

Contents

1	Introduction to Laser-Assisted Fabrication of Materials.	1
	Jyotsna Dutta Majumdar and Indranil Manna	
1.1	Introduction	1
1.2	Principle, Type, and Application of Laser	2
1.2.1	Solid-State Laser	3
1.2.2	Semiconductor or Diode Lasers	4
1.2.3	Gas-Based Lasers	5
1.2.4	Free-Electron Lasers	5
1.2.5	Ultra High Field Lasers.	5
1.2.6	Excimer Lasers	6
1.3	Laser–Matter Interaction for Material Processing	6
1.3.1	Lattice Heating.	6
1.3.2	Spatial Distribution of Deposited Energy.	7
1.3.3	Heat Transfer by Laser Irradiation	8
1.3.4	Plasma Formation During Laser Irradiation	9
1.3.5	Effect of Ultra High Power Laser Irradiation	10
1.4	Application of Laser	10
1.5	Laser Assisted Fabrication of Engineering Materials.	11
1.6	Laser Assisted Shaping	14
1.6.1	Laser Assisted Bending	14
1.6.2	Laser Rapid Prototyping	22
1.7	Laser Joining	28
1.8	Laser Machining.	35
1.8.1	Laser Cutting.	35
1.8.2	Laser Drilling.	40
1.8.3	Laser Cleaning.	42
1.9	Laser Surface Engineering.	43
1.9.1	Laser Transformation Hardening	44
1.9.2	Laser Surface Melting.	45
1.9.3	Laser Surface Alloying	47

1.9.4	Laser Composite Surfacing	53
1.9.5	Laser Shock Processing	54
1.9.6	Laser Surface Engineering of Ceramics	54
1.9.7	Laser Surface Engineering of Polymers	55
1.10	Summary and Future Scope	57
1.11	Future Challenges	58
	References	59
2	High Power Lasers in Material Processing Applications: An Overview of Recent Developments	69
	A. K. Nath	
2.1	Introduction	69
2.2	Recent Developments in High Power Lasers	74
2.2.1	High Power CO ₂ Laser	74
2.2.2	High Power Diode Laser	75
2.2.3	Nd:YAG Lasers	77
2.2.4	Diode Pumped Solid-State Rod Type and Slab Lasers	79
2.2.5	High Power Thin Disc Laser	81
2.2.6	Fiber Laser	82
2.2.7	Ceramic YAG Lasers	84
2.2.8	Excimer Lasers	85
2.2.9	High Average Power Pulsed Lasers	85
2.2.10	Ultrafast Lasers	86
2.3	Laser-Material Interaction	88
2.3.1	Basic Absorption Mechanism of Laser Radiation in Materials	88
2.3.2	Effect of Spatial Characteristic of Laser Beam	94
2.3.3	Effect of Laser Pulse Duration	94
2.3.4	Material Removal Mechanisms	95
2.3.5	Recent Developments in Laser Material Processing Applications	98
2.4	Conclusions	106
	References	106
3	Laser-Assisted Machining: Current Status and Future Scope	113
	M. Brandt and S. Sun	
3.1	Introduction	113
3.2	Engineering Materials and Their Machinability	114
3.2.1	Ceramics	114
3.2.2	Nickel-Based Superalloy: Inconel 718	114
3.2.3	Titanium and its Alloys	114
3.2.4	Hardened Steels	115
3.2.5	Metal Matrix Composites	115

3.3	Laser-Assisted Machining and its Principles	116
3.3.1	Traditional Laser-Assisted Machining	116
3.3.2	Non-Traditional Laser-Assisted Machining	117
3.4	Temperature Rise on the Workpiece Surface Due to Laser Radiation	118
3.5	Improvement of Machinability by Laser Beam Assistance.	127
3.5.1	Cutting Force and Specific Cutting Energy	127
3.5.2	Material Removal Mechanisms and Chip Formation	132
3.5.3	Proposition of a Physical Model for Chip Segmentation	136
3.5.4	Tool Materials and Wear.	141
3.5.5	Surface Integrity.	147
3.6	Optimization and Energy Efficiency of LAM.	150
3.7	Numerical Simulation of LAM.	151
3.8	Future Scope of LAM.	153
	References	154
4	Laser-Based Joining of Metallic and Non-Metallic Materials	159
	G. Padmanabham and B. Shanmugarajan	
4.1	Introduction	160
4.2	Classification of Laser-Based Joining Processes	161
4.3	Principle of Keyhole and Factors Affecting Keyhole Stability	162
4.4	Lasers and System Technology for Welding	163
4.5	Laser Welding Parameters	167
4.6	Pulsed Laser Welding	170
4.7	Laser Welding of Different Materials	174
4.7.1	Laser Welding of Steels	174
4.7.2	Aluminum Alloys	182
4.7.3	Titanium Alloys	187
4.7.4	Nickel-Based Alloys	188
4.7.5	Magnesium Alloys	190
4.7.6	Conducting Materials	191
4.7.7	Dissimilar Materials	192
4.8	Limitations of Laser Welding.	193
4.9	Laser Welding Process Control Tools	193
4.9.1	Seam Tracking.	193
4.9.2	Weld Monitors.	196
4.9.3	Gap Bridging by Wire Feed.	197
4.10	Innovations in Laser Welding	197
4.10.1	Laser Hybrid Welding.	197
4.10.2	Induction-Assisted Laser Welding	200
4.10.3	Remote Welding	200
4.10.4	Dual Beam Welding	201

4.11	Laser Brazing.	202
4.11.1	Zn-Coated Steels	203
4.11.2	Aluminum–Steel Brazing.	205
4.12	Laser Selective Soldering	205
4.13	Laser Welding of Non-Metallic Materials	206
4.13.1	Plastic Welding	206
4.13.2	Laser Joining of Metal and Plastic	207
4.14	Applications of Laser Welding and Brazing.	209
4.14.1	Tailor Welded Blanks	209
4.14.2	Medical Devices.	212
4.14.3	Automotive Body	213
4.14.4	Li-Ion Battery	213
4.14.5	Joining of Stiffeners to the Skin in the Fuselage Belly Area.	214
4.14.6	Solar Absorber Plates Cu/Al Plate-Cu Tube Welding	215
4.14.7	Laser Hybrid Pipeline Welding	216
	References	217

5	Direct Laser Cladding, Current Status and Future Scope of Application.	221
	A. Weisheit, A. Gasser, G. Backes, T. Jambor, N. Pirch and K. Wissenbach	
5.1	Introduction	221
5.2	Fundamentals of Direct Laser Cladding.	222
5.2.1	Laser Beam Sources and Specific Advantages of Laser Cladding.	222
5.3	Fundamentals of the Laser Cladding Process	223
5.3.1	Fundamentals of Laser Remelting.	223
5.3.2	Principle and Material Requirements for the Laser Cladding Process.	225
5.3.3	Powder Injection	226
5.4	Material Aspects of Laser Cladding	231
5.4.1	Materials	231
5.4.2	Microstructure	231
5.5	Applications.	231
5.6	Future Trends for Laser Cladding.	236
5.6.1	Micro Laser Cladding	236
5.6.2	Novel Materials	237
5.7	Additive Manufacturing.	239
	References	239

6	An Introduction to Laser-Assisted Microfabrication, Current Status and Future Scope of Application.	241
	A. Ostendorf	
6.1	Introduction	241
6.2	Laser Pulse Generation and Interaction with Matter	243
6.2.1	Gain Switching	243
6.2.2	Q-Switching	244
6.2.3	Cavity Dumping	246
6.2.4	Mode-Locking	247
6.2.5	Active Mode-Locking	249
6.2.6	Passive Mode-Locking	250
6.2.7	Interaction of Short Pulses with Matter	251
6.3	Basic Processes	253
6.3.1	Structuring by Material Removal	254
6.3.2	Generative Processes.	261
6.3.3	Nanostructuring	264
6.4	Applications.	267
6.4.1	Cardiovascular Implants	267
6.4.2	Solar Cell Processing	269
6.4.3	Machining of Nozzles	271
6.5	Summary and Conclusions.	273
	References	273
7	Laser Surface Processing of Polymers for Biomedical Applications.	275
	David Waugh and Jonathan Lawrence	
7.1	Polymers as Biomaterials and In Vitro Experimentation	275
7.1.1	Polymeric Biomaterials	275
7.1.2	In Vitro Experimentation of Materials.	277
7.2	Wettability in Biomaterials Surface Science.	280
7.2.1	Contact Angle and Wettability	281
7.3	Surface Modification Techniques	283
7.3.1	Radiation and Photografting.	283
7.3.2	Plasma Surface Modification	285
7.3.3	Ion and Electron Beam Processing	286
7.3.4	Laser Surface Modification	287
7.4	Experimental Technique	290
7.4.1	Laser Irradiation Procedure	290
7.4.2	Topography, Wettability Characteristics, and Surface Chemistry Analysis.	291
7.4.3	In Vitro Experimentation.	292
7.4.4	SEM and Optical Microscopy Analysis of In Vitro Samples	294
7.4.5	Statistical Analysis	294

7.5	Effect of Laser Patterning on Topography	295
7.6	Effect of Laser Irradiation on the Wettability Characteristics	295
7.7	Effect of Laser Patterning on Osteoblast Cell Bioactivity and SBF Response	303
7.7.1	SBF Response to Laser Patterning	303
7.7.2	Osteoblast Cell Bioactivity: 24 h After Seeding	304
7.7.3	Osteoblast Cell Bioactivity: 4 Days After Seeding	309
7.8	Summary	312
	References	314
8	Laser Micro and Nano Processing of Metals, Ceramics, and Polymers	319
	Wilhelm Pfleging, Robert Kohler, Isabelle Südmeyer and Magnus Rohde	
8.1	Introduction	319
8.2	Fundamental Aspects of Laser Material Processing.	322
8.3	Modeling and Simulation.	324
8.4	Polymer Materials	329
8.4.1	Thermally Driven Ablation	329
8.4.2	Cold Laser Ablation	331
8.4.3	Modification	334
8.5	Ceramics, Glass–Ceramics, and Glasses	335
8.5.1	Laser Patterning	335
8.5.2	Modification of Surfaces by Dispersing and Cladding	338
8.5.3	Structuring and Annealing of Battery Materials	346
8.6	Joining with Laser Beams	354
8.6.1	Welding of Thin Metal Sheets	354
8.6.2	Metal–Ceramics Joining	358
8.6.3	Laser Transmission Welding of Polymers	364
8.7	Conclusion.	367
	References	367
9	Temperature Monitoring by Optical Methods in Laser Processing	375
	I. Smurov and M. Doubenskaia	
9.1	Introduction	375
9.2	Theoretical Background of Pyrometry.	377
9.3	Diagnostics Facilities	379
9.3.1	Pyrometers Performance Data	379
9.4	Results and Discussion	383
9.4.1	Surface Temperature Evolution in Pulsed and Pulsed Periodic Laser Action of Millisecond Range	383

9.4.2	Laser Welding	389
9.4.3	Laser Cladding	399
9.4.4	Selective Laser Melting	414
9.5	Conclusions	418
	References	420

10 Emerging Laser Materials Processing Techniques for Future

	Industrial Applications	423
	L. M. Kukreja, R. Kaul, C. P. Paul, P. Ganesh and B. T. Rao	
10.1	Introduction	423
10.2	Laser Rapid Manufacturing	424
10.2.1	Laser Rapid Manufacturing of Colmonoy-6 Bushes	427
10.2.2	Laser Rapid Manufacturing of Low-Cost Tools	429
10.2.3	Laser Rapid Manufacturing of Porous Materials	432
10.2.4	Laser Rapid Manufacturing of Bimetallic Components	436
10.2.5	Mechanical Properties of Laser Rapid Manufactured Structures of Inconel 625 and Type 316L SS	444
10.2.6	Prognostication	447
10.3	Laser Surface Melting Treatment for Enhanced Resistance of Austenitic Stainless Steel Against Inter-Granular Corrosion	449
10.3.1	Laser Surface Treatment of Type 304 SS	449
10.3.2	Post-Weld Laser Surface Treatment of Type 316(N) SS Weld Metal	451
10.3.3	Pre-Weld Laser Surface Treatment of Type 304 SS	453
10.3.4	Prognostication	456
10.4	Laser Shock Peening Surface Treatment for Enhanced Fatigue Performance of Automobile Components	457
10.4.1	Laser Shock Peening Treatment with Pulsed Nd:YAG Laser	457
10.4.2	Prognostication	458
10.5	CO ₂ Laser-GTAW Hybrid Welding	459
10.5.1	Interaction of Gas Tungsten Arc (GTA) and Laser-Generated Plasma During Hybrid Welding	459
10.5.2	Prognostication	461
10.6	Laser Profile Cutting of Metal Sheets	461
10.6.1	Laser Piercing with Power Modulation for Improved Profile Cutting	461

10.6.2	Laser Power Modulation Controls Adverse Effects of Periodic Power Fluctuations.	465
10.6.3	Laser Cutting with Power Modulation Improves Cut Edge Quality	467
10.6.4	Laser-Assisted Oxygen (LASOX) Cutting of Thick Steel Plates.	469
10.6.5	Prognostication.	471
10.7	Summary and Conclusions.	471
	References	475
Index		479
Curriculum Vitae		483