

Contents

Foreword / vii

Preface / ix

1 HISTORY OF COMPOSITES, *Dominick V. Rosato* / 1

Introduction / 1 Evolution of Composites / 3 Baekeland's Progress / 4 Transfer Molding / 5 Progress at Formica—A Typical Case History / 5 Structural RP / 6 Military R&D / 6 First Successful RP Flight Structure / 7 Commercial Growth / 7 Consumption / 8 Reinforced Thermoplastics (RTP) / 9 Research and Development / 10 Chronology of Reinforced Plastics Composites and Machinery / 12

SECTION I/RAW MATERIALS

2 POLYESTER RESINS, *Melvin Rubin* / 23

Introduction / 23 Manufacturing / 24 Chemistry / 25 Properties / 28 Curing / 32 Reinforcing Materials / 42

3 EPOXY RESINS, *Elliot N. Dorman* / 46

Introduction / 46 Manufacture / 50 Commercial Resins / 53 Hardening Methods / 57 Modifications / 67 Resin Systems / 72 Applications / 73 Handling and Processing / 79

4 PHENOLICS AND SILICONES, *Harry J. Doyle and S. C. Harrier* / 85

Phenolic Resins / 85 Manufacture / 89 Silicone Resins / 106

5 HIGH TEMPERATURE RESISTANT POLYMERS, *Harold Levine* / 114

Introduction / 114 Basis for High Temperature Properties / 115 Various Considerations / 115 Kinds of High Temperature Resistant Polymers / 117 Future Considerations / 124

- 6 GLASS FILLED THERMOPLASTICS, Donald V. Rosato / 128**
Types of Composites / 128 Fabrication Techniques / 131
- 7 GLASS FIBERS, David G. Mettes / 143**
Introduction / 143 General Performance Characteristics / 143
Applications / 144 Fiber Production / 146 Glass
Compositions / 150 Forms of Commercial Fibers / 154 Surface
Treatments / 167 Principles for Using Glass Fiber Reinforced
Plastic / 169 Fabrications Processes / 173 Properties of Glass
Fiber Reinforced Plastic / 180 Future / 181
- 8 ASBESTOS, Donald V. Rosato / 182**
Introduction / 182 Types of Fibers / 184 Forms of
Asbestos / 185 Data on Asbestos Composites / 185
Applications / 188 Summary / 190
- 9 HIGH SILICA AND QUARTZ, Hugh Shulock / 191**
Definitions / 191 History / 192 Forms / 192 Uses / 192
Costs and Pricing / 193 Physical and Mechanical Properties / 195
Chemical Properties / 197 Thermal Properties / 197
Properties of Composites / 198
- 10 BORON FILAMENTS AND OTHER REINFORCEMENTS PRODUCED
BY CHEMICAL VAPOR PLATING, Lloyd E. Line, Jr. and
U. V. Henderson, Jr. / 201**
Introduction / 201 Production of Continuous Boron
Filament / 202 Properties of Boron Filaments / 204 Structure
and Morphology / 208 Other Filaments by Chemical Vapor
Plating / 231 Closing Remarks / 234
- 11 GRAPHITE REINFORCEMENT FOR PLASTIC COMPOSITES,
John C. Bowman and John H. Brannan / 237**
Introduction / 237 Yarns / 239 High Strength, High Modulus
Graphite Filaments / 241 Cloths / 243 Other
Constructions / 246 Graphite Fiber Composites / 247
- 12 WHISKERS AND THEIR COMPOSITES, John V. Milewski,
James J. Shyne, and Robert C. Shaver / 255**
Introduction / 255 Available Types and Forms of Whiskers and

Whisker Products / **258** Methodology in Compositing (with Whiskers) / **259** Applications / **272** New Fibers and Ideas with Whiskers / **274** Future Cost and Production of Whiskers / **279**

SECTION II/PROCESSING METHODS

13 HAND LAY-UP TECHNIQUES, *Armand G. Winfield* / **285**

A Simple Hand Lay-up / **289** A Complex Hand Lay-up / **293**
 Drapage Molding / **297** Spray-up / **299** Wet Lay-up—Low
 Compression Molding / **301** Moldless Lay-ups / **302** Direct
 Lay-ups or One-Shot Techniques / **303**

14 STRUCTURAL LAMINATE BAG MOLDING PROCESS,

Sam F. Monroe and Bill E. Chitwood / **306**

Introduction / **306** General Description of Processes / **307** The
 Bag Molding Team / **308** Bag Molding Materials and
 Properties / **311** Structural Property Determination and
 Relation / **313** Bag Molding Processing Specification / **315**
 Quality Control Procedures / **318** Production Procedures / **320**
 General Description of Curing Equipment / **326** Detailed Curing
 Operation / **328** Summary / **331**

15 MATCHED DIE MOLDING, FABRIC, MAT AND PREFORM,

George Lubin / **335**

Introduction / **335** Definitions / **335** Scope / **336** Molding
 Considerations / **337** Mat Materials for Molding / **338**
 Continuous Fiber Mats / **338** Mold Taper for Matched
 Molds / **339** Chopped Glass Preforms / **339** Directed Fiber
 Preform Process / **343** Wet Slurry Process / **344** Preform
 Screens / **345** Preform Binders / **346** Molding with Fabrics / **348**
 Vacuum Injection Molding / **349** Displacement or "No Pressure"
 Matched Mold Molding / **355** Flexible Plunger Molding / **355**
 Molding Presses / **356** Nonmetallic Mold Materials / **358**
 Matched Metal Die Molding / **359** Matched Mold Materials and
 Mold Design / **359** The Positive Types of Molds / **360** Transfer
 Molds / **361** Open Flash Molds / **362** The Cut Off Mold / **363**
 Complex or Combination Molds / **364** Resins for Pressure
 Molding / **364** Summary / **367**

- 16 REINFORCED MOLDING COMPOUNDS, *Robert P. Young* / 369**
Definition / 369 History / 370 Properties / 372
Applications / 387 Materials / 392 Formulation / 398
Compounding / 401 Molding / 408 Mold Construction / 413
Molding Presses / 416 Design / 418
- 17 PREPREGS, *Herman Reffe* / 421**
History / 421 Prepreg Defined / 423 Prepreg Advantages / 423
Molding of Prepregs / 424 Resin-Reinforcement Combinations
—End Uses / 425 Prepreg Unidirectional Materials / 427
Prepregs for Ablative Applications / 431 Prepreg Mechanical
Properties Data / 432 A Look Ahead / 435
- 18 FILAMENT WINDING, *A. M. Shibley* / 438**
Introduction / 438 Basic Materials for Winding / 439 The
Winding Process / 449 Behavior of Filament Wound
Composites / 462 Summary / 482
- 19 CONTINUOUS PRODUCTION METHODS,
W. Brandt Goldsworthy / 485**
- 20 HONEYCOMB AND SANDWICH CONSTRUCTION,
Donald V. Rosato / 494**
Introduction / 494 Materials of Construction / 496 Design
Criteria / 514 Optimum Material Selection / 526 Filament
Wound Technology / 529 Fabrication / 533 Test Methods / 538
- 21 ABLATION, *Harry J. Doyle* / 540**
Definition / 540 Analysis / 540 History / 542
Applications / 544 Material Characteristics / 545
Environmental Effects / 547 Pyrolyzed and Graphitized
Plastics / 548 Modified Phenolic Ablators / 550
- 22 JOINING AND MACHINING TECHNIQUES, *S. Dastin* / 552**
Introduction / 552 Mechanical Fastening of Composites / 552
Adhesive Bonding of Composites / 565 Machining Techniques
for Composites / 584

SECTION III/DESIGN

- 23 DESIGN OF COMPOSITE MATERIALS, *V. G. Grinius and J. V. Noyes* / 595**
Introduction / 595 Analytical Methods / 596
Micromechanics / 597 Macromechanics / 616
- 24 BORON-EPOXY AIRCRAFT STRUCTURES, *R. N. Hadcock* / 628**
Introduction / 628 Comparative Mechanical Properties / 631
"Narmco 5505" Boron-Epoxy Composite / 633 Multidirectional Laminates / 643 Structural Analysis and Design / 653
- 25 TESTING OF REINFORCED PLASTICS, *George Epstein* / 661**
Introduction / 661 Documents on Test Methods for Reinforced Plastics / 664 General Considerations / 668 Testing of Raw Materials for Reinforced Plastics / 671 Nondestructive Test Methods for Reinforced Plastics / 691
- 26 TESTING METHODS FOR ADVANCED COMPOSITES, *Glenn C. Grimes and M. E. Bronstad* / 708**
General Test Methods / 708 Method AC-I, Advanced Composites Tension Test / 708 Method AC-II, Advanced Composites Flexure Test / 713 Method AC-III, Advanced Composites Interlaminar Shear Test (Short Beam Shear) / 717 Method AC-IV, Advanced Composites Tension/Compression with Sandwich Beam Test / 719 Other Test Methods / 725 Method X-1, Advanced Composites Compression Test / 725 Elevated Temperature Tests / 730 Method X-2, Advanced Composites Compression Test / 732 Method X-3, Advanced Composites Shear Modulus, G Test / 734 Method X-4, Advanced Composites Void Content Test (ASTM) / 739

SECTION IV/APPLICATIONS

- 27 MARINE APPLICATIONS, *N. Fried* / 747**
Introduction / 747 Marine Structural Laminates / 748
Response to Marine Environment / 751 Design of Marine Structures / 756 Applications / 756 Current and Future Developments / 767 Summation—Concluding Remarks / 781

28 REINFORCED PLASTICS FOR TRANSPORTATION ON WHEELS,*Robert S. Morrison / 784*Introduction / **784** Production vs Materials Costs / **785**FRP Properties as Related to Transportation / **786**What Reinforced Plastics to Use—Where and Why / **788**Resins and Reinforcements / **791** The Cross-over or Break-even
Point / **791** Improved, Mechanized, Automated Equipment / **793**Mechanization Not Enough / **794** Improved Equipment / **795**Low-Cost, High-Quality Auto and Truck Finishes / **796** Cases in
Point / **797** Conclusions / **800****29 PLASTICS IN AIRCRAFT AND AEROSPACE, *Dominick V. Rosato
and George Lubin / 801***Introduction / **801** Aircraft / **801** Applications / **805**Aerospace / **817****GLOSSARY / 833****APPENDIX / 867****INDEX / 884**