Improving the thermal properties of fluoroelastomer (Viton GF-600S) using acidic surface modified carbon nanotube

Javad Heidarian¹,²*, Aziz Hassan¹ and Nor Mas Mira Abd Rahman¹

¹Polymer and Composite Materials Research Laboratory, Department of Chemistry, University of Malaya - UM, Kuala Lumpur, Malaysia
²Polymer and Science Technology Division, Research Institute of Petroleum Industry - RIPI, Tehran, Iran

*heidarianj@um.edu.my; heidarianj@yahoo.com

Abstract

Acid surface modified carbon nanotube (MCNT)-, Carbon nanotube (CNT)-filled fluoroelastomer (FE) and unfilled-FE were prepared (MCNT/FE, CNT/FE and FE). The compounds were subjected to thermogravimetric analysis (TGA) and heat air aging, and characterized by Energy Dispersive X-Ray (EDX). Results showed that MCNT improved the thermal properties of FE, resulting in a larger amount of FE and char remaining in the temperature range of 400-900 °C relative to unfilled FE and CNT/FE. The MCNT/FE TGA curve shifted towards higher temperatures compared to CNT/FE and FE. The same results also revealed that higher percentages of FE were undegraded or less degraded especially near MCNT in the temperature range of 400-540 °C. Energy Dispersive X-Ray (EDX) results indicated that the percentage of carbon and fluorine in the residue of TGA scans, up to 560 °C, of MCNT/FE were the same as CNT/FE, and were higher than FE. EDX results of TGA residue (run up to 900 °C) showed that most of the undegraded FE, which was not degraded at temperatures below 560 °C, was degraded from 560 °C to 900 °C in both MCNT/FE and CNT/FE, with the char in MCNT/FE being more than that in CNT/FE. EDX analysis of thermal aged specimens under air showed that, with increasing aging time, a greater percentage of C, O and F was lost from the surface of filler/FE and FE. The order of element loss after 24 hour aging time was: MCNT/FE > FE > CNT/FE.

Keywords: nanocomposites, fluoroelastomer, acidic surface modified, carbon nanotube, thermal properties, thermal aging.

1. Introduction

Viton is a synthetic rubber and fluoroelastomer (FE). Viton® GF-600S is a terpolymer of hexafluoro-propylene, vinylidene fluoride and tetra-fluoroethylene with a cure site monomer. It is a peroxide cure, 70% fluorine FE[1,2].

Normally, in the formulation of FE, carbon black (CB) is used. Replacing CB with surface modified CNT (MCNT) is expected to improve the thermal properties of FE, which is very effective in making O-rings especially for the oil and gas industries[3-5]. MCNT is also expected to improve thermo-oxidative degradation resistance of FE composites when subjected to thermal aging conditioning in air.

MCNT improves the properties of fluoropolymers, such as crystallinity, electrical response, mechanical properties, viscoelastic behavior, etc, and therefore their thermal stability. This finding has been reported by a number of researchers and examples of literatures and the reasons for the changes in these properties are mentioned bellow.

It has been reported[6] that the use of multi-walled carbon nanotubes (MWCNTs)-embedded in fluorinated rubber leads to a rubber nanocomposite with cellulation structure. This structure possesses improved thermal resistance. Pham et al.[7] observed that with increased MWCNT loading in FE/MWCNTs nanocomposites, there is a steady increase in the decomposition temperature. Interactions between CNT and fluoropolymers and the effect of surface area of CNT on the active interfacial area between them were investigated by a number of researchers, for examples: A strong interaction between fluoropolymers and CNT was reported by He et al.[8]. The high aspect ratio of nanotubes also leads to a great increase in the active interfacial area between CNT and the fluoropolymer chain as reported by Chae et al.[7]. An energetic relationship between the surface of CNT and fluoropolymer has been reported by Levi et al.[9].

CNT can change the mechanical and thermo-mechanical properties of polyvinilydienefluoride (PVDF)[9-11] or the mechanical properties of polytetrafluoroehtylene (PTFE) [12,13]. CNT can also change the degree of crystallinity of fluoropolymers and, therefore, their properties[14-18].

Sementsov et al.[11] reported that in nanocomposites of PTFE and MWCNT, the concentration and nature of oxygen containing MWCNT surface groups influences the strength parameters of the composite material. Wen et al.[17] prepared (PVDF)/MWCNTs nanocomposites and studied the melt viscoelastic behavior of the composite. The results showed that PVDF/MWCNTs-g-OH (OH grafted) nanocomposites exhibit more significant solid-like behavior than PVDF/MWCNTs nanocomposites. Huang et al.[16] showed that the interfacial interaction between the single walled carbon nanotubes (with hydroxyl groups) and PVDF has an effect on inducing crystallinity. The thermal stability of the PTFE composites is also enhanced by the presence of CNT as reported by Park et al.[18]. The temperatures recorded at maximum decomposition rate were affected by the type of surface modification of MWCNT. The thermograms