

INTRODUCTION	XVIII
REASON FOR THE STUDY AND ITS IMPORTANCE	XVIII
OBJECTIVES OF THIS STUDY AND ITS CONTRIBUTION.....	XVIII
AUDIENCE FOR THIS REPORT	XVIII
SCOPE AND CONTENT OF THIS REPORT.....	XIX
METHODOLOGY AND INFORMATION SOURCES.....	XX
ANALYST CREDENTIALS.....	XX
RELATED BCC REPORTS	XX
BCC ONLINE SERVICES.....	XXII
DISCLAIMER	XXII
EXECUTIVE SUMMARY	XXIII
<i>SUMMARY TABLE TOTAL WORLD MARKET PROJECTIONS FOR NANOPARTICLES IN BIOMEDICAL, PHARMACEUTICAL AND COSMETIC APPLICATIONS, THROUGH 2012 (\$ MILLIONS)</i>	XXIII
<i>SUMMARY FIGURE TOTAL WORLD MARKET SHARE PROJECTIONS FOR BIOMEDICAL, PHARMACEUTICAL AND COSMETIC APPLICATIONS OF NANOPARTICLES, 2006–2012 (%)</i>	XXIV
OVERVIEW	1
TERMINOLOGY.....	1
PRODUCTS AND PROPERTIES.....	2
<i>TABLE 1 SUMMARY OF PROPERTY CHANGES AT THE NANOCRYSTALLINE-SIZE SCALE</i>	2
CATALYTIC	2
ELECTRICAL.....	3
MAGNETIC	3
Magnetic (Continued).....	4
MECHANICAL.....	5
OPTICAL AND ELECTRONIC	6
HISTORICAL BACKGROUND.....	6
HISTORICAL BACKGROUND (CONTINUED)	7
<i>FIGURE 1 TIMELINE OF INDUSTRY EVENTS, 1920-2000</i>	8
NANOPARTICLE TECHNOLOGIES.....	9
PARTICLE PRODUCTION	9
TECHNOLOGIES FOR PRODUCING INORGANIC NANOPARTICLES	9
<i>TABLE 2 CLASSES OF INORGANIC NANOPARTICLE PRODUCTION METHODS</i>	10
<i>TABLE 3 PARTICLE PRODUCTION TECHNOLOGIES AND COMPANIES USING THEM</i>	10
<i>TABLE 3 (CONTINUED)</i>	11
Gas-Phase Processing.....	11

Gas Condensation with Thermal Evaporation	11
Vacuum Evaporation on Running Liquids (VERL)	12
<i>FIGURE 2 SCHEMATIC OF THE MODIFIED VERL PROCESS TO PRODUCE METAL NANOSUSPENSIONS</i>	13
Thermal Plasma Synthesis	13
Combustion Synthesis	14
Wet-Chemical Processes	14
Chemical Precipitation	14
Hydrothermal Processing	15
Sol-Gel Processing	16
<i>FIGURE 3 SOL-GEL SYNTHESIS FLOW CHART</i>	16
Solid-State Processes	16
High-Energy Milling	17
Mechanochemical Synthesis	17
TECHNOLOGIES FOR PRODUCING ORGANIC NANOPARTICLES	18
Lipids	18
Dendrimers	18
PRODUCING STABLE DISPERSIONS	19
PRODUCTION OF COATINGS, COMPONENTS, AND DEVICES	19
COATINGS	20
Slurry-Coating Routes	20
Dip Coating	20
Spin Coating	20
Comparison with Vapor-Deposition Techniques	21
<i>TABLE 4 COMPARISON OF COATING TECHNOLOGIES</i>	21
Electrophoretic Deposition	22
Jet-Printing Process	22
Thermal Spray Coating	22
Direct Production of Nanostructured Coatings and Bulk Solids	23
Electrodeposition	23
Amorphous Crystallization	24
COMPONENTS AND DEVICES	25
Consolidation of Nanoparticles into Components	25
Three-Dimensional Gel Lamination	25
Dynamic-Magnetic Consolidation	26
Field-Assisted Sintering Techniques	26
Quasi-Isostatic Pressure Process	27
Shockwave Compaction	27
Sinter Forging	28
Severe Plastic Deformation	29
SELF-ASSEMBLY OF NANOPARTICLES	29

“BRICKS-AND-MORTAR” APPROACH ORDERS GOLD PARTICLES	29
MICELLES ENABLE ASSEMBLY OF NANOLAMINATES	30
VIRAL BIOTEMPLATE ORGANIZES NANOMETAL PARTICLES INTO ARRAYS.....	31
MAGNETIC NANOPARTICLE DISPERSIONS SELF-ASSEMBLE INTO ORDERED ARRAYS.....	32
U.S. PATENT ANALYSIS	32
Introduction	32
Trends by Country.....	33
Trends by Assignee.....	33
<i>FIGURE 4 U.S. PATENT TRENDS BY ASSIGNEE’S COUNTRY (NUMBER OF PATENTS ISSUED BETWEEN 10/15/2005 AND 10/15/2007)</i>	34
<i>FIGURE 5 SHARES OF U.S. PATENTS BY ASSIGNEE (%)</i>	35
<i>TABLE 5 COMPANIES AND INSTITUTIONS AWARDED TWO OR MORE NANOMATERIAL-RELATED PATENTS BETWEEN OCTOBER 15, 2005 AND OCTOBER 15, 2007</i>	36
Trends by Emphasis: Production versus Application	36
<i>FIGURE 6 SHARES OF PATENTS ISSUED BY EMPHASIS (%)</i>	37
INDUSTRY STRUCTURE	38
PRODUCERS	38
<i>TABLE 6 COMPANIES WORLDWIDE INVOLVED IN NANOPARTICLE DEVELOPMENT OR PRODUCTION FOR BIOMEDICAL AND COSMETIC APPLICATIONS</i>	38
<i>TABLE 7 (CONTINUED)</i>	39
<i>FIGURE 7 GEOGRAPHICAL DISTRIBUTION OF COMPANIES INVOLVED IN NANOPARTICLE DEVELOPMENT OR PRODUCTION FOR BIOMEDICAL AND COSMETIC APPLICATIONS (%)</i>	40
COMMERCIAL PRODUCTS	41
NANOPARTICLE PRICING	41
<i>TABLE 7 FACTORS THAT IMPACT THE PRICING OF NANOPARTICLES</i>	42
COMMERCIALIZATION STRATEGIES.....	42
INTERNATIONAL COMPETITION	43
REGULATORY ENVIRONMENT	44
REGULATION IN THE U.S.....	44
U.S. Food and Drug Administration.....	44
Medical Devices.....	44
Drugs and Biologicals	45
Combination Products	46
U.S. Environmental Protection Agency.....	46
Other Agencies.....	47

REGULATION OVERSEAS	47
GOVERNMENT FUNDING	48
NATIONAL NANOTECHNOLOGY INITIATIVE (NNI)	48
<i>TABLE 8 NNI BUDGET REQUESTS FOR NATIONAL INSTITUTES OF HEALTH, 2004–2008 (\$ MILLIONS)</i>	49
<i>FIGURE 8 RECENT TRENDS IN U.S. NATIONAL NANOTECHNOLOGY INITIATIVE SPENDING ON BIOMEDICAL R&D NANOTECHNOLOGY RESEARCH, FY 2004–2008 (BUDGET REQUESTS IN \$ MILLIONS)</i>	49
THE ADVANCED TECHNOLOGY PROGRAM (ATP)	50
Background	50
Relevant Awards	50
<i>TABLE 9 ADVANCED TECHNOLOGY PROGRAM AWARDS RELATED TO BIOMEDICAL, PHARMACEUTICAL, AND COSMETIC APPLICATIONS OF NANOPARTICLES, 1999–2008 (\$ MILLIONS)</i>	50
SMALL BUSINESS INNOVATION RESEARCH (SBIR) AND SMALL BUSINESS TECHNOLOGY TRANSFER (STTR) PROGRAMS	51
Background	51
Relevant Awards	51
<i>TABLE 10 RECIPIENTS OF THREE OR MORE NANOMATERIALS-RELATED PHASE I SBIR/STTR AWARDS, 1991–2007 (NUMBERS ARE LOWER-BOUNDS)</i>	52
WORLD MARKETS	53
INTRODUCTION	53
WORLD MARKETS OVERVIEW	53
OVERALL MARKET FOR NANOPARTICLES IN BIOMEDICAL, PHARMACEUTICAL, AND COSMETIC APPLICATIONS	53
<i>FIGURE 9 WORLD MARKET PROJECTIONS FOR NANOPARTICLES IN BIOMEDICAL, PHARMACEUTICAL AND COSMETIC APPLICATIONS, 2006–2012 (\$ MILLIONS)</i>	54
<i>FIGURE 10 WORLD MARKET FORECAST FOR NANOPARTICLES IN BIOMEDICAL, PHARMACEUTICAL, AND COSMETIC APPLICATIONS, 2006–2012 (MILLION KG)</i>	54
MARKET SEGMENTATION BY APPLICATION	55
Segmentation in Terms of Value	55
<i>TABLE 11 WORLD MARKET PROJECTIONS FOR NANOPARTICLES IN BIOMEDICAL, PHARMACEUTICAL, AND COSMETIC APPLICATIONS BY TYPE OF APPLICATION IN TERMS OF VALUE, THROUGH 2012 (\$ MILLIONS)</i>	55
<i>TABLE 11 (CONTINUED)</i>	56
<i>FIGURE 11 WORLD NANOPARTICLES MARKET SHARE PROJECTIONS BY APPLICATION, 2006–2012 (%)</i>	57

Segmentation in Terms of Volume.....	57
<i>TABLE 12 WORLD MARKET PROJECTIONS FOR NANOPARTICLES IN BIOMEDICAL, PHARMACEUTICAL, AND COSMETIC APPLICATIONS BY APPLICATION IN TERMS OF VOLUME, THROUGH 2012 (KG)</i>	58
MARKET SEGMENTATION BY MATERIAL TYPE.....	58
Segmentation in Terms of Value	59
<i>TABLE 13 WORLD MARKET PROJECTIONS FOR NANOPARTICLES IN BIOMEDICAL, PHARMACEUTICAL, AND COSMETIC APPLICATIONS BY MATERIAL TYPE IN TERMS OF VALUE, THROUGH 2012 (\$ MILLIONS)</i>	59
<i>FIGURE 12 WORLD MARKET SHARE PROJECTIONS FOR NANOPARTICLES BY MATERIAL TYPE, 2006–2012 (%)</i>	60
Segmentation in Terms of Volume.....	61
<i>TABLE 14 WORLD MARKET PROJECTIONS FOR NANOPARTICLES IN BIOMEDICAL, PHARMACEUTICAL, AND COSMETIC APPLICATIONS BY MATERIAL TYPE IN TERMS OF VOLUME, THROUGH 2012 (KG)</i>	61
DETAILED MARKET ANALYSIS.....	61
ANTIMICROBIAL MATERIALS	61
Background.....	62
Materials, Production, and Technical Requirements.....	63
Commercial and Regulatory Status.....	63
Antimicrobial Materials	64
<i>TABLE 15 ANTIMICROBIAL PRODUCTS INCORPORATING SILVER NANOPARTICLES</i>	65
Nucryst Pharmaceuticals.....	65
Surfacine Development Co.....	66
Try Co.....	66
Fraunhofer Institute.....	66
Mineral Supplements	67
World Markets.....	67
<i>FIGURE 13 PROJECTED TRENDS IN THE WORLD MARKET FOR NANOPARTICULATE SILVER USED IN ANTIMICROBIAL APPLICATIONS, 2006–2012 (\$ MILLIONS)</i>	68
Antimicrobial Dressings	68
<i>TABLE 16 WORLD MARKET PROJECTIONS FOR NANOPARTICULATE SILVER, THROUGH 2012 (KG/\$ MILLIONS)</i>	69
Dietary Supplements	69
BIOLOGICAL DETECTION AND LABELING.....	70
Background.....	70
Materials, Production, and Technical Requirements.....	70
<i>TABLE 17 BASIC REQUIREMENTS OF DIAGNOSTIC TESTS</i>	71
Commercial and Regulatory Status.....	71

Established Applications	72
Colloidal Gold	72
TABLE 18 RAPID DIAGNOSTIC TESTS THAT USE GOLD	
NANOPARTICLES AS LABELS	73
Nanoprobes, Inc.	74
Orasure Technologies, Inc.....	74
Dendrimers	74
Emerging Technologies and Applications.....	74
TABLE 19 EMERGING NANOPARTICLE-BASED TECHNOLOGIES	
FOR BIODETECTION AND LABELING BY COMPANY.....	75
TABLE 20 COMPARISON OF VARIOUS TYPES OF EMERGING	
NANOPARTICULATE LABELING TECHNOLOGIES	75
BioCrystal, Ltd.	76
Evident Technologies.....	76
MagnaBioSciences, LLC.....	76
Microcosm, Inc.....	77
Nanocrystal Technologies, LP.....	78
Nanosphere, Inc.	78
NymoxPharmaceutical Corp.....	79
Quantum Dot Corp.	79
TABLE 21 COMPARISON BETWEEN QDOTS AND CONVENTIONAL	
ORGANIC DYES.....	80
World Markets	80
TABLE 22 WORLD MARKET PROJECTIONS FOR NANOPARTICLES	
IN BIODETECTION AND LABELING APPLICATIONS, THROUGH	
2012 (KG/\$ MILLIONS)	81
FIGURE 14 PROJECTED TRENDS IN THE WORLD MARKET FOR	
NANOPARTICLES USED IN BIODETECTION AND LABELING	
APPLICATIONS, 2006–2012 (\$ MILLIONS).....	81
Colloidal Gold.....	82
TABLE 23 WORLD MARKET PROJECTIONS FOR	
NANOPARTICULATE GOLD USED IN BIOLABELING	
APPLICATIONS, THROUGH 2012 (KG/\$ MILLIONS).....	82
Dendrimers.....	82
TABLE 24 WORLD MARKET PROJECTIONS FOR DENDRIMERS	
USED IN BIOLABELING APPLICATIONS, THROUGH 2012	
(KG/\$ MILLIONS)	83
Semiconductor Nanoparticles.....	83
TABLE 25 WORLD MARKET PROJECTIONS FOR SEMICONDUCTOR	
NANOPARTICLES USED IN BIOLABELING APPLICATIONS,	
THROUGH 2012 (KG/\$ MILLIONS).....	84
Superparamagnetic Particles	85
TABLE 26 WORLD MARKET PROJECTIONS FOR	
SUPERPARAMAGNETIC NANOPARTICLES USED IN	

<i>BIOLABELING APPLICATIONS, THROUGH 2012</i>	
<i>(KG/\$ MILLIONS)</i>	85
BIOMAGNETIC SEPARATIONS	86
Background	86
Materials, Production, and Technical Requirements.....	87
Commercial and Regulatory Status.....	88
<i>TABLE 27 PRODUCERS OF SUPERPARAMAGNETIC</i>	
<i>MICROSPHERES FOR BIOLOGICAL SEPARATION</i>	
<i>APPLICATIONS</i>	89
World Markets	89
<i>TABLE 28 WORLD MARKETS FOR IRON OXIDE NANOPARTICLES</i>	
<i>IN BIOMAGNETIC SEPARATIONS, THROUGH 2012</i>	
<i>(KG/\$ MILLIONS)</i>	89
<i>FIGURE 15 PROJECTED TRENDS IN THE WORLD MARKET FOR</i>	
<i>NANOPARTICULATE IRON OXIDE USED IN BIOSEPARATION</i>	
<i>APPLICATIONS, 2006–2012 (\$ MILLIONS)</i>	90
DRUG DELIVERY	91
Background	91
<i>TABLE 29 CRITERIA FOR A NANOPARTICULATE DRUG DELIVERY</i>	
<i>VEHICLE</i>	91
Materials, Production, and Technical Requirements.....	91
Commercial and Regulatory Status.....	92
<i>TABLE 30 COMPANIES ACTIVE IN THE DEVELOPMENT OF</i>	
<i>NANOPARTICLES FOR DRUG-DELIVERY APPLICATIONS</i>	92
Cytimmune Sciences.....	93
<i>TABLE 31 TIMELINE OF NEW DRUG DEVELOPMENT PROCESS</i>	93
PowderMed, Ltd.....	94
SkyePharma	94
Starpharma	95
World Markets	95
<i>TABLE 32 WORLD MARKET PROJECTIONS FOR DENDRIMER-</i>	
<i>BASED DRUG DELIVERY SYSTEMS, THROUGH 2012</i>	
<i>(KG/\$ MILLIONS)</i>	96
MAGNETIC RESONANCE IMAGING (MRI) CONTRAST	
AGENTS	97
Background	97
<i>TABLE 33 TYPES OF CONTRAST AGENTS USED FOR MRI IMAGING</i>	97
Materials, Production, and Technical Requirements.....	98
Commercial and Regulatory Status.....	98
<i>TABLE 34 SUPERPARAMAGNETIC IRON OXIDE CONTRAST MEDIA:</i>	
<i>REGULATORY AND MARKETING STATUS</i>	99
World Markets	99

<i>TABLE 35 WORLD MARKET PROJECTIONS FOR NANOPARTICULATE IRON OXIDE USED IN MRI CONTRAST MEDIA, THROUGH 2012 (KG/\$ MILLIONS)</i>	100
<i>FIGURE 16 PROJECTED TRENDS IN THE WORLD MARKET FOR NANOPARTICULATE IRON OXIDE USED IN MRI CONTRAST APPLICATIONS, 2006–2012 (\$ MILLIONS)</i>	100
TRANSFECTION REAGENTS	101
Background	101
Materials, Production, and Technical Requirements.....	102
Commercial and Regulatory Status.....	102
World Markets	102
<i>TABLE 36 WORLD MARKET PROJECTIONS FOR DENDRIMERS USED IN TRANSFECTION REAGENTS, THROUGH 2012</i>	103
<i>FIGURE 17 PROJECTED TRENDS IN THE WORLD MARKET FOR DENDRIMERS USED IN TRANSFECTION REAGENTS, 2006–2012 (\$ MILLIONS)</i>	103
ANTIOXIDANTS.....	104
Background	104
Materials, Production, and Technical Requirements.....	105
Commercial and Regulatory Status.....	105
World Markets	106
<i>TABLE 37 WORLD MARKET PROJECTIONS FOR SILICA HYDRIDE NANOPARTICLES USED IN NUTRACEUTICALS, THROUGH 2012 (KG/\$ MILLIONS)</i>	106
<i>FIGURE 18 PROJECTED TRENDS IN THE WORLD MARKET FOR SILICA HYDRIDE NANOPARTICLES USED IN ANTIOXIDANT NUTRACEUTICAL, 2006–2012 (\$ MILLIONS)</i>	106
ORTHOPEDIC AND DENTAL APPLICATIONS	107
Background	107
Materials, Production, and Technical Requirements.....	108
Commercial and Regulatory Status.....	109
<i>TABLE 38 COMPANIES ACTIVE IN DEVELOPING NANOPARTICLE-BASED BIOACTIVE CERAMICS</i>	109
World Markets	110
<i>TABLE 39 WORLD MARKET PROJECTIONS FOR NANOPARTICLE-BASED SYNTHETIC BONE AND TOOTH ENAMELS, THROUGH 2012 (KG/\$ MILLIONS)</i>	111
<i>FIGURE 19 PROJECTED TRENDS IN THE WORLD MARKET FOR NANOPARTICULATE HYDROXYAPATITE, 2006–2012 (\$ MILLIONS)</i>	111
World Markets (Continued).....	112
SUNSCREENS AND UV-PROTECTIVE COSMETICS	113
Background	113

<i>TABLE 40 SUNSCREEN INORGANIC AND ORGANIC ACTIVE INGREDIENTS.....</i>	<i>114</i>
Materials, Production, and Technical Requirements.....	115
<i>TABLE 41 TECHNICAL REQUIREMENTS FOR NANOPARTICLES IN UV-SHIELDING APPLICATIONS.....</i>	<i>115</i>
Commercial and Regulatory Status.....	116
<i>TABLE 42 PRODUCERS OF TIO₂ AND ZNO PARTICLES AND DISPERSIONS.....</i>	<i>116</i>
Commercial and Regulatory Status (Continued).....	117
<i>TABLE 43 SUNSCREEN AND DAILY-USE SKIN PROTECTION PRODUCTS CONTAINING NANOPARTICULATE TIO₂ AND ZNO.....</i>	<i>118</i>
Recent Developments.....	118
Process for Preparing Passivated TiO ₂ Nanoparticles.....	119
Titanium Dioxide Coated with Silicon Dioxide.....	119
Coated TiO ₂ Nanoparticles.....	119
World Markets.....	119
<i>TABLE 44 PROJECTED TRENDS IN WORLDWIDE SUNSCREEN SALES, THROUGH 2012 (\$ BILLIONS).....</i>	<i>120</i>
<i>FIGURE 20 PROJECTED TRENDS IN THE WORLD MARKET FOR TIO₂ AND ZNO NANOPARTICLES USED IN SUNCREENS AND OTHER SKIN CARE PRODUCTS, 2006–2012 (\$ MILLIONS).....</i>	<i>120</i>
<i>TABLE 45 WORLD MARKET PROJECTIONS FOR TIO₂ AND ZNO NANOPARTICLES IN SUNSCREEN APPLICATIONS, THROUGH 2012 (KG/\$ MILLIONS).....</i>	<i>121</i>
COMPANY PROFILES.....	122
ADVANCED NANOTECHNOLOGY, LTD.....	122
AMAG PHARMACEUTICALS, INC.....	122
ALTAIR NANOTECHNOLOGIES, INC.....	123
ANGSTROM MEDICA, INC.....	124
APHIOS CORP.....	124
ARGONIDE CORP.....	125
BANGS LABORATORIES, INC.....	125
BASF AG.....	126
BERKELEY ADVANCED BIOMATERIALS, INC.....	127
BIOPHAN TECHNOLOGIES, INC.....	127
CAPSULATION NANOSCIENCE AG.....	127
CYTIMMUNE SCIENCES, INC.....	128
DENDRITECH, INC.....	128
DENDRITIC NANOTECHNOLOGIES, INC.....	128
DOW CHEMICAL CO.....	129
DONG SEO, INC.....	130
DYNAL BIOTECH ASA.....	130
ELEMENTIS SPECIALTIES.....	130

EMD CHEMICALS, INC.....	131
EVIDENT TECHNOLOGIES.....	131
EVONIK DEGUSSA GMBH	132
FLAMEL TECHNOLOGIES S.A.	133
INFRAMAT CORP.....	133
INVITROGEN CORP.....	133
ISHIHARA SANGYO KAISHA, LTD.....	134
KEMIRA SPECIALTY	135
MAGNABIOSCIENCES, LLC.....	135
MICROCOSM, INC.....	136
MICROMOD PARTIKELTECHNOLOGIE GMBH.....	136
NANOCARRIER CORP., LTD.	137
NANOPHASE TECHNOLOGIES CORP.....	137
NANOPROBES, INC.	138
NANOSPHERE, INC.....	138
NOVAVAX, INC.....	139
NUCRYST PHARMACEUTICALS	140
NYMOX PHARMACEUTICAL CORP.	140
ORASURE TECHNOLOGIES, INC.....	141
ORTHOVITA, INC.	142
OSI PHARMACEUTICALS, INC.....	142
PHARMASOL GMBH.....	143
POLYSCIENCES, INC.	143
POWDERMED, LTD.....	144
QUANTUM DOT CORP.	144
QIAGEN N.V.....	145
RBC LIFE SCIENCES, INC.....	145
SACHTLEBEN CHEMIE GMBH	145
SHOWA DENKO K.K.	146
SKYEPHARMA, PLC	146
SOMALOGIC, INC.	147
STARPHARMA HOLDINGS, LTD.	147
SURFACINE DEVELOPMENT CO.	147
TAYCA CORP.	148