Iranian Polymer Journal (2020) 29:553–567
https://doi.org/10.1007/s13726-020-00818-4

ORIGINAL RESEARCH

Devulcanization of ground tire rubber: thermo-oxidation followed by microwave exposure in the presence of devulcanizing agent

Oscar Buitrago-Suescún[1] · **Rodrigo Britto**[2]

Received: 6 September 2019 / Accepted: 23 April 2020 / Published online: 2 May 2020

Abstract
The disposal of recycled tires is a problem that has gained considerable importance since it has involved the environmental as well as various disciplines and points of view. Currently, the burning and outdoor storage of disposed tires are forbidden practices because of their polluting effect, damage to health and the fact that they contribute to the spread of diseases due to vectors such as insects. Therefore, it is important to research alternative methods that provide added value. In this work, waste ground tire rubber was treated by applying a combination of oxidation with potassium permanganate/hydrogen peroxide, followed by microwave exposure in the presence of a devulcanizing agent. Devulcanized tire rubber was analyzed by Fourier transform infrared spectroscopy, differential scanning calorimetry, thermogravimetric analysis, cross-link density and sol fraction. Styrene butadiene rubber composites were prepared using devulcanized tire rubber and sulfur cure system. The blends were mixed in a two roll mill laboratory. The vulcanized specimens were obtained by compression molding. Curing properties, tensile and tear strength, elongation at break, hardness (Shore A units), abrasion resistance (mm^3), and compression set of these rubber composites were evaluated and the morphology of the fractured surfaces from tensile specimens were analyzed with scanning electron microscopy. The results showed that microwave exposure with devulcanizing agent reduced the cross-link density and increased the soluble fraction of rubber tire. Improved flow through viscosity reduction (low torque) and higher mechanical strength were obtained by compounding styrene butadiene rubber with ground rubber tire (thermo-oxidized followed by microwave exposure with devulcanizing agent), whose market values were similar to those obtained for virgin styrene butadiene rubber/silica composite.

Keywords Tire rubber · Devulcanization · Microwave · Styrene butadiene rubber · Composites

Introduction

Waste tire rubber (WTR) composites are formed by a complex mixture of ingredients: natural and synthetic rubbers, carbon black, silica, plasticizers, antioxidants, process aids as activators and accelerators, sulfur, steel cord and fibers made from nylon, polyester and cellulose [1, 2]. Mechanical properties of tire rubber such as good elastic behavior at large deformation and high energy absorbing capacity are achieved by forming a three-dimensional network of rubber chains through sulfur bridges. This process, called vulcanization [3], is a thermo-chemical process (140–220 °C) where sulfur atoms are chemically linked to rubber molecules to form carbon–sulfur–carbon (C–S–C) and carbon–sulfur–sulfur–…–carbon (C–Sx–C) bonds [4]. Vulcanization is an irreversible process at standard conditions of temperature and pressure. In this sense, waste tires cannot be reprocessed like thermoplastic materials [5], because the rubber network makes vulcanized rubber insoluble and non-melting, causing significant difficulties for WTR recycling [6, 7]. Inadequate disposal of tires causes environmental risk such as fire, and produces an enabling ambience for rodents, mosquitoes and other plagues [8] that can kill the advantageous bacteria of the soil [3].

WTR is mainly used as fuel (heat value of 32.6 MJ/kg) in cement production, steam, electrical energy, pulp, paper, lime and steel. However, this is a method that does not take into account environmental considerations [9]. Rubber recycling is growing in importance because of partial

✉ Oscar Buitrago-Suescún
oscar.buitrago@unimilitar.edu.co

[1] Departmento de Ingeniería Industrial, Facultad de Ingeniería, Universidad Militar Nueva Granada, Bogotá, Colombia

[2] School of Management, Universidad de los Andes, Bogotá, Colombia