PE International 2023

Plasma Dicing of GaN on Si Wafers

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Panasonic CONNECT

PE INTERNATIONAL CONFERENCE ANGELTECH

Agenda

1. Introduction
   - Panasonic Connect introduction
   - Process Automation Business Division introduction

2. Plasma dicing for GaN on Si
   - Background
   - Total solution for GaN on Silicon device

3. Equipment lineup for Dry Etching and Plasma Dicing
   - Dry etching equipment
   - Plasma dicing equipment
   - Introduction of Plasma Dicing Demo Center

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Panasonic Group Structure

Up to March 2022

Panasonic Corporation

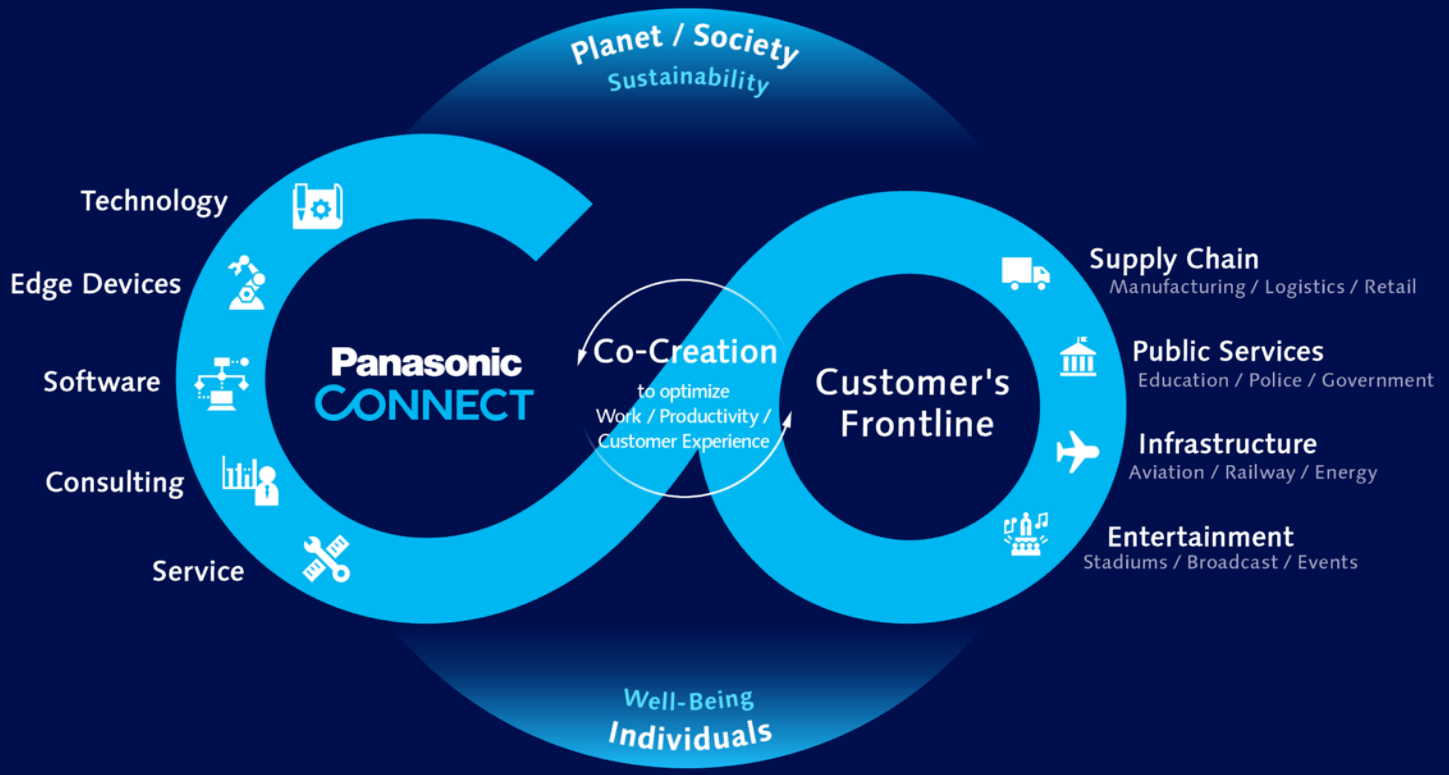
- Corporate Strategy & Technology Sector
- Lifestyle Updates Business Division
- Automotive Company
- Entertainment & Communication Business Division
- Housing Systems Business Division
- **Connected Solutions Company**
- Industry Company
- Energy Company
- Operational Excellence Company

From April 2022

Panasonic Holdings Corporation

- Panasonic Corporation
  - China and Northeast Asia Company
  - Living Appliances and Solutions Company
  - Heating & Ventilation A/C Company
  - Cold Chain Solutions Company
  - Electric Works Company
- Panasonic Automotive Systems Co., Ltd.
- Panasonic Entertainment & Communication Co., Ltd
- Panasonic Housing Solutions Co., Ltd.
- **Panasonic Connect Co., Ltd.**
- Panasonic Industry Co., Ltd.
- Panasonic Energy Co., Ltd.
- Panasonic Operational Excellence Co., Ltd.

Change Work, Advance Society, Connect to Tomorrow.

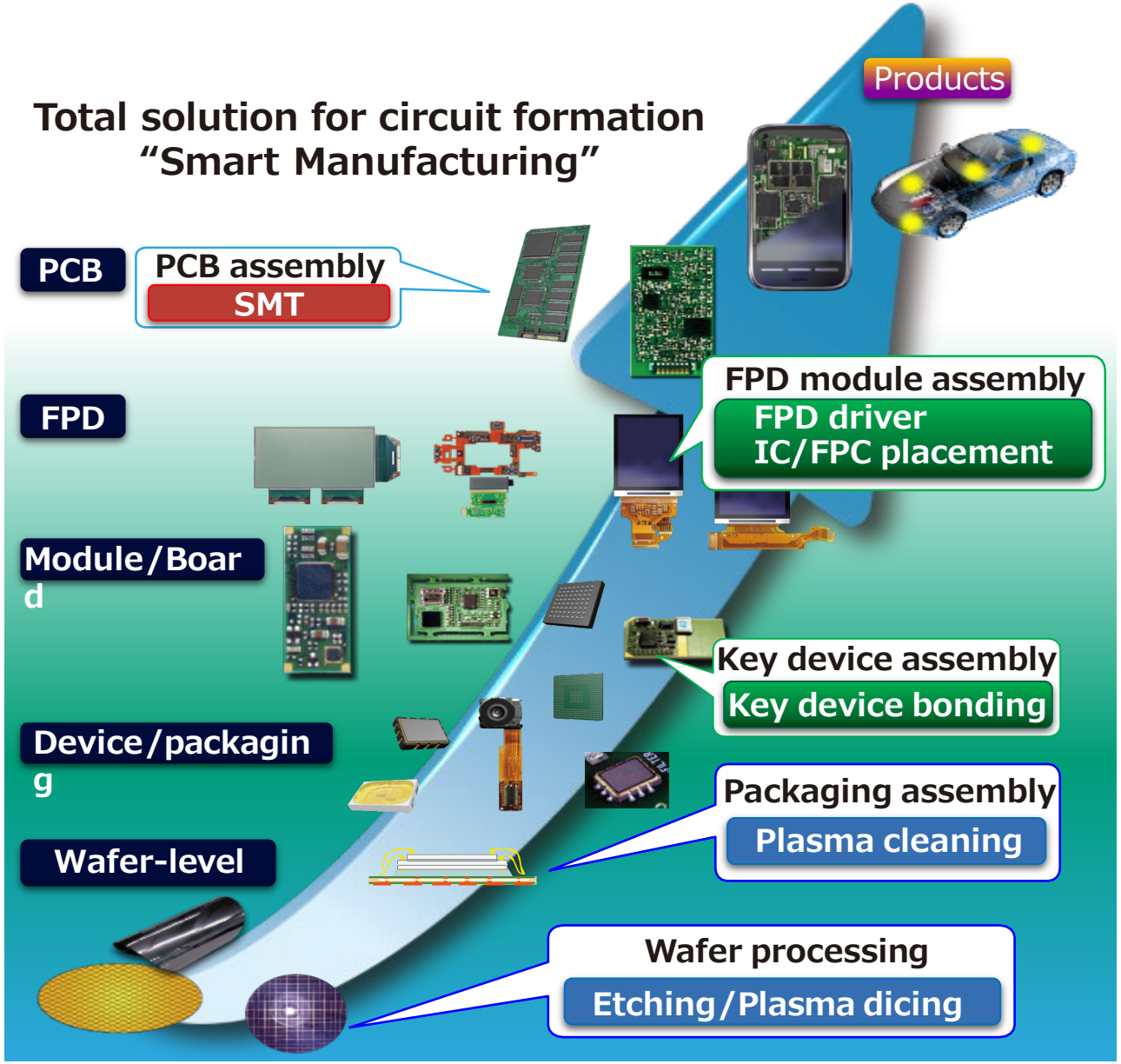


A better future through “Gemba Process Innovation”

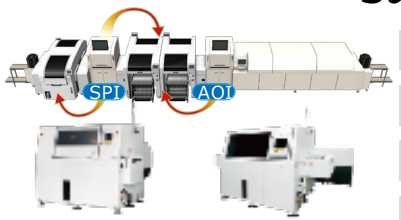
By leveraging Gemba Process Innovation to solve challenges we work alongside our customers with the ultimate goal of creating efficiency, a better society and a sustainable future.

Process Automation Business Division

Total solution for circuit formation “Smart Manufacturing”



Surface mounting



Surface mounting for electronic circuit board

- Chip mounter
- Screen printer
- Insertion machine for lead component
- Insertion machine for odd-shape component

High-precision bonding

FPD Driver IC/FPC placement

- COG bonder/FOG bonder

Key device placement

- Die bonder/Flip chip bonder

High-precision processing

In this presentation

Etching and dicing

- **Dry etcher**
- **Plasma dicer**

Cleaning

- Plasma cleaner

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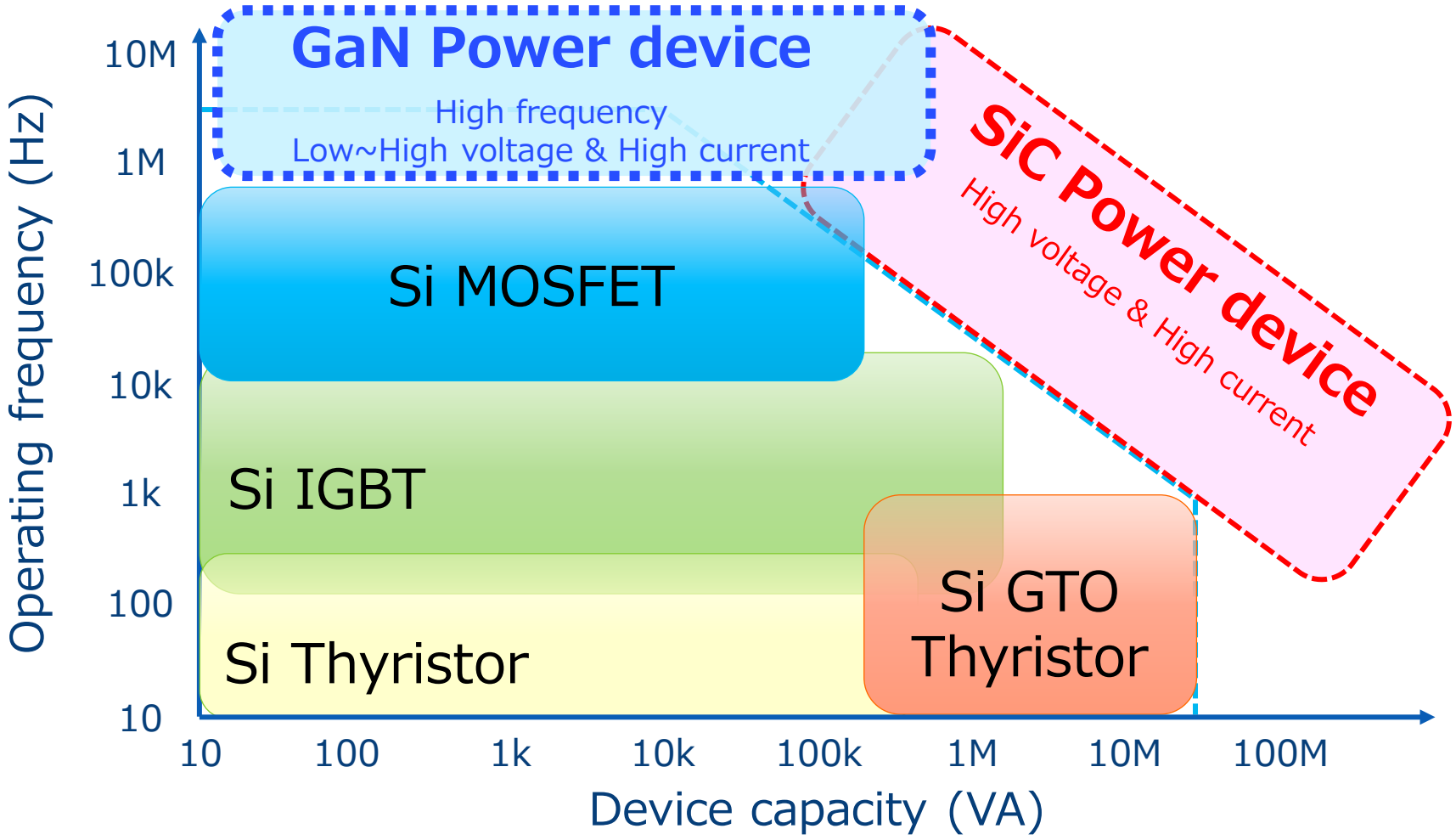
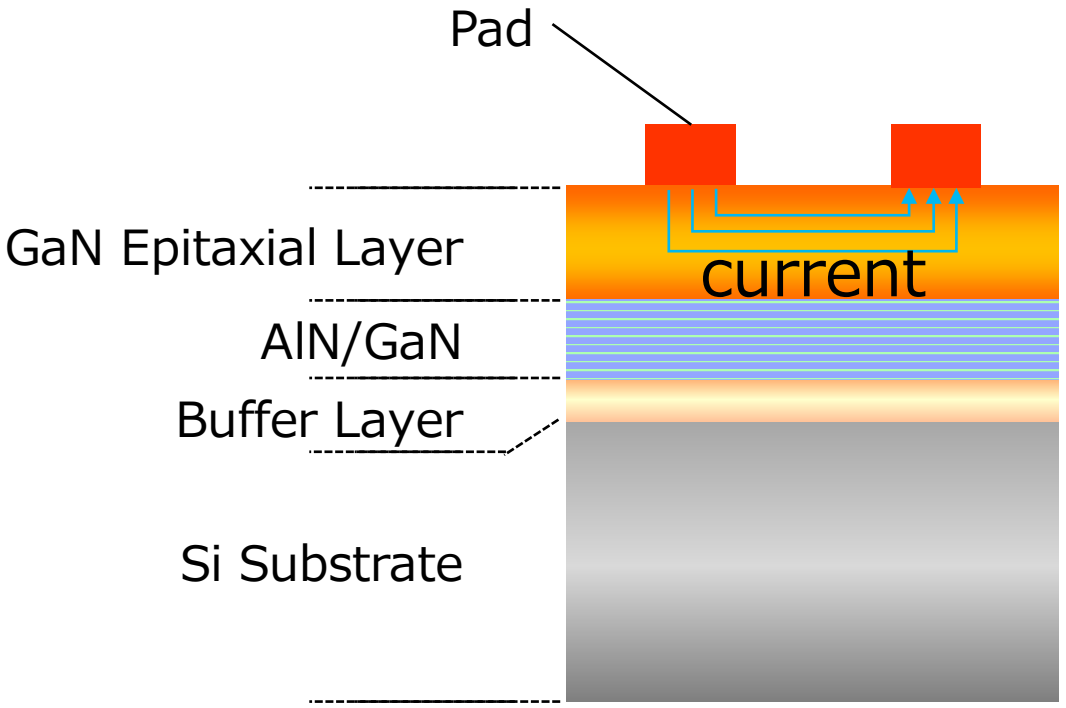
Applicable area of GaN power device



GaN power devices are effective for high operating frequency region

Device structure of GaN on Silicon Power Devices



ex) GaN HEMT device

Feature of GaN on Silicon power device

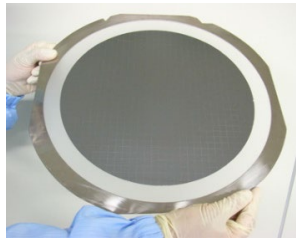
- Withstand high voltage
- Excellent switching characteristics
- Low current loss
- **Low production cost** compared to other compound power devices

➡ **Strong demand due to low production cost**

Panasonic proposes further low-cost production by using plasma dicing

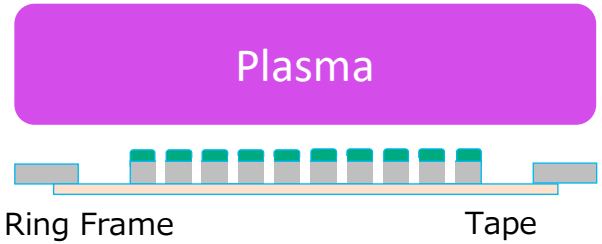
Principles and Benefits of Plasma Dicing

■ Outline of Plasma Dicing

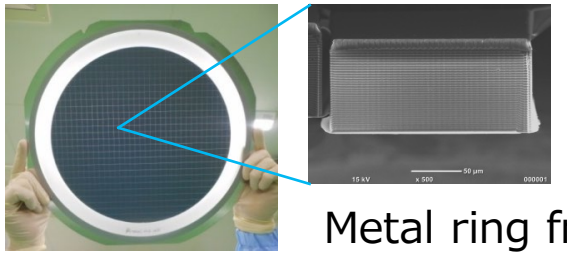


Wafer is mounted on metal ring frame and tape

Wafer is transferred into the Process Chamber



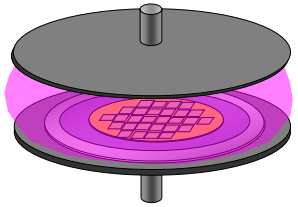
Wafer is transferred from the Process Chamber



Fully diced wafer by Plasma Dicing

Metal ring frame and tape have no damage

■ Benefits of Plasma Dicing



Plasma Dicing by chemical reactance of gas

1. High Productivity & Low CoO

- **Narrow dicing width and kerf margin by elimination cracks increases the amount of dies**
- **Parallel processing**

2. No Damage & No Chipping

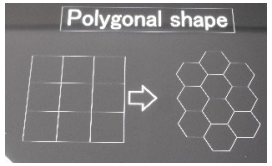
- Dicing of thin & fragile wafers w/o damage
- Possible to reduce the kerf margin
- Possible to dice with low device damage

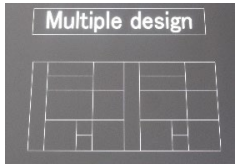
3. No Dust & No Particle

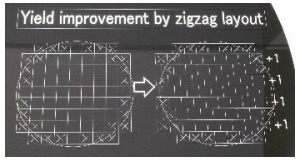
- Clean chemical etching process
- No mechanical dust, debris, vibrations etc.
- Potential to reduce inspections

4. Variant Chip Shape & Layout

- Flexible die shapes and non-orthogonal layouts

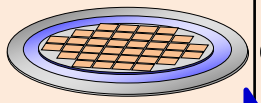
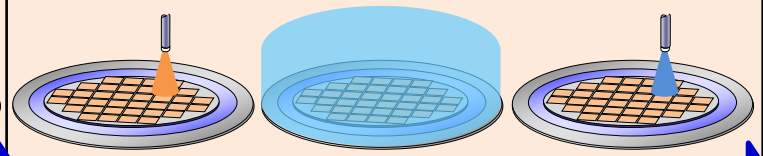
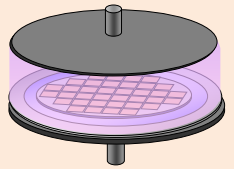
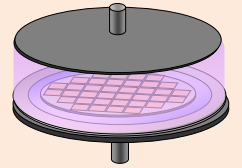
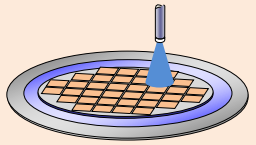
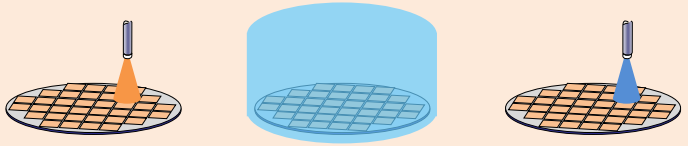
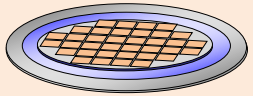




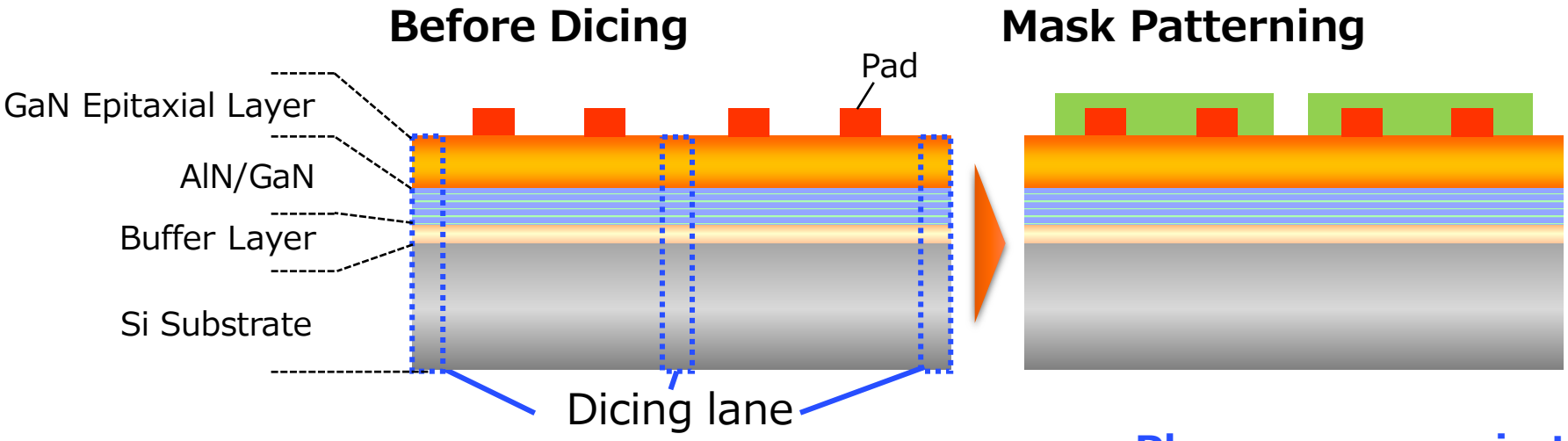


Panasonic proposes further low-cost production by using plasma dicing

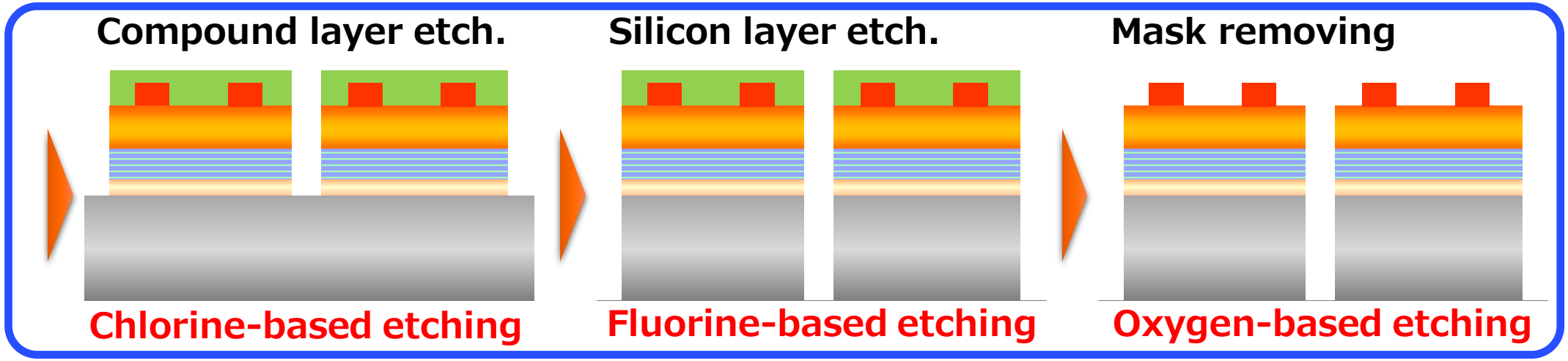
Plasma Dicing Process Flow for GaN on Si Devices

Wafer thickness	Process				
	Tape mounting	Mask Patterning	Tape mounting	Plasma Dicing	Mask Stripping
< 200µm		Coat Exposure Development 			Ashing  or Chemical Cleaning 
≧ 200µm	-				
Equipment	Tape mounter	EVG101 series 	Tape mounter	APX300-DM 	APX300-DM or wet station 

Plasma Dicing for GaN on Silicon Wafers



Plasma process in the same chamber



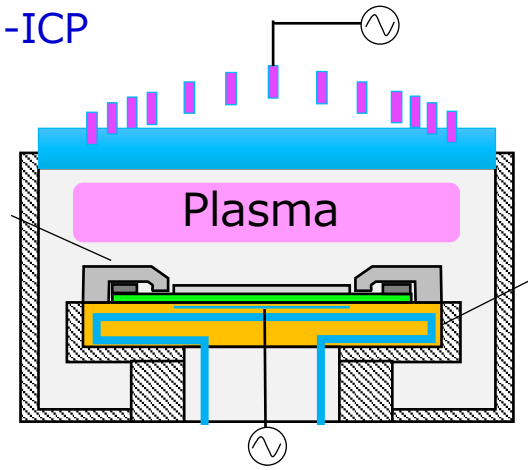
Various materials must be processed in the same chamber

Feature of APX300-DM for GaN on Silicon Wafers

■ Equipment Information

Patented Enhanced-ICP

Patented Dicing Ring Cover



Patented Panasonic Original ESC Electrode

・APX300-DM has optimized elemental technologies for Plasma Dicing

Configuration of APX300-DM Process Chamber

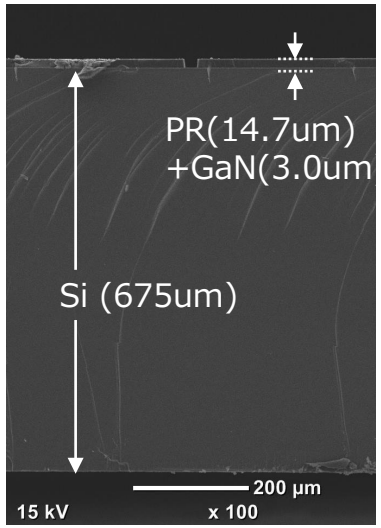
1. Enhanced ICP Plasma Source : High density and uniform plasma
2. Plasma Dicing ESC Electrode & Dicing Ring Cover
   - ・Patented Panasonic design enables the Plasma Dicing process to be performed on wafers mounted on ring frame with tape
   - ・Strong chucking force and cooling enables almost all dicing (DC) tape to be used.
   - ・Eliminates exposure of the tape and frame to plasma
3. Etching performance
   - ・Process chamber that can use both Fluorine-based and Chlorine-based etching gasses. Compound Semiconductor etching is possible
   - ・Multi layer dicing (GaN, AlGaN, SiO2, SiN, DAF & Si) is possible

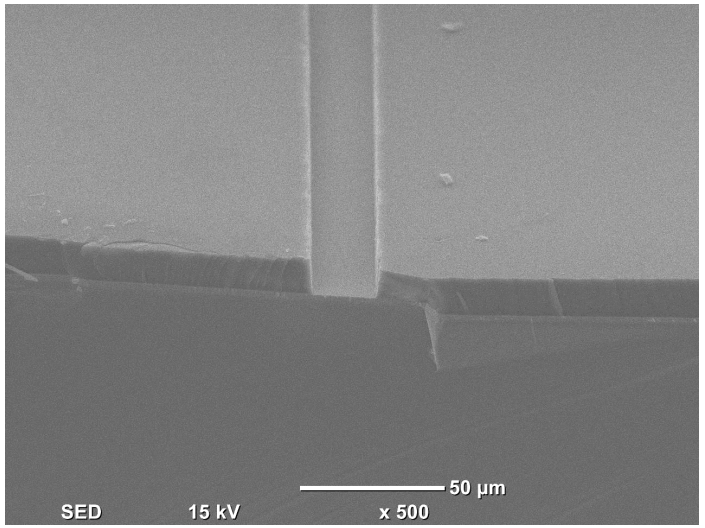
APX300-DM can use various gas types for each layer, and integrate this with high productivity dicing of GaN on Silicon wafers.

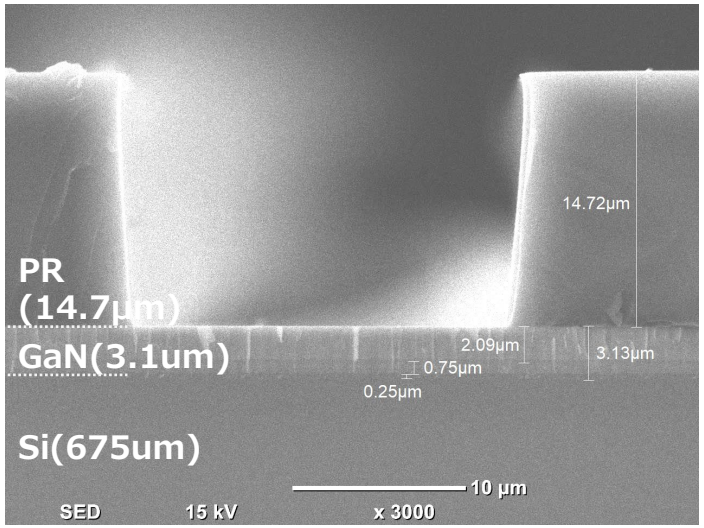
Evaluation of Plasma Dicing with GaN on Silicon Wafers

■ Sample Information

- Si wafer size: 6inch
- Thickness : 675um * non BG
- GaN layer structure :
  GaN(2000nm)/AlNGaN(800nm)/AlN(200nm)
- Chip pitch : 1.38x1.67mm
- PR material : Novolak Photo Resist (PR)
  positive type
- PR thickness : 14.7μm
- Dicing line width : 5, 10, 15, 20μm





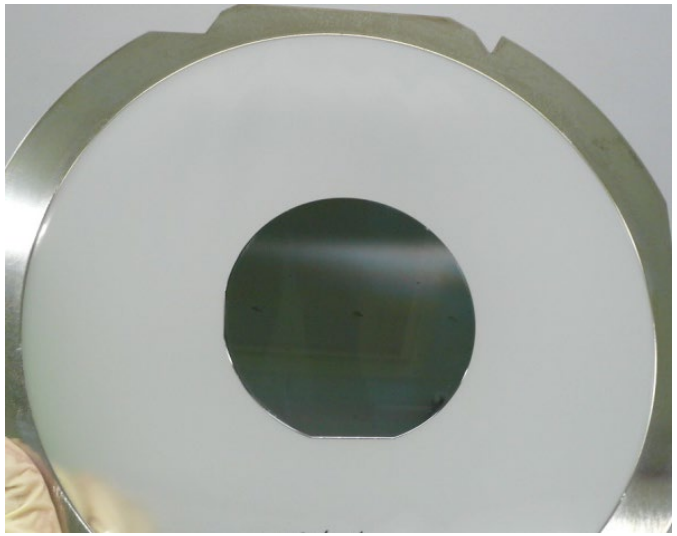


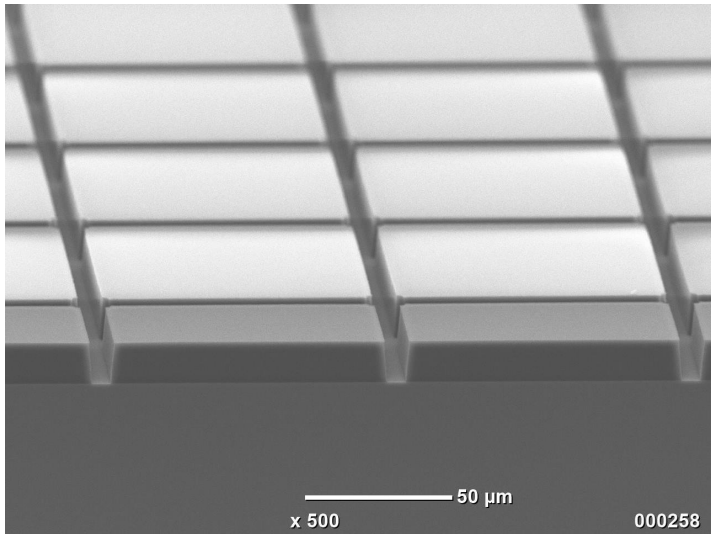
Structure of GaN on Silicon wafer after mask patterning @ 20um line

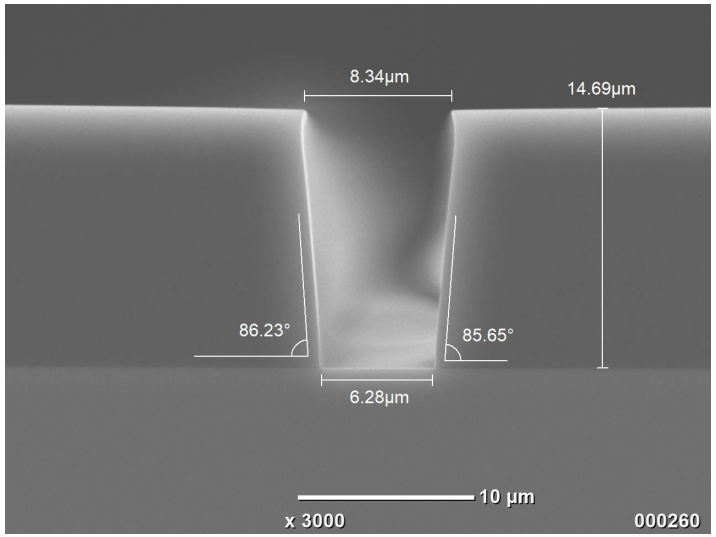
Example of Photo-lithography on FFC with thick PR

■ High Aspect Ratio PR for GaAs wafer

- Equipment : EVG101
- Resist : Novolak Photo Resist (PR)
- Wafer : GaAs wafer (150μmt) - 4inch







PR thickness :14.6μm
Dicing width : 6.3μm
Chip pitch : 100x100um
A/R = 2.3

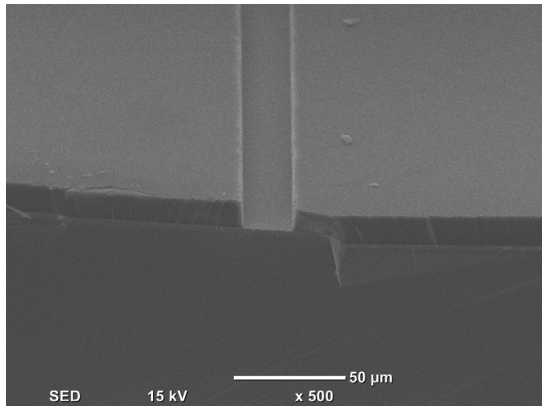
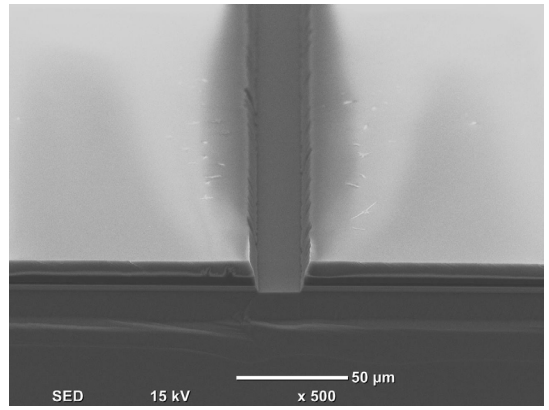
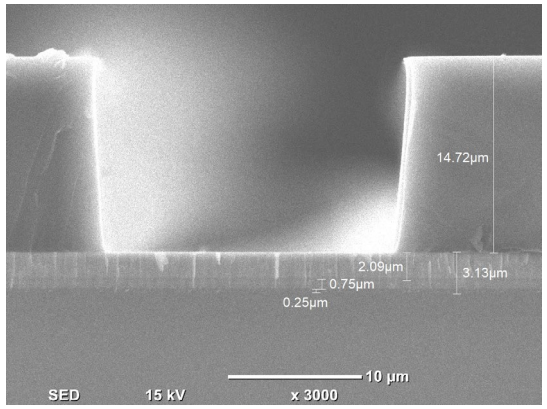
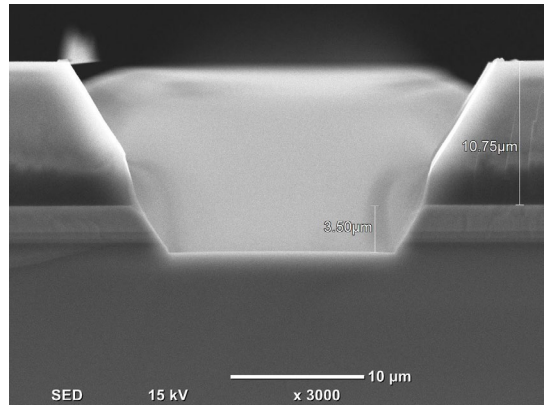
GaN Layer Etching : Basic Specification

■ Etching Condition

- Equipment : APX300-DM
- Etching gas : chlorine gas base
- Etching time : 4 min.

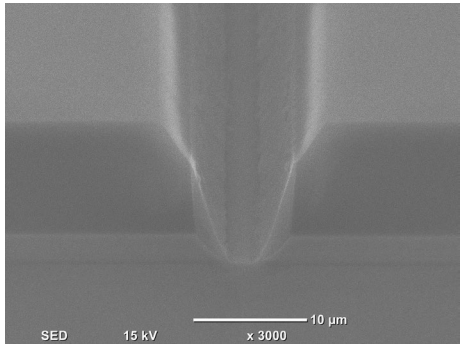
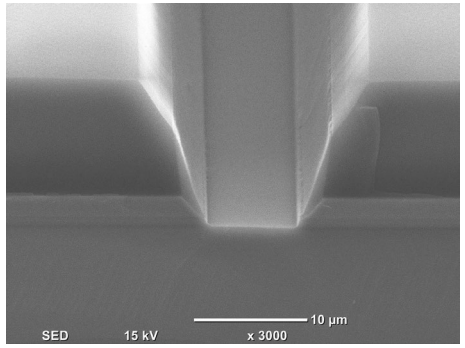
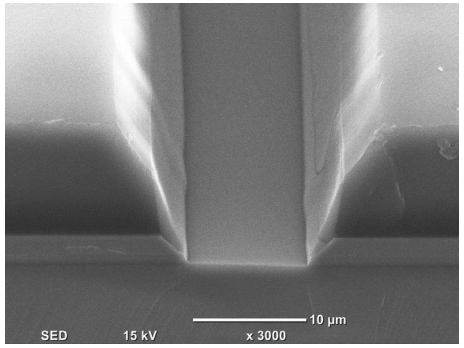
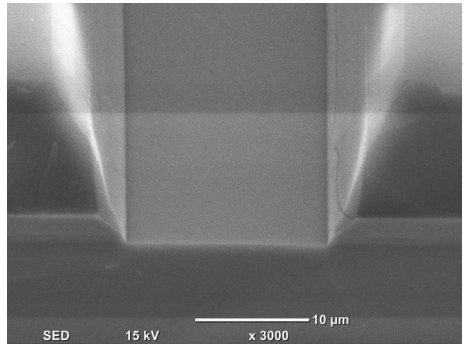
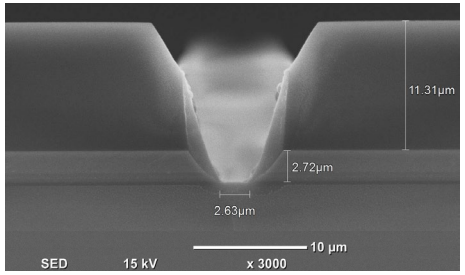
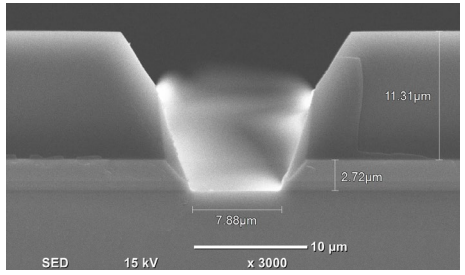
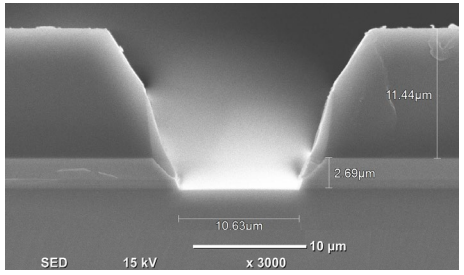
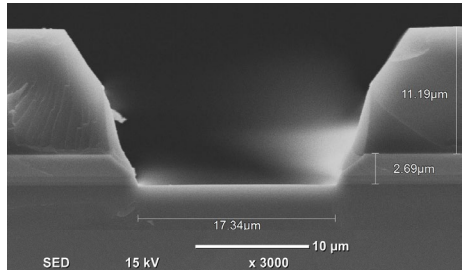
■ Etching Specification

- GaN Etching rate : 0.94um/min.
- Selectivity(GaN+AlGaN+AlN / PR) : 0.89

	Before GaN etch	After GaN etch
SEM		
		

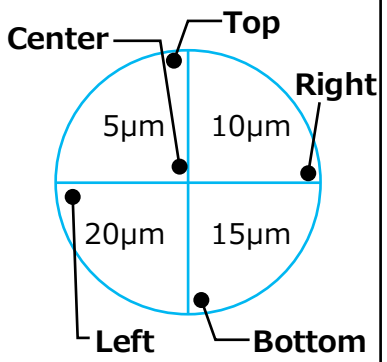
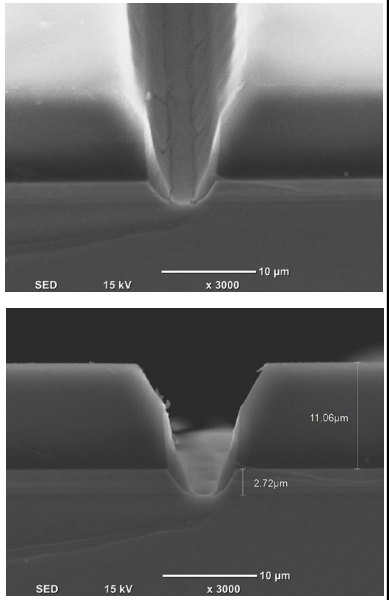
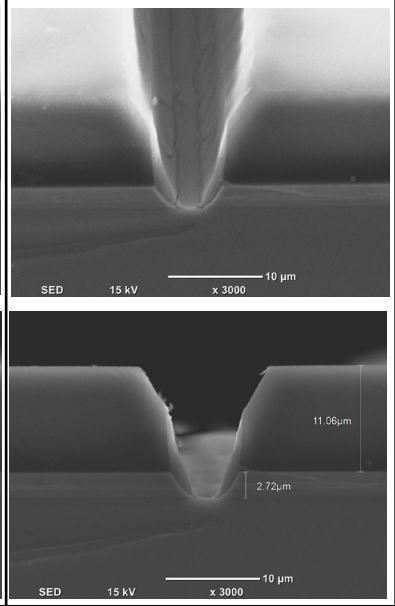
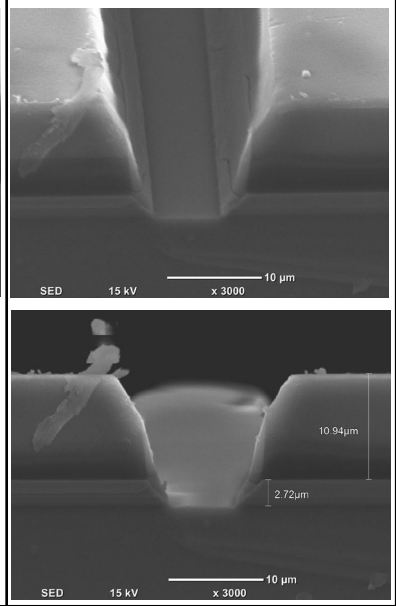
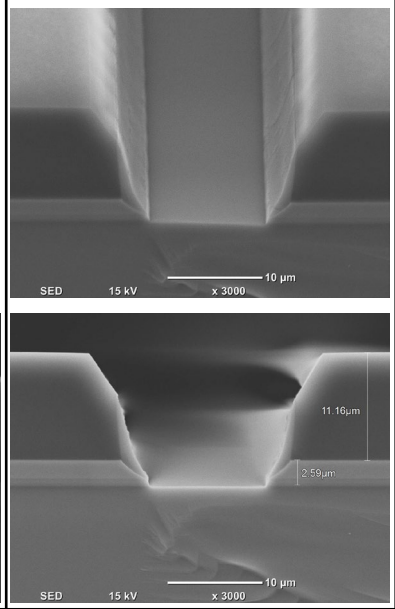
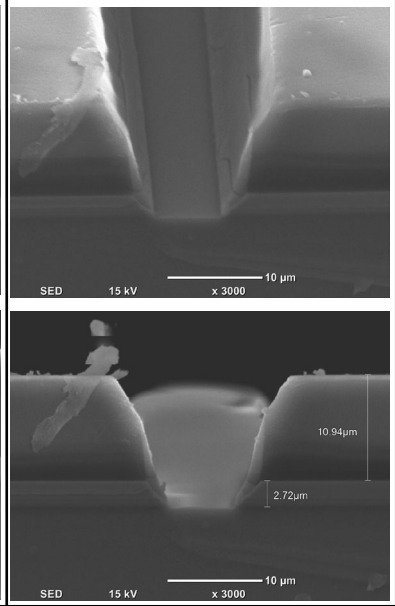
GaN multi layer can be etched

GaN Layer Etching : Etching rate dependency on dicing width

	Dicing width [μm]			
	5μm	10μm	15μm	20μm
SEM				
Etching time 3 min.				
GaN rate [μm/min.]	0.91	0.91	0.90	0.90
PR sel.	0.94	0.94	0.97	0.89

GaN etching rate is similar, regardless of dicing line width

GaN Layer Etching : Etching rate uniformity on the wafer

	Wafer position				
	Center	Top	Bottom	Left	Right
SEM  **Etching time : 3 min.**					
GaN rate [μm/min.]	0.91	0.91	0.86	0.91	0.90
	(Ave.) 0.90μm/min. (Unif.) ±2.41%				
PR sel.	0.94	0.87	0.85	0.90	0.83

Uniform processing on the entire wafer area is achieved

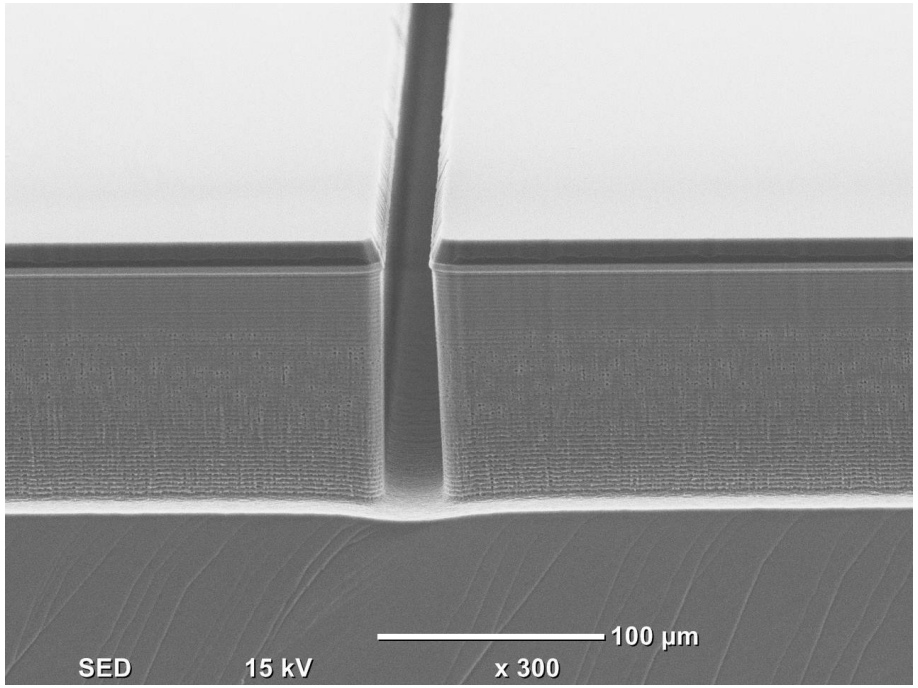
Si Layer Etching : Basic Specification

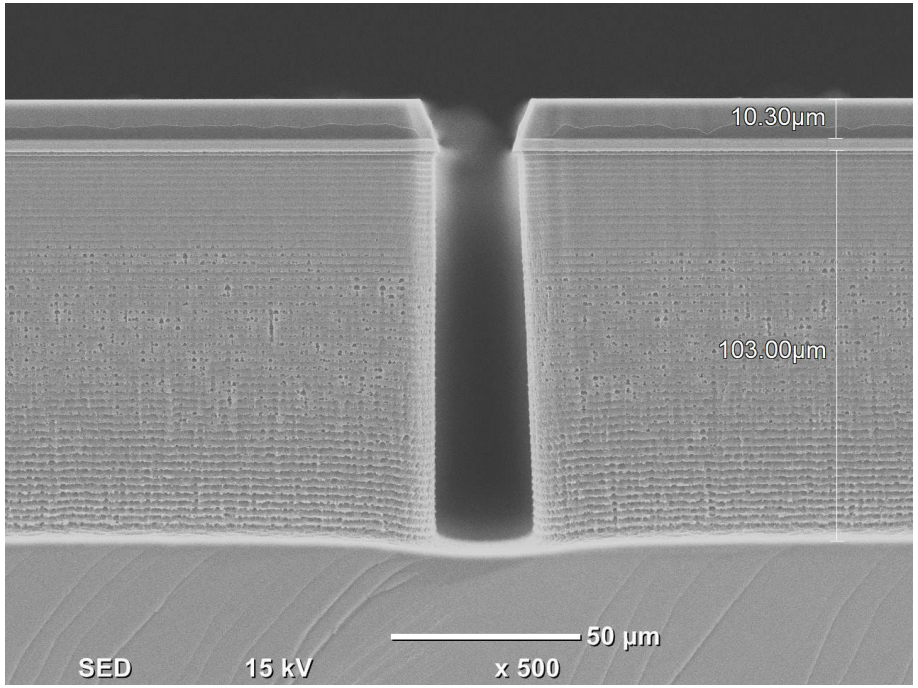
■ Etching Condition

- Equipment : APX300-DM
- Etching gas : chlorine gas base -> florine gas base
- Etching time : 4 min. -> 8/5 min.

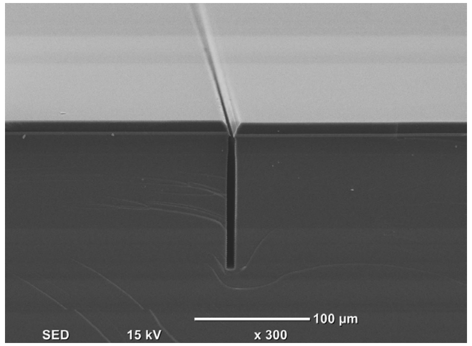
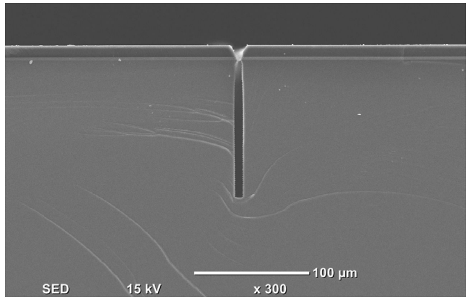
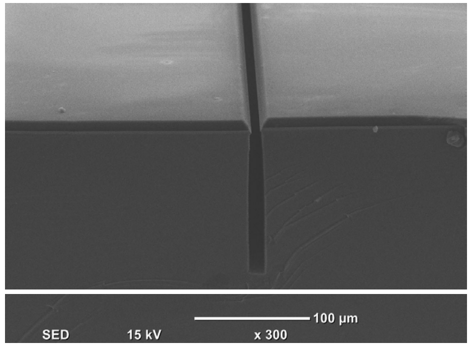
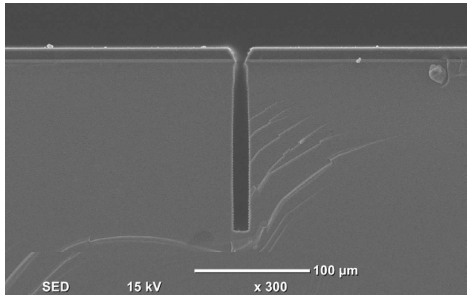
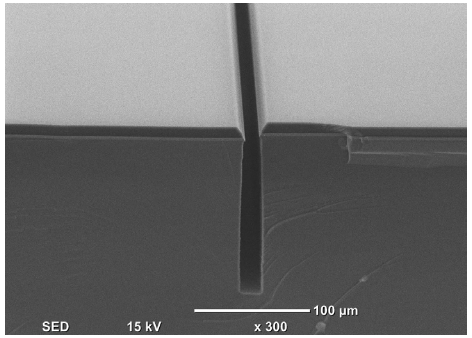
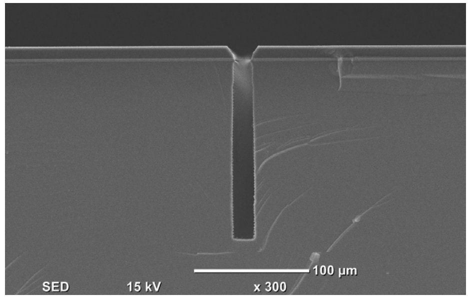
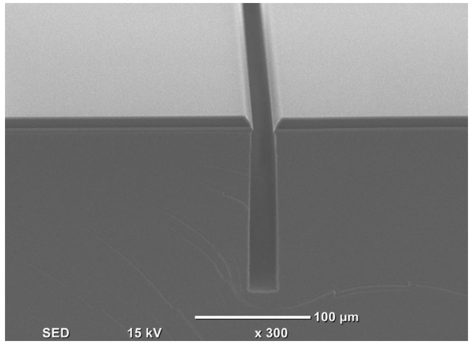
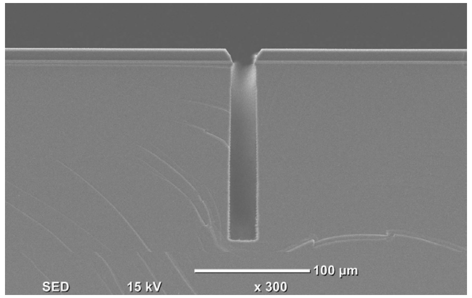
■ Etching Specification

- Si Etching rate : 12.1 um/min.
- Selectivity(Total etching depth / PR) : 82.4

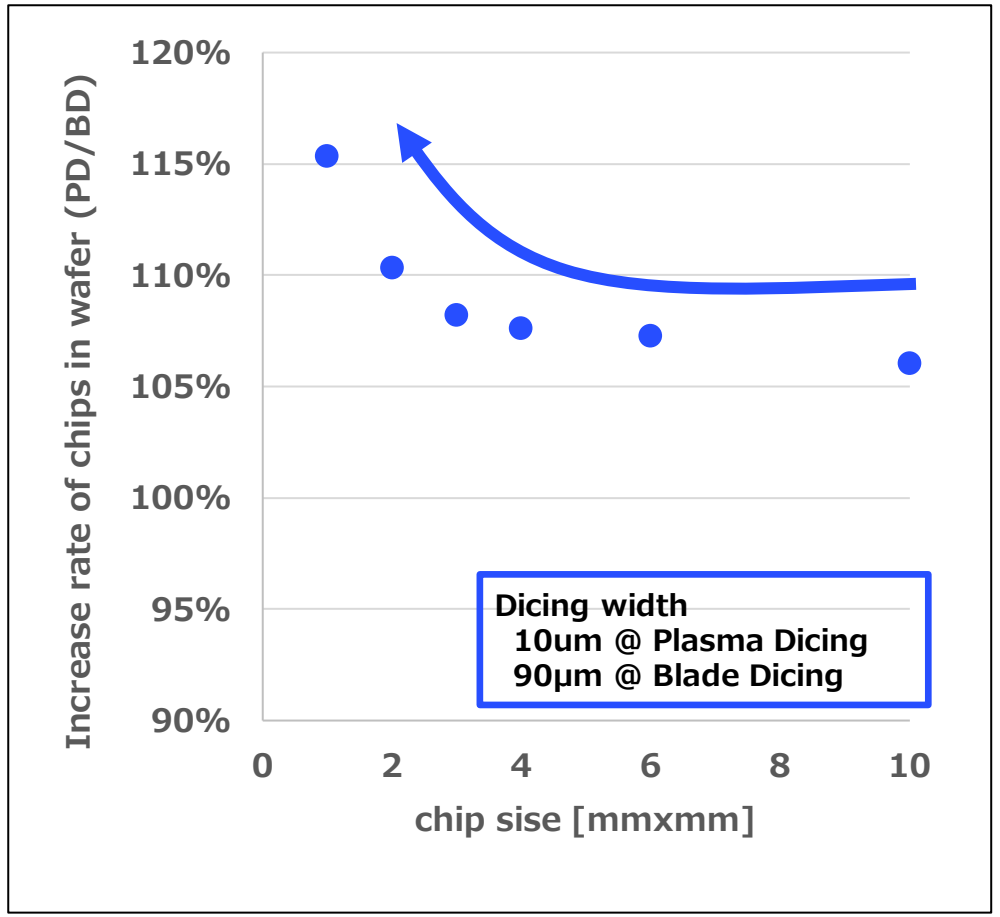


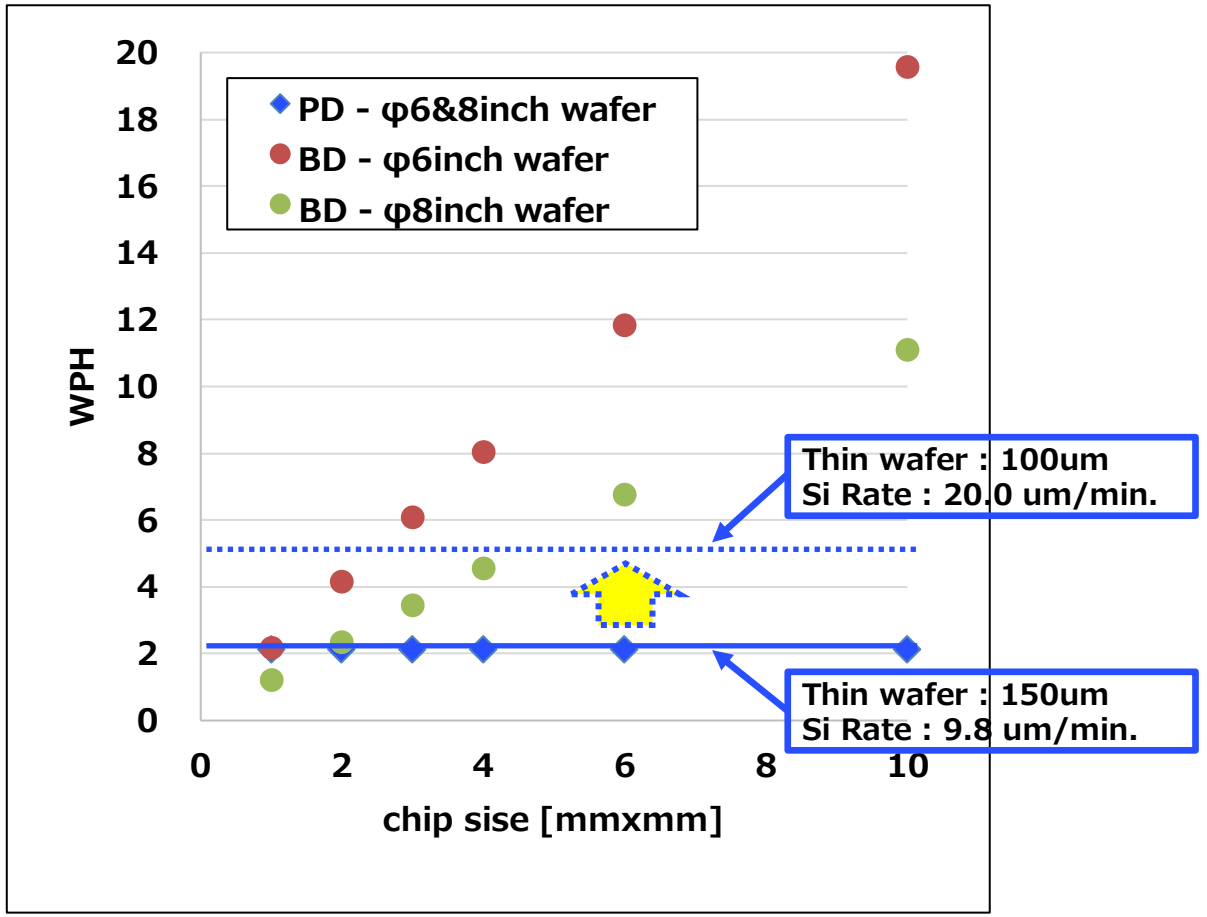


Si Layer Etching : Etching rate dependency on dicing width

	Dicing width [µm]			
	5µm	10µm	15µm	20µm
SEM	 	 	 	 
Si rate [µm/min.]	9.8	11.9	12.6	12.5
PR sel.	0.94	0.94	0.97	0.89

Increase Rate of PD/BD and WPH estimation





Dicing width reduction can increase the chip yield by about 15%

WPH should be improved by higher Si etching rate and thinner wafer thickness

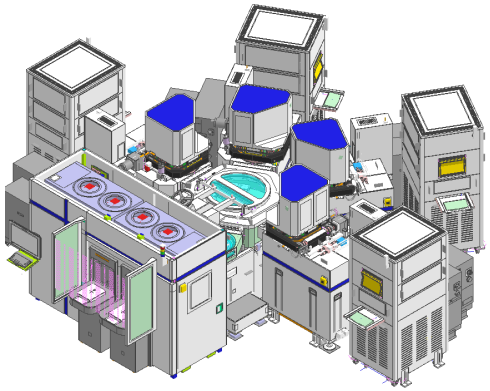
Agenda

1. Introduction
   - Panasonic Connect introduction
   - Process Automation Business Division introduction

2. Plasma dicing for GaN on Si
   - Background
   - Total solution for GaN on Silicon device

3. Equipment lineup for Dry Etching and Plasma Dicing
   - Plasma dicing equipment
   - Dry etching equipment
   - Introduction of Plasma Dicing Demo Center

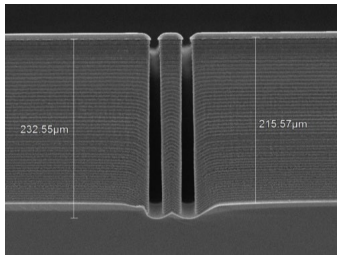
Plasma Dicing Solutions for Various Semiconductors

Machine/Specification	Applicable Device
APX300-DM 	**Compound semiconductor, small chip, MEMS and R&D** Material : Si / SiO2 / SiN / SiCN / GaAs / GaN etc., Wafer size : φ4 ~ 8inch wafer with frame for φ8inch φ12inch wafer with frame for φ12inch Max. chamber : 1ch (single chamber type)
New APX300-PD 	**Memory (DRAM, NAND), Image sensor, Logic** Material : Si / SiO2 / SiN / SiCN etc., Wafer size : φ8~12inch wafer with frame for φ12inch Max. chamber : 4ch (multi chamber type)

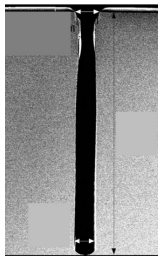
■Narrow street etching

Si dicing 5um X 175um

Si double line 10um X 220um

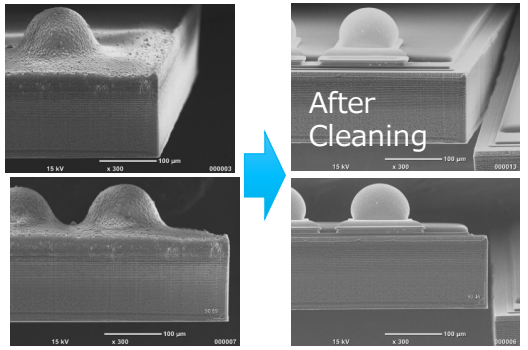


GaAs Plasma dicing 15um X 160um



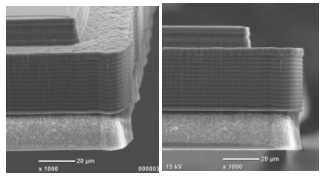
■Characteristic plasma etching

Ball bump/Device-layer/Si

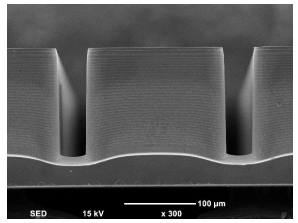


After Plasma dicing **After Washing**

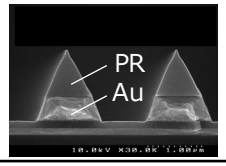
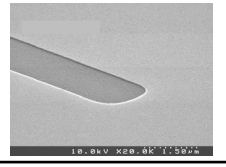
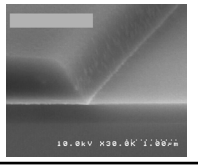
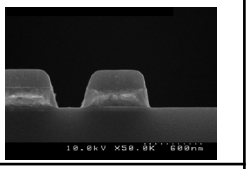
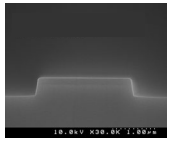
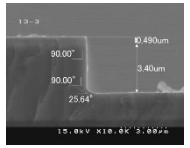
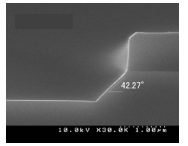
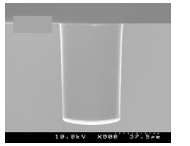
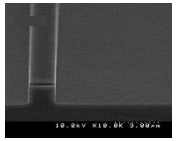
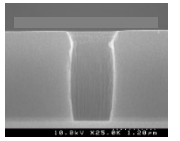
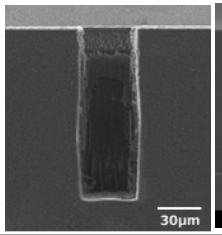
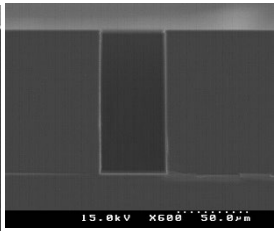
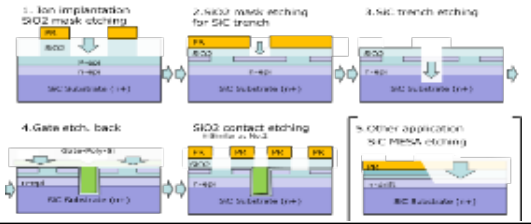
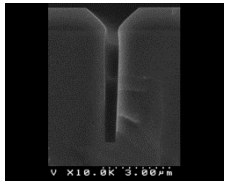
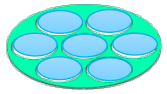
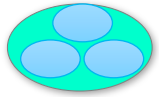
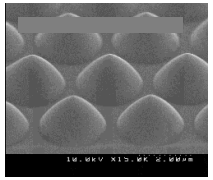
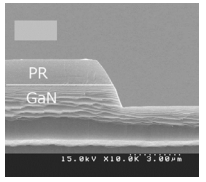
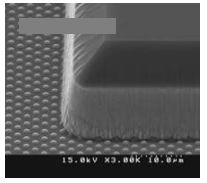
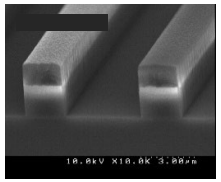
Si with DAF



GaAs smooth sidewall



Dry Etching Solutions for Compound Semiconductors

Machine/Specification	Applicable Device
 **New** APX300-S **FS-ICP**	**Long MTBC*1 ICP Process for Non-volatile materials** Au / PZT / Pt for Piezo MEMS Magnetic film, Metal wiring for MEMS and Magnetic sensor Capacitor for compound *1 MTBC : mean-time-between-clean Au  NiCo  NiFe  Pt 
 APX300-S **MSC-ICP**	**High Precision Multi-Spiral-Coil ICP Process** GaAs High Frequency / Optronics (Recess, GaAs MESA, VIA) GaN High Frequency / Optronics (Recess, MESA, Isolation) InP Optronics (MESA, VIA) SiC Power (MESA, Trench, Etch. Back) Passivation (SiO2, SiN, BCB, PI, etc.) GaAs MESA  GaN Isolation  SiC MESA  GaAs VIA  InP MESA  BCB 
 APX300-S **BM-ICP**	**High Density Plasma Process** Si / SiC VIA for GaN HEMT All SiC trench process (SiO2 mask, Trench, Etch-Back) SiC VIA  Si VIA  SiC total flow  SiC Trench 
 APX300 Batch processing	**Batch Processing for Mass-production** LED (PSS, GaN MESA, GaN Isolation, SiO2, etc.) SiO2 mask etching, etc.  Φ4” x 7  Φ6” x 3 PSS  GaN MESA  GaN Isolation  SiO2 Mask 

Demo Centers in Osaka

■ Plasma Dicing Demo Center

Location: Osaka, Japan
Floor Space: 230m^2
Wafer size: Φ200mm up to Φ300mm
Equipment: Plasma Dicer, Plasma Cleaner, Back-grinder, Photo-lithography, Laser Patterning, Measurement tools, etc.

■ Dry Etching Demo Center

Location : Osaka, Japan
Floor Space : 275m^2
Wafer: Up to Φ200mm or 340mm tray
Equipment: Dry Etcher, Plasma Cleaner, Measurement tools, etc.

Panasonic provides and supports customers with the "Total Solutions Approach" for Plasma Dicing and Dry Etching, together with our partners.

Conclusions and Acknowledgments

Plasma dicing for GaN on silicon

Panasonic can propose Plasma Dicing technology to singulate GaN on Silicon wafers.
Panasonic developed and demonstrated suitable process flows for GaN on Silicon wafers :

1. Photo-lithography :
   photo-lithography with / without metal ring and tape can be performed.
2. Plasma Dicing :
   - GaN multi layer can be fully cut by using Chlorine-based gases.
   - Si layer also can be etched by using Flourine-based gases in the same chamber for GaN layer.

Panasonic continue to improve Plasma Dicing technology for GaN on Silicon and intend to expand its application to other compound semiconductors such as GaN, etc.

- High etching rate,

Acknowledgments:

Thank you very much to EV Group for their cooperation, and to several other chemical manufacturers.

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Visit our website

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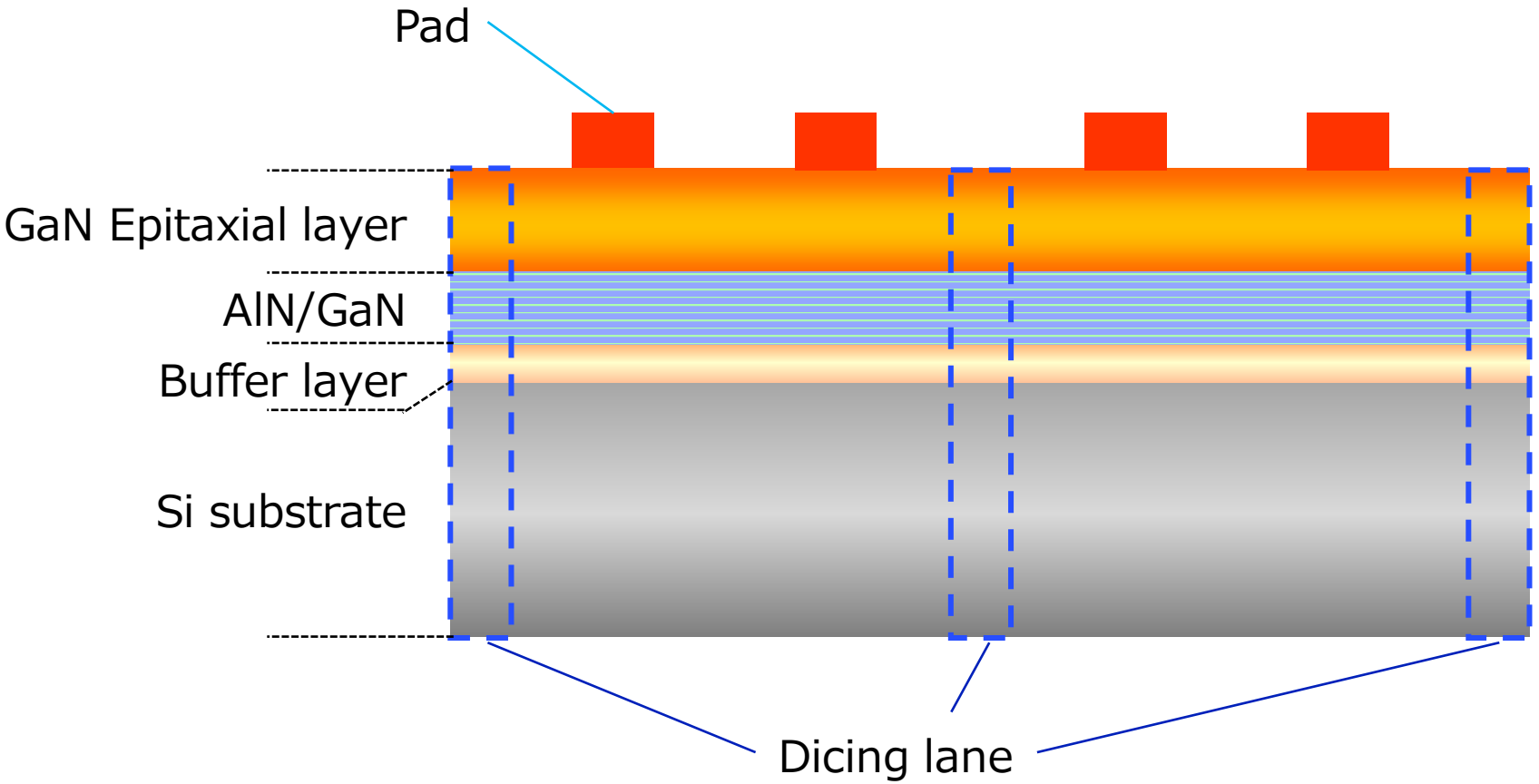
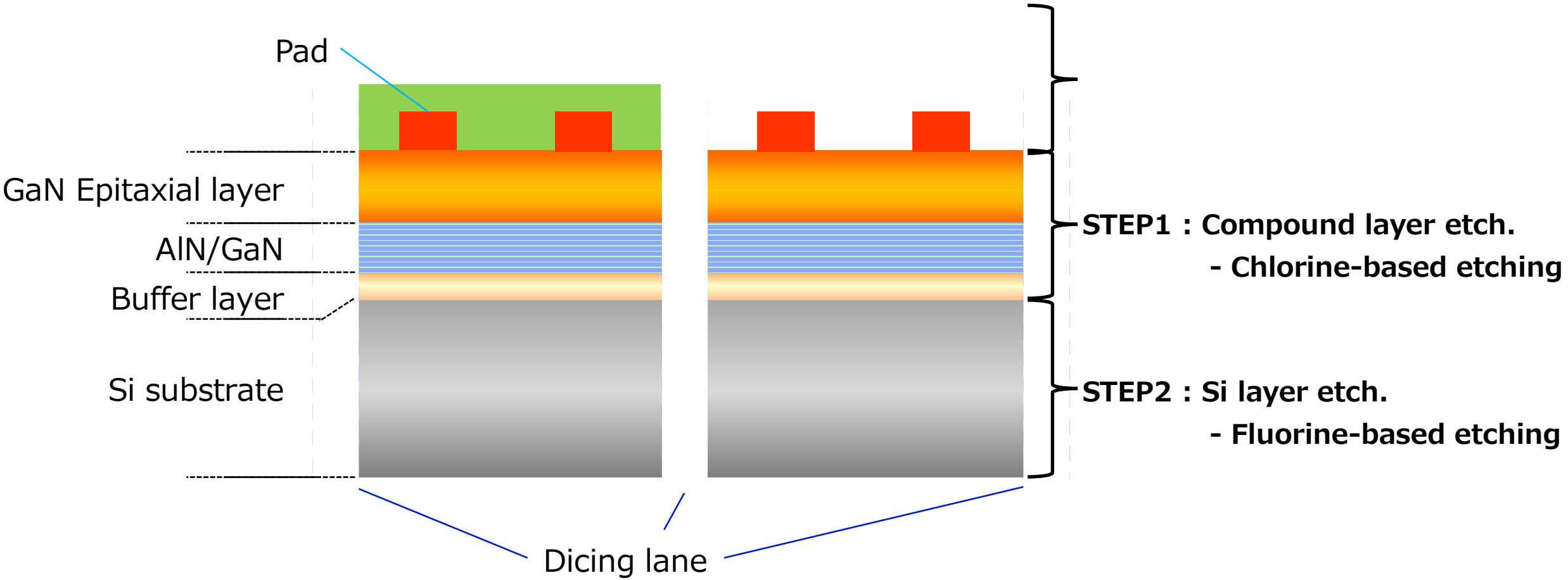
CONNECT

Plasma dicing for GaN on Silicon

Initial condition



Plasma dicing for GaN on Silicon



Plasma dicing for GaN on Silicon