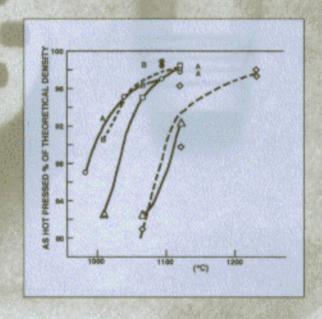
Ceramic Fabrication Technology



Roy W. Rice

Contents

	eface brevia	tions	iii xi
1.	BAC	CKGROUND AND OVERVIEW	1
	1.1	Introduction	1
	1.2	Why Ceramics and Which Ones	3
	1.3	Political and Economic Factors Impacting Development	
		and Application of Advanced Ceramics	8
	1.4	Cost and Profit Factors	12
	1.5	Overview of Ceramic Fabrication Technology	21
	1.6	Summary and Conclusions	24
	Refe	erences	25
2.	PREPARATION OF CERAMIC POWDERS		
	2.1	Introduction and Background	27
	2.2		
		Chemical Salt Precipitation and Calcination	29
	2.3	Production of Other Single and Mixed-Oxide Powders via	
		Salt Precursor Decomposition	35
		•	

viii			Contents
	2.4	Direct Production of Oxide Powders	41
	2.5	Processing of Nonoxide Powders	48
	2.6	Powder Particle Coating and Characterization	57
	2.7	Powder and Particle Characterization	60
	2.8	Discussion, Summary, and Conclusions	62
	Refe	erences	63
3.	USE	OF ADDITIVES IN POWDER PREPARATION	
		OOTHER RAW MATERIALS AND	
	NO	NDENSIFICATION USES	73
	3.1	Introduction	73
	3.2	Use of Additives in Preparing Ceramic Powders	74
	3.3	, U	78
	3.4	Use of Additives in the Growth of Ceramic and Related	
		Whiskers and Platelets	83
	3.5	Use of Additives in Other Ceramic Processing, Especially	
		Melt Processing	85
	3.6	Discussion, Summary, and Conclusions	90
	Keie	erences	91
4.		MING AND PRESSURELESS SINTERING OF POWER-	
-	DER	RIVED BODIES	99
	4.1	Introduction	99
	4.2	Powder Consolidation Under Pressure with Little Binder	
		and Plastic Flow	100
		4.2.1 Die Pressing	100
		4.2.2 Hydrostatic/isostatic pressing	110
	4.3	Plastic Forming	113
		4.3.1 Extrusion	113
		4.3.2 Injection molding	118
	4.4	Colloidal Processing	121
٠.		4.4.1 Slip, tape, and pressure casting	121
		4.4.2 Electrophoretic deposition (EPD)	126
	4.5	Miscellaneous Powder Consolidation Technologies	129
	4.6	Binder Systems, Drying, Green Machining, Binder-Burnout,	
	47	and Bisque Firing/Machining	131
	4.7	Sintering Discussion and Summers	135
	4.8	Discussion and Summary rences	138
	L'GIG	TCHCC8:	141

ts.	ix
1 \$	ix

5.	TICE	OF ADDITIVES TO AID DENSIFICATION	147
J.			
	5.1	Introduction	147
	5.2		149
	5.3		155
	5.4		166
		5.4.1 Aluminates	166
		5.4.2 Silicates	167
		5.4.3 Ferrites	
		5.4.4 Electrical ceramics	
		Nonoxides	
		Ceramic Composites	-
		Discussion and Conclusions	
	Refe	rences	187
6.	OTI	IER GENERAL DENSIFICATION AND FABRICATION	
	ME	THODS	205
	6.1	Introduction	205
	6.2	Hot Pressing	206
		6.2.1 Practice and results	206
		6.2.2 Extending practical capabilities of hot pressing	215
	6.3	Press Forging and Other Deformation Forming	
		Processes	220
	6.4	Hot Isostatic Pressing	225
	6.5	Reaction Processing	228
	6.6	Melt Processing	246
		6.6.1 Glasses and polycrystalline bodies	246
		6.6.2 Single crystals	205 206 206 215 220 225 228 246 246 251 257 259 261
		6.6.3 Eutectic ceramics and directional crystallization	
		of glasses	257
	6.7	Summary	259
	Refe	rences	261
7.	CDE	CIAL EADDICATION METHODS	270
7.		CIAL FABRICATION METHODS	
	7.1	Introduction	270
	7.2	Fabrication of Filaments, Fibers, and Related Entities for	
		Reinforcement and Other Applications	270
		7.2.1 Introduction to miscellaneous and polymer-derived	÷
		ceramic fibers	270

x	Contents

X				Content
		7.2.2	Preparation of ceramic fibers from ceramic power	lers
			and by conversion of other fibers	27:
		7.2.3	CVD of ceramic filaments and melt-derived	
		•	fibers and filaments	27
		7.2.4	Fiber and filament behavior, uses in composites,	
			and future directions	28
	7.3	Fabric	eation of Porous Bodies	28:
			Introduction	28
		7.3.2	Porous bodies via ceramic bead and balloon and	
			other fabrication methods	28
	7.4		Prototyping/Solid Freeform Fabrication (SFF)	29:
			Introduction and methods	29:
		7.4.2	SFF applications, comparisons, and trends	29
	7.5		nic Fiber Composites	30:
	7.6			30
	7.7	Discus	ssion and Summary	30
	Refe	erences	,	31
8.	CROSSCUTTING, MANUFACTURING FACTORS, AND			
	FAB	BRICATION		
	8.1	Introd	uction	31
	8.2	Import	tant Crosscutting Factors	31
•		8.2.1	Anion/gaseous impurities and outgassing prior to	
•			or during densification	31
		8.2.2	Effects of alternate heating methods	32:
		8.2.3	Fabrication of ceramic composites	32:
	8.3	Manuf	facturing Factors	329
		8.3.1	Machining and surface finishing	329
		8.3.2	Component inspection and nondestructive	
			evaluation (NDE)	333
		8.3.3	Attachment and joining	33:
		Fabric	ation Overview and Opportunities to Improve	
	8.4		acturing Processes	341
	8.4	Manui		
		Manuf rences	3	348
Ina	Refe			348 353