

---

# CONTENTS

---

|                              |   |              |
|------------------------------|---|--------------|
| <b>Foreword</b>              |   | <b>xi</b>    |
| <b>Preface</b>               |   | <b>xiii</b>  |
| <b>Acknowledgments</b>       |   | <b>xvii</b>  |
| <b>About the Authors</b>     |   | <b>xxi</b>   |
| <b>List of Abbreviations</b> |   | <b>xxiii</b> |
| <b>Chapter 1</b>             | <b>Introduction</b>                         | <b>1</b>     |
| 1.1                          | Prototype Fundamentals                      | 1            |
| 1.2                          | Historical Development                      | 7            |
| 1.3                          | Fundamentals of Rapid Prototyping           | 11           |
| 1.4                          | Advantages of Rapid Prototyping             | 14           |
| 1.5                          | Commonly Used Terms                         | 18           |
| 1.6                          | Classifications of Rapid Prototyping System | 19           |
|                              | References                                  | 22           |
|                              | Problems                                    | 23           |
| <b>Chapter 2</b>             | <b>Rapid Prototyping Process Chain</b>      | <b>25</b>    |
| 2.1                          | Fundamental Automated Processes             | 25           |
| 2.2                          | Process Chain                               | 26           |
| 2.3                          | 3D Modeling                                 | 27           |
| 2.4                          | Data Conversion and Transmission            | 28           |
| 2.5                          | Checking and Preparing                      | 29           |
| 2.6                          | Building                                    | 31           |

|                  |  |            |
|------------------|--|------------|
| 2.7              | Postprocessing   | 31         |
|                  | References   | 33         |
|                  | Problems   | 33         |
| <b>Chapter 3</b> | <b>Liquid-Based Rapid Prototyping Systems</b>  | <b>35</b>  |
| 3.1              | 3D Systems' Stereolithography Apparatus (SLA)  | 35         |
| 3.2              | Cubital's Solid Ground Curing (SGC)  | 54         |
| 3.3              | D-MEC's Solid Creation System (SCS)  | 64         |
| 3.4              | CMET's Solid Object Ultraviolet-Laser Printer (SOUP)   | 68         |
| 3.5              | Teijin Seiki's Soliform System   | 74         |
| 3.6              | Autostrade's E-Darts   | 81         |
| 3.7              | Meiko's Rapid Prototyping System for the Jewelry Industry  | 84         |
| 3.8              | Other Similar Commercial RP Systems  | 90         |
| 3.9              | Two Laser Beams  | 91         |
| 3.10             | Rapid Freeze Prototyping   | 93         |
| 3.11             | Microfabrication   | 101        |
|                  | References   | 105        |
|                  | Problems   | 108        |
| <b>Chapter 4</b> | <b>Solid-Based Rapid Prototyping Systems</b>   | <b>111</b> |
| 4.1              | Cubic Technologies' Laminated Object Manufacturing (LOM)   | 111        |
| 4.2              | Stratasys' Fused Deposition Modeling (FDM)   | 124        |
| 4.3              | Kira's Paper Lamination Technology (PLT)   | 133        |
| 4.4              | 3D Systems' Multi-Jet Modeling System (MJM)  | 139        |
| 4.5              | Solidscape's ModelMaker and PatternMaster  | 145        |
| 4.6              | Beijing Yinhua's Slicing Solid Manufacturing (SSM), Melted Extrusion Modeling (MEM) and Multi-Functional RPM Systems (M-RPM) | 150        |
| 4.7              | CAM-LEM's CL 100   | 154        |

|                  |   |            |
|------------------|---|------------|
| 4.8              | Ennex Corporation's Offset Fabbers                                | 159        |
| 4.9              | The Shape Deposition Manufacturing Process                        | 162        |
|                  | References  | 168        |
|                  | Problems  | 170        |
| <b>Chapter 5</b> | <b>Powder-Based Rapid Prototyping Systems</b>                     | <b>173</b> |
| 5.1              | 3D Systems' Selective Laser Sintering (SLS)                       | 173        |
| 5.2              | EOS's EOSINT Systems  | 184        |
| 5.3              | Z Corporation's Three-Dimensional Printing (3DP)                  | 193        |
| 5.4              | Optomec's Laser Engineered Net Shaping (LENS)                     | 199        |
| 5.5              | Soligen's Direct Shell Production Casting (DSPC)                  | 204        |
| 5.6              | Fraunhofer's Multiphase Jet Solidification (MJS)                  | 211        |
| 5.7              | Acram's Electron Beam Melting (EBM)                               | 214        |
| 5.8              | Aeromet Corporation's Lasform Technology                          | 217        |
| 5.9              | Generis' RP Systems (GS)  | 222        |
| 5.10             | Therics Inc.'s Theriform Technology                               | 224        |
| 5.11             | Extrude Hone's Prometal™ 3D Printing Process                      | 227        |
|                  | References  | 231        |
|                  | Problems  | 234        |
| <b>Chapter 6</b> | <b>Rapid Prototyping Data Formats</b>                             | <b>237</b> |
| 6.1              | STL Format  | 237        |
| 6.2              | STL File Problems   | 239        |
| 6.3              | Consequences of Building a Valid and Invalid<br>Tessellated Model | 243        |
| 6.4              | STL File Repair   | 245        |
| 6.5              | Other Translators   | 273        |
| 6.6              | Newly Proposed Formats  | 276        |
| 6.7              | Standard for Representing Layered Manufacturing<br>Objects        | 288        |
|                  | References  | 289        |
|                  | Problems  | 291        |

|                          |  |            |
|--------------------------|--|------------|
| <b>Chapter 7</b>         | <b>Applications and Examples</b>                   | <b>295</b> |
| 7.1                      | Application-Material Relationship                  | 295        |
| 7.2                      | Finishing Processes                                | 297        |
| 7.3                      | Applications in Design                             | 298        |
| 7.4                      | Applications in Engineering, Analysis and Planning | 299        |
| 7.5                      | Applications in Manufacturing and Tooling          | 303        |
| 7.6                      | Aerospace Industry                                 | 319        |
| 7.7                      | Automotive Industry                                | 324        |
| 7.8                      | Biomedical Industry                                | 327        |
| 7.9                      | Jewelry Industry                                   | 335        |
| 7.10                     | Coin Industry                                      | 336        |
| 7.11                     | Tableware Industry                                 | 338        |
|                          | References   | 341        |
|                          | Problems   | 346        |
| <b>Chapter 8</b>         | <b>Evaluation and Benchmarking</b>                 | <b>349</b> |
| 8.1                      | Using Bureau Services                              | 349        |
| 8.2                      | Setting Up a Service Bureau                        | 350        |
| 8.3                      | Technical Evaluation Through Benchmarking          | 365        |
| 8.4                      | Industrial Growth                                  | 384        |
| 8.5                      | Further Development Trends                         | 384        |
|                          | References   | 389        |
|                          | Problems   | 391        |
| <b>Appendix</b>          | <b>List of RP Companies</b>                        | <b>393</b> |
| <b>CD-ROM Attachment</b> |  | <b>401</b> |
| <b>CD-ROM User Guide</b> |  | <b>403</b> |
| <b>Index</b>             |  | <b>411</b> |