

Contents

1	Laser Physics for Materials Scientists: A Primer	1
	Richard F. Haglund	
1.1	Introduction	1
1.2	Fundamentals of Laser-Materials Interactions.	4
1.3	Fundamentals of Laser Physics.	7
1.3.1	Electromagnetic Waves in a Medium with Gain and Absorption.	7
1.3.2	Creating Gain in a Laser Medium	8
1.3.3	Laser Oscillators: Theory	9
1.3.4	Mode-Locked Oscillators.	12
1.3.5	Laser Amplifiers.	13
1.4	Laser Systems Used in Materials Processing	15
1.4.1	Laser Oscillators.	15
1.4.2	Amplified Laser Systems.	20
1.4.3	Control of Laser Pulse Duration.	22
1.5	A Tunable Picosecond Laser for Polymer Processing in the Mid-Infrared	24
1.6	Conclusion.	27
	References	27
2	Material Response to Laser Energy Deposition (Thermal and Hyperthermal Processes).	29
	Juergen Reif	
2.1	Introduction	29
2.2	Basic Considerations.	30
2.2.1	Thermodynamics	31
2.2.2	Deposition of Laser Energy	32
2.3	Beyond Thermal Equilibrium (<i>Hyperthermal Processes</i>)	36
2.3.1	Homogeneous Boiling.	36
2.3.2	Ultrashort Excitation: Self-organized Nano-structure Formation	37
2.4	Summary	40
	References	41

3	Non-Thermal Material Response to Laser Energy Deposition. . . .	43
	Wolfgang Kautek and Oskar Armbruster	
3.1	Introduction	43
3.2	Response of Metals.	44
3.2.1	The Two-Temperature Model.	44
3.2.2	Hot Electron Transport	47
3.2.3	Hot Electron Pressure	49
3.2.4	Hot Electron Emission	51
3.3	Response of Dielectrics and Semiconductors	53
3.3.1	Impact/Avalanche and Multiphoton Ionization	53
3.3.2	Non-Thermal Melting	56
3.3.3	Coulomb Explosion	59
3.3.4	Photochemical Ablation.	60
3.3.5	3D Stereolithography	61
3.4	Conclusion.	62
	References	64
4	Atomic Movies of Laser-Induced Structural and Phase Transformations from Molecular Dynamics Simulations	67
	Chengping Wu, Eaman T. Karim, Alexey N. Volkov and Leonid V. Zhigilei	
4.1	Introduction	67
4.2	Representation of Laser Excitation in Classical Molecular Dynamics.	69
4.3	Atomic Movies from MD Simulations of Laser-Material Interactions	72
4.3.1	Laser Melting.	73
4.3.2	Generation of Crystal Defects	76
4.3.3	Photomechanical Spallation	81
4.3.4	Phase Explosion and Cluster Ejection	86
4.3.5	Matrix-Assisted Pulsed Laser Evaporation.	89
4.4	Concluding Remarks and Future Directions.	92
	References	94
5	Continuum Models of Ultrashort Laser–Matter Interaction in Application to Wide-Bandgap Dielectrics.	101
	Nadezhda M. Bulgakova and Vladimir P. Zhukov	
5.1	Introduction	102
5.2	Ultrafast Laser Excitation of Wide-Bandgap Dielectrics	102
5.3	Volume Modifications of Wide-Bandgap Dielectrics.	106
5.3.1	Propagation of Focused Laser Beams Through Non-linear Absorbing Media	106
5.3.2	2D Model of Electron Plasma Generation upon Laser Beam Focusing Inside Transparent Solids.	109

5.3.3	Single-Pulse Material Heating and Laser-Induced Stresses	115
5.3.4	Comments on Multipulse Irradiation Regimes	118
5.4	Concluding Remarks	120
	References	121
6	Attosecond Pulses for Atomic and Molecular Physics.	125
	Francesca Calegari, Giuseppe Sansone and Mauro Nisoli	
6.1	Introduction	125
6.2	High-Peak-Power Few-Cycle Pulses	126
6.2.1	Optical Parametric Amplification for the Generation of mJ-Energy Pulses with Stable CEP.	126
6.2.2	Hollow-Fiber Compression Technique.	127
6.2.3	High-Energy Pulse Compression by Using Gas Ionization	128
6.3	Active and Passive Stabilization of the CEP of Femtosecond Pulses	129
6.4	Generation of Isolated Attosecond Pulses	130
6.4.1	Polarization Gating	131
6.4.2	Ionization Gating	133
6.4.3	Two-Color Gating with Infrared Pulses.	134
6.5	Attosecond Metrology	135
6.6	Application of Isolated Attosecond Pulses to Molecular Physics: Electron Localization in D ₂	137
6.7	Conclusions	139
	References	139
7	Laser Interactions for the Synthesis and In Situ Diagnostics of Nanomaterials	143
	David B. Geohegan, Alex A. Puretzky, Mina Yoon, Gyula Eres, Chris Rouleau, Kai Xiao, Jeremy Jackson, Jason Readle, Murari Regmi, Norbert Thonnard, Gerd Duscher, Matt Chisholm and Karren More	
7.1	Introduction	143
7.2	Cluster and Nanoparticle Growth in Pulsed Laser Vaporization	145
7.3	Characterization and Modeling of Ultrasmall Nanoparticle “Building Blocks”.	147
7.4	Carbon Nanostructure Synthesis in Laser Vaporization	150
7.4.1	Fullerenes	150
7.4.2	Single-Wall Carbon Nanotubes	151
7.4.3	Single-Wall Carbon Nanohorns	153
7.5	Laser Diagnostics of Single-Wall Carbon Nanotube Growth by Chemical Vapor Deposition.	154

7.6	Graphene and Beyond: Laser Processing for 2D Layered Materials.	164
7.6.1	Mechanical and Chemical Exfoliation Methods and Laser Processing	164
7.6.2	Laser Interactions in the Synthesis and Characterization of Graphene and other 2D Nanosheets.	165
7.7	Summary	168
	References	169
8	Laser-Mediated Nanoparticle Synthesis and Self-Assembling	175
	Paolo M. Ossi, Nisha R. Agarwal, Enza Fazio, Fortunato Neri and Sebastiano Trusso	
8.1	Introduction	176
8.2	Propagation of an Ablation Plasma Through an Ambient Gas	177
8.3	Synthesis of Nanoparticles in the Expanding Plasma.	184
8.4	Nanoparticle Self-Assembling on a Substrate and Film Growth	189
8.5	Nanoparticle Production Via Pulsed Laser Ablation in Liquid	192
8.6	Nanoparticle Synthesis Using fs Laser Pulses.	198
8.7	Nanoparticle-Assembled Surfaces with Directed Artificial Roughness: Selected Applications.	202
8.8	Conclusions and Perspectives.	209
	References	210
9	Nano-cluster Assembled Films, Produced by Pulsed Laser Deposition, for Catalysis and the Photocatalysis.	213
	A. Miotello and N. Patel	
9.1	Introduction	214
9.2	Cobalt NPs Produced by PLD for Hydrolysis of Chemical Hydrides	214
9.2.1	Co NPs Embedded in B-Matrix Film (Co-NP-B-MA).	214
9.2.2	Co-NP-B-MA Nano-catalyst Supported Over Rough Carbon Films.	218
9.3	Co-oxide NPs Produced by PLD for Photocatalysis Application	221
9.3.1	Co ₃ O ₄ NPs Assembled Coating Photocatalyst	221
9.4	Conclusions	224
	References	224

10 Multifunctional Oxides Obtained by PLD: Applications as Ferroelectric and Piezoelectric Materials.	227
N. D. Scarisoreanu, Maria Dinescu and F. Craciun	
10.1 Introduction	228
10.2 Relaxor Ferroelectric PLZT Thin Films	232
10.2.1 PLZT 9/65/35 Thin Films	232
10.2.2 PLZT 22/20/80 Thin Films	236
10.3 Relaxor Ferroelectric PMN-PT Thin Films	243
10.4 Lead-Free SBN Thin Films	247
10.5 Lead-Free Ferroelectric NBT-BT Thin Films	258
10.6 Conclusions	263
10.7 Perspectives	264
References	266
11 Biomaterial Thin Films by Soft Pulsed Laser Technologies for Biomedical Applications	271
Ion N. Mihailescu, Adriana Bigi, Eniko Gyorgy, Carmen Ristoscu, Felix Sima and Ebru Toksoy Oner	
11.1 Introduction	272
11.2 MAPLE Set-up	273
11.3 MAPLE Layers for DDS	275
11.3.1 Bisphosphonate–Hydroxyapatite Thin Films	275
11.3.2 RNase A	277
11.3.3 Levan	282
11.4 MAPLE Layers for BS	285
11.4.1 IgG	285
11.5 MAPLE Layers for BCI	287
11.5.1 Magnesium and Strontium Doped Octacalcium Phosphate Thin Films	287
11.6 Conclusions	290
References	290
12 MAPLE and MALDI: Theory and Experiments	295
Anna Paola Caricato	
12.1 Introduction	295
12.2 MALDI: Basic Principles and Applications	297
12.3 MAPLE: Basic Principles	299
12.4 MAPLE: Applications and Influence of Deposition Parameters	304
12.4.1 Polymer Film Deposition	305
12.4.2 Maple Deposition of Bilayer Polymeric Structures	306
12.4.3 Organic Materials, Active Protein and Bioactive Thin Films	308

- 12.4.4 Influence of Deposition Parameters. 310
- 12.4.5 Deposition of Colloidal Nanoparticles/Nanorods. 314
- 12.5 Discussion 317
- 12.6 Conclusions 319
- References 320

- 13 Laser Nanofabrication of Soft Matter 325**
Marta Castillejo, Tiberio A. Ezquerro, Mohamed Oujja
and Esther Rebollar
- 13.1 Soft Matter 325
- 13.2 Laser Nanofabrication 327
- 13.3 Laser Induced Periodic Surface Structures
of Thin Polymer Films 328
 - 13.3.1 LIPSS Formation and Mechanisms 328
 - 13.3.2 Application of LIPSS Polymer Substrates
for Surface Enhanced Raman Spectroscopy 335
- 13.4 Laser Foaming of Biopolymer Films. 337
 - 13.4.1 The Role of Wavelength and Pulse Duration
in Laser Foaming 337
 - 13.4.2 Cell Culture on Laser Foamed Biopolymer Films. 340
- 13.5 Conclusions 341
- References 342

- 14 Industrial Applications of Laser-Material Interactions
for Coating Formation 345**
Peter Schaaf and Daniel Höche
- 14.1 Introduction 345
 - 14.1.1 The Free Electron Laser 346
 - 14.1.2 Direct Laser Synthesis. 347
 - 14.1.3 Protective Coatings and TiN 348
- 14.2 Experiments. 349
 - 14.2.1 Sample Preparation and Setup 349
 - 14.2.2 Analysis Methods 350
- 14.3 Results 350
 - 14.3.1 FEL Irradiation at CW-Mode. 350
 - 14.3.2 FEL Irradiation at Pulsed Mode 352
- 14.4 Conclusions 355
- References 356

- 15 Ultrafast Laser Micro- and Nano-Processing of Glasses 359**
Koji Sugioka
- 15.1 Introduction 359
- 15.2 Surface Micromachining 361

15.3	Internal Modification and 3D Micro/Nanofabrication	362
15.3.1	Photonic Device Fabrication	362
15.3.2	Microfluidic Device Fabrication	364
15.3.3	Optofluidic Device Fabrication	369
15.4	Processing by Pulse Shaping Technique	374
15.5	Summary	376
	References	377
Index	381



<http://www.springer.com/978-3-319-02897-2>

Lasers in Materials Science

(Eds.)M. Castillejo; P.M. Ossi; L. Zhigilei

2014, XVI, 387 p. 203 illus., 74 illus. in color., Hardcover

ISBN: 978-3-319-02897-2