## **Contents**

1	Volker Schmidt and Maria R. Belegratis					
	1.1		metics as Inspiration for Laser-Based Methods	1		
	and Applications					
		1.1.1	Laser Sources	2		
		1.1.2	Laser Processing	6		
		1.1.3	Biomimetic Processes Involving Laser Radiation	6		
	Refe	rences .		11		
2	Dire	ct Laser	Writing	13		
	Sasc	ha Engel	hardt			
	2.1	Introdu	action	13		
	2.2	Experi	mental Setup	14		
	2.3	Two P	Photon Absorption	15		
	2.4	Chemi	cal Processes for Direct Laser Writing	19		
		2.4.1	Photopolymerization	19		
		2.4.2	Photocrosslinking	20		
		2.4.3	Photoactivation	21		
	2.5	Princip	oles of Direct Laser Writing	22		
		2.5.1	Voxel Formation	27		
		2.5.2	Determining the Size of Voxels	30		
		2.5.3	Spherical Aberration	30		
		2.5.4	Viscosity	32		
		2.5.5	Shrinkage	33		
		2.5.6	Damaging Effects	35		
		2.5.7	Mechanical Properties	37		
	2.6	Advan	ced Setups for Direct Laser Writing	38		
		2.6.1	Process Speed	38		
		2.6.2	Enhanced Resolution	41		
		2.6.3	Large Structures	43		
	2.7 Direct Laser Writing in 3D Cell Culture					
		and Tissue Engineering				
		2.7.1	Photocrosslinking of Proteins for Biomimetic			
			3D Structures	51		

x Contents

		2.7.2	Photopolymerisation of Synthetic Polymers	
			for Biomimetic 3D Structures	53
		2.7.3	Photoactivation of Hydrogels	54
	2.8	Conclu	usion	55
	Refe	rences .		56
3	Bion	nimetic l	Photonic Materials by Direct Laser Writing	67
	Marl	k D. Turi	ner, Gerd E. Schröder-Turk and Min Gu	
	3.1	Introdu	uction	67
	3.2	Three-	Dimensional Direct Laser Writing	70
	3.3	Chiral	Structures in Self-Assembly and Circular	
		Dichro	oism in Biology	73
	3.4	Direct	Laser Writing of 3D Biomimetic Microstructures	73
	3.5		usion and Outlook	77
	Refe			78
		•		0.0
4			ser Sintering and Its Biomedical Applications	83
			d Min Wang	0.0
	4.1		uction to Rapid Prototyping Technologies	83
		4.1.1	Stereolithography Apparatus	84
		4.1.2	Two-Photon Polymerization	85
		4.1.3	Fused Deposition Modeling	86
		4.1.4	3D Plotting	86
		4.1.5	3D Printing	87
		4.1.6	Selective Laser Sintering	87
	4.2		ve Laser Sintering	88
		4.2.1	Principle of Selective Laser Sintering	
			and Modification of Commercial SLS Machines	88
		4.2.2	Materials for SLS	91
		4.2.3	SLS Parameters	93
		4.2.4	Optimization of SLS Parameters	93
		4.2.5	Applications of SLS in the General	
			Manufacturing Industry	94
	4.3		dical Applications of SLS	95
		4.3.1	Physical Models for Surgical Planning	95
		4.3.2	Medical Device Prototypes	96
		4.3.3	Medical Implants and Prostheses	96
		4.3.4	Tissue Engineering Scaffolds	97
		4.3.5	Drug or Biomolecule Delivery Systems	101
	4.4	Summ	ary	103
	Refe	rences .		104

Contents xi

5.2 Biomimetic Design-Mimicking Aspects of a Natural Organism			Assemblies by Matrix-Assisted Pulsed	
5.1 Introduction 5.2 Biomimetic Design-Mimicking Aspects of a Natural Organism. 5.3 Scaffold Fabrication and Deposition Methods 5.4 Basics of MAPLE. 5.4.1 Experimental Conditions and Mechanisms of MAPLE. 5.4.2 Reliability 5.5 MAPLE: From the Origin to Biomimetics. 5.5.1 Application to Organics. 5.5.2 Application to Organic-Inorganic Composites 5.5.3 Application to Inorganics 6.6 Conclusion and Perspectives  References  Laser Additive Manufacturing of Metals Claus Emmelmann, Jannis Kranz, Dirk Herzog and Eric Wycisk 6.1 Process Basics 6.2.1 Building Chamber Dimensions 6.2.2 Layer Thickness 6.2.3 Scanspeed 6.2.4 Laser Beam Power 6.2.5 Exposure and Scan Strategy 6.2.6 Hatching 6.2.7 Available Metals and Alloys for LAM 6.3 Part Quality 6.3.1 Density 6.3.2 Strength 6.3.3 Hardness 6.3.4 Residual Stresses 6.3.5 Accuracy Grade 6.3.6 Subsurface Quality 6.5 Future Development 6.6 Biomimetic Application Areas of LAM 6.7 Summary and Conclusion				
6.2 Biomimetic Design-Mimicking Aspects of a Natural Organism.  6.3 Scaffold Fabrication and Deposition Methods  6.4 Basics of MAPLE.  6.4.1 Experimental Conditions and Mechanisms of MAPLE.  6.5.2 Reliability  6.5.5 MAPLE: From the Origin to Biomimetics.  6.5.1 Application to Organics.  6.5.2 Application to Organic-Inorganic Composites.  6.5.3 Application to Inorganics.  6.6 Conclusion and Perspectives.  6.6 Conclusion and Perspectives.  6.1 Process Basics.  6.2 Process Parameters.  6.2.1 Building Chamber Dimensions.  6.2.2 Layer Thickness.  6.2.3 Scanspeed.  6.2.4 Laser Beam Power.  6.2.5 Exposure and Scan Strategy.  6.2.6 Hatching.  6.2.7 Available Metals and Alloys for LAM.  6.3 Part Quality.  6.3.1 Density.  6.3.2 Strength.  6.3.3 Hardness.  6.3.4 Residual Stresses.  6.3.5 Accuracy Grade.  6.3.6 Subsurface Quality.  6.4 Designs for LAM.  6.5 Future Development.  6.6 Biomimetic Application Areas of LAM.  6.7 Summary and Conclusion.	Felix			
of a Natural Organism.  5.3 Scaffold Fabrication and Deposition Methods  5.4 Basics of MAPLE.  5.4.1 Experimental Conditions and Mechanisms of MAPLE.  5.4.2 Reliability  5.5 MAPLE: From the Origin to Biomimetics.  5.5.1 Application to Organics.  5.5.2 Application to Organic-Inorganic Composites  5.5.3 Application to Inorganics  5.6 Conclusion and Perspectives  References  Laser Additive Manufacturing of Metals  Claus Emmelmann, Jannis Kranz, Dirk Herzog and Eric Wycisk  6.1 Process Basics  6.2 Process Parameters  6.2.1 Building Chamber Dimensions  6.2.2 Layer Thickness  6.2.3 Scanspeed  6.2.4 Laser Beam Power  6.2.5 Exposure and Scan Strategy  6.2.6 Hatching  6.2.7 Available Metals and Alloys for LAM  6.3.1 Density  6.3.2 Strength  6.3.3 Hardness  6.3.4 Residual Stresses  6.3.5 Accuracy Grade  6.3.6 Subsurface Quality  5.4 Designs for LAM  5.5 Future Development  5.6 Biomimetic Application Areas of LAM  Summary and Conclusion	5.1			
Scaffold Fabrication and Deposition Methods Basics of MAPLE.  5.4.1 Experimental Conditions and Mechanisms of MAPLE.  5.4.2 Reliability  5.5 MAPLE: From the Origin to Biomimetics  5.5.1 Application to Organics.  5.5.2 Application to Organic-Inorganic Composites  5.5.3 Application to Inorganics  6.6 Conclusion and Perspectives  References  Laser Additive Manufacturing of Metals  Claus Emmelmann, Jannis Kranz, Dirk Herzog and Eric Wycisk  6.1 Process Basics  6.2 Process Parameters  6.2.1 Building Chamber Dimensions  6.2.2 Layer Thickness  6.2.3 Scanspeed  6.2.4 Laser Beam Power  6.2.5 Exposure and Scan Strategy  6.2.6 Hatching  6.2.7 Available Metals and Alloys for LAM  6.3 Part Quality  6.3.1 Density  6.3.2 Strength  6.3.3 Hardness  6.3.4 Residual Stresses  6.3.5 Accuracy Grade  6.3.6 Subsurface Quality  6.5 Future Development  6.6 Biomimetic Application Areas of LAM  Summary and Conclusion	5.2			
5.4.1 Experimental Conditions and Mechanisms of MAPLE.  5.4.2 Reliability  5.5 MAPLE: From the Origin to Biomimetics  5.5.1 Application to Organics.  5.5.2 Application to Organic-Inorganic Composites  5.5.3 Application to Inorganics  6.6 Conclusion and Perspectives  References  Laser Additive Manufacturing of Metals  Claus Emmelmann, Jannis Kranz, Dirk Herzog and Eric Wycisk  6.1 Process Basics  6.2 Process Parameters  6.2.1 Building Chamber Dimensions  6.2.2 Layer Thickness  6.2.3 Scanspeed  6.2.4 Laser Beam Power  6.2.5 Exposure and Scan Strategy  6.2.6 Hatching  6.2.7 Available Metals and Alloys for LAM  6.3 Part Quality  6.3.1 Density  6.3.2 Strength  6.3.3 Hardness  6.3.4 Residual Stresses  6.3.5 Accuracy Grade  6.3.6 Subsurface Quality  6.5 Future Development  6.6 Biomimetic Application Areas of LAM  Summary and Conclusion				
5.4.1 Experimental Conditions and Mechanisms of MAPLE.  5.4.2 Reliability  5.5 MAPLE: From the Origin to Biomimetics  5.5.1 Application to Organics.  5.5.2 Application to Organic-Inorganic Composites  5.5.3 Application to Inorganics  6.6 Conclusion and Perspectives  References  Laser Additive Manufacturing of Metals  Claus Emmelmann, Jannis Kranz, Dirk Herzog and Eric Wycisk  6.1 Process Basics  6.2 Process Parameters  6.2.1 Building Chamber Dimensions  6.2.2 Layer Thickness  6.2.3 Scanspeed  6.2.4 Laser Beam Power  6.2.5 Exposure and Scan Strategy  6.2.6 Hatching  6.2.7 Available Metals and Alloys for LAM  6.3 Part Quality  6.3.1 Density  6.3.2 Strength  6.3.3 Hardness  6.3.4 Residual Stresses  6.3.5 Accuracy Grade  6.3.6 Subsurface Quality  6.4 Designs for LAM  6.5 Future Development  Biomimetic Application Areas of LAM  Summary and Conclusion	5.3	Scaffold	d Fabrication and Deposition Methods	
of MAPLE.  5.4.2 Reliability  5.5 MAPLE: From the Origin to Biomimetics  5.5.1 Application to Organics.  5.5.2 Application to Organic-Inorganic Composites  5.5.3 Application to Inorganics  6.6 Conclusion and Perspectives  References  Laser Additive Manufacturing of Metals  Claus Emmelmann, Jannis Kranz, Dirk Herzog and Eric Wycisk  6.1 Process Basics  6.2 Process Parameters  6.2.1 Building Chamber Dimensions  6.2.2 Layer Thickness  6.2.3 Scanspeed  6.2.4 Laser Beam Power  6.2.5 Exposure and Scan Strategy  6.2.6 Hatching  6.2.7 Available Metals and Alloys for LAM  6.3 Part Quality  6.3.1 Density  6.3.2 Strength  6.3.3 Hardness  6.3.4 Residual Stresses  6.3.5 Accuracy Grade  6.3.6 Subsurface Quality  6.5 Future Development  6.6 Biomimetic Application Areas of LAM.  Summary and Conclusion	5.4	Basics	of MAPLE	
5.4.2 Reliability 5.5 MAPLE: From the Origin to Biomimetics 5.5.1 Application to Organics 5.5.2 Application to Organic-Inorganic Composites 5.5.3 Application to Inorganics 6.6 Conclusion and Perspectives References  Laser Additive Manufacturing of Metals Claus Emmelmann, Jannis Kranz, Dirk Herzog and Eric Wycisk 6.1 Process Basics 6.2 Process Parameters 6.2.1 Building Chamber Dimensions 6.2.2 Layer Thickness 6.2.3 Scanspeed 6.2.4 Laser Beam Power 6.2.5 Exposure and Scan Strategy 6.2.6 Hatching 6.2.7 Available Metals and Alloys for LAM 6.3 Part Quality 6.3.1 Density 6.3.2 Strength 6.3.3 Hardness 6.3.4 Residual Stresses 6.3.5 Accuracy Grade 6.3.6 Subsurface Quality 6.4 Designs for LAM 6.5 Future Development 6.6 Biomimetic Application Areas of LAM. 6.7 Summary and Conclusion		5.4.1	Experimental Conditions and Mechanisms	
5.5 MAPLE: From the Origin to Biomimetics. 5.5.1 Application to Organics. 5.5.2 Application to Organic-Inorganic Composites. 5.5.3 Application to Inorganics. 6.6 Conclusion and Perspectives.  References  Laser Additive Manufacturing of Metals.  Claus Emmelmann, Jannis Kranz, Dirk Herzog and Eric Wycisk. 6.1 Process Basics. 6.2 Process Parameters. 6.2.1 Building Chamber Dimensions. 6.2.2 Layer Thickness. 6.2.3 Scanspeed. 6.2.4 Laser Beam Power. 6.2.5 Exposure and Scan Strategy. 6.2.6 Hatching. 6.2.7 Available Metals and Alloys for LAM. 6.3 Part Quality. 6.3.1 Density. 6.3.2 Strength. 6.3.3 Hardness. 6.3.4 Residual Stresses. 6.3.5 Accuracy Grade. 6.3.6 Subsurface Quality. 6.5 Future Development. 6.6 Biomimetic Application Areas of LAM. 6.7 Summary and Conclusion.			of MAPLE	
5.5.1 Application to Organics. 5.5.2 Application to Organic-Inorganic Composites 5.5.3 Application to Inorganics 5.6 Conclusion and Perspectives References  Laser Additive Manufacturing of Metals Claus Emmelmann, Jannis Kranz, Dirk Herzog and Eric Wycisk 6.1 Process Basics 6.2 Process Parameters 6.2.1 Building Chamber Dimensions 6.2.2 Layer Thickness 6.2.3 Scanspeed 6.2.4 Laser Beam Power 6.2.5 Exposure and Scan Strategy 6.2.6 Hatching 6.2.7 Available Metals and Alloys for LAM 6.3 Part Quality 6.3.1 Density 6.3.2 Strength 6.3.3 Hardness 6.3.4 Residual Stresses 6.3.5 Accuracy Grade 6.3.6 Subsurface Quality 6.4 Designs for LAM 6.5 Future Development 6.6 Biomimetic Application Areas of LAM 6.7 Summary and Conclusion		5.4.2	Reliability	
5.5.2 Application to Organic-Inorganic Composites 5.5.3 Application to Inorganics 5.6 Conclusion and Perspectives References  Laser Additive Manufacturing of Metals Claus Emmelmann, Jannis Kranz, Dirk Herzog and Eric Wycisk 6.1 Process Basics 6.2 Process Parameters 6.2.1 Building Chamber Dimensions 6.2.2 Layer Thickness 6.2.3 Scanspeed 6.2.4 Laser Beam Power 6.2.5 Exposure and Scan Strategy 6.2.6 Hatching 6.2.7 Available Metals and Alloys for LAM 6.3 Part Quality 6.3.1 Density 6.3.2 Strength 6.3.3 Hardness 6.3.4 Residual Stresses 6.3.5 Accuracy Grade 6.3.6 Subsurface Quality 6.4 Designs for LAM 6.5 Future Development 6.6 Biomimetic Application Areas of LAM 5.7 Summary and Conclusion	5.5	MAPLE	E: From the Origin to Biomimetics	
5.5.3 Application to Inorganics 5.6 Conclusion and Perspectives References  Laser Additive Manufacturing of Metals Claus Emmelmann, Jannis Kranz, Dirk Herzog and Eric Wycisk 6.1 Process Basics 6.2 Process Parameters 6.2.1 Building Chamber Dimensions 6.2.2 Layer Thickness 6.2.3 Scanspeed 6.2.4 Laser Beam Power 6.2.5 Exposure and Scan Strategy 6.2.6 Hatching 6.2.7 Available Metals and Alloys for LAM 6.3 Part Quality 6.3.1 Density 6.3.2 Strength 6.3.3 Hardness 6.3.4 Residual Stresses 6.3.5 Accuracy Grade 6.3.6 Subsurface Quality 6.5 Future Development 6.6 Biomimetic Application Areas of LAM 5.7 Summary and Conclusion		5.5.1	Application to Organics	
5.5.3 Application to Inorganics 5.6 Conclusion and Perspectives References  Laser Additive Manufacturing of Metals Claus Emmelmann, Jannis Kranz, Dirk Herzog and Eric Wycisk 6.1 Process Basics 6.2 Process Parameters 6.2.1 Building Chamber Dimensions 6.2.2 Layer Thickness 6.2.3 Scanspeed 6.2.4 Laser Beam Power 6.2.5 Exposure and Scan Strategy 6.2.6 Hatching 6.2.7 Available Metals and Alloys for LAM 6.3 Part Quality 6.3.1 Density 6.3.2 Strength 6.3.3 Hardness 6.3.4 Residual Stresses 6.3.5 Accuracy Grade 6.3.6 Subsurface Quality 6.5 Future Development 6.6 Biomimetic Application Areas of LAM 5.7 Summary and Conclusion		5.5.2	Application to Organic-Inorganic Composites	
Claus Emmelmann, Jannis Kranz, Dirk Herzog and Eric Wycisk Energy Process Basics Energy Process Parameters Energy Process		5.5.3	Application to Inorganics	
Laser Additive Manufacturing of Metals  Claus Emmelmann, Jannis Kranz, Dirk Herzog and Eric Wycisk  6.1 Process Basics  6.2 Process Parameters  6.2.1 Building Chamber Dimensions  6.2.2 Layer Thickness  6.2.3 Scanspeed  6.2.4 Laser Beam Power  6.2.5 Exposure and Scan Strategy  6.2.6 Hatching  6.2.7 Available Metals and Alloys for LAM  6.3 Part Quality  6.3.1 Density  6.3.2 Strength  6.3.3 Hardness  6.3.4 Residual Stresses  6.3.5 Accuracy Grade  6.3.6 Subsurface Quality  6.4 Designs for LAM  6.5 Future Development  6.6 Biomimetic Application Areas of LAM  Summary and Conclusion	5.6	Conclus	sion and Perspectives	
Laser Additive Manufacturing of Metals  Claus Emmelmann, Jannis Kranz, Dirk Herzog and Eric Wycisk  6.1 Process Basics  6.2 Process Parameters  6.2.1 Building Chamber Dimensions  6.2.2 Layer Thickness  6.2.3 Scanspeed  6.2.4 Laser Beam Power  6.2.5 Exposure and Scan Strategy  6.2.6 Hatching  6.2.7 Available Metals and Alloys for LAM  6.3 Part Quality  6.3.1 Density  6.3.2 Strength  6.3.3 Hardness  6.3.4 Residual Stresses  6.3.5 Accuracy Grade  6.3.6 Subsurface Quality  6.4 Designs for LAM  6.5 Future Development  6.6 Biomimetic Application Areas of LAM  Summary and Conclusion	Refe	rences	·	
Claus Emmelmann, Jannis Kranz, Dirk Herzog and Eric Wycisk 6.1 Process Basics 6.2 Process Parameters 6.2.1 Building Chamber Dimensions 6.2.2 Layer Thickness 6.2.3 Scanspeed 6.2.4 Laser Beam Power 6.2.5 Exposure and Scan Strategy 6.2.6 Hatching 6.2.7 Available Metals and Alloys for LAM 6.3 Part Quality 6.3.1 Density 6.3.2 Strength 6.3.3 Hardness 6.3.4 Residual Stresses 6.3.5 Accuracy Grade 6.3.6 Subsurface Quality 6.4 Designs for LAM 6.5 Future Development 6.6 Biomimetic Application Areas of LAM 6.7 Summary and Conclusion				
6.1 Process Basics 6.2 Process Parameters 6.2.1 Building Chamber Dimensions 6.2.2 Layer Thickness 6.2.3 Scanspeed 6.2.4 Laser Beam Power 6.2.5 Exposure and Scan Strategy 6.2.6 Hatching 6.2.7 Available Metals and Alloys for LAM 6.3 Part Quality 6.3.1 Density 6.3.2 Strength 6.3.3 Hardness 6.3.4 Residual Stresses 6.3.5 Accuracy Grade 6.3.6 Subsurface Quality 6.5 Future Development 6.6 Biomimetic Application Areas of LAM Summary and Conclusion				
6.2.1 Building Chamber Dimensions. 6.2.2 Layer Thickness. 6.2.3 Scanspeed. 6.2.4 Laser Beam Power. 6.2.5 Exposure and Scan Strategy. 6.2.6 Hatching. 6.2.7 Available Metals and Alloys for LAM. 6.3 Part Quality. 6.3.1 Density. 6.3.2 Strength. 6.3.3 Hardness. 6.3.4 Residual Stresses. 6.3.5 Accuracy Grade. 6.3.6 Subsurface Quality. 6.5 Future Development. 6.6 Biomimetic Application Areas of LAM. Summary and Conclusion.	Claus			
6.2.1 Building Chamber Dimensions. 6.2.2 Layer Thickness. 6.2.3 Scanspeed. 6.2.4 Laser Beam Power. 6.2.5 Exposure and Scan Strategy. 6.2.6 Hatching. 6.2.7 Available Metals and Alloys for LAM. 6.3 Part Quality. 6.3.1 Density. 6.3.2 Strength. 6.3.3 Hardness. 6.3.4 Residual Stresses. 6.3.5 Accuracy Grade. 6.3.6 Subsurface Quality. 6.5 Future Development. 6.6 Biomimetic Application Areas of LAM. 5.7 Summary and Conclusion.	6.1	Process	Basics	
6.2.2 Layer Thickness 6.2.3 Scanspeed 6.2.4 Laser Beam Power 6.2.5 Exposure and Scan Strategy 6.2.6 Hatching 6.2.7 Available Metals and Alloys for LAM 6.3 Part Quality 6.3.1 Density 6.3.2 Strength 6.3.3 Hardness 6.3.4 Residual Stresses 6.3.5 Accuracy Grade 6.3.6 Subsurface Quality 6.5.5 Future Development 6.6 Biomimetic Application Areas of LAM 5.7 Summary and Conclusion	6.2	Process	Parameters	
6.2.3 Scanspeed 6.2.4 Laser Beam Power 6.2.5 Exposure and Scan Strategy 6.2.6 Hatching 6.2.7 Available Metals and Alloys for LAM 6.3 Part Quality 6.3.1 Density 6.3.2 Strength 6.3.3 Hardness 6.3.4 Residual Stresses 6.3.5 Accuracy Grade 6.3.6 Subsurface Quality 6.5.5 Future Development 6.6 Biomimetic Application Areas of LAM 5.7 Summary and Conclusion		6.2.1	Building Chamber Dimensions	
6.2.4 Laser Beam Power 6.2.5 Exposure and Scan Strategy 6.2.6 Hatching 6.2.7 Available Metals and Alloys for LAM 6.3 Part Quality 6.3.1 Density 6.3.2 Strength 6.3.3 Hardness 6.3.4 Residual Stresses 6.3.5 Accuracy Grade 6.3.6 Subsurface Quality 6.4 Designs for LAM 6.5 Future Development 6.6 Biomimetic Application Areas of LAM 6.7 Summary and Conclusion		6.2.2	Layer Thickness	
6.2.5 Exposure and Scan Strategy. 6.2.6 Hatching. 6.2.7 Available Metals and Alloys for LAM. 6.3 Part Quality. 6.3.1 Density. 6.3.2 Strength. 6.3.3 Hardness. 6.3.4 Residual Stresses 6.3.5 Accuracy Grade 6.3.6 Subsurface Quality. 6.4 Designs for LAM. 6.5 Future Development 6.6 Biomimetic Application Areas of LAM. 6.7 Summary and Conclusion		6.2.3	Scanspeed	
6.2.6 Hatching 6.2.7 Available Metals and Alloys for LAM 6.3 Part Quality 6.3.1 Density 6.3.2 Strength 6.3.3 Hardness 6.3.4 Residual Stresses 6.3.5 Accuracy Grade 6.3.6 Subsurface Quality 6.4 Designs for LAM 6.5 Future Development 6.6 Biomimetic Application Areas of LAM 6.7 Summary and Conclusion		6.2.4	Laser Beam Power	
6.2.7 Available Metals and Alloys for LAM  6.3 Part Quality 6.3.1 Density 6.3.2 Strength 6.3.3 Hardness 6.3.4 Residual Stresses 6.3.5 Accuracy Grade 6.3.6 Subsurface Quality 6.4 Designs for LAM 6.5 Future Development 6.6 Biomimetic Application Areas of LAM Summary and Conclusion		6.2.5	Exposure and Scan Strategy	
6.3 Part Quality 6.3.1 Density 6.3.2 Strength 6.3.3 Hardness 6.3.4 Residual Stresses 6.3.5 Accuracy Grade 6.3.6 Subsurface Quality 6.4 Designs for LAM 6.5 Future Development 6.6 Biomimetic Application Areas of LAM 5.7 Summary and Conclusion		6.2.6	Hatching	
6.3.1 Density		6.2.7	Available Metals and Alloys for LAM	
6.3.2 Strength. 6.3.3 Hardness. 6.3.4 Residual Stresses 6.3.5 Accuracy Grade 6.3.6 Subsurface Quality. 6.4 Designs for LAM. 6.5 Future Development 6.6 Biomimetic Application Areas of LAM. 6.7 Summary and Conclusion	6.3	Part Qu	ıality	
6.3.3 Hardness 6.3.4 Residual Stresses 6.3.5 Accuracy Grade 6.3.6 Subsurface Quality 6.4 Designs for LAM 6.5 Future Development 6.6 Biomimetic Application Areas of LAM 6.7 Summary and Conclusion		6.3.1	Density	
6.3.4 Residual Stresses 6.3.5 Accuracy Grade 6.3.6 Subsurface Quality 6.4 Designs for LAM 6.5 Future Development 6.6 Biomimetic Application Areas of LAM 6.7 Summary and Conclusion		6.3.2	Strength	
6.3.5 Accuracy Grade 6.3.6 Subsurface Quality 6.4 Designs for LAM 6.5 Future Development 6.6 Biomimetic Application Areas of LAM 6.7 Summary and Conclusion		6.3.3		
6.3.6 Subsurface Quality		6.3.4	Residual Stresses	
6.3.6 Subsurface Quality		6.3.5	Accuracy Grade	
5.4 Designs for LAM		6.3.6		
Future Development	6.4	Designs		
Biomimetic Application Areas of LAM	6.5			
5.7 Summary and Conclusion	6.6			
•	6.7			
References				

xii Contents

7		nimetic Coatings by Pulsed Laser Deposition	163			
	7.1	Methods and Biomaterials	164			
	7.1	7.1.1 PLD Definition and Concept	164			
		·				
	7.0	7.1.2 Inorganic Biomaterials	166			
	7.2	PLD Background	168			
		7.2.1 Laser Sources	168			
		7.2.2 Targets and Set-Ups	169			
		7.2.3 Plasma Plume	170			
		7.2.4 Thin Films Growth and Characterization	176			
	7.3	Biomimetic Inorganic Biomaterial Thin Films	177			
		7.3.1 Ca Phosphates (CaPs)	177			
		7.3.2 Multistructures	179			
		7.3.3 Composite Nanostructures	181			
	7.4	Conclusions and Outlook	185			
	Refe	rences	186			
8	Lase	er Assisted Bio-printing (LAB) of Cells and Bio-materials				
		d on Laser Induced Forward Transfer (LIFT)	193			
	Bertrand Guillotin, Sylvain Catros and Fabien Guillemot					
	8.1	Laser Assisted Bio-printing for Biomimetic				
	0.1	Tissue Engineering	193			
	8.2	Technical Implementation of LAB for Cell				
	0.2	and Biomaterial Printing	196			
		8.2.1 Droplet Ejection Mechanism	197			
		8.2.2 Printing Resolution	199			
		8.2.3 LAB Parameters for Cell Printing	200			
	8.3	Applications	203			
	0.5	8.3.1 LAB Engineered Stem Cell Niche	204			
		8.3.2 Modelling Capillary Formation	204			
		8.3.3 Laser Assisted Bio-printed of Tissue	205			
		Engineering Products	205			
		8.3.4 In Vivo Printing	205			
	8.4	e e e e e e e e e e e e e e e e e e e	200			
		Conclusions and Perspectives	207			
	Reie	rences	207			
9		r-Based Biomimetic Tissue Engineering	211			
		nanuel Stratakis, Anthi Ranella and Costas Fotakis				
	9.1	Introduction	212			
	9.2	Laser Processing of Biomaterials for Biomimetic				
		Tissue Engineering Scaffolds	213			
		9.2.1 Overview of the Biomaterials Used for Laser-Based				
		Tissue Engineering Applications	213			

		9.2.2	Laser-Based Methodologies for Biomimetic	
			Tissue Engineering	215
		9.2.3	Laser Processing of Artificial Biomaterials	220
		9.2.4	Laser Processing of Natural Biomaterials	227
	9.3	Conclus	sions and Outlook	230
	Refer	ences		232
10	Lasei	r Process	sing of Natural Biomaterials	237
	Wand	le Zhang	, Peter H. Chung, Aping Zhang and Shaochen Chen	
	10.1	Introduc	ction	238
	10.2	Natural	Biomaterials	239
		10.2.1	Collagen	239
		10.2.2	Agarose	240
		10.2.3	Hyaluronic Acid	240
		10.2.4	Matrigel <sup>TM</sup>	241
	10.3	Laser P	rocessing Methodologies for Biomaterials	241
		10.3.1	Laser Processing System Setup	241
		10.3.2	Laser-Induced Cross-Linking	243
		10.3.3	Laser Ablation	248
		10.3.4	Laser Activation	252
	10.4	Summa	ry	253
	Refer			254
11	Futui	re Persp	ectives	259
		_	ratakis, Anthi Ranella and Costas Fotakis	
	11.1		Perspectives of Biomimetics and Laser Technology	260
Ind	ex			263
	<del>-</del>			