

THERMAL INTERFACE MATERIALS: TECHNOLOGIES, APPLICATIONS AND GLOBAL MARKETS



SMC071C
July 2015

Andrew McWilliams
Project Analyst

ISBN: 1-62296-122-6



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	2
SCOPE AND FORMAT	3
INFORMATION SOURCES AND METHODOLOGY	3
ANALYST'S CREDENTIALS	4
RELATED BCC RESEARCH REPORTS	4
BCC RESEARCH WEBSITE	5
DISCLAIMER	5
CHAPTER 2 EXECUTIVE SUMMARY	7
<i>SUMMARY TABLE GLOBAL THERMAL INTERFACE MATERIAL MARKET BY TYPE, THROUGH 2020 (\$ MILLIONS)</i>	7
<i>SUMMARY FIGURE GLOBAL THERMAL INTERFACE MATERIAL MARKET BY TYPE, 2014-2020 (%)</i>	7
CHAPTER 3 OVERVIEW	10
GENERAL DESCRIPTION OF THERMAL INTERFACE MATERIALS	10
DEFINITION	10
PROPERTIES	10
<i>TABLE 1 THERMAL INTERFACE MATERIAL PROPERTIES</i>	10
Thickness	11
Viscosity	11
Dielectric Strength	11
Thermal Conductivity	11
Thermal Contact Resistance	11
Thermal Impedance	12
Modulus	12
Thermal Expansion Coefficient	13
Operating Temperature	13
THERMAL INTERFACE MATERIAL TYPES	13
<i>TABLE 2 THERMAL INTERFACE MATERIAL TYPES</i>	13
THERMAL GREASES	14
THERMAL COMPOUNDS	14
THERMAL PADS	15
THERMAL TAPES	15
EPOXIES	16
PHASE-CHANGE MATERIALS	16
OTHER MATERIALS	16
END USES	17
<i>TABLE 3 GLOBAL THERMAL MANAGEMENT MARKET BY END USE, THROUGH 2020 (\$ MILLIONS)</i>	17
COMPUTERS	17
<i>FIGURE 1 GLOBAL PERSONAL COMPUTER SHIPMENTS BY TYPE, 2014-2020 (MILLION UNITS)</i>	17

TOPIC	PAGE NO.
<i>FIGURE 2 COMPUTER-RELATED MARKET FOR ALL THERMAL MANAGEMENT TECHNOLOGIES, 2014-2020 (\$ MILLIONS)</i>	18
TELECOMMUNICATIONS	19
<i>FIGURE 3 GLOBAL MOBILE PHONE HANDSET SHIPMENTS, 2014-2020 (MILLION UNITS)</i>	20
<i>FIGURE 4 GLOBAL MOBILE TELECOMMUNICATIONS INFRASTRUCTURE MARKET, 2014-2020 (\$ MILLIONS)</i>	20
<i>FIGURE 5 TELECOMMUNICATIONS-RELATED MARKET FOR ALL THERMAL MANAGEMENT TECHNOLOGIES, 2014-2020 (\$ MILLIONS)</i>	21
AUTOMOTIVE	22
<i>FIGURE 6 GLOBAL MOTOR VEHICLE PRODUCTION, 2014-2020 (MILLION UNITS)</i>	22
<i>FIGURE 7 MOTOR VEHICLE-RELATED MARKET FOR ALL THERMAL MANAGEMENT TECHNOLOGIES, 2014-2020 (\$ MILLIONS)</i>	23
CONSUMER ELECTRONICS PRODUCTS	23
<i>FIGURE 8 GLOBAL CONSUMER ELECTRONICS MARKET, 2014-2020 (\$ MILLIONS)</i>	23
<i>FIGURE 9 CONSUMER PRODUCT-RELATED MARKET FOR ALL THERMAL MANAGEMENT TECHNOLOGIES, 2014-2020 (\$ MILLIONS)</i>	24
MEDICAL AND OFFICE ELECTRONICS	25
<i>FIGURE 10 GLOBAL MEDICAL AND OFFICE ELECTRONICS MARKET BY TYPE, 2014-2020 (\$ MILLIONS)</i>	25
<i>FIGURE 11 MEDICAL AND OFFICE ELECTRONICS-RELATED MARKET FOR ALL THERMAL MANAGEMENT TECHNOLOGIES, 2014-2020 (\$ MILLIONS)</i>	26
INDUSTRIAL AND MILITARY ELECTRONICS	27
<i>FIGURE 12 GLOBAL INDUSTRIAL AND MILITARY ELECTRONICS MARKET BY TYPE, 2014-2020 (\$ MILLIONS)</i>	27
<i>FIGURE 13 OTHER INDUSTRIAL AND MILITARY MARKETS FOR ALL THERMAL MANAGEMENT TECHNOLOGIES, 2014-2020 (\$ MILLIONS)</i>	28
Light-Emitting Diodes	28
<i>FIGURE 14 GLOBAL SALES OF LIGHT-EMITTING DIODES, 2014-2020 (\$ MILLIONS)</i>	28
<i>FIGURE 15 LIGHT-EMITTING-DIODE RELATED MARKET FOR THERMAL MANAGEMENT TECHNOLOGIES, 2014-2020 (\$ MILLIONS)</i>	29
Renewable Energy	30
<i>FIGURE 16 GLOBAL SALES OF SOLAR PHOTOVOLTAIC AND WIND ENERGY SYSTEMS, 2014-2020 (\$ MILLIONS)</i>	30
<i>FIGURE 17 RENEWABLE ENERGY-RELATED FOR ELECTRONIC THERMAL MANAGEMENT TECHNOLOGIES, 2014-2020 (\$ MILLIONS)</i>	31
GEOGRAPHIC MARKETS	31
<i>TABLE 4 GLOBAL THERMAL MANAGEMENT MARKET BY REGION, THROUGH 2020 (\$ MILLIONS)</i>	32
NORTH AMERICA	32
EUROPE	32
OTHER ASIA-PACIFIC	32
MARKET SIZE AND SEGMENTATION	33
GROWTH TRENDS	33
<i>FIGURE 18 GLOBAL THERMAL INTERFACE PRODUCT MARKET, 2014-2020 (\$ MILLIONS)</i>	33
MATERIAL TYPE	33
<i>TABLE 5 GLOBAL THERMAL INTERFACE PRODUCT MARKET BY MATERIAL TYPE, THROUGH 2020 (\$ MILLIONS)</i>	33
<i>FIGURE 19 GLOBAL THERMAL INTERFACE PRODUCT MARKET BY MATERIAL TYPE, 2014-2020 (%)</i>	34

TOPIC	PAGE NO.
END USES	35
<i>TABLE 6 GLOBAL THERMAL INTERFACE PRODUCT MARKET BY END USE, THROUGH 2020 (\$ MILLIONS)</i>	35
<i>FIGURE 20 GLOBAL THERMAL INTERFACE PRODUCT MARKET BY END USE, 2014-2020 (%)</i>	36
GEOGRAPHIC MARKETS	37
<i>TABLE 7 MAJOR THERMAL INTERFACE PRODUCT MARKET BY REGION, THROUGH 2020 (\$ MILLIONS)</i>	37
<i>FIGURE 21 GLOBAL THERMAL INTERFACE PRODUCT MARKET BY REGION, 2014-2020 (%)</i>	37
CHAPTER 4 IMPORTANCE OF THERMAL MANAGEMENT	40
<i>FIGURE 22 CAUSES OF ELECTRONIC FAILURE (% OF OCCURRENCES)</i>	40
ENVIRONMENTAL AND REGULATORY FACTORS IN THERMAL MANAGEMENT	43
GLOBAL AND REGIONAL THERMAL MANAGEMENT MARKET TRENDS	44
<i>TABLE 8 GLOBAL THERMAL MANAGEMENT MARKET, THROUGH 2020 (\$ MILLIONS)</i>	44
<i>FIGURE 23 GLOBAL THERMAL MANAGEMENT TECHNOLOGY MARKET, 2014-2020 (\$ MILLIONS)</i>	44
<i>TABLE 9 GLOBAL THERMAL MANAGEMENT MARKET BY PRODUCT TYPE, THROUGH 2020 (\$ MILLIONS)</i>	45
<i>FIGURE 24 GLOBAL THERMAL MANAGEMENT PRODUCT MARKET SHARE TRENDS, 2014-2020 (%)</i>	45
CHAPTER 5 THERMAL INTERFACE MATERIALS	48
POLYMER COMPOSITES	48
POLYMERS	48
Silicones	49
Polyurethane	49
Acrylates	50
Epoxy	50
FILLERS	50
<i>TABLE 10 THERMAL INTERFACE FILLER MATERIAL PROPERTIES</i>	51
Ceramics	51
Alumina	51
Aluminum Nitride	52
Beryllium Oxide	52
Other Ceramic Fillers	52
Metals	52
Carbonaceous Materials	52
Carbon Fibers	53
Diamond	53
Graphene	53
Carbon Nanotubes	54
NANOSTRUCTURED POLYMERS	55
PHASE-CHANGE MATERIALS	56
PHASE-CHANGE MATERIAL TYPES	56
Paraffin	56
Non-Paraffin Organic Phase-Change Materials	57
Salt Hydrates	57

TOPIC	PAGE NO.
Eutectic Salts	57
Phase-Change Metal Alloys	57
Advantages and Disadvantages of Various Phase-Change Materials in Electronic Applications	57
<i>TABLE 11 SOLID AND LIQUID PHASE-CHANGE MATERIAL PROPERTIES</i>	58
ENCAPSULATION SYSTEMS	58
METALS	59
SOLDER	59
<i>TABLE 12 THERMAL SOLDERS</i>	60
METAL-MATRIX COMPOSITES	60
OTHER METAL INTERFACE MATERIALS	61
Liquid Metal	61
Soft Metal Alloy	61
CARBON-MATRIX COMPOSITES	61
DISPENSING	62
MANUAL DISPENSING	62
SILK-SCREENABLE INTERFACE MATERIALS	62
AUTOMATED DISPENSING	63
CHAPTER 6 THERMAL GREASES	65
SUMMARY	65
<i>FIGURE 25 GLOBAL THERMAL GREASES MARKET, 2014 TO 2020 (\$ MILLIONS)</i>	65
TECHNOLOGIES	65
GENERAL DESCRIPTION	65
MATERIALS	66
Matrix Materials	66
Filler Materials	67
Ceramics	67
<i>TABLE 13 CERAMIC FILLERS USED IN THERMAL GREASES</i>	67
Metals	67
<i>TABLE 14 METAL FILLERS USED IN THERMAL GREASES</i>	68
Carbon	68
APPLICATIONS AND END USES	68
<i>FIGURE 26 GLOBAL THERMAL GREASE MARKET BY END USE, 2014 (%)</i>	68
SUPPLIERS	69
<i>TABLE 15 THERMAL GREASE SUPPLIERS</i>	69
MARKETS	70
<i>TABLE 16 GLOBAL THERMAL GREASE MARKET, THROUGH 2020 (\$ MILLIONS)</i>	70
PRODUCT SEGMENTS	70
<i>FIGURE 27 CONSUMPTION OF SILICONE VERSUS SILICONE-FREE THERMAL GREASES, 2014 (%)</i>	70
<i>FIGURE 28 GLOBAL THERMAL GREASE MARKET BY FILLER MATERIAL TYPE, 2014 (%)</i>	71
<i>TABLE 17 GLOBAL THERMAL GREASE MARKET BY FILLER MATERIAL TYPE, THROUGH 2020 (\$ MILLIONS)</i>	72
<i>FIGURE 29 GLOBAL THERMAL GREASE PRODUCT MARKET BY TYPE, 2014-2020 (%)</i>	72
END-USER SEGMENTS	73

TOPIC	PAGE NO.
<i>TABLE 18 GLOBAL THERMAL GREASES MARKET BY END USE, THROUGH 2020 (\$ MILLIONS)</i>	73
<i>FIGURE 30 GLOBAL THERMAL GREASES MARKET BY END USE, 2014-2020 (%)</i>	73
GEOGRAPHIC SEGMENTS	74
<i>FIGURE 31 GLOBAL THERMAL GREASE MARKET BY REGION, 2014 (%)</i>	74
<i>TABLE 19 GLOBAL THERMAL GREASE MARKET BY REGION, THROUGH 2020 (\$ MILLIONS)</i>	75
<i>FIGURE 32 GLOBAL THERMAL GREASE MARKET BY REGION, 2014-2020 (%)</i>	76
CHAPTER 7 THERMAL COMPOUNDS	78
SUMMARY	78
<i>FIGURE 33 GLOBAL THERMAL COMPOUND MARKET, 2014-2020 (\$ MILLIONS)</i>	78
TECHNOLOGIES	78
GENERAL DESCRIPTION	78
THERMAL COMPOUND TYPES	79
APPLICATIONS AND END USES	79
<i>FIGURE 34 GLOBAL THERMAL COMPOUND MARKET BY END USE, 2014 (%)</i>	79
SUPPLIERS	80
<i>TABLE 20 THERMAL ELASTOMER SUPPLIERS</i>	80
MARKETS	81
<i>TABLE 21 GLOBAL THERMAL COMPOUND MARKET, THROUGH 2020 (\$ MILLIONS)</i>	81
END-USER SEGMENTS	81
<i>TABLE 22 GLOBAL THERMAL COMPOUND MARKET BY END USE, THROUGH 2020 (\$ MILLIONS)</i>	81
<i>FIGURE 35 GLOBAL THERMAL COMPOUND MARKET BY END USE, 2014-2020 (%)</i>	82
MAJOR GEOGRAPHIC MARKETS	83
<i>FIGURE 36 GLOBAL THERMAL COMPOUND MARKET BY REGION, 2014 (%)</i>	83
<i>TABLE 23 GLOBAL THERMAL COMPOUND MARKET BY REGION, THROUGH 2020 (\$ MILLIONS)</i>	84
<i>FIGURE 37 GLOBAL THERMAL COMPOUND MARKET BY REGION, 2014-2020 (%)</i>	84
CHAPTER 8 THERMAL PADS	86
SUMMARY	86
<i>FIGURE 38 GLOBAL THERMAL PAD MARKET, 2014-2020 (\$ MILLIONS)</i>	86
TECHNOLOGIES	86
GENERAL DESCRIPTION	86
MATERIALS	87
Elastomers	87
Fillers	87
Matrix Materials	87
USING THERMAL PADS	88
APPLICATIONS AND END USERS	88
<i>FIGURE 39 GLOBAL THERMAL PAD MARKET BY END USE, 2014 (%)</i>	88
SUPPLIERS	89
<i>TABLE 24 THERMAL PAD SUPPLIERS</i>	90
MARKETS	90
END-USE SEGMENTS	90

TOPIC	PAGE NO.
<i>TABLE 25 GLOBAL THERMAL PAD MARKET BY END USE, THROUGH 2020 (\$ MILLIONS)</i>	91
<i>FIGURE 40 GLOBAL THERMAL PAD MARKET BY END USE, 2014-2020 (%)</i>	91
MAJOR GEOGRAPHIC MARKETS	92
<i>FIGURE 41 GLOBAL THERMAL PAD MARKET BY REGION, 2014 (%)</i>	92
<i>TABLE 26 GLOBAL THERMAL PAD MARKET BY REGION, THROUGH 2020 (\$ MILLIONS)</i>	93
<i>FIGURE 42 GLOBAL THERMAL PAD MARKET BY REGION, 2014-2020 (\$ MILLIONS)</i>	94
CHAPTER 9 THERMAL ADHESIVE TAPES	96
SUMMARY	96
<i>FIGURE 43 GLOBAL THERMAL ADHESIVE TAPE MARKET, 2014-2020 (\$ MILLIONS)</i>	96
TECHNOLOGIES	96
GENERAL DESCRIPTION	96
MATERIALS	97
Carbon Nanotube Tapes	97
THERMAL ADHESIVE TAPE USE	98
APPLICATIONS AND END USES	98
<i>FIGURE 44 GLOBAL THERMAL ADHESIVE FILM AND TAPE MARKET BY END USE, 2014 (%)`</i>	98
SUPPLIERS	99
<i>TABLE 27 THERMAL ADHESIVE FILM AND TAPE SUPPLIERS</i>	100
MARKETS	100
END-USE SEGMENTS	100
<i>TABLE 28 GLOBAL THERMAL ADHESIVE FILM AND TAPE MARKET BY END USE, THROUGH 2020 (\$ MILLIONS)</i>	101
<i>FIGURE 45 GLOBAL THERMAL ADHESIVE FILM AND TAPE MARKET BY END USE, 2014-2020 (%)</i>	101
MAJOR GEOGRAPHIC MARKETS	102
<i>FIGURE 46 GLOBAL THERMAL ADHESIVE FILM AND TAPE MARKET BY REGION, 2014 (%)</i>	102
<i>TABLE 29 GLOBAL THERMAL ADHESIVE FILM AND TAPE MARKET BY REGION, THROUGH 2020 (\$ MILLIONS)</i>	103
<i>FIGURE 47 GLOBAL THERMAL ADHESIVE FILM AND TAPE MARKET BY REGION, 2014-2020 (%)</i>	103
CHAPTER 10 EPOXY THERMAL INTERFACE MATERIALS	106
SUMMARY	106
<i>FIGURE 48 GLOBAL EPOXY THERMAL INTERFACE MATERIAL MARKET, 2014-2020 (\$ MILLIONS)</i>	106
TECHNOLOGIES	107
GENERAL DESCRIPTION	107
MATERIALS	107
Resins and Hardeners	107
Fillers	108
Other Ingredients	108
THERMAL EPOXY APPLICATION	108
APPLICATIONS	108

TOPIC	PAGE NO.
<i>FIGURE 49 GLOBAL THERMAL ADHESIVE FILM AND TAPE MARKET BY END USE SEGMENTS, 2014 (%)</i>	109
SUPPLIERS	110
<i>TABLE 30 THERMAL EPOXY SUPPLIERS</i>	110
MARKETS	110
END-USE SEGMENTS	110
<i>TABLE 31 GLOBAL THERMAL EPOXY MARKET BY END USE, THROUGH 2020 (\$ MILLIONS)</i>	111
<i>FIGURE 50 GLOBAL THERMAL EPOXY MARKET BY END USE, 2014-2020 (%)</i>	111
MAJOR GEOGRAPHIC MARKETS	112
<i>FIGURE 51 GLOBAL THERMAL EPOXY MARKET BY REGION, 2014 (%)</i>	112
<i>TABLE 32 GLOBAL THERMAL EPOXY MARKET BY REGION, THROUGH 2020 (\$ MILLIONS)</i>	113
<i>FIGURE 52 GLOBAL THERMAL EPOXY MARKET BY REGION, 2014-2020 (%)</i>	114
CHAPTER 11 PHASE-CHANGE MATERIALS	116
SUMMARY	116
<i>FIGURE 53 GLOBAL PHASE-CHANGE THERMAL INTERFACE MATERIAL MARKET, 2014-2020 (\$ MILLIONS)</i>	116
TECHNOLOGIES	116
GENERAL DESCRIPTION	116
MATERIALS	117
APPLICATIONS AND END USES	117
<i>FIGURE 54 GLOBAL PHASE-CHANGE THERMAL INTERFACE MATERIAL MARKET BY END USE, 2014 (%)</i>	117
SUPPLIERS	118
<i>TABLE 33 PHASE-CHANGE MATERIAL SUPPLIERS</i>	118
MARKETS	118
END USERS	119
<i>TABLE 34 GLOBAL PHASE-CHANGE THERMAL INTERFACE MATERIAL MARKET BY END USE, THROUGH 2020 (\$ MILLIONS)</i>	119
<i>FIGURE 55 GLOBAL PHASE-CHANGE THERMAL INTERFACE MATERIAL MARKET BY END USE, 2014-2020 (%)</i>	119
MAJOR GEOGRAPHIC MARKETS	120
<i>FIGURE 56 GLOBAL PHASE-CHANGE THERMAL INTERFACE MATERIALS MARKET BY REGION, 2014 (%)</i>	120
<i>TABLE 35 GLOBAL PHASE-CHANGE THERMAL INTERFACE MATERIAL MARKET BY REGION, THROUGH 2020 (\$ MILLIONS)</i>	121
<i>FIGURE 57 GLOBAL PHASE-CHANGE THERMAL INTERFACE MATERIAL MARKET BY REGION, 2014-2020 (\$ MILLIONS)</i>	122
CHAPTER 12 METALLIC THERMAL INTERFACE MATERIALS	124
SUMMARY	124
<i>FIGURE 58 GLOBAL METAL THERMAL INTERFACE MATERIAL MARKET, 2014-2020 (\$ MILLIONS)</i>	124
TECHNOLOGIES	124
SOLDER	124
Materials	125
Application	125
Reflow Soldering	125

TOPIC	PAGE NO.
Solder Preforms	125
METAL-MATRIX COMPOSITES	125
Materials	126
Aluminum-Matrix Composites	126
Copper-Matrix Composites	126
OTHER METAL INTERFACE MATERIALS	126
Liquid Metals	127
Soft-Metal Alloys	127
APPLICATIONS AND END USES	127
<i>FIGURE 59 GLOBAL METALLIC THERMAL INTERFACE MATERIAL MARKET BY END USE, 2014 (%)</i>	127
TABLE	128
SUPPLIERS	128
<i>TABLE 36 METAL INTERFACE MATERIAL SUPPLIERS MARKET</i>	128
MARKET	129
<i>TABLE 37 GLOBAL METAL THERMAL INTERFACE MATERIAL MARKET BY TYPE, THROUGH 2020 (\$ MILLIONS)</i>	129
<i>FIGURE 60 GLOBAL METAL THERMAL INTERFACE MATERIALS MARKET BY TYPE, 2014-2020 (%)</i>	129
END-USE SEGMENTS	130
<i>TABLE 38 GLOBAL METAL THERMAL INTERFACE MATERIAL MARKET BY END USE, THROUGH 2020 (\$ MILLIONS)</i>	130
<i>FIGURE 61 GLOBAL METAL THERMAL INTERFACE MATERIAL MARKET BY END USE, 2014-2020 (%)</i>	130
MAJOR GEOGRAPHIC MARKETS	131
<i>FIGURE 62 GLOBAL METAL THERMAL INTERFACE MATERIALS MARKET BY REGION, 2014 (%)</i>	131
<i>TABLE 39 GLOBAL METAL THERMAL INTERFACE MATERIAL MARKET BY REGION, THROUGH 2020 (\$ MILLIONS)</i>	132
<i>FIGURE 63 GLOBAL METAL THERMAL INTERFACE MATERIALS MARKET BY REGION, 2014-2020 (\$ MILLIONS)</i>	133
CHAPTER 13 INDUSTRY STRUCTURE	135
MARKET SHARES	135
<i>TABLE 40 GLOBAL THERMAL MANAGEMENT INTERFACE MARKET LEADERS, 2014 (\$ MILLIONS/%)</i>	135
<i>FIGURE 64 GLOBAL THERMAL MANAGEMENT INTERFACE MARKET, 2014 (%)</i>	135
CHAPTER 14 COMPANY PROFILES	138
3M CO.	138
AAVID THERMALLOY LLC	138
AEGIS TECHNOLOGY	138
AI TECHNOLOGY	139
AKASA CORP.	139
ALENT PLC	139
AMETEK SPECIALTY METAL PRODUCTS INC.	140
AOS THERMAL COMPOUNDS	140
ARCTIC SILVER INC.	140
BERGQUIST CO.	140

TOPIC	PAGE NO.
CAST-COAT INC.	141
CHOMERICS	141
COOL POLYMERS INC.	141
COOLLABORATORY	142
COOLER MASTER CO. LTD.	142
DOW CORNING	142
ENERDYNE SOLUTIONS	143
EPIC RESINS	143
EPOXIES ETC.	143
HENKEL CORP.	143
HONEYWELL INTERNATIONAL	144
INDIUM CORP.	144
INNOVATION COOLING LLC	144
LAIRD TECHNOLOGIES	144
LORD CORP.	145
MASTER BOND	145
MATERION	145
MC-21 INC.	145
METAL MATRIX CAST COMPOSITES	146
MG CHEMICALS	146
MOMENTIVE	146
NUSIL TECHNOLOGY LLC	147
PARKER HANNIFIN	147
POLYCAST INDUSTRIES INC.	147
ROGERS CORP.	147
RUBBERCRAFT	148
SEAL KING INDUSTRIAL CO. LTD.	148
SHELDAHL	148
SHENZHEN WESTERN HEMISPHERE TECHNOLOGY CO.	148
SHIN-ETSU CHEMICAL CO. LTD.	149
STOCKWELL ELASTOMERICS INC.	149
T-GLOBAL TECHNOLOGY CO. LTD.	149
THERMAL TRANSFER COMPOSITES	149
TIMTRONICS	150
UNIVERSAL SCIENCE	150
VANGUARD PRODUCTS CORP.	150
WAKEFIELD-VETTE	151
ZALMAN TECH CO.	151
CHAPTER 15 PATENT ANALYSIS	153
THERMAL INTERFACE MATERIAL TYPES	153
<i>FIGURE 65 U.S. THERMAL INTERFACE MATERIAL PATENTS BY MATERIAL TYPE, THROUGH APRIL 20, 2015 (%)</i>	153
MATERIAL VERSUS APPLICATION-RELATED PATENTS	154
<i>FIGURE 66 U.S. THERMAL INTERFACE MATERIAL PATENTS BY TECHNOLOGY TYPE, THROUGH APRIL 20, 2015 (NUMBER)</i>	154
PATENT TRENDS OVER TIME	155

TOPIC	PAGE NO.
<i>FIGURE 67 U.S. THERMAL INTERFACE MATERIAL PATENT TRENDS OVER TIME, 2008-2014 (NUMBER OF PATENTS)</i>	155
<i>PATENT HOLDER NATIONALITIES</i>	156
<i>FIGURE 68 U.S. THERMAL INTERFACE MATERIAL PATENTS BY INVENTOR AND ASSIGNEE NATIONALITY, THROUGH APRIL 20, 2015 (%)</i>	156

LIST OF TABLES

TABLE HEADING	PAGE NO.
SUMMARY TABLE GLOBAL THERMAL INTERFACE MATERIAL MARKET BY TYPE, THROUGH 2020 (\$ MILLIONS)	7
TABLE 1 THERMAL INTERFACE MATERIAL PROPERTIES	10
TABLE 2 THERMAL INTERFACE MATERIAL TYPES	13
TABLE 3 GLOBAL THERMAL MANAGEMENT MARKET BY END USE, THROUGH 2020 (\$ MILLIONS)	17
TABLE 4 GLOBAL THERMAL MANAGEMENT MARKET BY REGION, THROUGH 2020 (\$ MILLIONS)	32
TABLE 5 GLOBAL THERMAL INTERFACE PRODUCT MARKET BY MATERIAL TYPE, THROUGH 2020 (\$ MILLIONS)	33
TABLE 6 GLOBAL THERMAL INTERFACE PRODUCT MARKET BY END USE, THROUGH 2020 (\$ MILLIONS)	35
TABLE 7 MAJOR THERMAL INTERFACE PRODUCT MARKET BY REGION, THROUGH 2020 (\$ MILLIONS)	37
TABLE 8 GLOBAL THERMAL MANAGEMENT MARKET, THROUGH 2020 (\$ MILLIONS)	44
TABLE 9 GLOBAL THERMAL MANAGEMENT MARKET BY PRODUCT TYPE, THROUGH 2020 (\$ MILLIONS)	45
TABLE 10 THERMAL INTERFACE FILLER MATERIAL PROPERTIES	51
TABLE 11 SOLID AND LIQUID PHASE-CHANGE MATERIAL PROPERTIES	58
TABLE 12 THERMAL SOLDERS	60
TABLE 13 CERAMIC FILLERS USED IN THERMAL GREASES	67
TABLE 14 METAL FILLERS USED IN THERMAL GREASES	68
TABLE 15 THERMAL GREASE SUPPLIERS	69
TABLE 16 GLOBAL THERMAL GREASE MARKET, THROUGH 2020 (\$ MILLIONS)	70
TABLE 17 GLOBAL THERMAL GREASE MARKET BY FILLER MATERIAL TYPE, THROUGH 2020 (\$ MILLIONS)	72
TABLE 18 GLOBAL THERMAL GREASES MARKET BY END USE, THROUGH 2020 (\$ MILLIONS)	73
TABLE 19 GLOBAL THERMAL GREASE MARKET BY REGION, THROUGH 2020 (\$ MILLIONS)	75
TABLE 20 THERMAL ELASTOMER SUPPLIERS	80
TABLE 21 GLOBAL THERMAL COMPOUND MARKET, THROUGH 2020 (\$ MILLIONS)	81
TABLE 22 GLOBAL THERMAL COMPOUND MARKET BY END USE, THROUGH 2020 (\$ MILLIONS)	81
TABLE 23 GLOBAL THERMAL COMPOUND MARKET BY REGION, THROUGH 2020 (\$ MILLIONS)	84
TABLE 24 THERMAL PAD SUPPLIERS	90
TABLE 25 GLOBAL THERMAL PAD MARKET BY END USE, THROUGH 2020 (\$ MILLIONS)	91
TABLE 26 GLOBAL THERMAL PAD MARKET BY REGION, THROUGH 2020 (\$ MILLIONS)	93
TABLE 27 THERMAL ADHESIVE FILM AND TAPE SUPPLIERS	100
TABLE 28 GLOBAL THERMAL ADHESIVE FILM AND TAPE MARKET BY END USE, THROUGH 2020 (\$ MILLIONS)	101
TABLE 29 GLOBAL THERMAL ADHESIVE FILM AND TAPE MARKET BY REGION, THROUGH 2020 (\$ MILLIONS)	103
TABLE 30 THERMAL EPOXY SUPPLIERS	110
TABLE 31 GLOBAL THERMAL EPOXY MARKET BY END USE, THROUGH 2020 (\$ MILLIONS)	111
TABLE 32 GLOBAL THERMAL EPOXY MARKET BY REGION, THROUGH 2020 (\$ MILLIONS)	113
TABLE 33 PHASE-CHANGE MATERIAL SUPPLIERS	118

TABLE HEADING	PAGE NO.
TABLE 34 GLOBAL PHASE-CHANGE THERMAL INTERFACE MATERIAL MARKET BY END USE, THROUGH 2020 (\$ MILLIONS)	119
TABLE 35 GLOBAL PHASE-CHANGE THERMAL INTERFACE MATERIAL MARKET BY REGION, THROUGH 2020 (\$ MILLIONS)	121
TABLE	128
TABLE 36 METAL INTERFACE MATERIAL SUPPLIERS	128
TABLE 37 GLOBAL METAL THERMAL INTERFACE MATERIAL MARKET BY TYPE, THROUGH 2020 (\$ MILLIONS)	129
TABLE 38 GLOBAL METAL THERMAL INTERFACE MATERIAL MARKET BY END USE, THROUGH 2020 (\$ MILLIONS)	130
TABLE 39 GLOBAL METAL THERMAL INTERFACE MATERIAL MARKET BY REGION, THROUGH 2020 (\$ MILLIONS)	132
TABLE 40 GLOBAL THERMAL MANAGEMENT INTERFACE MARKET LEADERS, 2014 (\$ MILLIONS/%)	135

LIST OF FIGURES

FIGURE TITLE	PAGE NO.
SUMMARY FIGURE GLOBAL THERMAL INTERFACE MATERIAL MARKET BY TYPE, 2014-2020 (%)	7
FIGURE 1 GLOBAL PERSONAL COMPUTER SHIPMENTS BY TYPE, 2014-2020 (MILLION UNITS)	17
FIGURE 2 COMPUTER-RELATED MARKET FOR ALL THERMAL MANAGEMENT TECHNOLOGIES, 2014-2020 (\$ MILLIONS)	18
FIGURE 3 GLOBAL MOBILE PHONE HANDSET SHIPMENTS, 2014-2020 (MILLION UNITS)	20
FIGURE 4 GLOBAL MOBILE TELECOMMUNICATIONS INFRASTRUCTURE MARKET, 2014-2020 (\$ MILLIONS)	20
FIGURE 5 TELECOMMUNICATIONS-RELATED MARKET FOR ALL THERMAL MANAGEMENT TECHNOLOGIES, 2014-2020 (\$ MILLIONS)	21
FIGURE 6 GLOBAL MOTOR VEHICLE PRODUCTION, 2014-2020 (MILLION UNITS)	22
FIGURE 7 MOTOR VEHICLE-RELATED MARKET FOR ALL THERMAL MANAGEMENT TECHNOLOGIES, 2014-2020 (\$ MILLIONS)	23
FIGURE 8 GLOBAL CONSUMER ELECTRONICS MARKET, 2014-2020 (\$ MILLIONS)	23
FIGURE 9 CONSUMER PRODUCT-RELATED MARKET FOR ALL THERMAL MANAGEMENT TECHNOLOGIES, 2014-2020 (\$ MILLIONS)	24
FIGURE 10 GLOBAL MEDICAL AND OFFICE ELECTRONICS MARKET BY TYPE, 2014-2020 (\$ MILLIONS)	25
FIGURE 11 MEDICAL AND OFFICE ELECTRONICS-RELATED MARKET FOR ALL THERMAL MANAGEMENT TECHNOLOGIES, 2014-2020 (\$ MILLIONS)	26
FIGURE 12 GLOBAL INDUSTRIAL AND MILITARY ELECTRONICS MARKET BY TYPE, 2014-2020 (\$ MILLIONS)	27
FIGURE 13 OTHER INDUSTRIAL AND MILITARY MARKETS FOR ALL THERMAL MANAGEMENT TECHNOLOGIES, 2014-2020 (\$ MILLIONS)	28
FIGURE 14 GLOBAL SALES OF LIGHT-EMITTING DIODES, 2014-2020 (\$ MILLIONS)	28
FIGURE 15 LIGHT-EMITTING-DIODE RELATED MARKET FOR THERMAL MANAGEMENT TECHNOLOGIES, 2014-2020 (\$ MILLIONS)	29
FIGURE 16 GLOBAL SALES OF SOLAR PHOTOVOLTAIC AND WIND ENERGY SYSTEMS, 2014-2020 (\$ MILLIONS)	30
FIGURE 17 RENEWABLE ENERGY-RELATED FOR ELECTRONIC THERMAL MANAGEMENT TECHNOLOGIES, 2014-2020 (\$ MILLIONS)	31
FIGURE 18 GLOBAL THERMAL INTERFACE PRODUCT MARKET, 2014-2020 (\$ MILLIONS)	33
FIGURE 19 GLOBAL THERMAL INTERFACE PRODUCT MARKET BY MATERIAL TYPE, 2014-2020 (%)	34
FIGURE 20 GLOBAL THERMAL INTERFACE PRODUCT MARKET BY END USE, 2014-2020 (%)	36
FIGURE 21 GLOBAL THERMAL INTERFACE PRODUCT MARKET BY REGION, 2014-2020 (%)	37
FIGURE 22 CAUSES OF ELECTRONIC FAILURE (% OF OCCURRENCES)	40
FIGURE 23 GLOBAL THERMAL MANAGEMENT TECHNOLOGY MARKET, 2014-2020 (\$ MILLIONS)	44
FIGURE 24 GLOBAL THERMAL MANAGEMENT PRODUCT MARKET SHARE TRENDS, 2014-2020 (%)	45
FIGURE 25 GLOBAL THERMAL GREASES MARKET, 2014 TO 2020 (\$ MILLIONS)	65
FIGURE 26 GLOBAL THERMAL GREASE MARKET BY END USE, 2014 (%)	68
FIGURE 27 CONSUMPTION OF SILICONE VERSUS SILICONE-FREE THERMAL GREASES, 2014 (%)	70
FIGURE 28 GLOBAL THERMAL GREASE MARKET BY FILLER MATERIAL TYPE, 2014 (%)	71

FIGURE TITLE	PAGE NO.
FIGURE 29 GLOBAL THERMAL GREASE PRODUCT MARKET BY TYPE, 2014-2020 (%)	72
FIGURE 30 GLOBAL THERMAL GREASES MARKET BY END USE, 2014-2020 (%)	73
FIGURE 31 GLOBAL THERMAL GREASE MARKET BY REGION, 2014 (%)	74
FIGURE 32 GLOBAL THERMAL GREASE MARKET BY REGION, 2014-2020 (%)	76
FIGURE 33 GLOBAL THERMAL COMPOUND MARKET, 2014-2020 (\$ MILLIONS)	78
FIGURE 34 GLOBAL THERMAL COMPOUND MARKET BY END USE, 2014 (%)	79
FIGURE 35 GLOBAL THERMAL COMPOUND MARKET BY END USE, 2014-2020 (%)	82
FIGURE 36 GLOBAL THERMAL COMPOUND MARKET BY REGION, 2014 (%)	83
FIGURE 37 GLOBAL THERMAL COMPOUND MARKET BY REGION, 2014-2020 (%)	84
FIGURE 38 GLOBAL THERMAL PAD MARKET, 2014-2020 (\$ MILLIONS)	86
FIGURE 39 GLOBAL THERMAL PAD MARKET BY END USE, 2014 (%)	88
FIGURE 40 GLOBAL THERMAL PAD MARKET BY END USE, 2014-2020 (%)	91
FIGURE 41 GLOBAL THERMAL PAD MARKET BY REGION, 2014 (%)	92
FIGURE 42 GLOBAL THERMAL PAD MARKET BY REGION, 2014-2020 (\$ MILLIONS)	94
FIGURE 43 GLOBAL THERMAL ADHESIVE TAPE MARKET, 2014-2020 (\$ MILLIONS)	96
FIGURE 44 GLOBAL THERMAL ADHESIVE FILM AND TAPE MARKET BY END USE, 2014 (%)`	98
FIGURE 45 GLOBAL THERMAL ADHESIVE FILM AND TAPE MARKET BY END USE, 2014-2020 (%)	101
FIGURE 46 GLOBAL THERMAL ADHESIVE FILM AND TAPE MARKET BY REGION, 2014 (%)	102
FIGURE 47 GLOBAL THERMAL ADHESIVE FILM AND TAPE MARKET BY REGION, 2014-2020 (%)	103
FIGURE 48 GLOBAL EPOXY THERMAL INTERFACE MATERIAL MARKET, 2014-2020 (\$ MILLIONS)	106
FIGURE 49 GLOBAL THERMAL ADHESIVE FILM AND TAPE MARKET BY END USE SEGMENTS, 2014 (%)	109
FIGURE 50 GLOBAL THERMAL EPOXY MARKET BY END USE, 2014-2020 (%)	111
FIGURE 51 GLOBAL THERMAL EPOXY MARKET BY REGION, 2014 (%)	112
FIGURE 52 GLOBAL THERMAL EPOXY MARKET BY REGION, 2014-2020 (%)	114
FIGURE 53 GLOBAL PHASE-CHANGE THERMAL INTERFACE MATERIAL MARKET, 2014-2020 (\$ MILLIONS)	116
FIGURE 54 GLOBAL PHASE-CHANGE THERMAL INTERFACE MATERIAL MARKET BY END USE, 2014 (%)	117
FIGURE 55 GLOBAL PHASE-CHANGE THERMAL INTERFACE MATERIAL MARKET BY END USE, 2014-2020 (%)	119
FIGURE 56 GLOBAL PHASE-CHANGE THERMAL INTERFACE MATERIALS MARKET BY REGION, 2014 (%)	120
FIGURE 57 GLOBAL PHASE-CHANGE THERMAL INTERFACE MATERIAL MARKET BY REGION, 2014-2020 (\$ MILLIONS)	122
FIGURE 58 GLOBAL METAL THERMAL INTERFACE MATERIAL MARKET, 2014-2020 (\$ MILLIONS)	124
FIGURE 59 GLOBAL METALLIC THERMAL INTERFACE MATERIAL MARKET BY END USE, 2014 (%)	127
FIGURE 60 GLOBAL METAL THERMAL INTERFACE MATERIALS MARKET BY TYPE, 2014-2020 (%)	129
FIGURE 61 GLOBAL METAL THERMAL INTERFACE MATERIAL MARKET BY END USE, 2014-2020 (%)	130
FIGURE 62 GLOBAL METAL THERMAL INTERFACE MATERIALS MARKET BY REGION, 2014 (%)	131

FIGURE TITLE	PAGE NO.
FIGURE 63 GLOBAL METAL THERMAL INTERFACE MATERIALS MARKET BY REGION, 2014-2020 (\$ MILLIONS)	133
FIGURE 64 GLOBAL THERMAL MANAGEMENT INTERFACE MARKET, 2014 (%)	135
FIGURE 65 U.S. THERMAL INTERFACE MATERIAL PATENTS BY MATERIAL TYPE, THROUGH APRIL 20, 2015 (%)	153
FIGURE 66 U.S. THERMAL INTERFACE MATERIAL PATENTS BY TECHNOLOGY TYPE, THROUGH APRIL 20, 2015 (NUMBER)	154
FIGURE 67 U.S. THERMAL INTERFACE MATERIAL PATENT TRENDS OVER TIME, 2008-2014 (NUMBER OF PATENTS)	155
FIGURE 68 U.S. THERMAL INTERFACE MATERIAL PATENTS BY INVENTOR AND ASSIGNEE NATIONALITY, THROUGH APRIL 20, 2015 (%)	156