POWER SEMICONDUCTORS: MARKETS MATERIALS, TECHNOLOGIES Table of Contents		
Chapter 1	Introduction	1-1
1.1	Evolution Of IGBT Chip Structure	1-4
1.2	Effects Of Miniaturization Of IGBT Chip	1-6
1.3	SiC Trench-Type MOSFET And Resistance Reduction As Compared With DMOSFET	1-7
1.4	Planar And Vertical (Trench) MOSFET	1-9
1.5	Schematic Of A FinFET	1-11
1.6	Schematic Of A MOSFET And Super Junction MOSFET	1-13
1.7	SIC U MOSFET	1-17
Chapter 2	Applications of Power Semiconductors	2-1
2.1	Forecast Of Solar Power	2-4
2.2	Full Bridge IGBT Topology	2-5
2.3	Block Diagram Of Microcontroller-Based Inverter	2-11
2.4	Worldwide Wind Turbine Shipments	2-14
2.5	Top Wind Power Capacity by Country	2-15
2.6	Bill Of Materials For A Typical 30-50kw Inverter	2-19
2.7	A Simple Diagram Of A HEV Traction Drive System.	2-22
2.8	A More Complex Diagram Of PEEM In A Plug-In Hybrid Electric Vehicle (PHEV)	2-23
2.9	Conducting And Switching Loses For Inverter	2-25
2.10	Unit Pricing Trends In Power Semiconductors	2-27
2.11	System And Component Costs For Wide Bandgap Semiconductors	2-31
2.12	Vertical And Lateral HEMT	2-37
2.13	GaN Lateral And GaN Vertical HEMTs In EVs	2-41
2.14	Market Drivers For LED Biz And Applications	2-44
2.15	SSL Vs. Classical Technologies	2-45
2.16	LED Performance Vs. Traditional Light Sources	2-46
2.17	Energy Production And Use Comparison	2-50

2.18	Typical LED Drive Circuit	2-53
2.19	Integration Of LED And LED Driver Using TSV	2-55
2.20	Simple Power MOSFET Motor Controller	2-60
2.21	Basic Operating Principle Of Inverter	2-66
2.1	Forecast Of Solar Power	2-4
2.2	Full Bridge IGBT Topology	2-5
2.3	Block Diagram Of Microcontroller-Based Inverter	2-11
2.4	Worldwide Wind Turbine Shipments	2-14
2.5	Top Wind Power Capacity by Country	2-15
2.6	Bill Of Materials For A Typical 30-50kw Inverter	2-19
2.7	A Simple Diagram Of A HEV Traction Drive System.	2-22
2.8	A More Complex Diagram Of PEEM In A Plug-In Hybrid Electric Vehicle (PHEV)	2-23
2.9	Conducting And Switching Loses For Inverter	2-25
2.10	Unit Pricing Trends In Power Semiconductors	2-27
2.11	System And Component Costs For Wide Bandgap Semiconductors	2-31
Chapter 3	Market Analysis	3-1
3.1	Position of Power Semiconductors in Semiconductor Market	3-9
3.2		
	Growth Potential of IGBTs and Power MOSFETs	3-11
3.3	Growth Potential of IGBTs and Power MOSFETs IGBT Market	3-11 3-18
3.3 3.3.1		
	IGBT Market	3-18
3.3.1	IGBT Market IGBT Technology Trends	3-18 3-18
3.3.1 3.3.2	IGBT Market IGBT Technology Trends IGBT TAM	3-18 3-18 3-18
3.3.1 3.3.2 3.3.3	IGBT Market IGBT Technology Trends IGBT TAM IGBT Market Growth By Applications	3-18 3-18 3-18 3-21
3.3.1 3.3.2 3.3.3 3.3.3.1	IGBT MarketIGBT Technology TrendsIGBT TAMIGBT Market Growth By ApplicationsAutomotive	3-18 3-18 3-18 3-21 3-21
3.3.1 3.3.2 3.3.3 3.3.3.1 3.3.3.2	IGBT MarketIGBT Technology TrendsIGBT TAMIGBT Market Growth By ApplicationsAutomotivePower Generation And Grid	3-18 3-18 3-18 3-21 3-21 3-23
3.3.1 3.3.2 3.3.3 3.3.3.1 3.3.3.2 3.3.3.3	IGBT MarketIGBT Technology TrendsIGBT TAMIGBT Market Growth By ApplicationsAutomotivePower Generation And GridConsumer Electronics	3-18 3-18 3-18 3-21 3-21 3-23 3-25
3.3.1 3.3.2 3.3.3 3.3.3.1 3.3.3.2 3.3.3.3 3.3.3.4	IGBT MarketIGBT Technology TrendsIGBT TAMIGBT Market Growth By ApplicationsAutomotivePower Generation And GridConsumer ElectronicsIndustrial Controls	3-18 3-18 3-18 3-21 3-21 3-23 3-25 3-27
3.3.1 3.3.2 3.3.3 3.3.3.1 3.3.3.2 3.3.3.3 3.3.3.4 3.3.3.5	IGBT MarketIGBT Technology TrendsIGBT TAMIGBT Market Growth By ApplicationsAutomotivePower Generation And GridConsumer ElectronicsIndustrial ControlsRailway/Train	3-18 3-18 3-18 3-21 3-21 3-23 3-25 3-27 3-27
3.3.1 3.3.2 3.3.3 3.3.3.1 3.3.3.2 3.3.3.3 3.3.3.4 3.3.3.5 3.3.3.6	IGBT MarketIGBT Technology TrendsIGBT TAMIGBT Market Growth By ApplicationsAutomotivePower Generation And GridConsumer ElectronicsIndustrial ControlsRailway/TrainEV Charging Systems	3-18 3-18 3-18 3-21 3-21 3-23 3-25 3-27 3-27 3-30
3.3.1 3.3.2 3.3.3 3.3.3.1 3.3.3.2 3.3.3.3 3.3.3.4 3.3.3.5 3.3.3.6 3.3.4	IGBT MarketIGBT Technology TrendsIGBT TAMIGBT Market Growth By ApplicationsAutomotivePower Generation And GridConsumer ElectronicsIndustrial ControlsRailway/TrainEV Charging SystemsIGBT Competitive Landscape	3-18 3-18 3-21 3-21 3-23 3-25 3-27 3-27 3-30 3-32

3.4	MOSFET TAM	3-37
3.4.1	MOSFET TAM Methodology	3-40
3.4.2	MOSFET Market Growth By Applications	3-40
3.4.2.1	Automotive	3-40
3.4.2.2	EV Charging	3-42
3.4.2.3	Industrial And Medical	3-42
3.4.2.4	Consumer	3-45
3.4.2.5	Telecom Network	3-46
3.4.3.6	Computing	3-48
3.4.4	MOSFET Competitive Landscape	3-48
3.4.4.1	Global And China Market Share	3-48
3.4.4.2	China Suppliers' Technology/Product Gaps Vs Global Peers	3-51
3.5	Emerging End Application Markets	3-52
3.5.1	Electric Vehicles	3-52
3.5.2	5G Infrastructure	3-56
3.4	Wide Bandgap Power Semiconductor Market	3-60
Chapter 4	Next-Generation Power Semiconductors	4-1
4.1	Expectations for Overcoming Silicon's Limitations	4-1
4.2	Expectations Of SiC and GaN as Next-Generation Substrates	4-3
4.3	Benefits of Wide Band Gap Semiconductors	4-3
4.4	SiC versus GaN	4-5
4.4.1	Material Properties	4-6
4.4.2	Material Quality	4-8
4.4.3	SiC Lateral Devices:	4-10
4.4.4	SiC Vertical Devices	4-10
4.4.5	GaN Lateral Devices	4-12
4.5	Fabrication of SiC devices	4-22
4.5.1	Bulk and Epitaxial Growth of SiC	4-22
4.5.1.1	Bulk Growth	4-22
4.5.1.2	Epitaxial Growth	4-23
4.5.1.3	Defects	4-23
4 5 0	Surface Preparation	4-25
4.5.2	Surface Freparation	4-2J

4.5.4	Lithography	4-28
4.5.5	Ion Implantation	4-28
4.5.6	Surface Passivation	4-29
4.5.7	Metallization	4-32
4.6	Fabrication of GaN devices	4-33
4.6.1	GaN Challenges	4-37
4.6.1.1	Costs	4-37
4.6.1.2	Reliability	4-40
4.6.1.3	Component Packaging and Thermal Reliability	4-41
4.6.1.4	Control	4-41
4.6.1.5	Device Modeling	4-42
4.7	Packaging	4-42
Chapter 5	Company Profiles	5-1
5.1	Power Semiconductor Companies	5-1
5.1.1	Infineon	5-1
5.1.2	Mitsubishi	5-3
5.1.3	Toshiba	5-4
5.1.4	STMicroelectronics	5-5
5.1.5	Vishay	5-6
5.1.6	Fuji Electric	5-8
5.1.7	Renesas	5-9
5.1.8	Semikron	5-10
5.1.9	NXP Semiconductors	5-11
5.1.10	Hitachi Power Semiconductor Device	5-12
5.1.11	X-Rel Semiconductor	5-13
5.1.12	Advanced Linear Devices	5-14
5.1.13	Nexperia	5-15
5.1.14	Rohm	5-15
5.1.15	Sanken Electric	5-16
5.1.16	Shindengen Electric	5-17
5.1.17	Microchip Technology	5-18
5.1.18	GeneSiC Semiconductor	5-19
5.1.19	Semisouth Laboratories	5-20

5.1.20	United Silicon Carbide	5-20
5.1.21	MicroGaN	5-21
5.1.22	Powerex	5-23
5.1.23	Nitronix	5-23
5.1.24	Transform	5-24
5.1.25	Allegro Microsystems	5-25
5.1.26	GaN Systems	5-26
5.1.27	Navitas Semiconductor	5-27
5.1.28	Alpha and Omega Semiconductor	5-27
5.1.29	ON Semiconductor	5-28
5.1.30	Jilin Sino-Microelectronics	5-29
5.1.31	BYD Microelectronics	5-30
5.1.32	Yangzhou Yangjie Electronic Technology	5-30
5.1.33	StarPower	5-31
5.1.34	Sino Micro	5-31
5.1.35	Yangjie	5-32
5.1.36	Jiejie	5-32
5.1.37	GoodArk	5-33
5.1.38	NCE Power	5-33
	List of Figures	1
1.1	Evolution Of IGBT Chip Structure	1-4
1.2	Effects Of Miniaturization Of IGBT Chip	1-6
1.3	SiC Trench-Type MOSFET And Resistance Reduction As Compared With DMOSFET	1-7
1.4	Planar And Vertical (Trench) MOSFET	1-9
1.5	Schematic Of A FinFET	1-11
1.6	Schematic Of A MOSFET And Super Junction MOSFET	1-13
1.7	Process Flow For Super Junction MOSFET	1-14
2.1	Forecast Of Solar Power	2-4
2.2	Full Bridge IGBT Topology	2-5
2.3	PV Inverter Market Distribution	2-8
2.4	Block Diagram Of Microcontroller-Based Inverter	2-11
2.5	Worldwide Wind Turbine Shipments	2-14

2.6	Top Wind Power Capacity by Country	2-15
2.7	Bill Of Materials For A Typical 30-50kw Inverter	2-20
2.8	A Simple Diagram Of A HEV Traction Drive System.	2-22
2.9	A More Complex Diagram Of PEEM In A Plug-In Hybrid Electric Vehicle (PHEV)	2-23
2.10	Conducting And Switching Loses For Inverter	2-25
2.11	Unit Pricing Trends In Power Semiconductors	2-27
2.12	HEV/EV Shipment Forecast	2-31
2.13	System And Component Costs For Wide Bandgap Semiconductors	2-32
2.14	Vertical And Lateral HEMY	2-34
2.15	GaN Lateral And GaN Vertical HEMTs In EVs	2-38
2.16	Market Drivers For LED Biz And Applications	2-41
2.17	SSL Vs. Classical Technologies	2-42
2.18	LED Performance Vs. Traditional Light Sources	2-43
2.19	Energy Production And Use Comparison	2-46
2.20	Typical LED Drive Circuit	2-49
2.21	Integration Of LED And LED Driver Using TSV	2-52
2.22	Simple Power MOSFET Motor Controller	2-57
2.23	Basic Operating Principle Of Inverter	2-63
2.24	System Block Diagram Of An Air Conditioner	2-65
3.1	Mitsubishi's IGBT (Insulated Gate Bipolar Transistor) Generations	3-3
3.2	Infineon's MOSFET Generations	3-4
3.3	Intel's FinFET Design	3-5
3.4	Fuji's MOSFET versus Super Junction MOSFET	3-6
3.5	NEC's GaN-on-Si Power Transistor	3-7
3.6	Fujitsu's GaN-on-SiC HEMT Transistor	3-8
3.7	Power Semiconductor Market Forecast	3-10
3.8	Power Semiconductor Market Shares	3-12
3.9	Market Forecast For Super Junction MOSFET	3-15
3.10	SJ MOSFETs as an Interim Solution	3-16
3.11	Global IGBT Shares By Application	3-19
3.12	China IGBT Shares By Application	3-20
3.13	Global And China Automotive IGBT Forecast	3-22
3.14	Global And China Power Generation IGBT Forecast	4-24

3.15	Global And China Consumer IGBT Forecast	3-26
3.16	Global And China Industrial IGBT Forecast	3-28
3.17	Global And China Industrial IGBT Forecast	3-29
3.18	Global And China EV Charging IGBT Forecast	3-31
3.19	Global IGBT Module Market Shares	3-33
3.20	Global IGBT Discrete Market Shares	3-34
3.21	Global MOSFET Shares By Application	3-38
3.22	China MOSFET Shares By Application	3-39
3.23	Global And China Automotive MOSFET Forecast	3-41
3.24	Global And China EV Charging MOSFET Forecast	3-43
3.25	Global And China Industrial MOSFET Forecast	3-44
3.26	Global And China Consumer MOSFET Forecast	3-46
3.27	Global And China Telecom MOSFET Forecast	3-47
3.28	Global And China Telecom MOSFET Forecast	3-49
3.29	MOSFET Market Shares	3-50
3.30	Power Demands For ICE And EV	3-55
3.31	5G Demand for Power Semiconductors	3-57
3.32	Forecast of Wide Bandgap Semiconductor Market	3-64
4.1	Silicon-Based Devices Reaching Maturity	4-2
4.2	Enhancement Mode GaN On Si Transistor	4-14
4.3	AlGaN/GaN HEMT, GaN MOSFET, MOS-HEMT	4-18
4.4	GaN HEMT Material Structure On Si Substrate	4-36
4.5	Power Package Integration Roadmap	4-44
	List of Tables	
2.1	Product Families And The Principal End Uses Of	
	Power Products	2-2
2.2	Forecast Of On-Grid Inverters By Type	2-8
2.3	EV Shipment Forecast	2-29
2.4	Advantages And Disadvantages Of GaN Lateral HEMTs	2-39
2.5	Light Source Comparison	2-49
2.6	Forecast Of GaN And SiC Power Devices By End Applications	2-77
3.1	Power Semiconductor Forecast for Electric Vehicles	3-54
3.2	5G Semiconductor Total Available Market Forecast	3-59

4.1	Physical Properties Of Select Semiconductor Materials	4-4
4.2	Wide Bandgap Material Properties	4-7
4.3	Lattice Constant And CTE Of Semiconductor Starting Material	4-11
4.4	GaN FET Vs Si MOSFET Characteristics	4-16
4.5	Standard Chemical Solution For Surface Preparation Of SiC Substrates	4-26
4.6	Interface Trap Densities For 4H-SiC Under Different Process Conditions.	4-31