< New market survey report >

Power Modules & Component Materials -2017-

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Subjects of survey

<Subjects of survey>

▼ Power module:

- All IGBT modules including IPM type,
- Any SiC power modules with 600V or greater, but excluding diode modules

▼ Components:

- Ceramic substrate for power device
- Sinter joining material

<Companies surveyed>

▼ Power module manufacturer

- Mitsubishi Electric, Infineon, Fuji Electric, Semikron, On Semiconductor, Hitachi Power Semiconductor Device, Sanken Electric, ABB, Microsemi, Vishay, IXYS, Kyocera, STM, Wolfspeed, Rohm, Others

▼ Ceramic substrate supplier

- Denka, Toshiba Material, DOWA Metaltech, Mitsubishi Materials, Kyocera, NGK, Hitachi Metals, Rogers, KCC

▼ Sinter joining material supplier

- Alent, Henkel, Heraeus, Nihon Handa, Namics, Kyocera, Hitachi Chemical, Sumitomo Bakelite, DOWA Electronics Materials, Sneju, Tanaka, Nihon Superior, Harima Chemicals, Mitsui Mining & Smelting, Mitsubishi Materials, Others

Focal points of survey

▼ Power Modules

1. Market Trends of IGBT power module and SiC power module
   - By application, by module capacity and by packaging technology
   - By SiC and Si-base chips
2. Core technology trends for high reliability of modules
   - Trends of new lineup and expansion of the module manufacturers
   - Alternative technologies of bonding wire, solder join and ceramic substrate with metal baseplate

▼ Module component materials

1. Ceramic substrate
   - Market Trends by application and by substrate material
   - Trends of the substrate material market by application market trend
2. Sinter joining material
   - Market Trends Ag sintering materials by application, by type (w/ resin, or w/o)
   - Development status by supplier
     - Specifications and performances of products
     - Development situations of Cu and Ni sintering materials

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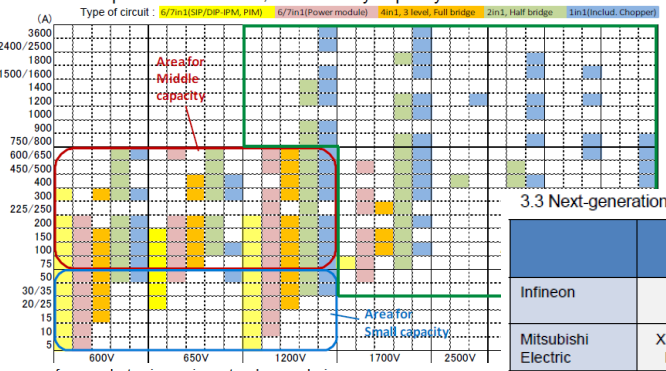
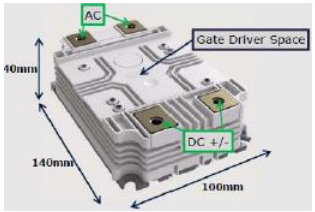
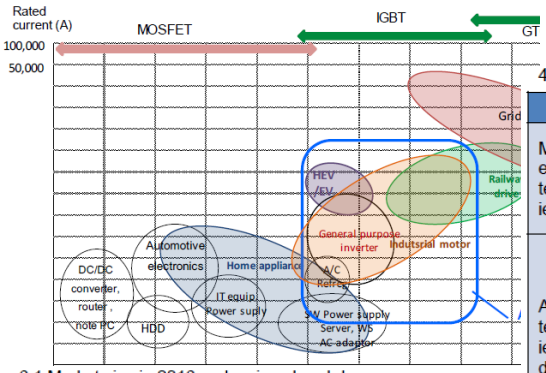




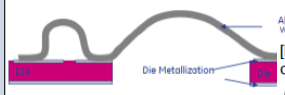
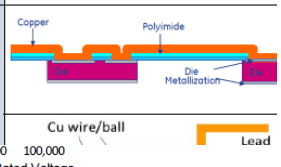
3.3 Next-generation high-capacity power modules in 2-in-1 packages

	Module name	Dimensions	1200V
Infineon	XHP	LV: 100x HV: 100x	
Mitsubishi Electric	X-Series New Dual HVIGBT module	LV: 100x HV: 100x	
Hitachi Power Semi. Dev.	nHPD²	LV: 94x HV: 94x	
ABB	LinPak	LV: 100x	

1.4 Coverage of power electronics equipment and power devices



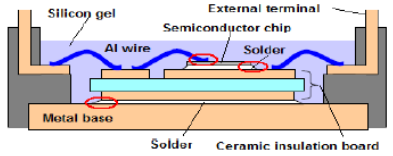
4.4.1 Connection by components replacing bonding wires

	Structure image figure
Major existing technologies	
Alternate technologies under developm	

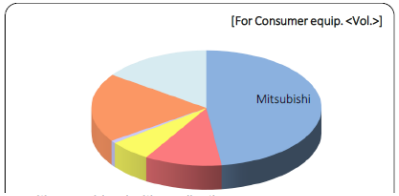
[Comparisons of structure of module by type and main component materials]

Case type	Type of module	Molded type
IGBT power module/IPM(small ~ large module)	Application module	DIP/SIP type IPM, T-PM (mid. capacity module)
Cross sectional diagram		
34x48x12mm (Aprox. 20 cm³) ~ 140x190x48mm (Aprox. 1,300 cm³)	Outline size	33x19x3.6mm (Aprox. 2.2 cm³) ~ 64x56x7.5mm (Aprox. 27 cm³)
Silicone gel (coat inside of case)	Encapsulant	EMC (by Transfer mold), Liquid (by potting)
Bonding wire (Al, Cu), Al ribbon, DLB	Circuit connection	Bonding wire (Al, Au*1), DLB
Ceramic board (Al_2O_3, AlN, Si_3N_4)	Insulation/circuit	Leadframe, IMS, DCB

4.3 Reliability and joining parts of power modules

Failure points by thermal stress	Bonding portion	Linear CTE of com
	Between wire (Al/Cu) and chip	Al: 23.6 x 10^{-6}/deg.C, Si: 3.5 x 10^{-6}/deg.C
	Between chip and insulating substrate	Si: 3.5 x 10^{-6}/deg.C Al_2O_3: 7.1 x 10^{-6}/deg.C
	Between insulating substrate and base plate	Al_2O_3: 7.1 x 10^{-6}/deg.C Cu: 16.8 x 10^{-6}/deg.C

[Manufacturers' share of IGBT power module market for consumer equipment in 2016 (in volume & amount)]



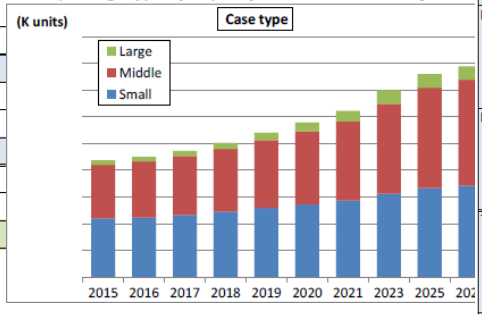
5.1 List of market entry situation of IGBT module companies

	By capacity			By device function		By type of package	
	Small	Middle	Large	IPM	Power M	TM	Case
			✓		✓		✓
	✓	✓	✓		✓	Partially	✓
	✓	✓	✓	✓	✓		✓
Hitachi P.S. D. *		Partially	✓		✓		✓
	✓	✓	✓	✓	✓	✓	✓
	✓	✓	✓		✓	✓	✓
	✓	✓			✓		✓
		✓	✓	Partially	✓		✓
	✓	✓	✓	✓	✓	✓	✓
	Partially			✓	Partially	✓	Partially

6.1 Market size in 2016 and various breakdowns

		Volume (K modules)						
		Consumer	Industrial	Automotive	New energy	Railway	(Sub) total	C
Small	TM				0	0		
	Case							
	(Sub) total							
Middle	TM	0						
	Case	0						
	(Sub) total	0						
Large	TM	0						
	Case	0						
	(Sub) total	0						
Total	TM							
	Case							
	(Sub) total							

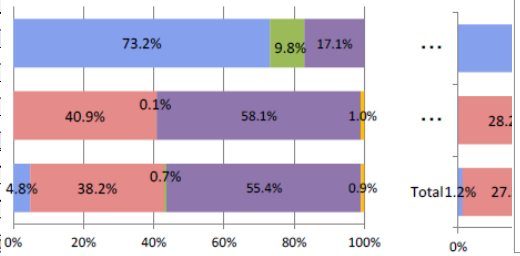
[Market size forecast of IGBT power module of each package type by capacity in volume & amount]



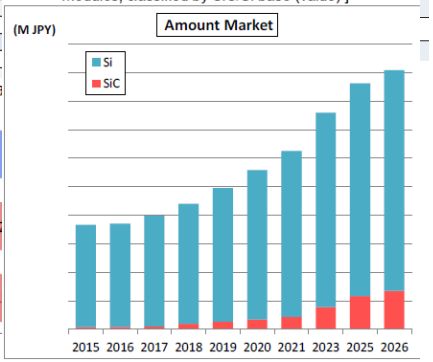
6.3.5 Classified by module capacities combined with applications

		2015	2016	2017	2018	2019	2020	2021	2023	2025	2026
Small	Consumer										
	Industrial										
	Automotive										
	New energy										
	Railway	0	0	0	0	0	0	0	0	0	
Middle	Consumer	0	0	0	0	0	0	0	0	0	
	Industrial										
	Automotive										
	New energy										
	Railway	0									
Large	Consumer	0									
	Industrial										
	Automotive										
	New energy										
	Railway										
Total	Consumer										
	Industrial										
	Automotive										
	New energy										
	Railway										
	(M JPY)		370								

[SiC power module market classified by package type, with brea



[Forecast of the changes of market size of power modules, classified by SiC/Si base (value)]



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-from a chapter of “Trends of main components” -

1. Ceramic substrates for power devices

1.1 Ceramic substrate material [Property and description of characteristics of ceramic materials]

	Ceramic material	Thermal conductivity W/m·K	Bending moment MPa	Fracture toughness MPa·m$^{1/2}$	Linear CTE ×10^{-6}/K	Diele strer kV/r
Property of ceramic materials	Al nitride	70~250	… ~ …	.. ~ ..	.. ~ ..	>
	Alumina	20~30	… ~ …	.. ~ ..	.. ~ ..	>
	Zirconia toughened alumina	20~30				
	Si nitride	60~90				
Description of characteristics of ceramic materials	Al nitride	High thermal c and the CTE is Taking these a which high diel				
	Alumina	This is less ex It is used for c				
	Zirconia toughened alumina	While the ther bending stren Its price is roug erode the low-				

2.1 Situation of entry to the market of ceramic substrates for power devices

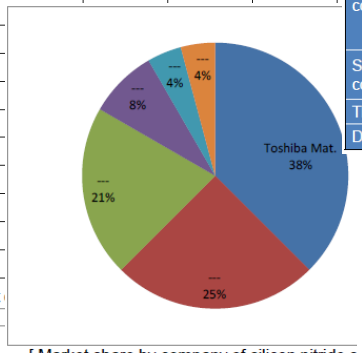
	Particle			Plain substrate			
	Al_2O_3	Si_3N_4	AlN	Al_2O_3	Si_3N_4	AlN	A
Ube Industries							
NGK Electronics Devices							
Kyocera							
Denka		Mass	In-house		In-house	In-house	
Toshiba Materials							
Tovo Alminium							

3.1 Results in value terms [Sales results of major ceramic substrate companies]

	AlN substrate	Si_3N_4 substrate	Al_2O_3 substrate	Al_2O_3-ZrO_2 substrate	Total
Rogers					
Denka					
DOWA Metaltech					
NGK Electronics Devices					
KCC					
Toshiba Materials					
Mitsubishi Materials					
Hitachi Metals					
Kyocera					
Others					
Total					

4.1 Market size of ceramic substrate, classified by application

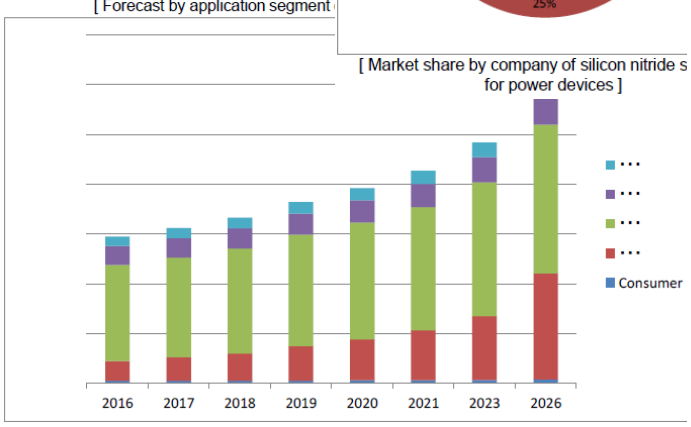
	Type	Consumer	Automotive	Industrial	Railway	New energy
Amount : MJPY	AlN substrate	0				
	Si_3N_4 substrate	0				
	Al_2O_3 substrate					
	Al_2O_3-ZrO_2 substrate	0				
	Total					
Volume : m^2	AlN substrate	0				
	Si_3N_4 substrate	0				
	Al_2O_3 substrate					
		0				



[Market background of ceramic substrate for power devices]

Type of substrate	Market trends
Aluminum nitride substrate	Market size railway seg of this subs grow stead
Silicon nitride substrate	Currently, t market size 2026. The main a high fractu aluminum r the double It is regard superiority point.
Alumina substrate	Market size In small an low price a reach 16.2
Zirconia toughened alumina substrate	The marke However, v silicon nitri meet the c

[Forecast by application segment



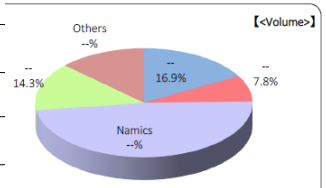
[Market share by company of silicon nitride s for power devices]

2. Sinter joining materials

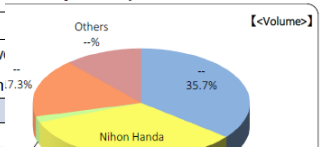
1.2 Overview of sinter joining materials for power devices

Constituents of sintering material and items of process technology		Influence,
Supply forms of the material	Paste, film, preform	→ application
Metal particles — Type	Ag, Cu, Ni, Au and others	→
Metal particles — Size	nm class, sub-μm class, μm class	→
With resin	Without resin, with resin (thermosetting, thermoplastic)	→
Application method	Dispensing, printing, pin transfer	→
Pre-bake	Temperature and time	→
Atmosphere type	Air, N_2, H_2, mixed gas of N_2 and H_2	→
Sintering — Heating	Temperature and time	→
Sintering — Pressurized	Pressureless, combined heating and pressurizing	→ Damage, v

[Shares by manufacturers in the market of Ag sinter



[Shares by manufacturers in the market of Ag sir



[Comparison of the characteristics of sinter joining material, classified by metal, based on

		Ag	Cu	Ni
Metal particle size		Several nm ~ 10μm		
Sintering condition	Temperature	150 ~ 300 deg.C		
	Pressurization combined	Yes / No		
	Atmosphere	Air or N_2		
Surface finishing of component to be joined		Au, Ag, Cu possible in some case		
Thermal conductivity		60 ~ 300 W/m·K		
Die shear strength		20 ~ 50 MPa		

[Estimate changes in market size of sinter joining material by application]

		2016	2017	2018	2019	2020	20
Volome (K units)	Power module						
	% to LY*	-	…%	…%	…%	…%	
	Power discrete						
	% to LY*	-	…%	…%	…%	…%	
	…						
	% to LY*	-	…%	…%	…%	…%	
	…						
	% to LY*	-	…%	…%	…%	…%	
	Total						
	% to LY*	-	…%	…%	…%	…%	
Amount	Power module						
				…%	…%	…%	
				…%	…%	…%	
				…%	…%	…%	

[List of companies of market entry and development, classified by material types]

	Sintering metal			Resin		Material form	
	Ag	Cu	Others	Less	contained	Paste	Film
Alent	✓			✓	✓	✓	✓
…							
DIC							
DOWA Electronics Materials							
…							
Harima Chemicals							
Henkel							
Heraeus							
Hitachi Chemical							
…							
Kyocera							
Kyoritsu							
Mitsubi							
Mitsui M							
Namics							
Nihon D							
…							
Nihon S							
Senju M							
Sumitor							
Tanaka I							
…							

2.3 Performance specifications of the materials of major companies

Company name	Product name	Sintering metal	Before curing		Cured properties					Storage conditions
			Viscosity	Thixotropic Index	Thermal conductivity	Volume resistance	Die Shear strength	Elastic Modulus	CTE	
		-	Pa.s	-	W/m*K	μΩ - cm	MPa (RT)	GPa (25deg.C)	ppm/ deg.C	deg.C/ month
		-	25deg.C	0.5rpm/5rpm	Laser flash	LCR meter	-	DMA	TMA	-
Alent (Alpha)										
	SSP 2020	Ag	19	5	> 100	48	19.6~29.4 *0 >> 39.2 *0	12.5	--	--
Heraeus										

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