



Microscopic Deformation Behavior and Crack Resistance Mechanism of Core–Shell Structures in Highly-Toughened PP/PA6/EPDM-g-MA Ternary Blends

Majid Mehrabi-Mazidi and Mir Karim Razavi-Aghjeh*

Highly-toughened blends, comprising polypropylene, polyamide 6, and maleic anhydride-grafted ethylene-propylene-diene monomer rubber (PP/PA6/EPDM-g-MA), of core–shell morphology are prepared and impact of microstructural development, at different PA6:EPDM-g-MA weight ratios (fixed at 30 wt%), on macroscopic mechanical and fracture characteristics of blends is studied through in-depth analysis of micromechanical deformations operating in the blends. The role of dispersion state of modifier domains on nucleation and evolution of various microscopic deformations accompanying the fracture process under impact and quasi-static fracture tests is closely examined. Increase in EPDM-g-MA:PA6 ratio develops agglomerated core–shell domains in the form of extended island-like structures. While impact data show significant synergistic toughening effect of dispersed composite domains in ternary blends compared with PP/EPDM-g-MA (70/30) binary blend, fracture works show a sole dependence on rubbery fraction. Fractography examinations reveal deformation of dispersed domains, development of multiple voids, and highly deformed craze-like void-fibrillar structures within core–shell structures as well as at their interfaces with surrounding matrix. The importance of deformation zones in activation and promotion of matrix shear yielding is clarified, while their function as crack nucleation and subsequent crack propagation trajectories is highlighted. The stability of void-fibrillar zones is found essential for extensive plastic deformation and premature failure prevention.

1. Introduction

Fracture toughness, particularly the impact toughness, is an important criterion to select a polymeric material for engineering applications. It has long been recognized that the most efficient approach to improve the fracture toughness of polymers is the addition of a suitable rubber in the form of discrete particles dispersed in the parent polymeric matrix.^[1–3] The level of increase in toughness is determined by the rubber content, rubber particle size and size distribution, interfacial interaction between phases, internal structure of the rubbery phase, as well as some physical properties of the rubbery component.^[1,3–5] The simultaneous use of soft rubbery component with a rigid polymeric phase can counterbalance some inevitable loss of stiffness, strength, and creep resistance associated with the rubber toughening. In these multiphase systems (ternary blends), the macroscopic mechanical properties are strongly affected by the arrangement and distribution of modifier phases with respect to each other in the matrix, that is, the phase morphology,^[5–9] among which it is shown that the encapsulated

phase morphology usually shows superior stiffness-toughness balance than the separately dispersed one.^[10–13] In the vast majority of nonreactive and reactive core–shell ternary blends, the rigid modifier phase usually forms the core which is engulfed by the soft rubbery shell.^[8,10,13–27]

In ternary blends of core–shell morphology, study on the structure–property relationships, with emphasis placed on the improving the impact toughness, has attracted a great attention in recent years.^[8,10,13,20–30] This is because very useful design criteria can be established when correlating the macroscopic performance with microscopic deformations. These criteria could subsequently be used for developing new materials with tailored microstructure and, consequently, superior performance.^[18,19] The results reported in the literature demonstrate the crucial role of interface and/or interphase thickness (rubbery shell, in the case of core–shell systems) and the size of dispersed domains to achieve effective toughening, mostly evidenced by post-mortem fractography of impact specimens.^[8,13,19,21–29] The size of composite droplets can be controlled by a

Dr. M. Mehrabi-Mazidi
Advanced Polymeric Materials Department
Plus Polymer (vara polymer pishro) Company Ltd.
Shahriar, Tehran 3313193688, Iran

Dr. M. Mehrabi-Mazidi, Prof. M. K. Razavi-Aghjeh
Institute of Polymeric Materials
Sahand University of Technology
Sahand New Town, Tabriz 51335-1996, Iran
E-mail: karimrazavi@sut.ac.ir

Dr. M. Mehrabi-Mazidi, Prof. M. K. Razavi-Aghjeh
Faculty of Polymer Engineering
Sahand University of Technology
Sahand New Town, Tabriz 51335-1996, Iran

The ORCID identification number(s) for the author(s) of this article can be found under <https://doi.org/10.1002/mame.202100174>

DOI: 10.1002/mame.202100174