

CRITICAL MATERIALS IN GLOBAL NANOTECHNOLOGY MARKETS



AVM103A
January 2014

Andrew McWilliams
Project Analyst

ISBN: 1-56965-667-3

bcc | Research
Market Forecasting

BCC Research
49 Walnut Park, Building 2
Wellesley, MA 02481 USA
866-285-7215 (toll-free within the USA),
or (+1) 781-489-7301
www.bccresearch.com
information@bccresearch.com

TABLE OF CONTENTS

TOPIC	PAGE NO.
CHAPTER 1 INTRODUCTION	2
STUDY BACKGROUND	2
STUDY GOALS AND OBJECTIVES	2
INTENDED AUDIENCE	3
SCOPE OF REPORT	3
METHODOLOGY AND INFORMATION SOURCES	4
ANALYST CREDENTIALS	4
RELATED BCC RESEARCH REPORTS	5
BCC RESEARCH ONLINE SERVICES	6
DISCLAIMER	6
CHAPTER 2 EXECUTIVE SUMMARY	8
<i>SUMMARY TABLE CRITICAL MATERIALS WITH THE GREATEST IMPACT ON EXISTING NANOTECHNOLOGY MARKETS, THROUGH 2018 (\$ MILLIONS)</i>	8
<i>SUMMARY FIGURE MARKET IMPACTS VS. OPPORTUNITIES CREATED BY CRITICAL MATERIALS, 2018 (\$ MILLIONS)</i>	8
CHAPTER 3 OVERVIEW	11
DEFINITIONS	11
CRITICAL MATERIALS	11
<i>TABLE 1 SUMMARY OF MATERIALS IDENTIFIED AS BEING AT RISK OF SUPPLY DISRUPTIONS</i>	11
NANOTECHNOLOGY	12
<i>TABLE 2 MAJOR CATEGORIES OF NANOMATERIALS</i>	13
CRITICAL MATERIALS COVERED IN THIS REPORT	14
<i>TABLE 3 CRITICAL MATERIALS, THEIR IMPACTS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY</i>	14
ANTIMONY	15
Existing Nanotechnology Applications	15
Potential Nanotechnology Substitutes	15
Fire Retardants	16
Batteries	16
Transparent Conductive Coatings	16
BARIUM	16
Existing Nanotechnology Applications	16
Capacitors	16
Potential Nanotechnology Substitutes	17
Capacitors	17
GALLIUM	17
Existing Nanotechnology Applications	17
Photovoltaics	17
Potential Nanotechnology Substitutes	17
Photovoltaics	17
Light-Emitting Diodes	17
INDIUM	18
Existing Nanotechnology Applications	18

TOPIC	PAGE NO.
Potential Nanotechnology Substitutes	18
Conducting Thin Films	18
Photovoltaics	18
MAGNESIUM	18
Existing Nanotechnology Applications	18
Magnesium Oxide Nanoparticles	18
Potential Nanotechnology Substitutes	19
Nanocomposite Fire Retardants	19
Refractory Ceramic Nanocomposites	19
NIOBIUM	19
Potential Nanotechnology Substitutes	19
Superalloys	19
Superconductors	19
PLATINUM GROUP METALS	20
Existing Nanotechnology Applications	20
Environmental Catalysts	20
Fuel Cell Catalysts	20
Potential Nanotechnology Substitutes	20
Environmental Catalysts	20
Fuel Cells	20
RARE EARTHS	20
Existing Nanotechnology Applications	21
Biomedical Markers	21
LEDs	21
Potential Nanotechnology Substitutes	21
Permanent Magnets	21
Optical Amplifiers	21
Rechargeable Batteries	22
Lighting	22
RHENIUM	22
Potential Nanotechnology Substitutes	22
Rhenium Nanoalloy	22
TANTALUM	23
Potential Nanotechnology Substitutes	23
Capacitors	23
TELLURIUM	23
Potential Nanotechnology Substitutes	23
Photovoltaics	23
TUNGSTEN	24
Existing Nanotechnology Applications	24
Potential Nanotechnology Substitutes	24
MARKET IMPACTS	24
EXISTING NANOTECHNOLOGY APPLICATIONS POTENTIALLY AFFECTED	24
<i>TABLE 4 CONSUMPTION OF CRITICAL MATERIALS IN EXISTING NANOTECHNOLOGY APPLICATIONS, THROUGH 2018 (\$ MILLIONS)</i>	25
SUBSTITUTES	25
<i>TABLE 5 MARKET FOR NANOTECHNOLOGY APPLICATIONS THAT REPLACE OR REDUCE CONSUMPTION OF CRITICAL MATERIALS, THROUGH 2018 (\$ MILLIONS)</i>	25

TOPIC	PAGE NO.
CHAPTER 4 ANTIMONY	28
SUMMARY	28
<i>FIGURE 1 ANTIMONY: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)</i>	28
DESCRIPTION AND PROPERTIES	29
PRODUCTION AND DEMAND	29
PRODUCTION	29
<i>FIGURE 2 WORLD MINE PRODUCTION OF ANTIMONY, 2011 (%)</i>	29
DEMAND	30
NANOSCALE ANTIMONY APPLICATIONS	31
ANTIMONY TIN OXIDE CONDUCTIVE COATINGS	31
Description	31
Production	31
<i>TABLE 6 NANOSCALE ANTIMONY TIN OXIDE PRODUCERS</i>	31
Applications	32
Infrared Attenuating Coatings	32
Antistatic Coatings	32
Transparent Electrodes	32
Markets	33
<i>TABLE 7 GLOBAL CONSUMPTION OF NANOSCALE ANTIMONY USED IN THIN FILM COATINGS, THROUGH 2018 (\$ MILLIONS)</i>	33
NANOTECHNOLOGY SUBSTITUTES FOR ANTIMONY	33
<i>TABLE 8 GLOBAL MARKET FOR NANOTECHNOLOGY-BASED SUBSTITUTES FOR ANTIMONY, THROUGH 2018 (\$ MILLIONS)</i>	34
FIRE RETARDANTS	34
Fire Retardant Nanomaterials	34
Description	34
EVA/montmorillonite	35
Polypropylene/Montmorillonite	35
Cotton/Montmorillonite Nanocomposite Fibers	35
Markets	35
<i>TABLE 9 GLOBAL CONSUMPTION OF NANOCOMPOSITE FIRE RETARDANT MATERIALS, THROUGH 2018 (\$ MILLIONS)</i>	36
EVA/Clay Nanocomposite	36
Cotton/Montmorillonite Nanocomposites	36
BATTERY MATERIALS	37
Description	37
Market	38
<i>TABLE 10 GLOBAL CONSUMPTION OF NANOPARTICLES USED IN RECHARGEABLE LITHIUM ION BATTERIES, THROUGH 2018 (\$ MILLIONS)</i>	39
TRANSPARENT CONDUCTIVE COATINGS	39
Description	39
Carbon-Nanotube-Based Coatings	39
Graphene-Based Coatings	39
Market	40
<i>TABLE 11 GLOBAL MARKET FOR NANOSTRUCTURED REPLACEMENT FOR ANTIMONY TRANSPARENT CONDUCTIVE COATINGS, THROUGH 2018 (\$ MILLIONS)</i>	40
Carbon-Nanotube-Based Coatings	40

TOPIC	PAGE NO.
Graphene-Based Coatings	41
IR ATTENUATING COATINGS	41
Description	41
Semiconductor Nanomaterial	41
Ceramic Nanocomposite	41
Other Nanomaterials	41
Market	42
<i>TABLE 12 GLOBAL CONSUMPTION OF NANOTECHNOLOGY-BASED ALTERNATIVES TO ATO IR-ATTENUATING COATINGS, THROUGH 2018 (\$ MILLIONS)</i>	42
CHAPTER 5 BARIUM	44
SUMMARY	44
<i>FIGURE 3 BARIUM: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)</i>	44
DESCRIPTION AND PROPERTIES	45
PRODUCTION AND DEMAND	45
PRODUCTION	45
<i>FIGURE 4 WORLD MINE PRODUCTION OF BARITES, 2012 (%)</i>	45
DEMAND	46
NANOSCALE BARIUM APPLICATIONS	47
MULTILAYER CERAMIC CAPACITORS	47
<i>TABLE 13 MULTILAYER CERAMIC CAPACITOR PRODUCERS</i>	47
<i>TABLE 14 GLOBAL CONSUMPTION OF BARIUM TITANATE NANOPARTICLES IN MULTILAYER CERAMIC CAPACITOR APPLICATIONS, THROUGH 2018 (\$ MILLIONS)</i>	47
NANOTECHNOLOGY SUBSTITUTES FOR BARIUM	48
CAPACITORS	48
<i>TABLE 15 POTENTIAL MARKET FOR STRONTIUM TITANATE NANOPARTICLES AS A SUBSTITUTE FOR BARIUM TITANATE CERAMIC CAPACITOR APPLICATIONS, THROUGH 2018 (\$ MILLIONS)</i>	49
CHAPTER 6 GALLIUM	51
SUMMARY	51
<i>FIGURE 5 GALLIUM: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)</i>	51
DESCRIPTION AND PROPERTIES	52
PRODUCTION AND DEMAND	52
PRODUCTION	52
DEMAND	53
NANOSCALE GALLIUM APPLICATIONS	53
PHOTOVOLTAICS	53
<i>TABLE 16 MANUFACTURERS OF CIGS THIN FILM PVS</i>	54
<i>TABLE 17 MARKET FOR GALLIUM NANOPARTICLES/PRECURSORS USED IN CIGS PV FABRICATION, THROUGH 2018 (\$ MILLIONS)</i>	54
NANOTECHNOLOGY SUBSTITUTES FOR GALLIUM	55
<i>TABLE 18 POTENTIAL MARKET FOR NANOTECHNOLOGY-BASED GALLIUM SUBSTITUTES, THROUGH 2018 (\$ MILLIONS)</i>	55
DYE-SENSITIZED SOLAR CELLS	55
<i>TABLE 19 COMPANIES MANUFACTURING OR DEVELOPING DSSC PVS</i>	56

TOPIC	PAGE NO.
<i>TABLE 20 GLOBAL CONSUMPTION OF TITANIUM DIOXIDE NANOPARTICLES IN PHOTOVOLTAICS, THROUGH 2018 (\$ MILLIONS)</i>	56
LIGHT-EMITTING DIODES	57
Organic Light-Emitting Diodes	58
<i>TABLE 21 GLOBAL SHIPMENTS OF OLED LIGHTING MATERIALS FOR BACKLIGHTING APPLICATIONS (\$ MILLIONS)</i>	59
Carbon Nanotube LEDs	59
CHAPTER 7 INDIUM	62
SUMMARY	62
<i>FIGURE 6 INDIUM: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY (\$ MILLIONS)</i>	62
DESCRIPTION AND PROPERTIES	63
PRODUCTION AND DEMAND	63
PRODUCTION	63
<i>FIGURE 7 WORLD REFINERY PRODUCTION OF INDIUM, 2012 (%)</i>	63
DEMAND	64
NANOSCALE INDIUM APPLICATIONS	65
PHOTOVOLTAICS	65
<i>TABLE 22 GLOBAL CONSUMPTION OF INDIUM NANOPARTICLES/PRECURSORS USED IN CIGS PV FABRICATION, THROUGH 2018 (\$ MILLIONS)</i>	66
NANOTECHNOLOGY SUBSTITUTES FOR INDIUM	66
<i>TABLE 23 GLOBAL MARKET FOR NANOTECHNOLOGY-BASED SUBSTITUTES FOR INDIUM, THROUGH 2018 (\$ MILLIONS)</i>	67
TRANSPARENT CONDUCTIVE COATINGS	67
PHOTOVOLTAICS	67
<i>TABLE 24 GLOBAL MARKET FOR NANOTECHNOLOGY-BASED SUBSTITUTES FOR INDIUM USED IN PHOTOVOLTAIC APPLICATIONS, THROUGH 2018 (\$ MILLIONS)</i>	68
Copper Gallium Selenide PVs	68
<i>TABLE 25 PROJECTED SUBSTITUTION OF GALLIUM NANOPARTICLES/PRECURSORS FOR INDIUM USED IN CIGS PVS, THROUGH 2018 (\$ MILLIONS)</i>	68
Dye-Sensitized Solar Cells	69
CHAPTER 8 MAGNESIUM	71
SUMMARY	71
<i>FIGURE 8 MAGNESIUM: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)</i>	71
DESCRIPTION AND PROPERTIES	72
PRODUCTION AND DEMAND	72
PRODUCTION	72
<i>FIGURE 9 GLOBAL MAGNESIUM PRODUCTION, 2012 (% OF TOTAL PRODUCTION/METRIC TONS)</i>	72
DEMAND	73
NANOSCALE MAGNESIUM APPLICATIONS	74
MAGNESIUM NANOPARTICLES	74
<i>TABLE 26 GLOBAL CONSUMPTION OF MAGNESIUM AND MAGNESIUM OXIDE NANOPARTICLES, THROUGH 2018 (\$ MILLIONS)</i>	74
NANOTECHNOLOGY SUBSTITUTES FOR MAGNESIUM	74
<i>TABLE 27 POTENTIAL OPPORTUNITIES FOR NONMAGNESIUM-CONTAINING NANOCOMPOSITES, THROUGH 2018 (\$ MILLIONS)</i>	75

TOPIC	PAGE NO.
NANOCOMPOSITE FIRE RETARDANTS	75
<i>TABLE 28 GLOBAL CONSUMPTION OF NONMAGNESIUM-CONTAINING FIRE RETARDANT NANOCOMPOSITES, THROUGH 2018 (\$ MILLIONS)</i>	75
REFRACTORY CERAMIC NANOCOMPOSITES	76
<i>TABLE 29 GLOBAL CONSUMPTION OF REFRACTORY NANOCOMPOSITES, THROUGH 2018 (\$ MILLIONS)</i>	76
CHAPTER 9 NIOBIUM	78
SUMMARY	78
<i>FIGURE 10 NIOBIUM: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)</i>	78
DESCRIPTION AND PROPERTIES	79
PRODUCTION AND DEMAND	79
PRODUCTION	79
<i>FIGURE 11 WORLD MINE PRODUCTION OF NIOBIUM, 2012 (% TOTAL PRODUCTION/METRIC TONS PRODUCED)</i>	79
DEMAND	80
<i>FIGURE 12 GLOBAL CONSUMPTION OF NIOBIUM (% TOTAL CONSUMPTION/METRIC TONS CONSUMED)</i>	80
NANOSCALE NIOBIUM APPLICATIONS	82
NANOTECHNOLOGY SUBSTITUTES FOR MAGNESIUM	82
<i>TABLE 30 GLOBAL MARKET FOR NANOTECHNOLOGY-BASED SUBSTITUTES FOR NIOBIUM, THROUGH 2018 (\$ MILLIONS)</i>	82
NANOSTRUCTURED STEEL	82
<i>TABLE 31 GLOBAL CONSUMPTION OF NANOSTRUCTURED STEEL, THROUGH 2018 (\$ MILLIONS)</i>	83
SUPERCONDUCTING NANOMATERIALS	83
<i>TABLE 32 GLOBAL CONSUMPTION OF NANOSTRUCTURED SUPERCONDUCTORS, THROUGH 2018 (\$ MILLIONS)</i>	84
CHAPTER 10 PLATINUM GROUP METALS	86
SUMMARY	86
<i>FIGURE 13 PLATINUM GROUP METALS: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)</i>	86
DESCRIPTION AND PROPERTIES	87
PRODUCTION AND DEMAND	87
PRODUCTION	87
<i>FIGURE 14 GLOBAL PGM SUPPLY, 2012 (% OF TOTAL SUPPLY/METRIC TONS)</i>	87
Mine Production	88
<i>FIGURE 15 WORLD MINE PRODUCTION OF PLATINUM GROUP METALS, 2008-2012 (METRIC TONS)</i>	88
<i>TABLE 33 GLOBAL MINE PRODUCTION OF PGMS, 2012 (METRIC TONS/ % OF TOTAL MINE PRODUCTION)</i>	90
Recycling	91
DEMAND	91
<i>FIGURE 16 GROSS DEMAND FOR PGMS BY SECTOR, 2012 (% OF TOTAL DEMAND)</i>	91
<i>FIGURE 17 GLOBAL LIGHT-VEHICLE ASSEMBLIES, 2007-2018 (MILLION UNITS)</i>	92
NANOSCALE APPLICATIONS OF PLATINUM GROUP METALS	94
<i>TABLE 34 MARKET FOR PGM NANOPARTICLES IN EXISTING APPLICATIONS, THROUGH 2018 (\$ MILLIONS)</i>	94

TOPIC	PAGE NO.
CATALYTIC CONVERTERS	94
TABLE 35 GLOBAL CONSUMPTION OF NANOSCALE THIN FILM MATERIALS IN CATALYTIC CONVERTERS, THROUGH 2018 (\$ MILLIONS)	96
FUEL CELLS	96
TABLE 36 GLOBAL SALES OF FUEL CELLS THAT USE PLATINUM NANOCATALYSTS, THROUGH 2018 (\$ MILLIONS)	97
TABLE 37 FUEL CELL CONSUMPTION OF PLATINUM THIN FILM CATALYSTS, THROUGH 2018 (\$ MILLIONS/%)	98
NANOTECHNOLOGY SUBSTITUTES FOR PLATINUM GROUP METALS	98
SUBSTITUTES FOR PLATINUM NANOCATALYSTS	98
Vehicle Exhaust Remediation Catalysts	98
Fuel Cell Catalysts	98
Refinery and Petrochemical Catalysts	100
CHAPTER 11 RARE EARTHS	102
SUMMARY	102
FIGURE 18 RARE EARTHS: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)	102
DESCRIPTION AND PROPERTIES	103
TABLE 38 RARE EARTH ELEMENTS	103
PRODUCTION AND DEMAND	104
PRODUCTION	104
FIGURE 19 TRENDS IN CHINESE EXPORT QUOTAS FOR RARE EARTH ELEMENTS, 2006-2012 (METRIC TONS)	105
FIGURE 20 INDIVIDUAL REE SHARES OF TOTAL GLOBAL REE PRODUCTION (%)	105
DEMAND	107
FIGURE 21 RARE EARTH ELEMENT USAGE BY APPLICATION (%)	107
TABLE 39 RARE EARTH ELEMENT APPLICATIONS	108
TABLE 40 RARE EARTH ELEMENTS CONSIDERED CRITICAL	109
NANOSCALE APPLICATIONS OF RARE EARTHS	109
RARE EARTH NANOPHOSPHORS	109
TABLE 41 RARE-EARTH-DOPED METAL OXIDE NANOPHOSPHOR MARKET BY APPLICATION, THROUGH 2018 (\$ MILLIONS)	110
NANOTECHNOLOGY SUBSTITUTES FOR RARE EARTHS	110
TABLE 42 MARKET OPPORTUNITIES FOR NANOTECHNOLOGY-BASED SUBSTITUTES FOR RARE EARTH APPLICATIONS, THROUGH 2018 (\$ MILLIONS)	110
PERMANENT MAGNETS	111
TABLE 43 GLOBAL CONSUMPTION OF MAGNETIC NANOCOMPOSITES FOR ELECTRICAL AND ELECTRONIC APPLICATIONS, THROUGH 2018 (\$ MILLIONS)	112
OPTICAL AMPLIFIERS	112
TABLE 44 COMPANIES INVOLVED IN QUANTUM DOT OPTICAL AMPLIFIER RESEARCH AND DEVELOPMENT	113
TABLE 45 GLOBAL CONSUMPTION OF QUANTUM DOTS USED IN OPTICAL AMPLIFIERS, THROUGH 2018 (\$ MILLIONS)	113
RECHARGEABLE BATTERIES	113
LIGHTING	114
TABLE 46 GLOBAL SHIPMENTS OF OLED LIGHTING MATERIALS FOR ARCHITECTURAL LIGHTING APPLICATIONS, THROUGH 2018 (\$ MILLIONS)	114
CHAPTER 12 RHENIUM	116

TOPIC	PAGE NO.
SUMMARY	116
<i>FIGURE 22 RHENIUM: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)</i>	116
DESCRIPTION AND PROPERTIES	117
PRODUCTION AND DEMAND	117
PRODUCTION	117
DEMAND	118
<i>FIGURE 23 GLOBAL RHENIUM CONSUMPTION BY APPLICATION, 2012 (%)</i>	118
NANOTECHNOLOGY SUBSTITUTES FOR RHENIUM	119
NANORHENIUM COMPOSITE ALLOY	119
<i>TABLE 47 PROJECTED CONSUMPTION OF NANOSCALE RHENIUM IN JET AND ROCKET PROPULSION SYSTEMS, THROUGH 2018 (\$ MILLIONS)</i>	119
CHAPTER 13 TANTALUM	121
SUMMARY	121
<i>FIGURE 24 TANTALUM: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)</i>	121
DESCRIPTION AND PROPERTIES	122
PRODUCTION AND DEMAND	122
PRODUCTION	122
<i>FIGURE 25 TANTALUM PRODUCTION BY SOURCE, 2011 (%)</i>	123
<i>FIGURE 26 PRIMARY PRODUCTION OF TANTALUM BY COUNTRY/REGION, 2010 (%)</i>	123
DEMAND	124
<i>FIGURE 27 WORLDWIDE CONSUMPTION OF TANTALUM, 2000-2011 (METRIC TONS PER YEAR)</i>	125
NANOTECHNOLOGY SUBSTITUTES FOR TANTALUM	125
<i>TABLE 48 PROJECTED CONSUMPTION OF NANOMATERIALS USED IN CAPACITIVE ENERGY STORAGE DEVICES, THROUGH 2018 (\$ MILLIONS)</i>	126
CAPACITORS	126
Carbon-Nanotube-Based Ultracapacitors	126
<i>TABLE 49 PROJECTED CONSUMPTION OF CARBON NANOTUBES USED IN ULTRACAPACITORS, THROUGH 2018 (METRIC TONS/\$ MILLIONS)</i>	127
Aerogel Capacitors	127
<i>TABLE 50 PROJECTED CONSUMPTION OF CARBON AEROGELS USED IN SUPERCAPACITORS, THROUGH 2018 (METRIC TONS/\$ MILLIONS)</i>	128
Other Technologies	128
CHAPTER 14 TELLURIUM	130
SUMMARY	130
<i>FIGURE 28 TELLURIUM: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)</i>	130
DESCRIPTION AND PROPERTIES	131
PRODUCTION AND DEMAND	131
PRODUCTION	131
<i>FIGURE 29 WORLD REFINERY PRODUCTION OF TELLURIUM BY COUNTRY, 2012 (%)</i>	131
DEMAND	132
<i>FIGURE 30 TELLURIUM APPLICATIONS, 2012 (% OF DEMAND)</i>	132
NANOSCALE SUBSTITUTES FOR TELLURIUM	133
PHOTOVOLTAICS	133

TOPIC	PAGE NO.
CHAPTER 15 TUNGSTEN	135
SUMMARY	135
<i>FIGURE 31 TUNGSTEN CARBIDE: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)</i>	135
DESCRIPTION AND PROPERTIES	135
PRODUCTION AND DEMAND	136
PRODUCTION	136
<i>FIGURE 32 GLOBAL PRODUCTION OF TUNGSTEN CONCENTRATE (% OF TOTAL PRODUCTION/METRIC TONS)</i>	136
DEMAND	137
NANOSCALE TUNGSTEN APPLICATIONS	138
TUNGSTEN CARBIDE NANOCOMPOSITES	138
<i>TABLE 51 GLOBAL CONSUMPTION OF NANOCOMPOSITES IN TUNGSTEN CARBIDE TOOLS, THROUGH 2018 (\$ MILLIONS)</i>	138
NANOTECHNOLOGY SUBSTITUTES FOR TUNGSTEN	139
NEW HARDMETAL	139
<i>TABLE 52 GLOBAL CONSUMPTION OF NANOADDITIVES USED IN TUNGSTEN CARBIDE SUBSTITUTES, THROUGH 2018 (\$ MILLIONS)</i>	139
CHAPTER 16 COMPANY PROFILES	141
ANTIMONY	141
NANOSCALE SUBSTITUTES	141
A123 Systems Inc.	141
Advanced Glazings Ltd.	141
Altair Nanotechnologies Inc.	142
Elementis Specialties	142
Kabelwerk Eupen AG	142
Nanocor Inc.	142
NEI Corp.	143
Southern Clay Products Inc.	143
Sud-Chemie AG	143
Unidym	144
BARIUM	144
NANOSCALE APPLICATIONS	144
TPL Inc.	144
NANOSCALE SUBSTITUTES	145
Cooper Bussman	145
FastCAP Systems Corp.	145
GALLIUM	145
NANOSCALE APPLICATIONS	145
Miasole	145
Nanosolar Inc.	146
NANOSCALE SUBSTITUTES	146
Cyrium Technologies Inc.	146
G24 Innovations Ltd.	146
General Electric Global Research	147
Lumiotec	147

TOPIC	PAGE NO.
Merck OLED Materials GMBH	148
Novald AG	148
Osram Opto Semiconductors GMBH	149
Philips Lumileds Lighting Company	149
Solaronix SA	149
INDIUM	149
MAGNESIUM	150
NANOSCALE APPLICATIONS	150
Bayer AG	150
NANOSCALE SUBSTITUTES	150
NIOBIUM	150
NANOSCALE APPLICATIONS	150
Bayer AG	150
NANOSCALE SUBSTITUTES	151
NanoSteel Co. Inc.	151
Sandvik Materials Technology AB	151
Single Quantum B.V.	151
PLATINUM GROUP METALS	152
NANOSCALE APPLICATIONS	152
Johnson Matthey plc	152
Mazda Motor Corp.	152
Rhodia SA	152
NANOSCALE SUBSTITUTES	153
Clean Diesel Technologies Inc.	153
Evonik Degussa GmbH	153
Headwaters Nanokinetix Inc.	154
Nanostellar	155
NexTech Materials Ltd.	155
QuantumSphere Inc.	156
RARE EARTHS, APPLICATIONS AND SUBSTITUTES	156
NANOSCALE APPLICATIONS	156
Alps Electric Co. Ltd.	156
Forge Europa Ltd.	157
NANOSCALE SUBSTITUTES	157
Evident Technologies	157
RHENIUM	158
THE BOEING COMPANY	158
TANTALUM	158
NANOSCALE SUBSTITUTES	158
Dais Analytic Corp.	158
TELLURIUM	158
NANOSCALE SUBSTITUTES	158
TUNGSTEN	159
NANOSCALE SUBSTITUTES	159
Exote Oy	159

LIST OF TABLES

TABLE HEADING	PAGE NO.
SUMMARY TABLE CRITICAL MATERIALS WITH THE GREATEST IMPACT ON EXISTING NANOTECHNOLOGY MARKETS, THROUGH 2018 (\$ MILLIONS)	8
TABLE 1 SUMMARY OF MATERIALS IDENTIFIED AS BEING AT RISK OF SUPPLY DISRUPTIONS	11
TABLE 2 MAJOR CATEGORIES OF NANOMATERIALS	13
TABLE 3 CRITICAL MATERIALS, THEIR IMPACTS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY	14
TABLE 4 CONSUMPTION OF CRITICAL MATERIALS IN EXISTING NANOTECHNOLOGY APPLICATIONS, THROUGH 2018 (\$ MILLIONS)	25
TABLE 5 MARKET FOR NANOTECHNOLOGY APPLICATIONS THAT REPLACE OR REDUCE CONSUMPTION OF CRITICAL MATERIALS, THROUGH 2018 (\$ MILLIONS)	25
TABLE 6 NANOSCALE ANTIMONY TIN OXIDE PRODUCERS	31
TABLE 7 GLOBAL CONSUMPTION OF NANOSCALE ANTIMONY USED IN THIN FILM COATINGS, THROUGH 2018 (\$ MILLIONS)	33
TABLE 8 GLOBAL MARKET FOR NANOTECHNOLOGY-BASED SUBSTITUTES FOR ANTIMONY, THROUGH 2018 (\$ MILLIONS)	34
TABLE 9 GLOBAL CONSUMPTION OF NANOCOMPOSITE FIRE RETARDANT MATERIALS, THROUGH 2018 (\$ MILLIONS)	36
TABLE 10 GLOBAL CONSUMPTION OF NANOPARTICLES USED IN RECHARGEABLE LITHIUM ION BATTERIES, THROUGH 2018 (\$ MILLIONS)	39
TABLE 11 GLOBAL MARKET FOR NANOSTRUCTURED REPLACEMENT FOR ANTIMONY TRANSPARENT CONDUCTIVE COATINGS, THROUGH 2018 (\$ MILLIONS)	40
TABLE 12 GLOBAL CONSUMPTION OF NANOTECHNOLOGY-BASED ALTERNATIVES TO ATO IR-ATTENUATING COATINGS, THROUGH 2018 (\$ MILLIONS)	42
TABLE 13 MULTILAYER CERAMIC CAPACITOR PRODUCERS	47
TABLE 14 GLOBAL CONSUMPTION OF BARIUM TITANATE NANOPARTICLES IN MULTILAYER CERAMIC CAPACITOR APPLICATIONS, THROUGH 2018 (\$ MILLIONS)	47
TABLE 15 POTENTIAL MARKET FOR STRONTIUM TITANATE NANOPARTICLES AS A SUBSTITUTE FOR BARIUM TITANATE CERAMIC CAPACITOR APPLICATIONS, THROUGH 2018 (\$ MILLIONS)	49
TABLE 16 MANUFACTURERS OF CIGS THIN FILM PVS	54
TABLE 17 MARKET FOR GALLIUM NANOPARTICLES/PRECURSORS USED IN CIGS PV FABRICATION, THROUGH 2018 (\$ MILLIONS)	54
TABLE 18 POTENTIAL MARKET FOR NANOTECHNOLOGY-BASED GALLIUM SUBSTITUTES, THROUGH 2018 (\$ MILLIONS)	55
TABLE 19 COMPANIES MANUFACTURING OR DEVELOPING DSSC PVS	56
TABLE 20 GLOBAL CONSUMPTION OF TITANIUM DIOXIDE NANOPARTICLES IN PHOTOVOLTAICS, THROUGH 2018 (\$ MILLIONS)	56
TABLE 21 GLOBAL SHIPMENTS OF OLED LIGHTING MATERIALS FOR BACKLIGHTING APPLICATIONS (\$ MILLIONS)	59
TABLE 22 GLOBAL CONSUMPTION OF INDIUM NANOPARTICLES/PRECURSORS USED IN CIGS PV FABRICATION, THROUGH 2018 (\$ MILLIONS)	66
TABLE 23 GLOBAL MARKET FOR NANOTECHNOLOGY-BASED SUBSTITUTES FOR INDIUM, THROUGH 2018 (\$ MILLIONS)	67
TABLE 24 GLOBAL MARKET FOR NANOTECHNOLOGY-BASED SUBSTITUTES FOR INDIUM USED IN PHOTOVOLTAIC APPLICATIONS, THROUGH 2018 (\$ MILLIONS)	68
TABLE 25 PROJECTED SUBSTITUTION OF GALLIUM NANOPARTICLES/PRECURSORS FOR INDIUM USED IN CIGS PVS, THROUGH 2018 (\$ MILLIONS)	68
TABLE 26 GLOBAL CONSUMPTION OF MAGNESIUM AND MAGNESIUM OXIDE NANOPARTICLES, THROUGH 2018 (\$ MILLIONS)	74

TABLE HEADING	PAGE NO.
TABLE 27 POTENTIAL OPPORTUNITIES FOR NONMAGNESIUM-CONTAINING NANOCOMPOSITES, THROUGH 2018 (\$ MILLIONS)	75
TABLE 28 GLOBAL CONSUMPTION OF NONMAGNESIUM-CONTAINING FIRE RETARDANT NANOCOMPOSITES, THROUGH 2018 (\$ MILLIONS)	75
TABLE 29 GLOBAL CONSUMPTION OF REFRACTORY NANOCOMPOSITES, THROUGH 2018 (\$ MILLIONS)	76
TABLE 30 GLOBAL MARKET FOR NANOTECHNOLOGY-BASED SUBSTITUTES FOR NIOBIUM, THROUGH 2018 (\$ MILLIONS)	82
TABLE 31 GLOBAL CONSUMPTION OF NANOSTRUCTURED STEEL, THROUGH 2018 (\$ MILLIONS)	83
TABLE 32 GLOBAL CONSUMPTION OF NANOSTRUCTURED SUPERCONDUCTORS, THROUGH 2018 (\$ MILLIONS)	84
TABLE 33 GLOBAL MINE PRODUCTION OF PGMs, 2012 (METRIC TONS/ % OF TOTAL MINE PRODUCTION)	90
TABLE 34 MARKET FOR PGM NANOPARTICLES IN EXISTING APPLICATIONS, THROUGH 2018 (\$ MILLIONS)	94
TABLE 35 GLOBAL CONSUMPTION OF NANOSCALE THIN FILM MATERIALS IN CATALYTIC CONVERTERS, THROUGH 2018 (\$ MILLIONS)	96
TABLE 36 GLOBAL SALES OF FUEL CELLS THAT USE PLATINUM NANOCATALYSTS, THROUGH 2018 (\$ MILLIONS)	97
TABLE 37 FUEL CELL CONSUMPTION OF PLATINUM THIN FILM CATALYSTS, THROUGH 2018 (\$ MILLIONS/%)	98
TABLE 38 RARE EARTH ELEMENTS	103
TABLE 39 RARE EARTH ELEMENT APPLICATIONS	108
TABLE 40 RARE EARTH ELEMENTS CONSIDERED CRITICAL	109
TABLE 41 RARE-EARTH-DOPED METAL OXIDE NANOPHOSPHOR MARKET BY APPLICATION, THROUGH 2018 (\$ MILLIONS)	110
TABLE 42 MARKET OPPORTUNITIES FOR NANOTECHNOLOGY-BASED SUBSTITUTES FOR RARE EARTH APPLICATIONS, THROUGH 2018 (\$ MILLIONS)	110
TABLE 43 GLOBAL CONSUMPTION OF MAGNETIC NANOCOMPOSITES FOR ELECTRICAL AND ELECTRONIC APPLICATIONS, THROUGH 2018 (\$ MILLIONS)	112
TABLE 44 COMPANIES INVOLVED IN QUANTUM DOT OPTICAL AMPLIFIER RESEARCH AND DEVELOPMENT	113
TABLE 45 GLOBAL CONSUMPTION OF QUANTUM DOTS USED IN OPTICAL AMPLIFIERS, THROUGH 2018 (\$ MILLIONS)	113
TABLE 46 GLOBAL SHIPMENTS OF OLED LIGHTING MATERIALS FOR ARCHITECTURAL LIGHTING APPLICATIONS, THROUGH 2018 (\$ MILLIONS)	114
TABLE 47 PROJECTED CONSUMPTION OF NANOSCALE RHENIUM IN JET AND ROCKET PROPULSION SYSTEMS, THROUGH 2018 (\$ MILLIONS)	119
TABLE 48 PROJECTED CONSUMPTION OF NANOMATERIALS USED IN CAPACITIVE ENERGY STORAGE DEVICES, THROUGH 2018 (\$ MILLIONS)	126
TABLE 49 PROJECTED CONSUMPTION OF CARBON NANOTUBES USED IN ULTRACAPACITORS, THROUGH 2018 (METRIC TONS/\$ MILLIONS)	127
TABLE 50 PROJECTED CONSUMPTION OF CARBON AEROGELS USED IN SUPERCAPACITORS, THROUGH 2018 (METRIC TONS/\$ MILLIONS)	128
TABLE 51 GLOBAL CONSUMPTION OF NANOCOMPOSITES IN TUNGSTEN CARBIDE TOOLS, THROUGH 2018 (\$ MILLIONS)	138
TABLE 52 GLOBAL CONSUMPTION OF NANOADDITIVES USED IN TUNGSTEN CARBIDE SUBSTITUTES, THROUGH 2018 (\$ MILLIONS)	139

LIST OF FIGURES

FIGURE TITLE	PAGE NO.
SUMMARY FIGURE MARKET IMPACTS VS. OPPORTUNITIES CREATED BY CRITICAL MATERIALS, 2018 (\$ MILLIONS)	8
FIGURE 1 ANTIMONY: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)	28
FIGURE 2 WORLD MINE PRODUCTION OF ANTIMONY, 2011 (%)	29
FIGURE 3 BARIUM: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)	44
FIGURE 4 WORLD MINE PRODUCTION OF BARITES, 2012 (%)	45
FIGURE 5 GALLIUM: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)	51
FIGURE 6 INDIUM: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY (\$ MILLIONS)	62
FIGURE 7 WORLD REFINERY PRODUCTION OF INDIUM, 2012 (%)	63
FIGURE 8 MAGNESIUM: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)	71
FIGURE 9 GLOBAL MAGNESIUM PRODUCTION, 2012 (% OF TOTAL PRODUCTION/METRIC TONS)	72
FIGURE 10 NIOBIUM: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)	78
FIGURE 11 WORLD MINE PRODUCTION OF NIOBIUM, 2012 (% TOTAL PRODUCTION/METRIC TONS PRODUCED)	79
FIGURE 12 GLOBAL CONSUMPTION OF NIOBIUM (% TOTAL CONSUMPTION/METRIC TONS CONSUMED)	80
FIGURE 13 PLATINUM GROUP METALS: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)	86
FIGURE 14 GLOBAL PGM SUPPLY, 2012 (% OF TOTAL SUPPLY/METRIC TONS)	87
FIGURE 15 WORLD MINE PRODUCTION OF PLATINUM GROUP METALS, 2008-2012 (METRIC TONS)	88
FIGURE 16 GROSS DEMAND FOR PGMS BY SECTOR, 2012 (% OF TOTAL DEMAND)	91
FIGURE 17 GLOBAL LIGHT-VEHICLE ASSEMBLIES, 2007-2018 (MILLION UNITS)	92
FIGURE 18 RARE EARTHS: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)	102
FIGURE 19 TRENDS IN CHINESE EXPORT QUOTAS FOR RARE EARTH ELEMENTS, 2006-2012 (METRIC TONS)	105
FIGURE 20 INDIVIDUAL REE SHARES OF TOTAL GLOBAL REE PRODUCTION (%)	105
FIGURE 21 RARE EARTH ELEMENT USAGE BY APPLICATION (%)	107
FIGURE 22 RHENIUM: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)	116
FIGURE 23 GLOBAL RHENIUM CONSUMPTION BY APPLICATION, 2012 (%)	118
FIGURE 24 TANTALUM: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)	121
FIGURE 25 TANTALUM PRODUCTION BY SOURCE, 2011 (%)	123
FIGURE 26 PRIMARY PRODUCTION OF TANTALUM BY COUNTRY/REGION, 2010 (%)	123
FIGURE 27 WORLDWIDE CONSUMPTION OF TANTALUM, 2000-2011 (METRIC TONS PER YEAR)	125
FIGURE 28 TELLURIUM: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)	130
FIGURE 29 WORLD REFINERY PRODUCTION OF TELLURIUM BY COUNTRY, 2012 (%)	131
FIGURE 30 TELLURIUM APPLICATIONS, 2012 (% OF DEMAND)	132

FIGURE TITLE	PAGE NO.
FIGURE 31 TUNGSTEN CARBIDE: RISKS AND OPPORTUNITIES FOR THE NANOTECHNOLOGY INDUSTRY, 2012-2018 (\$ MILLIONS)	135
FIGURE 32 GLOBAL PRODUCTION OF TUNGSTEN CONCENTRATE (% OF TOTAL PRODUCTION/METRIC TONS)	136