

**THE INFLUENCE OF PROCESSING HISTORY ON THE  
FRACTURE SURFACES OF HDPE, HDPE AND  
PET BLENDS, NYLON 6,6, AND PEI**

Ms. Chatchayanee Kumcharoen

A Thesis Submitted in Partial Fulfillment of the Requirements  
for the Degree of Master of science  
The Petroleum and Petrochemical College  
Chulalongkron University  
in Academic Partnership with  
The University of Michigan, The University of Oklahoma  
and Case Western Reserve University  
1996  
ISBN 974-633-847-1

**Thesis Title** : The Influence of Processing History on the Fracture Surfaces of HDPE, HDPE and PET blends, Nylon 6,6 and PEI

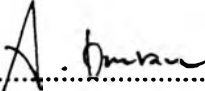
**By** : Ms. Chatchayanee Kumcharoen

**Program** : Polymer Science

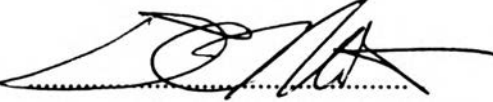
**Thesis Advisors** : 1. Asst. Prof. David C. Martin  
2. Assoc. Prof. Kanchana Trakulcoo


---

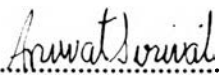
Accepted by the Petroleum and Petrochemical College, Chulalongkorn University, in Partial Fulfillment of the Requirements for the Degree of Master of Science.

  
..... Director of the College  
(Prof. Somchai Osuwan)

Thesis Committee

  
.....  
(Asst. Prof. David C. Martin)

  
.....  
(Assoc. Prof. Kanchana Trakulcoo)

  
.....  
(Assoc. Prof. Anuvat Sirivat)

## ABSTRACT

## 942001 : MAJOR POLYMER SCIENCE

KEYWORDS: FRACTOGRAPHY / MORPHOLOGY / FRACTURE SURFACE / PROCESSING HISTORY / HDPE / PEI / NYLON 6,6 : CHATCHAYANEE KUMCHAROEN : THE INFLUENCE OF PROCESSING HISTORY ON THE FRACTURE SURFACES OF HDPE, HDPE AND PET BLENDS, NYLON 6,6, PEI : THESIS ADVISORS : ASST. PROF. DAVID C. MARTIN, PH.D. AND ASSOC. PROF. KANCHANA TRAKULCOO, PH.D., 54 PP. ISBN 974-633-847-1

The effects of reprocessing on the mechanical fracture surfaces of engineering plastics; Nylon 6,6 and polyether imide (PEI) were studied and compared with commodity plastics; HDPE and HDPE-PET blends. The fracture surfaces were examined by scanning electron microscope with gold coated surface. Fractography of each material showed sharp differences and the processing history had some effects on the morphological structure. In virgin and reprocessed HDPE, the fracture surfaces exhibited discontinuous growth bands perpendicular to the crack direction. The crack morphology of reprocessed engineering plastics showed a mirror region in the crack initiation step and hackle lines in the crack propagation step.

## บทคัดย่อ

ชัชฎาณี คำเจริญ: ผลของการนำกลับมาผลิตใหม่ต่อรอยแตกของพื้นผิวของโพลิเอทิลีนความหนาแน่นสูง พลาสติกผสมของโพลิเอทิลีนความหนาแน่นสูง และโพลิเอทิลีนเทรฟทาเลต, ไนลอน 6,6 และโพลิเอเทอร์อะมาด์ อ.ที่ปรึกษา : ผศ.ดร. เดวิด ซี มาร์ติน, รศ. ดร. กัญญา ตระกูลฤ 54 หน้า ISBN 974-633-847-1

เมื่อเปรียบเทียบ โครงสร้างอนุภาคของพื้นผิวรอยแตกระหว่างพลาสติกวิศวกรรม (ไนลอน 6,6 และ โพลิเอเทอร์อะมาด์) และพลาสติกทางการค้า (โพลิเอทิลีนความหนาแน่นสูงและพลาสติกผสมของโพลิเอทิลีนความหนาแน่นสูงและโพลิเอทิลีนเทรฟทาเลต) ด้วยกล้องจุลทรรศน์อิเล็กตรอนแบบกราดลำแสง โดยชิ้นงานจะเคลือบด้วยทองคำก่อนนำมาศึกษา การแตกของวัสดุจะแตกต่างกันขึ้นกับชนิดของวัสดุ และจำนวนครั้งในการนำกลับมาผลิตใหม่ของวัสดุแต่ละชนิด กลไกการแตกของโพลิเอทิลีน ความหนาแน่นสูงบริสุทธิ์ และโพลิเอทิลีนความหนาแน่นสูงที่นำกลับมาผลิตใหม่แสดงแถบการขยายตัวที่ไม่ต่อเนื่องในทิศทางที่ตั้งฉากกับทิศทางของการแตกและการแผ่ขยายของรอยแตก ส่วนจุดเริ่มต้นของการแตกของพลาสติกวิศวกรรมมักจะเริ่มต้นด้วยบริเวณของมิลเลอร์ และขยายรอยแตกต่อไปด้วยลักษณะของเส้นเฮกเคิล

## ACKNOWLEDGMENTS

The author is grateful to my advisors, Asst. Prof. David C. Martin for the helpful suggestions and I would like to give my special thanks to Assoc. Prof. Kanchana Trakulcoo who contributed a good deal to this work.

I would like to express my appreciation to the TOTAL exploration and production Thailand for the scholarship support. I also wish to thank all of the staff and my friends at the Petroleum and Petrochemical College, Chulalongkorn University, for their help and kindness.

Finally, special thanks to my parents and my sisters for encouraging and supporting in everything for my study and all of my life.

**TABLE OF CONTENTS**

<b>CHAPTER</b>		<b>PAGE</b>
	Title Page	i
	Abstract	iii
	Acknowledgments	v
	Table of Contents	vi
	List of Tables	viii
	List of Figures	ix
<b>I</b>	<b>INTRODUCTION</b>	
	1.1 General Morphology of the Fracture Surface	1
	1.1.1 Mirror Region	2
	1.1.2 Hackle Region	2
	1.1.3 Wallner Lines	3
	1.1.4 Discontinuous Growth Bands	3
	1.1.5 Parabolic Marking	4
	1.2 Background and Literature Review	4
	1.3 Objectives	6
<b>II</b>	<b>EXPERIMENTAL PART</b>	
	2.1 Materials	7
	2.2 Processing	7

<b>CHAPTER</b>	<b>PAGE</b>
2.3 Specimen Preparation	8
2.4 Mechanical Test	9
2.5 Scanning Electron Microscope	9
<b>III RESULTS AND DISCUSSION</b>	
3.1 High Density Polyethylene	10
3.1.1 Fractography of High Density Polyethylene	10
3.1.2 Effects of Processing History	14
3.2 HDPE and PET Blends	18
3.2.1 Effects of Processing History	18
3.2.2 Ternary Blends : HDPE/PET/MA	21
3.3 Nylon 6,6	24
3.3.1 Fractography of Nylon 6,6	24
3.3.2 Tensile Fracture Surface of Nylon 6,6	28
3.3.3 Effects of Processing History	29
3.4 Polyetherimide	31
3.4.1 Tensile Fracture Surface of Polyetherimide	31
3.4.2 Impact Fracture Surface of Polyetherimide	34
3.4.3 Effects of Processing History	34
<b>IV CONCLUSIONS</b>	<b>39</b>
<b>REFERENCES</b>	

**LIST OF TABLES**

<b>TABLE</b>		<b>PAGE</b>
2.1	Typical extrusion parameter for HDPE, HDPE/PET, Nylon and PEI	8
2.2	Compression molding condition for HDPE, HDPE/PET, Nylon and PEI	9



## LIST OF FIGURES

FIGURE	PAGE
3.1 A schematic of impact fracture surface of HDPE Semicrystalline polymer.	11
3.2 SEM photograph of half circular region and patchy region of impact fracture surface of HDPE.	11
3.3 SEM photograph of propagation region of impact fracture surface of HDPE (a) x100 (b) x3500.	13
3.4 SEM photograph of impact fracture surface of HDPE (a) Virgin (b) Reprocessed material.	15
3.5 SEM photograph of post-consumer HDPE showing the discontinuous growth bands of impact fracture surface.	16
3.6 SEM photograph showing impurity of the impact fracture surface in (a) patchy region (b) discontinuous growth bands.	17
3.7 SEM photograph of impact fracture surface of blends at ratio 95/5 (x500) (a) initial process (b) reprocessed 5 passes.	19
3.8 SEM photograph of impact fracture surface of blends at ratio 95/5 (x2,000) (a) initial process (b) reprocessed 5 passes.	20
3.9 SEM photograph of (a) binary blends at ratio 90/10 and (b) ternary blends at ratio 85/10/5	22
3.10 SEM photograph of ternary blends (x5,000) (a) impact fracture surface at ratio 75/20/5 (b) tensile fracture surface at ratio 75/20/5.	23

<b>FIGURE</b>	<b>PAGE</b>
3.11 A schematic of impact fracture surface of Nylon 6,6: (a) impact fracture surface; (b) impact break.	25
3.12 SEM photograph of impact fracture surface of mirror region and hackle region of Nylon 6,6.	26
3.13 SEM photograph of hackle lines at higher magnification.	26
3.14 SEM photograph of impact fracture surface of secondary crack of Nylon 6,6.	27
3.15 SEM photograph of tensile fracture surface of Nylon 6,6. (a) crack generate by defect and (b) nucleation during specimen was stretched.	28
3.16 SEM photograph of impact fracture surface showing mirror region and hackle region of Nylon 6,6.	30
3.17 SEM photograph showing transition region of tensile fracture surface of PEI.	32
3.18 SEM photograph showing rough region of tensile fracture surface of PEI.	32
3.19 SEM photograph of tensile fracture surface of PEI.	33
3.20 SEM photograph of impact fracture surface of PEI (a) showing area near the notch (b) showing the latter field along the crack direction.	35
3.21 SEM photograph of impact fracture surface of reprocessed PEI (a) x35 (b) x500.	36
3.22 SEM photograph of impact fracture surface of PEI showing Wallner lines (a) Interspersed in hackle lines (b) at higher magnification.	38