastomer among the synthetic rubbers since its introduction in 1963 [4]. It represents 7 % of world rubber consumption and it is most widely used for non-tire rubber [5]. This polymeric material is not serviceable and is most often discarded after a certain period of time. Discarded rubber products constitute the major part of accumulated non-biodegradable wastes [6]. Reutilizing of EPDM rubber is an interesting topic with regards to the continuous market growth of EPDM. Blending of natural rubber/recycled ethylene–propylene–diene rubber (NR/R-EPDM) has been studied previously [7–9]; however, these studies only focused on the compounding, thermal stability and mechanical properties of the blends. To widen the focus, the study on the effect of various vulcanizing systems namely accelerated sulfur vulcanization (semi-EV and EV), mixed sulfur/peroxide vulcanization (semi-EV/peroxide and EV/peroxide) and peroxide vulcanization have been carried out.

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