

INTRODUCTION .....	XXVII
STUDY GOALS AND OBJECTIVES.....	XXVII
REASONS FOR DOING THE STUDY .....	XXVII
CONTRIBUTION OF THE STUDY AND FOR WHOM .....	XXVII
SCOPE AND FORMAT .....	XXVII
METHODOLOGY AND INFORMATION SOURCES.....	XXVIII
RELATED REPORTS.....	XXVIII
BCC ONLINE SERVICES.....	XXVIII
DISCLAIMER .....	XXIX
 SUMMARY.....	 XXX
<i>SUMMARY TABLE GLOBAL FORECAST OF SMART MATERIALS AND PRODUCT</i>	
<i>MARKET, THROUGH 2010 (\$ MILLION)</i> .....	XXXI
<i>SUMMARY FIGURE GLOBAL FORECAST OF SMART MATERIALS AND PRODUCT</i>	
<i>MARKET, 2000-2010 (\$ MILLION)</i> .....	XXXII
 OVERVIEW .....	 1
HISTORY .....	1
CURRENT STATE OF SMART MATERIALS TECHNOLOGY.....	1
DEFINITION OF MATERIALS .....	2
PIEZOELECTRIC .....	2
<i>TABLE 1 SIGNIFICANT DISCOVERIES IN THE HISTORY OF PIEZOELECTRICS</i> .....	3
Crystals.....	3
Lithium Niobate (LiNbO <sub>3</sub> ).....	3
Lithium Tantalate (LiTaO <sub>3</sub> ).....	4
Ceramic .....	4
<i>TABLE 2 PROPERTY CHARACTERISTICS OF PIEZOELECTRIC CERAMICS</i> .....	4
<i>TABLE 2 (CONTINUED)</i> .....	5
PZTs.....	5
Barium Titanate (BaTiO <sub>3</sub> ).....	5
Lead Metaniobate .....	6
Lead Titanate.....	6
Polymers.....	6
PVDF—Polyvinylidene Fluoride .....	6
PVDF-TRFE .....	7
PTFE .....	7
Composites .....	7
ELECTROSTRICTIVE.....	7
<i>TABLE 3 PIEZOELECTRIC MATERIALS VS. ELECTROSTRICTIVE MATERIALS</i> .....	8
Lead Magnesium Niobate-Lead Titanate.....	8
Polymers.....	8
MAGNETOSTRICTIVE .....	9
Terfenol-D®.....	9
Metglas.....	9
<i>TABLE 4 PIEZOELECTRIC MATERIALS VS. MAGNETOSTRICTIVE MATERIALS</i> .....	9

THERMORESPONSIVE.....	9
Shape Memory Alloys.....	9
CU Based Alloys and Nickel-Titanium Alloys.....	9
TABLE 5 TRANSFORMATION VARIABLES FOR SOME SHAPE MEMORY ALLOYS.....	10
TABLE 6 HISTORY OF APPLICATIONS FOR SHAPE MEMORY ALLOYS.....	11
TABLE 7 NITINOL PROPERTIES.....	11
TABLE 8 COMPARISON BETWEEN NI-TI ALLOYS AND COPPER-BASED ALLOYS.....	12
Shape Memory Polymers.....	12
TABLE 9 ADVANTAGES OF SMPS VS. SMAS.....	12
TABLE 10 DISADVANTAGES OF SMPS VS. SMAS.....	13
FLUIDS.....	13
Electrorheological Fluids.....	13
Magnetorheological Fluids.....	13
OTHERS.....	14
Electrochromic Materials.....	14
Metal Oxides and Polymers.....	14
Chemoresponsive Materials.....	14
Fiber Optics.....	14
Sensor-based Materials.....	14
Biomimetic.....	15
Hydroresponsive Materials.....	15
Gels.....	15
INDICATORS FOR THE SMART MATERIALS INDUSTRY.....	16
TABLE 11 PERCENTAGE IMPACT OF MAJOR COMPETITIVE FACTORS ON THE GROWTH OF SMART MATERIALS (%).....	16
INDUSTRY DYNAMICS.....	17
MACRO-ECONOMIC INDICATORS.....	17
EFFECTS ON THE SMART MATERIALS INDUSTRY.....	18
Smart Sensing.....	18
CONSUMER/BUSINESS NEEDS.....	18
FACTORS OF POTENTIAL GROWTH.....	19
PIEZOELECTRIC.....	19
MAGNETOSTRICTIVE.....	19
THERMORESPONSIVE.....	19
FLUIDS.....	19
ELECTROCHROMIC.....	19
GOVERNMENT REGULATIONS.....	20
GLOBAL MARKETS.....	21
MARKET BY TYPE OF SMART MATERIAL.....	21
TOTAL MARKET SIZE.....	21
TABLE 12 GLOBAL FORECAST FOR SMART MATERIAL AND COMPONENT MARKET BY TYPE, THROUGH 2010 (\$ MILLION).....	21
FIGURE 1 GLOBAL FORECAST FOR SMART MATERIAL AND COMPONENT MARKET BY TYPE, 2003-2010 (\$ MILLIONS).....	22
LEADING MANUFACTURERS.....	22
MARKET BY MATERIAL TYPES.....	23

Piezoelectric .....	23
<i>TABLE 13 GLOBAL FORECAST OF PIEZOELECTRIC MATERIALS AND     COMPONENTS BY TYPE, THROUGH 2010 (\$ MILLIONS)</i> .....	23
<i>TABLE 13 (CONTINUED)</i> .....	24
<i>FIGURE 2 GLOBAL FORECAST OF PIEZOELECTRIC MATERIALS AND     COMPONENTS BY TYPE, THROUGH 2010 (\$ MILLIONS)</i> .....	24
Ceramics .....	25
Crystals .....	26
Market Growth .....	26
Polymers and Composites.....	27
Electrostrictive.....	28
<i>TABLE 14 GLOBAL FORECAST FOR SALES OF ELECTROSTRICTIVE MATERIALS     AND COMPONENTS BY TYPE, THROUGH 2010 (\$ MILLION)</i> .....	28
Magnetostrictive .....	29
<i>TABLE 15 FORECAST OF GLOBAL PRODUCTION OF MAGNETOSTRICTIVE     MATERIALS BY TYPE, THROUGH 2010 (\$ MILLION)</i> .....	29
Market Drivers.....	30
Market Drivers (Continued).....	31
Thermoresponsive.....	32
<i>TABLE 16 GLOBAL FORECAST OF MATERIAL AND COMPONENT PRODUCTION     OF THERMORESPONSIVE MATERIALS BY TYPE, THROUGH 2010 (\$ MILLION)</i> .....	32
Nickel Titanium and Alloys.....	32
Cu-based Alloys.....	33
Polymers.....	34
Smart Fluids .....	35
<i>TABLE 17 WORLDWIDE PRODUCTION OF SMART FLUID MATERIALS BY TYPE,     THROUGH 2010 (\$ MILLION)</i> .....	35
Automotive Applications .....	35
Automotive Applications (Continued) .....	36
Architectural/Civil Engineering Market.....	37
Architectural/Civil (Continued) .....	38
Architectural/Civil (Continued) .....	39
Biomimetic Materials .....	40
<i>TABLE 18 GLOBAL FORECAST FOR PRODUCTION OF BIOMIMETIC MATERIALS     BY TYPE, THROUGH 2010 (\$ MILLIONS)</i> .....	40
Hydroresponsive Gels .....	40
Other Biomimetic Materials.....	41
Other Smart Materials.....	41
<i>TABLE 19 WORLDWIDE GLOBAL FORECAST AND COMPONENT MATERIAL     PRODUCTION OF OTHER SMART MATERIALS BY TYPE, THROUGH 2010 (\$     MILLIONS)</i> .....	41
Other Smart Materials (Continued) .....	42
SMART MATERIALS MARKET BY REGION.....	43
PIEZOELECTRIC/ELECTROSTRICTIVE .....	43
<i>TABLE 20 GLOBAL FORECAST OF PIEZOELECTRIC/ELECTROSTRICTIVE     MATERIALS AND COMPONENTS MANUFACTURING BY REGIONAL SHARE,     THROUGH 2010 (% OF UNITS)</i> .....	43
MAGNETOSTRICTIVE .....	44

<i>TABLE 21 GLOBAL FORECAST OF MAGNETOSTRICTIVE MATERIALS</i>	
<i>MANUFACTURING BY REGIONAL SHARE, THROUGH 2010 (% OF UNITS)</i> .....	44
THERMORESPONSIVE.....	45
<i>TABLE 22 GLOBAL FORECAST OF THERMORESPONSIVE MATERIALS</i>	
<i>MANUFACTURING BY REGIONAL SHARE, THROUGH 2010 (% OF UNITS)</i> .....	45
SMART FLUIDS .....	46
<i>TABLE 23 GLOBAL FORECAST OF SMART FLUID MANUFACTURING BY</i>	
<i>REGIONAL SHARE, THROUGH 2010 (% OF UNITS)</i> .....	46
INDUSTRY STRUCTURE .....	46
INTRODUCTION.....	46
ROLE OF PARTICIPANTS .....	47
<i>FIGURE 3 MARKET PARTICIPANTS IN A SMART PRODUCT MANUFACTURING</i>	
<i>PROCESS</i> .....	47
MANUFACTURERS .....	48
Smart Materials Manufacturer Market Share.....	49
<i>TABLE 24 SHARE OF GLOBAL SMART MATERIALS AND COMPONENTS</i>	
<i>MANUFACTURER MARKET, 2004 (\$ MILLIONS)</i> .....	49
<i>TABLE 25 MARKET SHARE OF MANUFACTURES OF</i>	
<i>PIEZOELECTRIC/ELECTROSTRICTIVE MATERIALS, 2004 (\$ MILLIONS)</i> .....	50
<i>TABLE 26 SMART MATERIALS SALES, REGIONAL MARKET SHARE, 2004 (% OF</i>	
<i>TOTAL SALES \$ MILLION)</i> .....	51
MARKET NEEDS .....	51
MARKET USES/CONSUMPTION .....	52
SMART SENSING UTILIZATION .....	52
DISTRIBUTION OF SMART MATERIALS .....	52
PROFILES OF PARTICIPANTS.....	53
LEADING MANUFACTURERS.....	53
<i>TABLE 27 LEADING MANUFACTURERS</i> .....	53
<i>TABLE 27 (CONTINUED)</i> .....	54
Piezoelectric Manufacturers.....	55
Advanced Cerametrics, Inc., U.S.....	55
Alpha Ceramics Inc., U.S.....	55
American Piezo Ceramics Inc., U.S.....	55
AVX Corp, U.S. ....	55
Cedrat Technologies SA, France .....	56
Ceramica Celec, Argentina.....	56
Ceram Tec AG, Germany.....	56
Channel Industries Inc., U.S.....	57
Cilas, France .....	57
CTS Corp., U.S.....	57
Denso Corp., Japan.....	58
Edo Corp., U.S.....	58
Epcos, Germany .....	59
EXFO Burleigh Products Group Inc. (formerly	
Burleigh Instruments), U.S. ....	59
Ferroperm Piezoceramics A/S, Denmark.....	59
Fuji Ceramics Corp., Japan.....	60

Fuji Titanium Industry Co., Ltd., Japan .....	60
Kyocera, Japan.....	60
Lockheed Martin, U.S.....	60
Matsushita Electronic Components Co. Ltd., Japan.....	61
Measurement Specialties, Inc. (MSI), U.S.....	61
Megacera, Japan .....	61
Midé Technology Corp., U.S. ....	62
Morgan Electroceramics, U.S.....	62
Murata, Japan.....	62
Nanomotion, Israel .....	63
NEC Tokin, Japan .....	63
NGK Insulators Ltd., Japan.....	63
Noliac A/S, Denmark .....	63
NTK Technologies, Japan.....	64
Oceana Sensor Technology Co., U.S.....	64
PCB Piezotronics Inc., U.S. ....	64
PI Ceramic, Germany .....	64
Piezo Kinetics, Inc. (PKI), U.S.....	65
Piezomechanik GmbH, Germany .....	65
Piezotech, France .....	65
Raytheon, U.S. ....	65
Sakai Chemical Industry Co., Ltd., Japan .....	65
Sensor Technology Ltd., Canada.....	66
Sinoceramics, U.S. ....	66
TDK Corp., Japan .....	66
Tera Xtal, China .....	67
Valpey-Fisher Corp., U.S.....	67
Xinetics Inc., U.S.....	67
Electrostrictive Manufacturers .....	67
Ecertec Ltd., U.K. ....	67
SRI International, U.S.....	67
Magnetostrictive Manufacturers.....	68
Adaptronics, U.S. ....	68
AMM Technologies, U.S. ....	68
Buckbee Mears, U.S.....	68
Elna Magnetics, U.S. ....	68
Etrema Products, Inc., U.S.....	68
Gansu Tianxing Rare Earth Functional Materials, China .....	69
Hitachi Metals, Ltd., Japan.....	69
Light Engineering, U.S.....	70
Marotta Controls Inc., U.S. ....	70
Namco, Japan.....	70
Thermoresponsive Manufacturers.....	70

Admedes Schuessler GmbH, Germany .....	70
Aerofit Products Inc., U.S. ....	71
Alloy International Inc., U.S. ....	71
Dynalloy, Inc., U.S. ....	71
Fine Tubes Ltd., U.K. ....	71
Fort Wayne Metals Research Products Corp., U.S. ....	71
Furukawa Electric Co., Ltd., Japan .....	72
Memry Corp., U.S. ....	72
Mitsubishi Heavy Industries, Japan.....	72
Mnemo Science, Germany .....	73
Nanomuscle, U.S.....	73
New England Precision Grinding, Inc., U.S. ....	73
Nitinol Devices and Components, Inc., U.S. ....	74
Special Metals Corp., U.S. ....	74
Sportswire LLC, U.S.....	74
TiNi Alloy Company, U.S. ....	74
Fluid (Electrorheological and Magnetorheological)	
Manufacturers .....	74
Lord Corp., U.S. ....	74
Electrochromic Manufacturers .....	75
Pilkington, U.K. ....	75
Hydroresponsive Gels.....	75
Foster-Miller, U.S. ....	75
Smart Materials Inc., U.S. ....	76
Fibre Optics Manufacturers.....	76
Axsys Technologies, U.S. ....	76
New Scale Technologies, Inc., U.S. ....	76
Biomimetic .....	76
Biomimetic Products Inc., U.S. ....	76
Additional Company Listings .....	77
<i>TABLE 28 OTHER SIGNIFICANT SMART MATERIAL MANUFACTURERS</i> .....	77
<i>TABLE 28 (CONTINUED)</i> .....	78
TRADE ORGANIZATIONS .....	78
VAMAS, International .....	78
Piezoceramic/Electrostrictive Material Organizations .....	79
Polecer, Europe .....	79
<i>TABLE 29 FULL POLECER MEMBERS</i> .....	79
<i>TABLE 29 (CONTINUED)</i> .....	80
<i>TABLE 29 (CONTINUED)</i> .....	81
<i>TABLE 30 ASSOCIATE POLECER MEMBERS, 2004</i> .....	81
<i>TABLE 30 (CONTINUED)</i> .....	82
ICAT, U.S. ....	82
<i>TABLE 31 REGULAR MEMBERS OF ICAT</i> .....	82
<i>TABLE 32 SIGNIFICANT GUEST MEMBERS OF ICAT</i> .....	83
TECHNOLOGY .....	84

INTRODUCTION .....	84
TECHNOLOGY TYPES.....	84
<i>TABLE 33 GLOBAL VALUE AND MARKET SHARE OF SMART MATERIALS AND COMPONENTS BY TECHNOLOGY TYPE AND REGION, 2005 (\$ MILLIONS)</i> .....	84
HISTORICAL TIMELINE.....	85
<i>TABLE 34 WORLDWIDE TECHNOLOGY DEVELOPMENT</i> .....	85
<i>TABLE 34 (CONTINUED)</i> .....	86
HISTORICAL TIMELINE (CONTINUED) .....	87
MANUFACTURING METHODS .....	88
PIEZOELECTRIC MATERIALS .....	88
Ceramics .....	88
<i>TABLE 35 TYPICAL MANUFACTURING PROCESS FOR PIEZOELECTRIC MATERIALS</i> .....	88
Crystals .....	89
Czochralski Method .....	89
Floating Zone Method.....	90
Ferroelectric Thin-Film Technology.....	90
Physical Vapor Deposition .....	91
Chemical Vapor Deposition.....	91
Sol-gel Processing.....	91
Thick-Film Growth Techniques .....	91
Tape Casting Method.....	92
Screenprinting.....	92
Aerosol Deposition Method .....	92
Polymer Composites .....	92
MAGNETOSTRICTIVE MATERIALS .....	93
Terfenol-D®.....	93
Metglas.....	93
THERMORESPONSIVE MATERIALS.....	93
Shape Memory Alloys .....	93
Other Manufacturing Processes.....	94
Thermoresponsive Thin-Film Technology .....	94
FLUIDS .....	94
ELECTROCHROMIC MATERIALS .....	95
COMPONENTS .....	95
DESIGN.....	96
PIEZOELECTRIC/ELECTROSTRICTIVE MATERIALS .....	96
Ceramics .....	96
Actuators .....	96
THERMORESPONSIVE MATERIALS.....	97
Polymers.....	97
NEW TECHNOLOGICAL DEVELOPMENTS.....	97
PATENTS.....	98
INTRODUCTION.....	98
PATENT ANALYSIS.....	98

Period of Study .....	98
Patents by Type of Smart Material .....	99
TABLE 36 WORLDWIDE SMART MATERIAL PATENTS, BY TYPE OF MATERIAL, 2003.....	99
TABLE 36 (CONTINUED) .....	100
Patents by Region of Origin .....	101
TABLE 37 WORLDWIDE SMART MATERIAL PATENTS BY REGION OF ORIGIN, 2003.....	101
Patents by Country.....	101
TABLE 38 GLOBAL SMART MATERIALS PATENTS BY COUNTRY OF ORIGIN (APPLICANT), 2003 .....	101
TABLE 38 (CONTINUED) .....	102
Patents by Material and Country of Origin .....	103
TABLE 39 GLOBAL SMART MATERIALS PATENTS (APPLICATIONS) BY MATERIAL AND COUNTRY/AREA OF ORIGIN, 2003.....	103
TABLE 39 (CONTINUED) .....	104
Patents by Area of Protection .....	105
TABLE 40 GLOBAL SMART MATERIAL PATENTS BY COUNTRY/AREA OF PROTECTION, 2003 .....	105
TABLE 41 GLOBAL SMART MATERIAL PATENTS BY COUNTRY/AREA OF PROTECTION AND TYPE OF MATERIAL, 2003 .....	106
TABLE 41 (CONTINUED) .....	107
Patents by Technology.....	107
TABLE 42 SMART MATERIAL PATENTS BY TECHNOLOGY, 2003.....	107
TABLE 42 (CONTINUED) .....	108
Patents by Application .....	109
TABLE 43 SMART MATERIALS PATENTS BY APPLICATION, 2003.....	109
MAIN PATENT HOLDERS .....	110
TABLE 44 SMART MATERIALS MAIN PATENT HOLDERS, 2003.....	110
TABLE 44 (CONTINUED) .....	111
R&D LEADERS.....	112
Overview .....	112
Overview (Continued).....	113
Research Centers by Region.....	114
Asia .....	114
Tohoku University, Japan.....	114
Tokyo Institute of Technology, Japan .....	115
Waseda University, Japan .....	115
U.S. ....	116
Office of Naval Research .....	116
DARPA.....	116
Virginia Tech .....	117
Langley Research Center .....	117
Pennsylvania State University.....	117
Europe .....	118
Polecer, Germany .....	118
International .....	118



PRODUCTS .....	119
INTRODUCTION .....	119
PIEZOELECTRIC/ELECTROSTRICTIVE PRODUCTS .....	119
CRYSTALS .....	119
Accelerometers.....	119
Electro-optic Devices .....	120
Optical Waveguides .....	120
Modulators .....	120
Oscillators .....	120
Pyroelectric Detectors.....	120
SAW (Surface Acoustic Wave).....	121
Wafers .....	121
CERAMIC, POLYMERS AND COMPOSITES .....	121
Actuators.....	121
Buzzers.....	122
Capacitors .....	122
Filters.....	122
Forks .....	122
Generators .....	122
Gyroscopes .....	123
Injectors .....	123
Intellifiber® .....	123
Memories.....	123
Motors .....	124
Multilayer Actuators .....	124
Resonators.....	124
Sensors .....	124
Sounders .....	125
Transducers .....	125
Transformers .....	125
Ultrasonic Motors .....	125
MARKET SIZE.....	126
<i>TABLE 45 GLOBAL FORECAST OF SALES FOR PRODUCTS THAT USE     PIEZOELECTRIC MATERIALS/COMPONENTS, THROUGH 2010 (\$ MILLIONS)</i> .....	126
<i>FIGURE 4 GLOBAL FORECAST OF SALES FOR PRODUCTS THAT USE     PIEZOELECTRIC MATERIALS/COMPONENTS, 2004-2010 (\$ MILLIONS)</i> .....	126
Actuators.....	127
Sensors .....	128
Market Drivers.....	129
Ultrasonic Motors .....	130
Transducers .....	131
Other Products.....	131
ELECTROSTRICTIVE.....	132
<i>TABLE 46 GLOBAL FORECAST OF SALES FOR END PRODUCTS BY TYPE THAT     USE ELECTROSTRICTIVE MATERIALS AND COMPONENTS, THROUGH 2010     (\$ MILLIONS)</i> .....	132

<i>FIGURE 5 GLOBAL FORECAST OF SALES FOR END PRODUCTS BY TYPE THAT USE ELECTROSTRICTIVE MATERIALS AND COMPONENTS, 2004-2010 (\$ MILLIONS)</i> .....	132
ELECTROSTRICTIVE (CONTINUED) .....	133
ELECTROSTRICTIVE (CONTINUED) .....	134
MAGNETOSTRICTIVE PRODUCTS .....	135
TERFENOL-D .....	135
Actuators .....	135
Composites .....	135
Sensors .....	135
Thick Films .....	135
Transducers .....	136
Valves .....	136
METGLAS .....	136
Magnaperm .....	136
Microlite and Microlite XP .....	136
Magamps .....	137
Powerlite .....	137
MARKET SIZE .....	137
<i>TABLE 47 GLOBAL FORECAST OF SALES FOR PRODUCTS THAT USE MAGNETOSTRICTIVE MATERIALS BY TYPE, THROUGH 2010 (\$ MILLIONS)</i> .....	137
<i>FIGURE 6 GLOBAL FORECAST OF SALES FOR PRODUCTS THAT USE MAGNETOSTRICTIVE MATERIALS BY TYPE, 2003-2010 (\$ MILLIONS)</i> .....	138
Actuators .....	138
Market Drivers.....	139
Sensors .....	140
Transducers.....	140
<i>TABLE 48 FORECAST OF MAGNETOSTRICTIVE TRANSDUCER PRODUCT SALES BY LEADING MANUFACTURER, THROUGH 2010 (\$ MILLIONS)</i> .....	141
<i>FIGURE 7 FORECAST OF MAGNETOSTRICTIVE TRANSDUCER PRODUCT SALES BY LEADING MANUFACTURER, 2003-2010 (\$ MILLIONS)</i> .....	141
Market Drivers.....	142
Magnetostrictive Valves .....	142
Magnetostrictive Valves (Continued).....	143
THERMORESPONSIVE PRODUCT TYPES .....	144
SHAPE MEMORY ALLOYS.....	144
Nitinol .....	144
Amplatzer .....	144
Archwires .....	144
Baskets .....	144
Filters .....	144
Flexinol® .....	145
Stents.....	145
POLYMERS.....	145
Diaplex .....	145
MARKET SIZE .....	146

<i>TABLE 49 GLOBAL FORECAST OF SALES FOR END PRODUCTS THAT USE THERMORESPONSIVE MATERIALS BY TYPE, THROUGH 2010 (\$ MILLIONS)</i> .....	146
<i>FIGURE 8 GLOBAL FORECAST OF SALES FOR END PRODUCTS THAT USE THERMORESPONSIVE MATERIALS BY TYPE, 2003-2010 (\$ MILLIONS)</i> .....	146
Stents .....	147
Other Medical Instruments and Dental Implants .....	147
Actuators.....	147
Other Products.....	147
Market Drivers .....	148
Orthodontics.....	148
Nitinol Stent-based Devices .....	149
Vascular Interventions .....	150
<i>TABLE 50 PRODUCTION ASSUMPTIONS FOR TYPICAL MINIMALLY INVASIVE ENDOVASCULAR REPAIRS USING NITINOL STENT-BASED DEVICES, THROUGH 2010</i> .....	151
Small Motors and Actuators.....	151
Other Products.....	151
Diaplex and Other Polymers .....	152
FLUID PRODUCTS.....	153
ELECTORHEOLOGICAL.....	153
Compositions of ERFs .....	153
Valves .....	153
MAGNETORHEOLOGICAL .....	153
Compositions of MRFs.....	153
Brake/Clutch Systems .....	153
Magneride .....	154
Rheonetic.....	154
Shock Absorbers.....	154
Vibration Dampers .....	154
MARKET SIZE.....	155
<i>TABLE 51 GLOBAL FORECAST OF SALES FOR PRODUCTS THAT USE RHEOLOGICAL FLUIDS BY TYPE, THROUGH 2010 (\$ MILLIONS)</i> .....	155
<i>FIGURE 9 GLOBAL FORECAST OF SALES FOR PRODUCTS THAT USE RHEOLOGICAL FLUIDS BY TYPE, 2004-2010 (\$ MILLIONS)</i> .....	155
Market Size (Continued) .....	156
Market Size (Continued) .....	157
Market Drivers .....	158
Electrorheological .....	159
Small MR Devices.....	159
BIOMIMETIC PRODUCTS.....	160
HYDRORESPONSIVE GELS.....	160
<i>TABLE 52 GLOBAL FORECAST OF PRODUCT SALES THAT USE BIOMIMETIC MATERIALS BY TYPE, THROUGH 2010 (\$ MILLIONS)</i> .....	161
<i>FIGURE 10 GLOBAL FORECAST OF PRODUCT SALES THAT USE BIOMIMETIC MATERIALS BY TYPE, 2004-2010 (\$ MILLIONS)</i> .....	161
OTHER PRODUCTS .....	162
ELECTROCHROMIC .....	162

Metal Oxides .....	162
Displays .....	163
Glasses.....	163
Rear-View Mirrors .....	163
MARKET SIZE.....	164
TABLE 53 GLOBAL FORECAST OF PRODUCT SALES THAT USE “OTHER” SMART MATERIALS BY TYPE, THROUGH 2010 (\$ MILLIONS).....	164
FIGURE 11 GLOBAL FORECAST OF PRODUCT SALES THAT USE “OTHER” SMART MATERIALS BY TYPE, 2003-2010 (\$ MILLIONS).....	164
Electrochromic .....	165
Market Drivers .....	166
Architectural Windows.....	166
Auto Mirrors .....	166
WORLDWIDE MARKET SUMMARY .....	167
TABLE 54 GLOBAL FORECAST OF PRODUCT SALES BY TYPE OF MATERIAL, THROUGH 2010 (\$ MILLIONS).....	167
FIGURE 12 GLOBAL FORECAST OF PRODUCT SALES BY TYPE OF MATERIAL, 2003-2010 (\$ MILLIONS).....	168
MANUFACTURERS.....	169
PARTICIPANTS AND REGIONAL ANALYSIS.....	169
TABLE 55 NUMBER OF END-PRODUCT MANUFACTURERS BY REGION, YEAR? .....	170
TABLE 56 LEADING END-PRODUCT MANUFACTURERS .....	171
COMPANY PROFILES.....	172
Piezoelectric/Electrostrictive Products .....	172
AVX Corp. (Kyocera Group), U.S. ....	172
Combined Systems, Inc., U.S. ....	172
Corning Inc., U.S.....	172
Covega (the former Codeon Corp.), U.S. ....	172
Denso Corp., Japan.....	172
Face International Corp., U.S. ....	173
Fujitsu Ltd., Japan .....	173
Head, Austria .....	173
Hitachi Ltd., Japan.....	173
IBM Corp., U.S.....	174
Infineon Technologies AG, Germany .....	174
JDS Uniphase, U.S. ....	174
Lockheed-Martin, U.S.....	175
Lucent Technologies, U.S. ....	175
Matsushita Denki Sangyo, Japan .....	175
NEC Tokin (formerly Tohoku Metal Industries Co., Ltd.), Japan.....	175
Olympus Optical, Japan .....	176
Omron Corp., Japan.....	176
Robert Bosch GmbH, Germany .....	176
Samsung Electronics Co. Ltd., Korea .....	176
Samsung Electro-Mechanics Co. Ltd, Korea .....	177

Samsung SDI Co. Ltd., Korea .....	177
SciMed Life Systems, U.S.....	177
Seiko Epson Corp., Japan.....	177
Siemens AG, Germany.....	178
Sony Corp., Japan.....	178
Spectra Inc., U.S. ....	178
Sumitomo Metal Industries Ltd., Japan.....	179
Toshiba KK, Japan .....	179
Xaar, U.K. ....	179
Xinetics, U.S.....	180
Magnetostrictive Product Manufacturers .....	180
Elna Magnetics, U.S. ....	180
Energen Inc., U.S.....	180
FeONIC plc, U.K.....	180
Thermoresponsive Product Manufacturers .....	180
@Medical Technologies N.V., Belgium.....	180
Advanced Cardiovascular Systems, U.S.....	181
AGA Medical Corp., U.S. ....	181
AMF, France .....	181
Boston Scientific, U.S. ....	181
Johnson Matthey, U.K.....	182
Nitinol Medical Technologies Inc., U.S.....	182
Raychem Corp., U.S.....	182
Fluid (Electrorheological and Magnetorheological)	
Product Manufacturers .....	182
CSA Engineering Inc., U.S. ....	182
Delphi Corp., U.S.....	183
Delphi Technologies Inc., U.S.....	183
General Motors Corp., U.S. ....	183
Electrochromic Device Manufacturers .....	183
AFG Industries, Inc., U.S. ....	183
Central Glass, Japan .....	184
Donnelly Corp., U.S. ....	184
Flabeg Group, Germany .....	184
Gentex, U.S. ....	184
Murakami-Kaimeido, Japan.....	185
Nikon, Japan.....	185
SAGE Electrochromics Inc., U.S. ....	185
Saint-Gobain, France.....	185
Hydrogel Product Manufacturers .....	186
Pleotint, U.S. ....	186
Biomimetic Product Manufacturers.....	186
Nexia Biotechnologies Inc., Canada.....	186
Other Product Manufacturers.....	187

*TABLE 57 OTHER SIGNIFICANT PRODUCT MANUFACTURERS ..... 187*

TECHNOLOGY.....	188
TRENDS .....	188
SWOT ANALYSIS OF CURRENT AND NEW DEVELOPMENT IN PRODUCTS AND MATERIALS .....	188
Lead-Free Environment .....	188
Novel Piezoceramics for Advanced Applications.....	189
TABLE 58 SWOT ANALYSIS OF CURRENT PZT PRODUCTS/MATERIALS.....	189
TABLE 59 SWOT ANALYSIS OF NEW SODIUM-LITHIUM NIOBATE DEVELOPMENTS/MATERIALS.....	190
TABLE 60 SWOT ANALYSIS OF NEW PMN-PT DEVELOPMENTS/MATERIALS.....	190
From Thermo- to Photo-Shifting Materials.....	190
TABLE 61 SWOT ANALYSIS OF CURRENT SHAPE MEMORY ALLOY PRODUCTS/MATERIALS.....	191
TABLE 62 SWOT ANALYSIS OF NEW SHAPE MEMORY POLYMER DEVELOPMENTS/MATERIALS.....	191
Next-Generation Automobiles.....	191
Microelectromechanical Systems .....	192
END-PRODUCT SALES BY REGION .....	192
TABLE 63 VALUE OF PRODUCT SALES BY REGION, THROUGH 2010 (\$ MILLION).....	192
TABLE 64 SHARE OF PRODUCT CONSUMPTION BY REGION AND TYPE, THROUGH 2010 (% OF UNITS).....	193
PIEZOELECTRIC MATERIALS .....	194
MAGNETOSTRICTIVE MATERIALS .....	194
THERMORESPONSIVE MATERIALS.....	195
SMART FLUIDS .....	196
ELECTROCHROMIC MATERIALS .....	196
NEW DEVELOPMENTS.....	196
MULTILAYER PIEZOELECTRIC ACTUATORS .....	196
PIEZOELECTRIC VIBRATING GYROSCOPES .....	197
HIGH-FREQUENCY ULTRASONIC SENSORS .....	197
SELF-HEATED BOOTS .....	198
SHAPE MEMORY POLYMERS FOR MEDICAL USE.....	198
APPLICATIONS.....	199
INTRODUCTION .....	199
CATEGORY GROUPS.....	200
SHORT TERM ANALYSIS .....	200
LONG TERM ANALYSIS .....	200
TABLE 65 GLOBAL FORECAST OF END-PRODUCT SALES BY APPLICATION, THROUGH 2010 (\$ MILLION).....	201
CUSTOMERS BY TYPE OF INDUSTRY .....	202
Communications .....	202
Automotive Industry .....	203
Medical Industry .....	203
Military Industry.....	204
APPLICATION CATEGORIES BY MATERIAL TYPE .....	204
COMMERCIAL .....	204

Aeronautics .....	204
Piezoelectric/Electrostrictive .....	204
Boeing 7E7 .....	204
Aerospace .....	205
Piezoelectric/Electrostrictive .....	205
NASA Sensors .....	205
Appliances .....	205
Piezoelectric/Electrostrictive .....	205
Gas Ignitors .....	205
Loudspeakers.....	205
Shock Sensors.....	205
Smoke Alarms .....	206
Ultrasonic Sensors .....	206
VCR Head Tracking Actuators .....	206
Thermoresponsive .....	206
Shape Memory Screws.....	206
Temperature Sensitive Flaps.....	207
Thermoresponsive Dishwashers.....	207
Automotive .....	207
Piezoelectric/Electrostrictive .....	207
Accelerometers .....	207
Antilock Braking Systems.....	208
Buzzers.....	208
Crash Sensors.....	208
Injectors .....	208
Knocking Sensors.....	209
Measurement Transducers .....	209
Magnetostrictive .....	209
Vibration Control Systems .....	209
Magnetorheological Fluids .....	209
Delphi's MagneRide System .....	209
Electrochromic .....	210
Rear-View Mirrors for Cars .....	210
Baby Care.....	210
Piezoelectric/Electrostrictive .....	210
Heartbeat Monitor .....	210
Communications .....	211
Magnetostrictive .....	211
Whispering Windows .....	211
SoundBug.....	212
Omnivox.....	212
Computers.....	212
Piezoelectric/Electrostrictive .....	212
Transformers .....	212

<i>TABLE 66 ADVANTAGES OF PIEZOELECTRIC MOTOR-TRANSFORMERS VS.</i>	
<i>ELECTROMAGNETIC AC/DC TRANSFORMERS.....</i>	
	<i>213</i>
Electronics.....	213
Piezoelectric/ Electrostrictive .....	213
CCD Image Sensors .....	213
Filters .....	214
Resonators .....	214
SAW Filters .....	214
Shock Sensors.....	214
Ultrasonic Cleaning .....	214
Optics .....	215
Piezoelectric/Electrostrictive .....	215
Cameras .....	215
Thermoresponsive.....	215
Frames for Eyeglasses .....	215
Printing .....	215
Piezoelectric/Electrostrictive .....	215
Electric Potential Sensors .....	215
Impact Printer Heads .....	215
Non-Impact Ink-jet Printers .....	216
Sports .....	216
Piezoelectric/Electrostrictive .....	216
Tennis Rackets and Skis .....	216
Sport Fishing Industries .....	217
Textiles.....	218
Thermoresponsive.....	218
Diaplex .....	218
Toys .....	218
Piezoelectric/Electrostrictive .....	218
The Musini.....	218
Thermoresponsive.....	218
Dolls.....	218
INDUSTRIAL.....	219
Actuators.....	219
Piezoelectric/Electrostrictive .....	219
Active and Passive Dampers.....	219
Anti-Vibration.....	219
Piezoelectric/Electrostrictive .....	219
The Hubble Case .....	219
Magnetostrictive .....	220
KelvinAll™ .....	220
Building.....	220
Electrochromic .....	220
Architecture .....	220
Civil Engineering.....	221



Cutting .....	221
Piezoelectric/Electrostrictive .....	221
Motion Guide Mechanisms.....	221
Cutting Error Correction Mechanisms .....	221
Dampers.....	221
Piezoelectric/Electrostrictive .....	221
Dampers.....	221
Magnetorheological Fluids .....	222
Dampers.....	222
Hydraulics.....	222
Piezoelectric/Electrostrictive .....	222
Valves.....	222
Resistance Controls .....	223
Piezoelectric/Electrostrictive .....	223
Sensors .....	223
Robotics.....	223
Piezoelectric/ Electrostrictive .....	223
Aerial Microphone Transducers .....	223
Sensors .....	223
Piezoelectric/Electrostrictive .....	223
Shock Sensors.....	223
MEDICAL.....	224
Biomedical.....	224
Thermoresponsive .....	224
Nitinol .....	224
Cardiology .....	224
Thermoresponsive.....	224
Pulmonary Embolism .....	224
Congenital Heart Defect.....	224
Dentistry .....	225
Thermoresponsive.....	225
Nitinol .....	225
Drug Delivery .....	225
Hydrogels .....	225
Algae.....	225
Implants.....	225
Magnetostrictive .....	225
Hearing Aids.....	225
Thermoresponsive.....	226
Nitinol .....	226
Instruments .....	226
Piezoelectric/Electrostrictive .....	226
Deformable Mirrors .....	226
Ultrasonic Cleaning .....	226

Thermoresponsive Shape Memory Alloys.....	226
Nitinol .....	226
Neurology.....	227
Piezoelectric/Electrostrictive .....	227
Medical Transducers.....	227
Prosthetics/Orthopedics .....	227
Thermoresponsive.....	227
Plates and Screws .....	227
Magnetorheological Fluids .....	228
Lord and Biedermann.....	228
Surgery.....	228
RESEARCH.....	228
Astronomy.....	228
Piezoelectric/Electrostrictive .....	228
Deformable Mirrors .....	228
Interferometry .....	229
Piezoelectric/ Electrostrictive .....	229
Interferometer.....	229
Optics .....	229
Piezoelectric/Electrostrictive .....	229
Microscope (Atomic).....	229
Spectroscopy.....	230
Piezoelectric/Electrostrictive .....	230
Spectroscopes.....	230
MILITARY.....	230
Aeronautics .....	230
Piezoelectric/Electrostrictive .....	230
Anti-tail Buffeting.....	230
Armoring.....	230
Communications .....	231
Piezoelectric/Electrostrictive/Fiber Optics.....	231
Satellite Communications .....	231
Guidance .....	231
Piezoelectric/Electrostrictive .....	231
Missile Guidance.....	231
Fiber Optics.....	231
Missiles Guidance and Navigation Systems.....	231
Navigation.....	232
Piezoelectric/Electrostrictive .....	232
Hydrophones.....	232
Piezoelectric/Electrostrictive/Magnetostrictive .....	232
Sonar .....	232
OTHERS.....	233
Chemical and Biological War.....	233

Piezoelectric/Electrostrictive .....	233
Detectors .....	233
Vending Machines .....	233
Piezoelectric/Electrostrictive .....	233
Bubble Sensors .....	233
TOTAL MARKET SIZE SUMMARY .....	234
Applications .....	234
TABLE 67 GLOBAL FORECAST OF PRODUCT SALES BY APPLICATION SECTOR, THROUGH 2010 (\$ MILLION) .....	234
Commercial .....	234
Industrial .....	235
Military.....	235
Regions .....	235
TABLE 68 PRODUCT CONSUMPTION VALUE BY MARKET APPLICATION AND REGION, 2005 (\$ MILLION).....	235
TABLE 68 (CONTINUED) .....	236
FUTURE APPLICATIONS.....	236
Piezoelectric .....	236
Lightweight Materials .....	236
EPAM .....	237
Micro Air Vehicles.....	237
Piezoelectric/Electrostrictive/Magnetostrictive .....	237
Silent Helicopters.....	237
Magnetostrictive .....	238
Vibration Damping .....	238
Thermoresponsive.....	238
SMAs and Other Smart Materials .....	238
Active Aerolastic Wing .....	238
Shape Memory Polymers .....	239
Aeronautics.....	239
Automotive.....	239
Surgery.....	240
Fluids .....	240
Magnetorheological.....	240
International Space Station (ISS) .....	240
Electrochromic .....	241
Dark Visors for Motorcyclers .....	241
Chemoresponsive.....	241
Baby Diapers.....	241
Biomimetic .....	241
Protective Bioskin Materials .....	241
Protective Bioskin Materials (Continued) .....	242
APPENDIX .....	243
SOURCES .....	243

BOOKS, MAGAZINES:.....	243
INTERNET WEB SITES: .....	243
INTERNET WEB SITES: (CONTINUED) .....	244
DATABASES/DIRECTORIES .....	245
ORGANIZATIONS/UNIVERSITIES/ASSOCIATIONS .....	245
ORGANIZATIONS/UNIVERSITIES/ASSOCIATIONS (CONTINUED) .....	246