

Contents

1	Introduction	1
1.1	Transparency	1
1.2	Transparent Materials	1
1.3	Important Issues on Transparency Important.	4
1.4	History of Solid-State Lasers	7
1.4.1	Lasers	7
1.4.2	Single Crystals	9
1.4.3	Transparent Ceramics	10
1.5	Performance of Solid-State Lasers.	13
1.5.1	Laser Materials.	13
1.5.2	Pumping Systems and Laser Resonators	14
1.6	Selection of Laser Material	14
1.6.1	Laser Active Ions	15
1.6.2	Host Materials	22
1.7	Other Applications of Transparent Ceramics.	23
1.8	Motivation and Objectives of the Book	23
1.9	Outline of the Book	23
	References.	25
2	Transparent Ceramic Materials.	29
2.1	Introduction	29
2.2	Simple Oxides	29
2.2.1	Alumina (Al_2O_3).	29
2.2.2	Zirconia (ZrO_2)	35
2.2.3	Sesquioxides	38
2.2.4	Magnesia (MgO)	46
2.3	Complex Oxides.	48
2.3.1	Garnet.	48
2.3.2	Spinel (MgAl_2O_4).	54

2.4	Electro-optic Ferroelectric Ceramics	60
2.4.1	PLZT Ceramics	61
2.4.2	Other Ferroelectric Ceramics	63
2.5	Mullite	66
2.6	Other Oxide Ceramics	68
2.6.1	Newly Emerged Oxide Ceramics	68
2.6.2	Transparent Ceramics Derived from Glasses	69
2.6.3	Multiphase Transparent Ceramics	71
2.7	Nonoxide Ceramics	72
2.7.1	AlON	72
2.7.2	Aluminum Nitride (AlN)	75
2.7.3	Sialon	75
2.8	Summary	77
	References.	77
3	Ceramic Powder Synthesis	93
3.1	Introduction	93
3.2	Synthesis of Precursor Powders	95
3.2.1	Solid-State Reaction Methods	95
3.2.2	Wet-Chemical Routes	122
3.3	Summary	175
	References.	175
4	Powder Characterization and Compaction	191
4.1	Introduction	191
4.2	Characterizations of Ceramic Powder	192
4.2.1	Physical Properties	192
4.2.2	Particle Size and Size Distribution	194
4.2.3	Particle Shapes	199
4.2.4	Measurement of Particle Size and Size Distribution	200
4.2.5	Surface Area	206
4.2.6	Porosity of Particles	208
4.2.7	Chemical Compositions	212
4.2.8	Crystal Structure and Phase Composition	215
4.2.9	Surface Properties	216
4.3	Compaction of Ceramic Powders	220
4.3.1	Packing of Particles	220
4.3.2	Additives and Ceramic Forming	225
4.3.3	Powder Compaction	230
4.3.4	Drying of Granular Ceramics	277
4.3.5	Binder Removal	279
4.3.6	Characterization of Green Bodies	280
4.4	Summary	281
	References.	281

5 Sintering and Densification (I)—Conventional

Sintering Technologies	291
5.1 Introduction	291
5.2 Fundamental Aspects of Sintering	292
5.2.1 Driving Forces of Sintering	292
5.2.2 Defects in Crystalline Solids	293
5.2.3 Diffusion in Crystalline Solids	304
5.2.4 Chemical Potential	312
5.2.5 Diffusional Flux Equations.	318
5.2.6 Vapor Pressure of Curved Surfaces	321
5.2.7 Diffusion in Ionic Crystals—Ambipolar Diffusion.	322
5.3 Solid-State and Viscous Sintering	325
5.3.1 Brief Description	325
5.3.2 Sintering Mechanisms	326
5.3.3 Grain Boundary Effects	327
5.3.4 Theory of Sintering	329
5.3.5 Scaling Laws	329
5.3.6 Analytical Methods	334
5.3.7 Numerical Simulation of Sintering	346
5.3.8 Phenomenological Sintering Equations.	349
5.3.9 Sintering Diagrams	350
5.3.10 Sintering at Pressures	351
5.3.11 Stress Intensification Factor	356
5.3.12 Sintering Stress.	358
5.3.13 Alternative Sintering Equations.	359
5.4 Liquid-Phase Sintering.	363
5.4.1 Brief Introduction	363
5.4.2 Characteristics of Liquid-Phase Sintering	363
5.4.3 Stages of Liquid-Phase Sintering.	366
5.4.4 Thermodynamic and Kinetic Factors	366
5.4.5 Grain Boundary Films	373
5.4.6 Mechanisms of Liquid-Phase Sintering	374
5.4.7 Hot Pressing with Liquid Phase	387
5.4.8 Phase Diagrams in Liquid-Phase Sintering	387
5.4.9 Activated Sintering and Vitrification	388
5.5 Concluding Remarks	389
References.	390

6 Sintering and Densification (II)—New Sintering Technologies 395

6.1 Introduction	395
6.2 Electric Current Activated/Assisted Sintering (ECAS)	395
6.2.1 Brief Description	395
6.2.2 Working Principles	396

6.2.3	Brief History of ECAS Processes	403
6.2.4	Modeling and Simulation	405
6.3	Microwave Sintering	453
6.3.1	Brief Introduction	453
6.3.2	Theoretical Aspects	455
6.3.3	Heat Transfer and Sintering	459
6.3.4	Nonthermal Effects	461
6.4	Summary	461
	References.	462
7	Sintering and Densification of Transparent Ceramics	467
7.1	Introduction	467
7.2	Vacuum Sintering	467
7.3	Hot Pressure (HP) Sintering	476
7.4	Hot Isostatic Pressure (HIP) Sintering	483
7.5	SPS Processed Transparent Ceramics.	488
7.6	MW-Processed Transparent Ceramics	502
7.7	Concluding Remarks	510
	References.	510
8	Grain Growth and Microstructure Development	519
8.1	Introduction	519
8.2	General Concepts	520
8.2.1	Features of Grain Growth	520
8.2.2	Microscopic Features of Grain Growth	520
8.2.3	Driving Force of Grain Growth	520
8.2.4	Abnormal Grain Growth	521
8.2.5	Grain Growth Control	523
8.3	Ostwald Ripening and LSW Theory	523
8.3.1	LSW Theory	525
8.3.2	Interface Reaction Mechanism	525
8.3.3	Diffusion-Controlled Mechanism.	527
8.3.4	Deviation and Modification of LSW Theory.	528
8.3.5	Time-Dependent Ostwald Ripening	528
8.4	Topological and Interfacial Tensions	529
8.5	Normal Grain Growth in Dense Solids	530
8.5.1	The Burke and Turnbull Model	530
8.5.2	Mean-Field Theory	532
8.5.3	Topological Analysis.	533
8.5.4	Simulation of Normal Grain Growth	534
8.6	Abnormal Grain Growth	535
8.6.1	Origins of Abnormal Grain Growth.	536
8.6.2	Applications of Abnormal Grain Growth	537

8.7	Grain-Boundary Mobility	553
8.7.1	Effect of Fine Second-Phase Particles	554
8.7.2	Effect of Dopants–Solute Drag	557
8.8	Grain Growth and Pore Evolution	560
8.8.1	Thermodynamics of Pore–Boundary Interactions.	560
8.8.2	Kinetics of Pore–Boundary Interactions	562
8.8.3	Grain Growth Kinetics.	563
8.9	Simultaneous Densification and Grain Growth	563
8.10	Strategies to Control Microstructure of Ceramics	568
8.10.1	Sintering at External Pressures	568
8.10.2	Use of Dopants and Inclusions	569
8.10.3	Use of Fine Particles with Uniform Packing.	570
8.10.4	Control of Firing Schedule.	570
8.10.5	Use of Liquid-Phase Sintering	573
8.11	Concluding Remarks	573
	References.	574
9	Laser Applications	581
9.1	Introduction	581
9.2	Ceramic Solid-State Lasers.	581
9.2.1	Pumping Schemes.	582
9.2.2	Radiative and Nonradiative Processes	587
9.2.3	Ceramic Laser Materials and Components	592
9.2.4	Practical Ceramic Lasers	593
9.3	Advanced Ceramic Lasers	642
9.3.1	Motivation and Overview	642
9.3.2	Composite Ceramic Lasers.	643
9.3.3	Fiber Ceramic Lasers	653
9.4	Summary.	659
	References.	659
10	Other Applications	675
10.1	Brief Introduction	675
10.2	Lighting.	675
10.2.1	Sapphire	676
10.2.2	Alumina Ceramics with Fine Grains	676
10.2.3	AlON (Aluminum Oxynitride)	678
10.2.4	YAG (Yttrium Aluminate Garnet).	678
10.2.5	Rare-Earth Oxide (Re_2O_3)	679
10.3	Scintillators	682
10.3.1	Brief Description	682
10.3.2	Properties of Scintillators	684
10.3.3	Transparent Ceramic Scintillators	690

10.4	Ceramic Electro-Optic Devices	696
10.5	Optical Systems (Lens)	701
10.6	Armors and Windows/Domes	704
10.6.1	Brief Description	704
10.6.2	Transparent Ceramics Armors	705
10.6.3	Transparent Armor Design and Dynamic Responses . . .	706
10.7	Other Applications	720
10.8	Conclusions	725
	References	726

Transparent Ceramics

Kong, L.B.; Huang, Y.Z.; Que, W.; Zhang, T.S.; Li, S.;

Zhang, J.; Dong, Z.L.; Tang, D.Y.

2015, XII, 734 p. 408 illus., 127 illus. in color.,

Hardcover

ISBN: 978-3-319-18955-0