

Contents

1	Introduction	1
1.1	Fascination and Motivation of Nanoparticle Research	1
1.2	Metal Oxides: Properties and Applications.....	3
	References	4
2	Aqueous and Nonaqueous Sol-Gel Chemistry	7
2.1	Introduction	7
2.2	Aqueous Sol-Gel Chemistry	9
2.3	Nonaqueous Sol-Gel Chemistry	12
2.4	Surfactant-Directed vs. Solvent-Controlled Nonaqueous Sol-Gel Approaches	14
	References	16
3	Surfactant-Assisted Synthesis	19
3.1	Hot-Injection Method	19
3.2	Heating-Up Method	23
3.3	Comparison of the Heating-Up and Hot-Injection Method ...	26
3.4	Solvothermal Synthesis	26
3.5	Microwave Technique	27
3.6	Seed-Mediated Growth	29
3.7	Self-Assembled Nanoparticles	31
3.8	Heterostructures/Multicomponent Nanoparticles	32
3.9	Nonaqueous Processes Using Traces of Water	35
3.10	Tabular Overview	36
	References	43
4	Solvent-Controlled Synthesis	53
4.1	Nanoparticles	53
4.1.1	Introduction	53
4.1.2	Experimental Set-up	54
4.1.3	Reaction of Metal Halides with Alcohols	55

4.1.4	Reaction of Metal Alkoxides, Acetates and Acetylacetonates with Alcohols.....	58
4.1.5	Reaction of Metal Alkoxides with Aldehydes and Ketones	62
4.1.6	Reaction of Metal Acetylacetonates with Amines and Nitriles	63
4.1.7	Others	64
4.1.8	Microwave Technique	65
4.1.9	Tabular Overview of Metal Oxide Nanoparticles	66
4.2	Organic-Inorganic Hybrid Materials	74
4.2.1	Introduction	74
4.2.2	Rare Earth Oxide Based Hybrid Nanoparticles	75
4.2.3	Tungsten Oxide Based Hybrid Materials	78
4.2.4	Hybrid Materials Synthesized in Other Solvents	78
4.3	Nonaqueous Routes Applied to Atomic Layer Deposition	81
	References	86
5	Reaction Mechanism	97
5.1	Introduction	97
5.2	Alkyl Halide Elimination	98
5.3	Ether Elimination	103
5.4	Ester and Amide Eliminations	105
5.5	C-C Bond Formation Between Alkoxy Groups.....	107
5.6	Aldol/Ketimine Condensation	112
5.7	Oxidation of Metals	118
5.8	Other Mechanisms.....	119
5.9	Discussion	120
	References	122
6	Assembly	129
6.1	Introduction	129
6.2	Oriented Attachment and Mesocrystals.....	130
6.3	Superlattices	135
6.4	Mesoporous Materials	140
	References	142
7	Characterization	147
7.1	Introduction	147
7.2	Transmission Electron Microscopy	148
7.2.1	The Operation Modes.....	148
7.2.2	HRTEM Image Simulations.....	153
7.2.3	TEM Studies of Nanostructures by Oriented Attachment.....	155
7.3	Powder X-ray Diffraction	159
7.4	Combination of a Range of Techniques	164

7.4.1	Hollandite-Type Vanadium Oxyhydroxide Nanorods ..	164
7.4.2	Lanthanide-Based Organic-Inorganic Hybrid Nanostructures.....	167
References	171
8	Properties and Applications	175
8.1	Introduction	175
8.2	Magnetic Properties	176
8.2.1	Magnetic Metal Oxides	176
8.2.2	Diluted Magnetic Semiconductors	177
8.3	Photoluminescent Metal Oxides	180
8.3.1	Rare Earth-Based Nanostructures	180
8.3.2	Semiconductor Nanoparticles	185
8.4	(Photo)catalysis	186
8.5	Gas Sensing	187
8.5.1	Introduction	187
8.5.2	Sensor Devices	188
8.5.3	Nanoparticles Made in Surfactant-Free Systems	189
8.5.4	Nanoparticles Made in Surfactant Systems.....	194
8.5.5	Sensing Layers Synthesized by ALD	194
8.6	Biomedical Applications	196
8.7	Other Applications	197
References	197
9	Summary, Conclusion and Outlook	205
Index	211

Metal Oxide Nanoparticles in Organic Solvents
Synthesis, Formation, Assembly and Application

Niederberger, M.; Pinna, N.

2009, XIII, 217 p., Hardcover

ISBN: 978-1-84882-670-0