

CHAPTER ONE: INTRODUCTION.....	1
STUDY GOALS AND OBJECTIVES.....	1
REASONS FOR DOING THE STUDY.....	1
INTENDED AUDIENCE.....	2
SCOPE OF REPORT.....	2
METHODOLOGY AND INFORMATION SOURCES.....	3
ANALYST'S CREDENTIALS.....	3
RELATED BCC REPORTS.....	4
BCC ONLINE SERVICES.....	4
DISCLAIMER.....	5
 CHAPTER TWO: SUMMARY.....	 6
<i>SUMMARY TABLE U.S. MARKET FOR STRUCTURAL CARBON</i> <i>MATERIALS BY USER SEGMENT, THROUGH 2016 (\$ MILLIONS)</i>	 6
<i>SUMMARY FIGURE U.S. MARKET FOR STRUCTURAL CARBON</i> <i>MATERIALS BY USER SEGMENT, 2010–2016 (\$ MILLIONS)</i>	 7
 CHAPTER THREE: INDUSTRY AND MARKETS OVERVIEW.....	 8
UNITED STATES MARKET.....	8
<i>FIGURE 1 UNITED STATES MARKET FOR ADVANCED</i> <i>STRUCTURAL CARBONS BY TYPE, 2010 (TOTAL = \$1.96</i> <i>BILLION)</i>	 9
<i>FIGURE 2 PROJECTED GROWTH RATE IN U.S. STRUCTURAL</i> <i>CARBONS MARKET, 2011–2016 (CAGR%)</i>	 10
GLOBAL MARKETS.....	10
<i>FIGURE 3 GLOBAL ADVANCED STRUCTURAL CARBONS MARKET</i> <i>BY TYPE, 2010 (TOTAL = \$4.9 BILLION) (%)</i>	 11
<i>FIGURE 4 GLOBAL STRUCTURAL CARBONS CONSUMPTION BY</i> <i>WORLD REGION, 2010 (%)</i>	 12
RESEARCH AND TECHNOLOGY TRENDS.....	12
INDUSTRY STRUCTURE.....	13
INDUSTRY STRUCTURE (CONTINUED).....	14
 CHAPTER FOUR: TECHNICAL OVERVIEW.....	 15
INTRODUCTION TO ADVANCED STRUCTURAL CARBON PRODUCTS.....	 15
IMPORTANCE OF MECHANICAL PROPERTIES.....	15
CARBON FIBERS.....	16
RAW MATERIALS FOR CARBON FIBERS.....	16
Types of Raw Materials.....	16
Rayon.....	17
PAN.....	17
Pitch.....	18
Raw Material and Fiber Properties Relationship.....	18

<i>TABLE 1 DEPENDENCE OF CARBON FIBER PROPERTIES ON RAW MATERIALS</i>	19
PAN-Based Fibers.....	19
Pitch-Based Fibers.....	19
Rayon-Based Fibers	20
MANUFACTURING PROCESS	20
PAN Carbon Fiber Process.....	20
Precursor Preparation	21
Polymerization	21
Spinning and Stretching.....	21
Stabilization	22
Carbonization.....	23
Surface Treatment	23
Sizing.....	24
Pitch Carbon Fiber Process.....	24
Precursor Preparation	24
Pitch Refining.....	24
Isotropic Pitch.....	25
Anisotropic or Mesophase Pitch.....	25
Thermal Modifications	26
Solvent Modification.....	26
Chemical Modification.....	26
Catalytic Modification	26
Melt Spinning.....	27
Stabilization	27
Carbonization.....	27
Graphitization.....	28
Viscose Rayon Carbon Fiber Process.....	28
Vapor-Grown Carbon Fibers	29
CHEMICAL AND PHYSICAL PROPERTIES.....	29
Structural Property Relationship for Carbon Fibers	29
Density	29
Modulus.....	30
Impact of Fiber Diameter.....	30
Electrical and Thermal Conductivity.....	30
Thermal Stability.....	30
<i>TABLE 2 STRUCTURAL PROPERTY RELATIONSHIPS FOR CARBON FIBERS DERIVED FROM VARIOUS PRECURSORS</i>	31
CARBON FIBER PRODUCT FORMS	31
Carbon Fiber Product Grades	31
PAN-Derived Fibers.....	31
Pitch-Derived Fibers.....	31
Tow.....	32
Carbon Fiber Cloth.....	32

Prepreg.....	32
RECENT DEVELOPMENTS IN MANUFACTURING TECHNOLOGIES	33
Microwave-Assisted Plasma (MAP) Process.....	33
Low Cost Carbon Fiber from Renewable Resources	34
Low Cost Carbon Fiber from Polyolefin.....	34
Ultraviolet (UV) Stabilization of PAN-based Carbon Fibers	35
Rapid Oxidation Step	35
Surface Modification of Carbon Fibers	36
Carbon Nanotube Reinforcement of Carbon Fibers	37
Continuous Carbon Fiber Produced from Carbon Nanotubes.....	37
Carbon Nanofibers.....	37
Activated Carbon Fibers.....	38
MANUFACTURERS OF PAN-BASED FIBERS	38
Small-Tow Manufacturers	39
Cyttec's Carbon Fiber Production.....	39
Hexcel's Carbon Fiber Production.....	40
Other Manufacturers.....	41
Large-Tow Carbon Fiber Manufacturers.....	42
Zoltek Companies, Inc.	42
Toho Tenax America	43
SGL Carbon Fibers and Composites	43
MANUFACTURERS OF PITCH-BASED CARBON FIBERS	44
CARBON FIBER COMPOSITES	45
Carbon-Fiber-Reinforced Polymer Composites (CFRP).....	46
Manufacturing Processes	46
Molding Processes	46
Roving Processes	46
Mechanical Properties	47
<i>TABLE 3 TYPICAL MECHANICAL PROPERTIES OF CARBON-FIBER-REINFORCED POLYMER COMPOSITES</i>	<i>47</i>
Carbon-Fiber-Reinforced Metal Composites (CFRM).....	47
Manufacturing Processes	48
Mechanical Properties	48
<i>TABLE 4 TYPICAL MECHANICAL PROPERTIES OF CARBON-FIBER-REINFORCED METAL COMPOSITES.....</i>	<i>48</i>
CARBON FOAMS	49
RAW MATERIALS	49
<i>TABLE 5 PROPERTIES OF PITCH RAW MATERIALS USED FOR CARBON FOAM MANUFACTURING (°C / %).</i>	<i>50</i>
MANUFACTURING PROCESS	50
Flash Process	50

Blowing Gases.....	51
Sol-Gel Process	51
CHEMICAL AND PHYSICAL PROPERTIES.....	51
<i>TABLE 6 PHYSICAL PROPERTIES OF PITCH-DERIVED CARBON</i>	
<i>FOAMS</i>	52
RECENT TRENDS IN CARBON FOAM TECHNOLOGY	52
Uniform-Density-Gradient Carbon Foams.....	52
Reinforced Carbon Foams	53
High-Thermal-Conductivity Carbon Foams.....	54
Magnetic Carbon Nanofoams.....	54
Low-Cost Carbon Foams	55
MANUFACTURERS OF CARBON FOAMS.....	55
Honeywell	55
POCO Graphite.....	56
Touchstone Research Laboratory.....	57
University of Dayton and Wright U.S. Air Force	
Laboratory Alliance.....	57
STRUCTURAL GRAPHITE	58
TYPES AND MANUFACTURING OF GRAPHITE MATERIALS.....	58
Natural Graphite.....	58
Synthetic Graphite	58
<i>FIGURE 5 SCHEMATIC OF MANUFACTURING PROCESS FOR</i>	
<i>SYNTHETIC GRAPHITE</i>	59
PHYSICAL AND CHEMICAL PROPERTIES.....	60
Crystalline Structure.....	60
<i>FIGURE 6 CRYSTALLINE STRUCTURE OF GRAPHITE</i>	60
Lubrication.....	61
Thermal Properties.....	61
Oxidation Resistance	61
Chemical Resistance.....	62
Mechanical Properties	62
<i>TABLE 7 PHYSICAL PROPERTIES OF GRAPHITE MATERIALS</i>	63
EMERGING TECHNOLOGIES	63
Porous Graphite.....	63
High-Temperature Graphite Process.....	64
Expandable Graphite	64
CARBON-CARBON STRUCTURAL COMPOSITES.....	64
TYPES OF STRUCTURAL COMPOSITE MATERIALS	64
Types of Structural Composite ... (Continued)	65
CARBON-REINFORCED CARBON MATRIX COMPOSITES.....	66
<i>TABLE 8 ADVANTAGES AND DISADVANTAGES OF CARBON-</i>	
<i>CARBON COMPOSITES</i>	67
DIFFERENCES BETWEEN GRAPHITE AND CARBON-	
CARBON COMPOSITES	67

<i>TABLE 9 COMPARISON OF PHYSICAL PROPERTIES OF GRAPHITE AND CARBON-CARBON COMPOSITES</i>	68
CHEMICAL AND PHYSICAL PROPERTIES.....	68
REINFORCEMENT ARCHITECTURE.....	69
One-Dimensional Architecture	69
Two-Dimensional Architecture	70
Three-Dimensional Architecture	70
Multidimensional Architecture.....	71
Foam Reinforcement	71
MANUFACTURING PROCESSES	72
Infiltration of Matrix Phase.....	72
Raw Materials for Matrix Phase.....	72
Chemical Vapor Infiltration Process.....	73
Temperature Gradient Process.....	73
Isothermal Process.....	74
Pressure Gradient Process	74
Liquid Pitch Infiltration Process.....	74
Raw Materials	74
Manufacturing Process.....	75
Low-Pressure Process.....	75
High-Pressure Process	75
Thermosetting Resins as Matrix Precursors	76
<i>FIGURE 7 REPRESENTATION OF CARBON-CARBON COMPOSITE MANUFACTURING PROCESS</i>	77
STRUCTURE AND PROPERTY RELATIONSHIPS	77
Microstructural Features	77
<i>TABLE 10 COMPARISON OF CARBON-CARBON COMPOSITES PROPERTIES MANUFACTURED BY VARIOUS PROCESSING ROUTES</i>	78
Mechanical Properties.....	79
Young's Modulus.....	79
Strength.....	80
Fatigue and Creep	80
Effect of Temperature on Mechanical Properties.....	80
Effect of Oxidation on Mechanical Properties	81
Thermal Properties.....	81
Friction and Wear Properties.....	82
OXIDATION PROTECTION FOR CARBON-CARBON COMPOSITES	82
TECHNOLOGY TRENDS.....	83
Oxidation Inhibition of Carbon-Carbon Composites.....	83
Rapid-Oxidative-Stabilization Composites.....	83
High-Purity Carbon-Carbon Composites.....	84
High-Density Carbon-Carbon Composites	84

Elimination of Need for Oxidative Stabilization of Carbon Composites.....	85
High Thermal Conductivity Carbon-Carbon Composites	85
Sequential Deposit of Carbon Matrix and <i>In Situ</i> Polymerization.....	86
Rapid Processing of Carbon-Carbon Composites	86
Protective Coatings.....	87
Detecting Flaws in the Carbon Composites	88
Carbon-Carbon Composites from Densified Carbon Foam.....	88
Low-Temperature Densification Using Sugar Pyrolysis	88
Thick Three Dimensional Preforms for Carbon-Carbon Composites.....	89
High-Strength Composites Developed by NASA and JPL.....	89
Carbon-Carbon Frictional Composites for Elevator Brakes.....	89
Joining Carbon-Carbon Composites	90
Nanotubes in Carbon-Carbon Composites	90
GRAPHENE	91
PROPERTIES.....	91
RAW MATERIALS AND PRODUCTION PROCESSES	92
Established Technologies	92
“Scotch Tape” Method.....	92
Epitaxial Method	93
Graphite Oxide Reduction Method	93
Experimental Approaches	94
Metal-Carbon Melt Method	94
Pyrolysis of Sodium Ethoxide Method	94
Production of Graphene from Carbon Nanotubes	95
Production of Graphene from Table Sugar	95
Dissolving Graphite in Chlorosulphonic Acid.....	95
“Molecular Wedge” Method	96
Radio Frequency Catalytic Chemical Vapor Deposition	96
COMPANIES DEVELOPING GRAPHENE STRUCTURAL MATERIALS	96
General Motors	97
Graftech.....	97
Graphenea.....	97
CHAPTER FIVE: COMMERCIAL APPLICATIONS.....	98
CARBON FIBER APPLICATIONS.....	98
TABLE 11 PROPERTIES AND APPLICATIONS OF CARBON FIBERS.....	98
AEROSPACE AND DEFENSE INDUSTRY.....	99
Space Vehicles	99
Unmanned Spacecraft	99
Manned Spacecraft.....	100

Launch Vehicles	100
Total U.S. Space Market	101
<i>TABLE 12 U.S. SPACE VEHICLE MARKET, THROUGH 2016 (\$</i>	
<i>BILLIONS)</i>	<i>101</i>
Defense Market.....	101
Defense Aviation	101
<i>TABLE 13 SALES OF U.S. MILITARY AIRCRAFT, THROUGH 2016 (\$</i>	
<i>BILLIONS)</i>	<i>102</i>
Missiles.....	103
<i>TABLE 14 U.S. MISSILE SHIPMENTS, THROUGH 2016 (\$ BILLIONS)....</i>	<i>103</i>
Commercial Aviation	103
Large Aircraft.....	104
<i>TABLE 15 DELIVERIES OF LARGE U.S.-MADE COMMERCIAL</i>	
<i>AIRCRAFT BY TYPE, THROUGH 2016 (UNITS)</i>	<i>105</i>
Carbon Fiber Consumption	105
<i>TABLE 16 CONSUMPTION OF CARBON-FIBER-REINFORCED</i>	
<i>COMPOSITES IN U.S.-MADE BOEING COMMERCIAL AIRLINERS</i>	<i>106</i>
GROUND TRANSPORT	106
Trains and Locomotives	107
Motor Vehicles	107
Motor Vehicles (Continued).....	108
INDUSTRIAL APPLICATIONS	109
WIND ENERGY	110
<i>TABLE 17 TRENDS IN U.S. WIND POWER CAPACITY, THROUGH</i>	
<i>2016 (MW)</i>	<i>110</i>
<i>TABLE 18 U.S. MARKET FOR WIND TURBINE ROTOR BLADES,</i>	
<i>THROUGH 2016 (\$ MILLIONS).....</i>	<i>111</i>
SPORTING GOODS.....	111
Golf Clubs.....	112
<i>TABLE 19 U.S. MARKET FOR CARBON FIBER COMPOSITE GOLF</i>	
<i>CLUBS, THROUGH 2016 (\$ MILLIONS).....</i>	<i>113</i>
Bicycles.....	113
Recreational Boating	113
Sport Fishing	114
<i>TABLE 20 U.S. SHIPMENTS OF CARBON FIBER FISHING RODS,</i>	
<i>THROUGH-2016 (\$ MILLIONS)</i>	<i>114</i>
Other Applications.....	115
INFRASTRUCTURE.....	115
New Bridge Construction	116
Bridge Repairs	117
Column Repairs	118
Seismic Retrofit.....	119
High-Strength Building Construction	120
Engineered Wood Products	121

Tension Leg Platform Tethers from Carbon Composites.....	121
Smarter and Stronger Concrete.....	122
New Manufacturing Process for Reinforced Concrete	122
THERMAL MANAGEMENT.....	123
Conductive Plastics	124
Carbon Nanotubes.....	125
OTHER APPLICATIONS	126
Biocompatibility Applications	126
Electrochemical Applications.....	126
Static Dissipation Applications.....	126
Lightweight Telescope Mirrors	127
Hollow Carbon Fibers in Molecular Sieve Applications	127
Emerging Energy Systems.....	127
Turtle Airship Uses Carbon Composites	128
CARBON FIBERS MARKET GROWTH.....	128
<i>TABLE 21 U.S. CONSUMPTION OF CARBON FIBERS, THROUGH</i>	
<i>2016 (THOUSAND LBS.)</i>	<i>129</i>
<i>FIGURE 8 U.S. CARBON FIBER CONSUMPTION BY INDUSTRY</i>	
<i>SEGMENT, 2010 VS. 2016 (%)</i>	<i>130</i>
<i>TABLE 22 U.S. MARKET FOR CARBON FIBERS, THROUGH 2016 (\$</i>	
<i>MILLIONS).....</i>	<i>131</i>
<i>FIGURE 9 U.S. CARBON FIBER MARKET BY INDUSTRY, 2010 VS.</i>	
<i>2016 (% OF TOTAL MARKET VALUE)</i>	<i>132</i>
CARBON FOAM APPLICATIONS	132
AEROSPACE AND DEFENSE	133
Radiators.....	133
Fire Barrier Applications	133
Brakes	133
GROUND TRANSPORTATION	133
Automotive Radiators.....	134
Shock Absorbers and Bumpers	134
Other Automotive Applications	134
INDUSTRIAL APPLICATIONS.....	135
Sandwich Panels.....	135
Electronic Heat Sinks.....	135
Phase-Change Materials	135
ENERGY.....	136
Batteries.....	136
Fuel Cells	136
Radiators	137
Humidifiers	137
Bipolar Plates.....	138
Supercapacitors	138
Nuclear Reactor Cores.....	138

Gas Storage.....	138
OTHER APPLICATIONS	139
Air Filtration Devices	139
Personal Cooling Devices	139
Health Care Applications	139
Acoustic Absorber Materials	139
CARBON FOAM MARKET GROWTH	140
<i>TABLE 23 U.S. CONSUMPTION OF CARBON FOAM, THROUGH 2016</i> <i>(THOUSAND LBS.).....</i>	<i>140</i>
<i>FIGURE 10 U.S. CONSUMPTION OF CARBON FOAM BY INDUSTRY</i> <i>SECTOR, 2010 VS. 2016 (% TOTAL CONSUMPTION).....</i>	<i>141</i>
<i>TABLE 24 U.S. CARBON FOAM MARKET GROWTH BY INDUSTRY,</i> <i>THROUGH 2016 (\$ MILLIONS).....</i>	<i>142</i>
STRUCTURAL GRAPHITE APPLICATONS	142
AEROSPACE AND DEFENSE	142
GROUND TRANSPORTATION	143
INDUSTRIAL APPLICATIONS	144
Chemical Industry Applications	144
Mechanical Applications	145
Bearings and Brushes.....	145
<i>TABLE 25 TYPICAL APPLICATIONS FOR GRAPHITE BEARINGS.....</i>	<i>146</i>
Seals	146
Friction Materials	146
Metallurgy.....	147
Glassware.....	148
Refractory Applications	148
ENERGY.....	149
Fuel Cells	149
Nuclear Industry Applications.....	150
Hydrogen Storage	150
STRUCTURAL GRAPHITE MARKET GROWTH	151
<i>TABLE 26 U.S. CONSUMPTION OF STRUCTURAL GRAPHITE BY</i> <i>INDUSTRY, THROUGH 2016 (THOUSAND LBS.).....</i>	<i>151</i>
<i>FIGURE 11 U.S. CONSUMPTION OF STRUCTURAL GRAPHITE BY</i> <i>INDUSTRY SEGMENT, 2010 VS. 2016 (% OF TOTAL LBS.</i> <i>CONSUMED).....</i>	<i>152</i>
<i>TABLE 27 U.S. MARKET FOR STRUCTURAL GRAPHITE BY</i> <i>INDUSTRY SEGMENT, THROUGH 2016 (\$ MILLIONS).....</i>	<i>153</i>
CARBON-CARBON COMPOSITES APPLICATIONS	153
AEROSPACE.....	153
Space Vehicle Thermal Protection Systems	154
Space Vehicle Thermal ... (Continued).....	155
Aircraft Engine Components.....	156
Aircraft Brakes	157

Other Aerospace Applications.....	158
GROUND TRANSPORTATION	158
INDUSTRIAL APPLICATIONS	159
Refractory Structures	160
Glass Industry	160
Corrosion-Resistant Structures	161
Thermal-Management Solutions	161
ENERGY.....	162
OTHER APPLICATIONS	162
Biocompatible Structures	162
CARBON-CARBON COMPOSITES MARKET GROWTH	162
<i>TABLE 28 U.S. CONSUMPTION OF CARBON-CARBON COMPOSITES</i>	
<i> BY INDUSTRY, THROUGH 2016 (THOUSAND LBS.).....</i>	<i>163</i>
<i>FIGURE 12 U.S. CARBON-CARBON COMPOSITES CONSUMPTION</i>	
<i> BY INDUSTRY TYPE, 2010 VS. 2016 (%)</i>	<i>164</i>
<i>TABLE 29 U.S. MARKET FOR CARBON-CARBON COMPOSITES BY</i>	
<i> INDUSTRY, THROUGH 2016 (\$ MILLIONS).....</i>	<i>165</i>
STRUCTURAL GRAPHENE APPLICATIONS	165
INDUSTRIAL APPLICATIONS	165
Thermal Management Solutions	165
ENERGY.....	166
Hydrogen Storage	166
Oxidized Graphene Sheets	166
Other Developments	167
MARKET GROWTH	167
<i>TABLE 30 U.S. CONSUMPTION OF STRUCTURAL GRAPHENE BY</i>	
<i> INDUSTRY, THROUGH 2016 (THOUSAND LBS.).....</i>	<i>168</i>
MARKETS FOR ADVANCED STRUCTURAL CARBONS	168
<i>TABLE 31 U.S. CONSUMPTION OF STRUCTURAL CARBONS BY</i>	
<i> TYPE OF MATERIAL, THROUGH 2016 (THOUSAND LBS.).....</i>	<i>169</i>
<i>FIGURE 13 STRUCTURAL CARBON PRODUCT SHARES OF TOTAL</i>	
<i> U.S. STRUCTURAL CARBON CONSUMPTION, 2010 VS. 2016 (%)</i>	<i>170</i>
<i>TABLE 32 U.S. MARKET FOR STRUCTURAL CARBON MATERIALS</i>	
<i> BY TYPE OF MATERIAL, THROUGH 2016 (\$ MILLIONS).....</i>	<i>171</i>
<i>FIGURE 14 STRUCTURAL CARBON PRODUCT SHARES OF TOTAL</i>	
<i> U.S. STRUCTURAL CARBON CONSUMPTION, 2010 VS. 2016 (%)</i>	<i>172</i>
CHAPTER SIX: INDUSTRY STRUCTURE AND MARKET DRIVERS.....	173
MARKETS FOR STRUCTURAL CARBON MATERIALS	173
MANUFACTURERS OF STRUCTURAL CARBONS	173
Carbon Fibers	174
<i>FIGURE 15 LEADING U.S. CARBON FIBER SUPPLIERS' SHARE OF</i>	
<i> TOTAL U.S. CONSUMPTION, 2010 (%)</i>	<i>174</i>
Carbon Foams	175

<i>FIGURE 16 LEADING U.S. CARBON FOAM SUPPLIERS' SHARE OF TOTAL U.S. CONSUMPTION, 2010 (%)</i>	175
Structural Graphite.....	176
<i>FIGURE 17 LEADING U.S. STRUCTURAL GRAPHITE SUPPLIERS' SHARE OF TOTAL U.S. CONSUMPTION, 2010 (%)</i>	176
Carbon-Carbon Composites.....	177
<i>FIGURE 18 LEADING U.S. CARBON-CARBON COMPOSITE SUPPLIERS' SHARE OF TOTAL U.S. CONSUMPTION, 2010 (%)</i>	177
SWOT ANALYSIS OF STRUCTURAL CARBONS INDUSTRY	178
Strengths.....	178
Weaknesses.....	178
Opportunities.....	178
Threats	179
MARKET DRIVERS	179
ECONOMIC FACTORS	179
LEGAL AND REGULATORY FACTORS	180
Price-Fixing in the Carbon Fibers and Composites Industry	180
Price-Fixing in the Graphite Industry.....	181
INDUSTRY FACTORS	181
Capacity Trends.....	181
Price Trends.....	182
New Technologies and New Entrants to the Business	182
Influence and Leverage	182
Buyers' Influence and Leverage	182
Suppliers' Influence and Leverage.....	183
Substitute Products	183
COMPETITIVE STRATEGIES IN THE STRUCTURAL CARBONS INDUSTRY	184
NEW BUSINESS DEVELOPMENT	184
COMPETITIVE PRICING	185
VERTICAL INTEGRATION.....	186
GLOBAL STRATEGIC ALLIANCES.....	186
SGL – BMW Joint Venture	186
SGL-Mitsubishi Joint Venture.....	186
Mitsubishi Rayon's Expansion Plans and Alliance with SGL	187
Zoltek-DeWind Supply Agreement	187
Zoltek and Chomarat.....	187
GrafTech and Ballard Power Systems.....	187
Zoltek and Leggett & Pratt	188
Hexcel and Airbus Industries	188
Hexcel and Boeing	188

CHAPTER SEVEN: INTELLECTUAL PROPERTY AND TECHNOLOGY	
TRENDS ANALYSIS	189
INTELLECTUAL PROPERTY ANALYSIS.....	189
<i>TABLE 33 PATENTS ISSUED TO LEADING MANUFACTURES IN</i>	
<i>STRUCTURAL CARBON MATERIALS TECHNOLOGY, 1996–2010</i>	190
TECHNOLOGY DEVELOPMENT TRENDS.....	190
TECHNOLOGY DEVELOPMENT TRENDS (CONTINUED).....	191
CHAPTER EIGHT: INTERNATIONAL ASPECTS OF STRUCTURAL	
CARBONS BUSINESS	192
<i>TABLE 34 GLOBAL MARKET FOR STRUCTURAL CARBON BY TYPE</i>	
<i>OF MATERIAL, 2010 (\$ MILLIONS)</i>	192
<i>FIGURE 19 COMPARISON OF ADVANCED STRUCTURAL CARBONS</i>	
<i>CONSUMPTION IN WORLD REGIONS BY TYPE OF MATERIAL,</i>	
<i>2010 (%)</i>	193
<i>TABLE 35 GLOBAL STRUCTURAL CARBONS MARKET GROWTH BY</i>	
<i>REGION, THROUGH 2016 (\$ MILLIONS)</i>	194
CHAPTER NINE: PROFILE OF MANUFACTURERS.....	195
U.S. MANUFACTURERS.....	195
AAR COMPOSITES	195
ADVANCED CARBON TECHNOLOGIES, INC.....	195
ADVANCED COMPOSITES, INC.....	196
AEROSPACE COMPOSITE PRODUCTS CO.	196
ALBANY ENGINEERED COMPOSITES.....	196
APPLIED SCIENCES, INC.	197
ASBURY CARBONS	197
BOEING CO.	198
BTG COMPOSITES, INC.	198
CARBON-CARBON ADVANCED TECHNOLOGIES, INC.....	198
CHOMARAT NORTH AMERICA	199
CYTEC CORP.....	199
FIBER MATERIALS, INC.....	200
FIBERSPAR CORP.	200
FORESEE ORTHOPEDIC PRODUCTS.....	201
GENERAL MOTORS CO.....	201
GOODRICH CORP.....	201
GRAFIL, INC.....	202
GRAPHITE METALLIZING CORP.	202
GRAPHITE SALES, INC.....	202
GRAFTECH INTERNATIONAL, LTD.	203
GRAPHTEK, LLC	203
HELWIG CARBON PRODUCTS, INC.	204
HEXCEL CORP.....	204
HITCO CARBON COMPOSITES, INC.....	205

HONEYWELL INTERNATIONAL, INC.	205
KIRKWOOD INDUSTRIES, INC.	206
MER CORP.	206
MINERALS TECHNOLOGY, INC.	207
MORGAN ADVANCED MATERIALS AND TECHNOLOGY	207
PLANSEE THERMAL MANAGEMENT SOLUTIONS	208
POCO GRAPHITE, INC.	208
ROC CARBON CO.	208
SCHUNK GRAPHITE TECHNOLOGY, LLC.	209
SGL CARBON GROUP	209
SHAMOKIN FILLER CO.	210
SIOUX MANUFACTURING CORP.	210
SPAULDING COMPOSITES CO.	210
SPENCER COMPOSITE CORP.	211
ST. MARYS CARBON CO.	211
SUPERIOR GRAPHITE CO.	211
TOHO TENAX AMERICA, INC.	212
TORAY CARBON FIBERS AMERICA, INC.	212
TOUCHSTONE RESEARCH LABORATORY, LTD.	213
TPI COMPOSITES, INC.	213
ULTRAMET, INC.	214
V2 COMPOSITE, INC.	214
YLA, INC.	214
ZOLTEK CORP.	215
INTERNATIONAL MANUFACTURERS	215
ANAORI CARBON CO., LTD.	215
ATLAS COMPOSITES, LTD.	215
C2 COMPOSITES	216
GRAPHENEA.	216
GRUPO ANTOLIN INGENIERIA S.A.	216
MERSEN GROUP	217
MITSUBISHI CHEMICAL CORP.	217
MITSUBISHI RAYON CO., LTD.	217
NIPPON GRAPHITE FIBER CORP	218
NIPPON SHEET GLASS CO., LTD.	218
TAIWAN CARBON TECHNOLOGY CO., LTD.	219
TOHO TENAX CO., LTD.	219
TORAY INDUSTRIES, INC.	220