AN INSIGHT ON PROCESSING AND CHARACTERIZATION OF IN-SITU AND IN-SITU HYBRID COMPOSITES WITH LIQUID CRYSTALLINE POLYMERS

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A Dissertation Submitted in Partial Fulfilment of the Requirements
for the Degree of Doctor of Philosophy
The Petroleum and Petrochemical College, Chulalongkorn University
in Academic Partnership with
The University of Michigan, The University of Oklahoma,
and Case Western Reserve University
2010

Thesis Title:	An insight on processing and characterization of in-situ and in-situ hybrid composites with liquid crystalline polymers
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ABSTRACT

4882001063: Polymer Science Program

Penwisa Pisitsak: An Insight on Processing and Characterization of In-Situ and In-Situ Hybrid Composites with Liquid Crystalline Polymers.

Thesis Advisors: Assoc. Prof. Rathanawan Magaraphan *(Thai Advisor)*, Prof. Sadhan C. Jana *(Overseas Co-Adviser)*

Keywords: In-situ composite/ Liquid crystalline polymer/ Multi-walled carbon nanotube/ Zinc oxide

Blends of a liquid crystalline polymer (LCP) and a thermoplastic are generally immiscible. They are termed as 'in–situ composites', taking into account of the formation of LCP fibrils capable of reinforcing the resulting blends. Blends of Vectra A950 (VA950) with poly(trimethylene terephthalate) (PTT) showed better melt processibility as a result of partial LCP fibrillation. The best LCP dispersion was found at the lowest processing temperature and the smallest LCP content. The modulus and thermal stability were improved. VA950 was found to accelerate the non–isothermal crystallization rate of the PTT phase by serving as a nucleating agent. The microwave–synthesized spherical zinc oxide (ZnO) particles were introduced to the blends of VA950 and poly(ethylene terephthalate) (PET). ZnO reduced the LCP fibrillation owing to its lubricating effect, retarded the PET melt crystallization rate, and yet improved the tensile modulus. An increase in the extent of triclinic crystalline phase of PET as induced by microwave radiation was promoted in the presence of VA950, yielding improved mechanical properties. Multi-walled carbon nanotubes (CNTs) were introduced to polycarbonate/ LCP blends where the LCP chosen were VA950 and Vectra V400P (V400P). CNTs showed better affinity with LCP and consequently prohibited LCP fibrillation leading to the disruption of conductive pathways. As a result, a greater CNT loading was required to reach a percolation threshold compared to the composites without LCP. The value of storage modulus showed improvement by the addition of CNTs or VA950.

บทคัดย่อ

เพ็ญวิสาข์ พิสิฏฐศักดิ์ : ชื่อหัวข้อวิทยานิพนธ์ (ภาษาไทย) การศึกษากระบวนการขึ้นรูปและวิเคราะห์สมบัติของอินซิทู และ อินซิทู ไฮบริด คอมพอสิต ซึ่งมีส่วนผสมของพอลิเมอร์ผลึกเหลว (An Insight on Processing and Characterization of In-Situ and In-Situ Hybrid Composites with Liquid Crystalline Polymers) อาจารย์ที่ปรึกษา : รศ.ดร. รัตนวรรณ มกรพันธุ์ (อ. คนไทย) และ ศ. ดร. ซัดฮาน ซี จานา (อ. ที่ปรึกษาร่วมชาวต่างประเทศ) 206 หน้า

พอลิเมอร์ผสมระหว่างพอลิเมอร์ผลึกเหลว (แอลซีพี) และเทอร์โมพลาสติกโดยทั่วไปเป็นพอลิเมอร์ผสมแบบไม่เข้ากัน พอลิเมอร์ผสมเช่นนี้มักถูกเรียกว่า อินซิทู คอมพอสิต เนื่องจากแอลซีพีที่เปลี่ยนรูปเป็นเส้นใยสามารถช่วยเสริมแรงได้ เมื่อผสมเวคตร้า เอ 950 (เวคตร้าเอ) เข้ากับพอลิไตรเมธิลีน เทเรพธาเลต (พีทีที) พบว่าสมบัติการไหลดีขึ้นเนื่องจากเวคตร้าเอบางส่วนอยู่ในรูปของเส้นใย การกระจายตัวของเวคตร้าเอดีที่สุดเมื่อผสมที่อุณหภูมิต่ำและใช้เวคตร้าเอน้อยที่สุด พบด้วยว่าเวคตร้าเอทำให้ค่ามอดูลัสและเสถียรภาพทางความร้อนดีขึ้น เวคตร้าเอยังเป็นตัวเหนี่ยวนำการเกิดผลึกของพีทีที ช่วยให้การตกผลึกแบบอุณหภูมิไม่คงที่ของพีทีทีเกิดเร็วขึ้น ต่อมาได้ทำการศึกษาพอลิเมอร์ผสมระหว่างเวคตร้าเอ กับ พอลิเอธิลีน เทเรพธาเลต (พีอีที) โดยเติมซิงค์-ออกไซด์ในรูปอนุภาคกลมซึ่งสังเคราะห์ขึ้นโดยใช้คลื่นไมโครเวฟ พบว่าซิงค์ออกไซด์ไปลดแรงเสียดทานในการไหลทำให้เส้นใยของเวคตร้าเอลดลง และยังลดความเร็วในการตกผลึกของพีอีทีอย่างไรก็ตามค่ามอดูลัสของคอมพอสิตยังคงเพิ่มขึ้น เมื่อผ่านคลื่นไมโครเวฟ พบว่าในระบบที่ผสมกับเวคตร้าเอให้ค่าระดับความเป็นผลึกชนิดไตรคลินิกสูงกว่าปกติ เป็นผลให้สมบัติเชิงกลของระบบดีขึ้นด้วย นอกจากนี้ยังได้ทำการศึกษาผลของการเติมท่อนาโนคาร์บอนชนิดผนังหลายชั้นลงในพอลิเมอร์ผสมของพอลิคาร์บอเนต/แอลซีพี โดยแอลซีพีที่เลือกใช้มีสองเกรดคือ เวคตร้าเอ และเวคตร้าวี 400พี พบว่าท่อนาโนคาร์บอกเลือกที่จะอยู่ในแอลซีพี ซึ่งมีผลทำให้เฟสของแอล-ซีพีขาดจากกัน ดังนั้นเส้นทางการนำไฟฟ้าจึงลดลง เป็นผลให้ต้องใช้ปริมาณท่อคาร์บอนเพื่อให้ถึงระดับเพอร์โคเลชั่นเทรชโฮลด์มากกว่าระบบที่ไม่ใส่แอลซีพี การผสมเวคตร้าเอหรือท่อนาโนคาร์บอนส่งผลให้ค่ามอดูลัสสะสมสูงขึ้น

ACKNOWLEDGEMENTS

The author would like to express her sincere gratitude to her adviser Dr. Rathanawan Magaraphan for her intensive suggestions, patience, and encouragement throughout this study.

The author would like to extend her gratitude to Dr. Sadhan C. Jana at The University of Akron (UA) for his guidance and support for partial work in this dissertation.

The author is grateful for the financial support provided by the Thailand Research Fund (TRF-RGJ Program), the Development and Promotion of Science and Technology Talents Project (DPST) scholarship, Polymer Processing and Polymer Nanomaterials Unit, the Asian Development Bank (ADB), The Petroleum and Petrochemical College, and National Center of Excellence for Petroleum, Petrochemicals, and Advanced Materials, Thailand.

Special thanks go to all of The Petroleum and Petrochemical College's faculties who have provided her with invaluable knowledge, and to the College staffs for their helpfulness at every stage of this research.

Also, the author would like to express her appreciation to the PPC friends and her friends in UA for their friendly assistance, cheerfulness, creative suggestions, and encouragement.

Finally, the author would like to dedicate this dissertation to her family for their love, understanding, and support.

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ABBREVIATIONS

CNT	Multi-Walled Carbon Nanotube
DSC	Differential Scanning Calorimetry
EDX	Energy Dispersive X-ray
HBA	p-Hydroxybenzoic Acid
HNA	2-Hydroxy-6-Naphthoic Acid
IV	Intrinsic Viscosity
LCP	Liquid Crystalline Polymer
PC	Polycarbonate
PET	Poly(ethylene terephthalate)
POM	Polyoxymethylene
PTT	Poly(trimethyelene terephthalate)
SAN	Poly(styrene-acrylonitrile)
SEM	Scanning Electron Microscopy
TEM	Transmission Electron Microscopy
TGA	Thermogravimetric Analysis
TP	Thermoplastic
V400P	Vectra V400P
VA	Vectra A950
VA950	Vectra A950
WAXD	Wide Angle X-ray Diffraction
XRD	X-Ray Diffractometer
ZnO	Zinc Oxide

LIST OF SYMBOLS

Ca	Capillary Number
η_m	Matrix Viscosity
γ	Shear Rate
τ	Shear Stress
σ	Interfacial Tension
R	Droplet Radius
T	Temperature
$K(T)$	Crystallization Rate Constant
ϕ	Cooling Rate
m	Ozawa Exponent
η_a	Melt Viscosity
E_a	Activation Energy
t	Time
$t_{0.5}$	Half-Time of Crystallization
T_{cp}	Peak Crystallization Temperature
T_{ci}	Initial Crystallization Temperature
T_{cf}	Final Crystallization Temperature
T_g	Glass Transition Temperature
T_m	Melting Temperature
T_{cc}	Cold-Crystallization Temperature
T_c	Melt-Crystallization Temperature
T_d	Decomposition Temperature
ΔH_c	Heat of Crystallization
ΔH^*_c	Normalized Heat of Crystallization
ΔH^*_m	Enthalpy of Fusion
ΔH^*_m	Normalized Enthalpy of Fusion
$C(T)$	Relative Degree of Crystallinity
X	Percent Crystallinity

X_t	Relative Degree of Crystallinity as a Function of Time
$X(T)$	Relative Degree of Crystallinity as a Function of Temperature
n	Avrami Exponent
Z_t	Rate Constant
D	Crystallite Size
λ	X-ray Wavelength
A_0	Constant
B	X-ray Diffraction Broadening
θ_B	Peak Angle
R	Electrical Resistance
ρ	Electrical Resistivity
A	Area
L	Length
σ	Specific Conductivity
λ_{31}	Wetting Coefficient
γ	Interfacial Energy
ω_{12}	Spreading Coefficient
θ	Contact Angle
η^*	Complex Viscosity
G'	Storage Modulus
f	Electric Field Frequency
Q	Dielectric per Unit Volume
ε	Relative Permittivity
δ	Loss Angle
ε_0	Absolute Permittivity of Free Space
E	Electric Field Strength
R	Universal Gas Constant