



# Contents

Contributors	xv
Preface	xvii
Introduction	xix

## Section 1 ADHESIVE BONDING

<b>Chapter 1. Understanding Adhesives</b> .....	<b>1-3</b>
Atoms	1-3
Molecules	1-4
Solvent	1-6
Polymers: Their Structure and Properties	1-9
Joint Formation	1-11
Curing Methods	1-14
<b>Chapter 2. Adhesion Theory and Review</b> .....	<b>2-1</b>
Introduction	2-1
Bonding Sequences	2-2
Surface Characterization	2-2
Theory	2-3
Contributory Factors	2-5
Mechanism for Bond Failure	2-8
Summation	2-14
<b>Chapter 3. Epoxy Adhesives</b> .....	<b>3-1</b>
Advantages	3-2
Chemical Modification of Base Epoxy Resin	3-4
Curing Agents and Their Modification	3-4

Fillers 3-6  
 Liquid Modifiers 3-8  
 Epoxies Alloyed with Other Resins 3-10  
 Typical Formulations of Epoxy Adhesives 3-12

**Chapter 4. Adhesive Bonding with Polyesters ..... 4-1**

Introduction 4-1  
 Commercial Polyester Resins 4-1  
 Commercial Reinforcements 4-3  
 Lamination of Glass Fabrics 4-3  
 Lamination of Woven Rovings 4-4  
 Lamination of Glass Fibers to Wood 4-5  
 Lamination of Glass Fibers to Metal 4-7  
 Lamination of Glass Fibers to Concrete 4-8  
 Laminations of Glass Fibers to Ceramics 4-10  
 Lamination of Glass Fibers to Foam and Honeycomb Substrates 4-11  
 Lamination of Glass Fibers to Other Plastics 4-12  
 Lamination of Glass Fibers to Gel Coats 4-13  
 Lamination of Gel Coats to Polyester-Glass Substrate 4-13  
 Putties, Filled Resins, Syntactics 4-15

**Chapter 5. Thermally Stable Heterocyclic Polymers as Adhesives ..... 5-1**

Background 5-1  
 Polybenzimidazole-based Adhesives 5-2  
 Polyimide-based Adhesives 5-3  
 New Approaches 5-6  
 Summary 5-8

**Chapter 6. Anaerobic Adhesives ..... 6-1**

Designing New Products with Anaerobic Adhesives—Liquid  
 Fastening and Bonding 6-1  
 Anaerobic Machinery Adhesives 6-6  
 Sealing Static Machinery Joints 6-14  
 How to Assure Successful Application of Anaerobic Machinery  
 Adhesives 6-15  
 Bonding with Anaerobic Structural Adhesives 6-19  
 Application Techniques 6-22

**Chapter 7. Sealants ..... 7-1**

Types of Sealants 7-1  
 Methods of Cure 7-2  
 Properties 7-6  
 Mechanical Properties 7-7  
 Applications 7-8  
 Design 7-10  
 Types of Sealant 7-12  
 Specifications 7-34

**Chapter 8. Hot-melt Adhesives** ..... **8-1**

- Introduction 8-1
- Characteristics 8-1
- Advantages 8-4
- Limitations 8-5
- How Hot-melt Adhesives Work 8-6
- Critical Properties 8-7
- Controlling Factors for Optimum Utilization 8-10
- Forms 8-16
- Equipment 8-17
- Handling of Hot Melts 8-18
- Guides to Running 8-21
- Direct Bonding and Heat Sealing 8-26
- Assisted Bonding 8-27
- Pressure-sensitive Hot Melts 8-28
- Troubleshooting 8-28
- Fields of Use 8-30

**Chapter 9. The Isocyanate or Urethane System in Adhesives and Sealants** **9-1**

- Safety Precautions in Handling Urethane Resins and Hardeners 9-11

**Chapter 10. Electromagnetic Bonding of Thermoplastic Materials** ..... **10-1**

- Electromagnetic Bonding of Thermoplastic Materials 10-1
- Principle of Electromagnetic Bonding 10-2
- Comparison of Process Over Other Conventional Techniques 10-2
- Advantages of Electromagnetic-bonding Technique 10-3
- Applications 10-3
- Heat Generated via Induction 10-4
- Theory of Induction Heating 10-5
- Induction Work Coil 10-6
- Joint Design 10-7

**Section 2 BONDING VARIOUS SUBSTRATES**

**Chapter 11. Bonding Aluminum** ..... **11-3**

- Surface Preparation 11-4
- Mechanical Cleaning 11-10
- Design Considerations 11-11
- Lap-Shear Joints 11-14
- Scarf Joints 11-20
- Butt Joint 11-21
- Peel Joints 11-21
- Corner Joints 11-22
- Angle Joints 11-24
- Flange Joints 11-25
- Other Joint Designs 11-28

<b>Chapter 12. Adhesive Bonding of Titanium and Its Alloys</b> .....	<b>12-1</b>
Introduction	12-1
Adherend Surface Preparation	12-2
Adhesive Selection	12-11
Novel Curing Techniques	12-21
<b>Chapter 13. Adhesive Bonding of Lead</b> .....	<b>13-1</b>
Forms of Lead	13-1
Properties and Grades of Lead	13-2
Choice of Adhesive	13-4
Stresses on Adhesive Bonds	13-7
Permanency of Adhesive Bonds	13-9
Design of Joints	13-13
Cleaning and Surface Preparation	13-13
<b>Chapter 14. Bonding Steels</b> .....	<b>14-1</b>
General Sequence of Practices	14-2
Method A	14-3
Method B. Carbon and Low-alloy Steels; The Hydrochloric Acid Etch	14-3
Method C. The Hydrochloric-Phosphoric-Hydrofluoric Etch	14-3
Method D. The Oxalic-Sulfuric Process	14-3
Method E	14-4
Method F	14-4
Method G	14-4
Method H	14-4
Method I	14-5
Method J	14-5
Method K	14-5
Method L	14-6
Method M	14-6
Method N	14-6
Tests for Proper Surface Preparation	14-7
Adhesive Selection	14-8
<b>Chapter 15. Principles of Magnesium Adhesive-bonding Technology</b> .....	<b>15-1</b>
Introduction	15-1
Understanding Magnesium	15-1
Surface Preparation	15-3
Design Aspects	15-6
Environmental Effects	15-6
Adhesive Selection	15-6
Summary	15-8
<b>Chapter 16. Bonding Elastomeric Compounds</b> .....	<b>16-1</b>
Elastomer Bonding—An Empirical Art	16-1
The Elastomeric Substrate	16-1
Structural Bonding	16-13
Nonstructural and Semistructural Bonding	16-17

<b>Chapter 17. Adhesive Bonding of Wood</b> .....	<b>17-1</b>
Properties of Wood That Affect Adhesive Bonding and Bond Performance	17-1
Preparation of Wood for Bonding	17-5
Types of Adhesives Used in Wood Bonding	17-7
Factors to Consider in Selection of an Adhesive for Wood Bonding	17-11
Joint Quality for a Given Adhesive	17-17
Some Typical Wood-bonding Applications	17-18
Test Methods and Specifications	17-26
<b>Chapter 18. Bonding Glass, Optics, Ceramics, and Related Substrates</b> ..	<b>18-1</b>
Optical Adhesives	18-1
Optically Transparent Adhesives	18-1
Glass Adhesives	18-2
Plastic Adhesives	18-2
Epoxies	18-5
Polysulfides, Polysulfide-Epoxies	18-6
Polyurethanes	18-6
Silicones	18-6
Neoprenes and Nitriles	18-6
Polyesters	18-6
Polycyanoacrylates	18-7
Cellulosics	18-7
Optical Identification	18-7
Testing-mounting Adhesives	18-7
Applying the Adhesive	18-8
Bonding Pad (Screw Supports)	18-8
Bonding Fiber Optics	18-9
Testing	18-12
Process Considerations	18-12
Bonding Glass	18-13
Method A	18-13
Method B	18-13
Bonding Ceramics, Pyrocerams, and Porcelain	18-13
Method A	18-14
Method B	18-14
<b>Chapter 19. Bonding Plastic Materials</b> .....	<b>19-1</b>
Solvents	19-2
Joining Technique	19-3
Acrylics	19-4
Acetates, Cellulose, and Related Plastics	19-6
Polycarbonates	19-7
Polyethylenes	19-9
Method A	19-10
Method B	19-10
Polypropylene	19-11
Phenylene Oxide	19-11
Polyamides (Nylon)	19-12

Polystyrene 19-12  
 Polyvinyl Alcohol (PVA), Polyvinyl Fluoride (PVF),  
 Polyvinyl Fluoride Acetate (PVAF),  
 and Polyvinyl Chloride (PVC) 19-13  
 Polyurethanes 19-15  
 Polysulfones 19-16  
 Polyethylene Tetrathalate, and Linear Polyesters (Mylar) 19-16  
 Method A 19-16  
 Method B 19-16  
 Method C 19-16  
 Method D 19-17  
 Fluorocarbons, Polytetrafluoroethylene (TFE),  
 Polyfluoroethylene (FEP), Polychlorotrifluoroethylene (CFE),  
 Polyvinylfluoride (PVF),  
 Polymonochlorotrifluoroethylene (KEL-F) 19-17  
 Amino Plastics (Urea and Melamine) 19-20  
 Polyether 19-20  
 Method A 19-20  
 Method B 19-21  
 Polyolefins 19-21  
 Phenoxies 19-21  
 Phenolics 19-21  
 Diallyl Phthalate 19-24  
 Silicones 19-25  
 Epoxy, Epoxide, and Epoxy Fiber Glass 19-25  
 Polyesters and Laminates 19-27  
 Inomers 19-27  
 Alkyds 19-27  
 Polyallomers 19-27  
 Conclusion 19-27

**Chapter 20. Honeycomb Structures . . . . . 20-1**

Introduction 20-1  
 The Effect of Filleting on Properties 20-2  
 Bare- vs. Bonded-honeycomb Compressive Properties 20-9  
 Analytical Determination of Honeycomb Stresses 20-14  
 Actual Stresses at the Adhesive Fillet 20-18  
 Experimental Procedures for Bonded Sandwich Construction 20-26  
 Sandwich Design 20-30  
 Definition of Terms 20-31

**Chapter 21. Surface Preparation for Bonding Beryllium and Other Adherends . . . . . 21-1**

Beryllium 21-1  
 Method A 21-2  
 Method B 21-2  
 Method C 21-2  
 Method D 21-2  
 Method E 21-3  
 Method F 21-3  
 Method G 21-3

Copper and Copper Alloys (Brass, Bronze) 21-3  
 Method A. Black Oxide Coating 21-3  
 Method B. Ammonium Persulfate Process 21-6  
 Method C. Ferric Chloride Process 21-6  
 Method D. Hydrochloric Acid–Ferric Chloride Process 21-6  
 Method E. Sodium Dichromate–Sulfuric Acid Process 21-6  
 Nickel and Nickel-base Alloys 21-6  
 Method A. Nitric Acid Process 21-6  
 Method B. Chromium Trioxide–Hydrochloric Acid Process 21-7  
 Method C. Manual Cleaning 21-7  
 Chromium and Chrome-plated Alloys 21-7  
 Zinc and Galvanized Metals 21-7  
 Tungsten and Tungsten Alloys 21-8  
 Cadmium, Silver, Gold Plating 21-8  
 Platinum 21-8  
 Tin 21-8  
 Iron (Cast) 21-8  
 Galvanized Metals 21-9  
 Graphite 21-9  
 Stonework 21-9  
 Brick 21-9  
 Jewels and Precious Stones 21-9  
 Leather 21-9  
 Concrete 21-9  
 Method A 21-9  
 Method B. Hydrochloric Acid No. 2 21-10

**Section 3 ADHESIVES FOR VARIOUS INDUSTRIES**

**Chapter 22. Adhesives in the Automobile Industry . . . . . 22-3**  
 Introduction 22-3  
 Structural Adhesive Bonding 22-6  
 Solvent or Evaporative Adhesive Bonding 22-11  
 Windshield/Back Light Adhesive Sealants 22-14  
 High-solids Sealers 22-19  
 Pressure-sensitive Adhesives 22-24  
 Hot-melt Adhesives 22-29  
 Summing Up 22-31

**Chapter 23. Adhesives in the Electronics Industry . . . . . 23-1**  
 Introduction 23-1  
 Bonding Requirements 23-2  
 Dielectric Adhesive Materials 23-2  
 Selection of Dielectric Adhesive 23-2  
 Design Considerations 23-5  
 Test Methods 23-5  
 Test Design Parameters 23-5  
 Vibration Tests 23-8  
 Summary 23-14

<b>Chapter 24. Adhesives for Space Systems</b> .....	<b>24-1</b>
Introduction	24-1
General Requirements	24-2
Typical Applications	24-4
Acknowledgments	24-22
<b>Chapter 25. Adhesives for the Construction Industry</b> .....	<b>25-1</b>
Construction Standards for Adhesives	25-2
Types of Adhesives Used in Construction	25-3
Intrinsic Qualities of Construction Adhesives	25-8
In the Future	25-9
<b>Chapter 26. Packaging Adhesives</b> .....	<b>26-1</b>
Corrugated	26-1
Folding-carton Adhesives	26-5
Laminating Adhesives	26-8
Tube-winding Adhesives	26-10
Setup-box Adhesives	26-12
Bag Adhesives	26-14
Label Adhesives	26-15
Machine Problems	26-17
<b>Chapter 27. Bonding Tools</b> .....	<b>27-1</b>
Plastic Bonding Tools	27-1
Composites to Form a Tool	27-5
Selection of Plastic Materials	27-6
<b>Chapter 28. Bonding Sandwich Fasteners</b> .....	<b>28-1</b>
Mechanically Installed Fasteners	28-2
Molded-in Inserts	28-5
Standard Test Procedures	28-6
<b>Chapter 29. Surgical and Dental Adhesives</b> .....	<b>29-1</b>
Surgical Adhesives	29-1
Dental Adhesives	29-3
<b>Chapter 30. Adhesives for the Handyman, Hobbyist, Sportsman, etc.</b> ..	<b>30-1</b>
Epoxies	30-3
Acrylics	30-4
Phenolics	30-4
Nitriles, Neoprenes, Butyls	30-4
Polysulfides	30-4
Cellulosics, Acetates, Butyrates	30-5
Polyurethanes	30-5
Silicones	30-5
Polyesters	30-5
Surface Preparation	30-6

Tooling 30-7  
 Adhesive Selection 30-8  
 Adhesive Mixing and Curing 30-8  
 Applying Adhesives 30-9  
 Curing Adhesives 30-9  
 Finishing 30-9  
 Repairs 30-10  
 Adhesives for the Hobbyist 30-15  
 Mold Making and Molding 30-18  
 Conclusions 30-19

**Section 4 TESTING, QUALITY CONTROL AND SPECIFICATIONS**

**Chapter 31. Techniques for Evaluation of Adhesives ..... 31-3**

Introduction 31-3  
 Tensile Tests 31-5  
 Shear Tests 31-7  
 Creep Testing 31-14  
 Peel Testing 31-18

**Chapter 32. Research and Development Adhesive Laboratory Testing .... 32-1**

Viscosity 32-2  
 Pot Life 32-3  
 Tack 32-4  
 Solids Content (Weight Loss) 32-4  
 Percent Volatiles 32-4  
 Penetration (Wetting) 32-5  
 Cure Rate 32-5  
 Hardness 32-5  
 Jell Time 32-5  
 Flow Tests 32-6  
 Lap Shear 32-6  
 Tensile Tests 32-7  
 Compressive-shear Test 32-11  
 Peel Tests 32-11  
 Creep Tests (See Chap. 30) 32-14  
 Fatigue Tests 32-14  
 Impact Tests 32-14  
 Cleavage Tests 32-14  
 Immersion Tests 32-15  
 Fire-resistance Tests 32-16  
 Bearing Strength 32-16  
 Compressive Strength and Modulus Compression 32-17  
 Ultimate Tensile Strength and Modulus of Elasticity 32-17  
 Testing Honeycomb and Sandwich Structures 32-17  
 Storage Tests 32-18  
 Elevated-temperature Tests 32-19  
 Static Heat Aging 32-19

**xiv Contents**

**Humidity-exposure Tests 32-21**

**Thermal-shock Tests 32-22**

**Core Shear Tests 32-25**

**Chapter 33. Specifications ..... 33-1**

**Military Specifications 33-4**

**Federal Specifications 33-8**

**Appendix follows Chapter 33**

**Glossary follows Appendix**

**Index follows Glossary**

