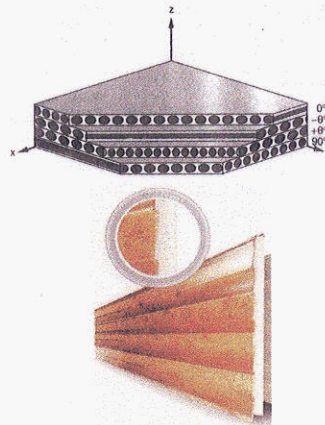
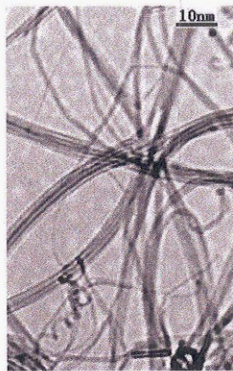




# Fiber-Reinforced Polymer Composites

---



Nittaya Rattanasom (Ph.D., Polymer Science)

Institute of Molecular Biosciences  
Mahidol University

# CONTENTS

---

	Page
CHAPTER 1: INTRODUCTION TO COMPOSITES.....	1
1.1 Definition and General Characteristics.....	1
1.2 Classification of Composites.....	2
1.2.1 Metal Matrix Composites (MMC's) .....	2
1.2.2 Ceramic Matrix Composites (CMC's) .....	3
1.2.3 Polymer Matrix Composites (PMC's) .....	4
1.3 Types of Polymer Matrix Composites.....	4
1.3.1 Particulate-reinforced Composites.....	4
1.3.2 Fiber-reinforced Composites.....	5
1.3.2.1 Short-fiber composites.....	5
1.3.2.2 Hybrid composites.....	5
1.3.2.3 Continuous-fiber composites.....	5
1.4 Advantages of Polymer Composites.....	8
1.5 Disadvantages of Polymer Composites.....	10
1.6 Polymer Composite Applications.....	11
CHAPTER 2: MATRIX MATERIALS AND FIBERS.....	18
2.1 Matrix Materials.....	18
2.1.1 Classification of Matrix Materials.....	18
2.1.2 Thermosets.....	19
2.1.2.1 Unsaturated polyester resins.....	19
2.1.2.2 Vinyl ester resins.....	21
2.1.2.3 Phenolic resins.....	22
2.1.2.4 Epoxy resins.....	24
2.1.3 Thermoplastics.....	27
2.1.3.1 High density polyethylene.....	27
2.1.3.2 Poly(ether ether ketone) .....	28
2.1.3.3 Poly(phenylene sulfide) .....	29

	Page
2.1.3.4 Thermoplastic polyimide.....	30
2.1.4 Comparison between Thermoplastics and Thermosets.....	31
2.1.5 Rubbers.....	32
2.1.5.1 Fluorocarbon rubber.....	32
2.1.5.2 Nitrile rubber and halogenated nitrile rubber.....	33
2.1.5.3 Polyurethane.....	34
2.2 Fibers.....	36
2.2.1 Terminology Used for Describing the Physical Nature of Reinforcing Fibers.....	39
2.2.2 Types of Fibers.....	39
2.2.2.1 Glass fibers.....	39
2.2.2.2 Carbon fibers.....	41
2.2.2.3 Aramid fibers.....	44
2.2.2.4 High strength polyethylene fibers.....	46
2.2.2.5 Boron fibers.....	47
2.2.2.6 Carbon nanotubes.....	49
CHAPTER 3: MANUFACTURING.....	52
3.1 Materials Used for Molding.....	52
3.1.1 Prepreg.....	52
3.1.2 Sheet Molding Compound.....	53
3.1.3 Dough Molding Compound.....	55
3.2 Fabrication Processes.....	56
3.2.1 Hand Lay-up Process.....	56
3.2.2 Spray-up Process.....	57
3.2.3 Vacuum Bagging and Pressure Bagging.....	58
3.2.4 Vacuum Bag and Autoclave Cure.....	59
3.2.5 Filament Winding.....	60
3.2.6 Pultrusion.....	61
3.2.7 Rotational Molding.....	63

	Page
3.2.8 Compression Molding.....	64
3.2.9 Resin Transfer Molding.....	64
3.2.10 Reinforced reaction injection molding and Structural Reaction Injection Molding.....	66
3.2.11 Injection Molding.....	68
CHAPTER 4: MECHANICS OF REINFORCEMENT.....	70
4.1 Unidirectional Continuous Fiber Composites.....	71
5.1.1 Longitudinal Tensile Loading.....	71
5.1.2 Transverse Tensile Loading.....	76
4.2 Short Fiber Composites.....	79
CHAPTER 5: FIBER-MATRIX INTERFACE.....	81
5.1 Significance of Polymer Composite Interface.....	81
5.2 Surface characterization.....	82
5.2.1 Surface Spectroscopy.....	82
5.2.2 Microscopy.....	82
5.2.3 Wettability Measurement.....	82
5.3 Interfacial Adhesion between Fiber and Matrix.....	83
5.3.1 Concept of Interfacial Strength.....	83
5.3.2 Evaluation of Interfacial Shear Strength.....	84
5.3.2.1 Single fiber pull-out test.....	84
5.3.2.2 Microbond test.....	85
5.3.2.3 Micro-debonding test.....	86
5.3.2.4 A single fiber fragmentation test or critical length method.....	87
5.3.2.5 Short beam shear test (ASTM D2344).....	88
5.4 Fiber-Matrix Failure.....	89
5.4.1 Mechanisms of Failure.....	89
5.4.2 Shape of Fiber Breaks.....	90
REFERENCES.....	92

APPENDIX A: List of abbreviations .....	99
APPENDIX B: List of selected symbols.....	101
INDEX.....	102