TOUGHNESS ENHANCEMENT OF POLYAMIDE 12 WITH NATURAL RUBBER VIA NON-REACTIVE AND REACTIVE COMPATIBILIZATIONS

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ABSTRACT

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This research work studied toughness enhancement of polyamide12 (Nylon12) by adding natural rubber (NR) via melt blending process. Copolymers of polystyrene/natural rubber (PS/NR) and polystyrene/maleated natural rubber (PS/MNR) were used as non-reactive and reactive compatibilizes, respectively. The result revealed that the non-reactive compatibilizer improved the compatibility between Nylon12 and NR via physical linkage, leading to a good dispersion of NR domains in Nylon12 matrix and the enhancement of impact energy by a factor of 3. The reactive compatibilizer was then used to increase the interfacial adhesion between Nylon12 and NR via chemical linkage. However, different mixing procedures of PS/MNR copolymer as well as maleic anhydride loading affected to crosslinked NR (gel) content and MA grafting efficiency. The result showed that PS/MNR copolymer prepared by two-step mixing and low MA loading had a lower gel content and a higher MA grafting efficiency. The reactive compatibilizer with various contents also affected to the properties of Nylon12/NR blend. The formation of succinimide linkages via an imidization reaction at Nylon12/NR interfaces caused an increase of shear viscosity and a reduction of extrudate swell while viscosity ratio approached to 1 with increasing PS/MNR content up to 7 phr. The rubber particle appeared to be spherical with diameter and interparticle distance less than 0.5 and 0.3 μm, respectively. The compatibilized blends showed the enhancement of mechanical properties especially impact energy increased by a factor of 5.

บทคัดย่อ

สราวลี แสงทวีป: การเพิ่มความเหนียวของพอลิเอไมด์สิบสองด้วยยางธรรมชาติโดยผ่านความเข้ากันได้แบบไม่มีและแบบมีปฏิกิริยา (Toughness Enhancement of Polyamide 12 with Natural Rubber via Non-Reactive and Reactive Compatibilizations) อ. ที่ปรึกษา : รศ. ดร. รัตนวรรณ มกรพันธุ์ และ ศ. ดร. ชัดฮาน ซี จานา 244 หน้า

งานวิจัยนี้ศึกษาเกี่ยวกับการเพิ่มความเหนียวของพอลิเอไมด์สิบสอง (ไนลอนสิบสอง) ด้วยการเติมยางธรรมชาติโดยผ่านกระบวนการผสมแบบสภาวะหลอมเหลว โดยมีพอลิเมอร์ร่วมของพอลิสไตรีนกับยางธรรมชาติและพอลิเมอร์ร่วมของพอลิสไตรีนกับยางธรรมชาติมาเลเอตทำหน้าที่เป็นสารเชื่อมประสานทั้งแบบไม่มีปฏิกิริยาและแบบมีปฏิกิริยา ตามลำดับ ผลพบว่าสารเชื่อมประสานแบบไม่มีปฏิกิริยาปรับปรุงความเข้ากันได้ของไนลอนสิบสองและยางธรรมชาติโดยผ่านการเชื่อมโยงทางกายภาพ นำไปสู่การกระจายตัวที่ดีของยางธรรมชาติในไนลอนสิบสองเมทริกซ์และการเพิ่มขึ้นของพลังงานการกระแทกประมาณ 3 เท่า สารเชื่อมประสานแบบมีปฏิกิริยาถูกใช้ต่อมา เพื่อเพิ่มการยึดติดที่พื้นผิวระหว่างไนลอนสิบสองและยางธรรมชาติโดยผ่านการเชื่อมโยงทางเคมี อย่างไรก็ตามกระบวนการผสมพอลิเมอร์ร่วมของพอลิสไตรีนกับยางธรรมชาติมาเลเอตที่แตกต่างกัน (การผสมแบบขั้นตอนเดียวและสองขั้นตอน) รวมทั้งปริมาณมาเลอิกแอนไฮไดรด์ มีผลต่อปริมาณการเชื่อมโยงของยาง (เจล) และประสิทธิภาพการกราฟต์มาเลอิกแอนไฮไดรด์ ซึ่งผลพบว่าพอลิเมอร์ร่วมของพอลิสไตรีนกับยางธรรมชาติมาเลเอตที่เตรียมโดยใช้กระบวนการผสมแบบสองขั้นตอนและมาเลอิกแอนไฮไดรด์ในปริมาณต่ำ มีปริมาณเจลน้อยกว่าและมีประสิทธิภาพการกราฟต์มาเลอิกแอนไฮไดรด์สูงกว่า นอกจากนั้นปริมาณของสารเชื่อมประสานแบบมีปฏิกิริยาที่แตกต่างกันมีผลต่อสมบัติต่างๆ ของพอลิเมอร์ผสมระหว่างไนลอนสิบสองและยางธรรมชาติด้วย ซึ่งการสร้างการเชื่อมต่อซัคซินิไมด์โดยผ่านปฏิกิริยาอิมิไดเซชันที่ส่วนต่อประสานของไนลอนสิบสองและยางธรรมชาติ เป็นสาเหตุของการเพิ่มขึ้นของค่าความหนืดแบบเฉือนและการลดลงของการบวมตัว ขณะที่อัตราส่วนความหนืดมีค่าใกล้เคียงหนึ่งเมื่อเพิ่มปริมาณสารเชื่อมประสานจนถึง 7 ส่วนในร้อยส่วนพอลิเมอร์ อนุภาคของยางจึงมีลักษณะเป็นทรงกลมด้วยขนาดและระยะห่างระหว่างอนุภาคที่น้อยกว่า 0.5 และ 0.3 ไมโครเมตร ตามลำดับ พอลิเมอร์ผสมที่ถูกปรับปรุงความเข้ากันได้จึงแสดงสมบัติเชิงกลที่ดีขึ้น โดยเฉพาะอย่างยิ่งค่าพลังงานการกระแทกเพิ่มขึ้น 5 เท่า

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ABBREVIATIONS

ATR-FTIR	Attenuated Total Reflection-Fourier Transform Infrared Spectroscopy
DCP	Dicumyl Peroxide
DSC	Differential Scanning Calorimetry
MA	Maleic Anhydride
NR	Natural Rubber
PA12	Polyamide 12 (Nylon12)
PS	Polystyrene
PS/MNR	Polystyrene/Maleated Natural Rubber Copolymer
PS/NR	Polystyrene/Natural Rubber Copolymer
SEM	Scanning Electron Microscopy
TGA	Thermogravimetric Analysis

LIST OF SYMBOLS

T_g	Glass Transition Temperature
T_m	Melting Temperature
T_c	Crystallization Temperature
χ_c	Degree of Crystallinity
τ	Shear Stress
$\dot{\gamma}$	Shear Rate
η	Viscosity
n	Power Law Index
K	Flow Consistency Index or Viscosity Coefficient Index
T	Temperature
R	Universal Gas Constant
E_a	Flow Activation Energy
D	Diameter
D_{ip}	Interparticle Distance
ϕ_c	Volume Fraction of Continuous Phase
ϕ_d	Volume Fraction of Disperse Phase
ϕ_r	Volume Fraction of Rubber Phase