SCREEN

Facing SiC challenges thanks to UV Laser Annealing Products from SCREEN

April 16th, 2024

SCREEN Semiconductor Solutions Co., Ltd.

80th Anniversary

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Introduction

- ♦ **Company Introduction – SCREEN**
- ♦ **Silicon Carbide Market Emergence**
- ♦ **Laser Annealing for the Semiconductor Industry**
- ♦ **Product Introduction – LT-3100**
- ♦ **Backside Ohmic Contact Formation with LT-3100**
- ♦ **Extending UV- Laser Annealing applications for SiC Devices**
- ♦ **Conclusion**

Company Introduction :
SCREEN

SCREEN Group Business & Organization

SCREEN Holdings

Corporate Philosophy

Purpose

Innovation for a Sustainable World

Sharing the Future	Building a better future for society with commitment and integrity
Personal Development	Realizing everyone's full potential through trust and teamwork
The Pursuit of Technological Excellence	Exploring technologies while integrating with innovative collaboration

Founder's Motto

Shi Ko Ten Kai	Broadening everyone's thoughts and horizons for innovation

Business Operating Company

- SCREEN Semiconductor Solutions
- SCREEN Graphic Solutions
- SCREEN Finetech Solutions
- SCREEN PE Solutions
- SCREEN Advanced System Solutions

Subsidiaries of Holding Company

Functional Support Company

- SCREEN IP Solutions

Subsidiaries of the Business Operating Company

Overseas Bases: Europe

● Head Office

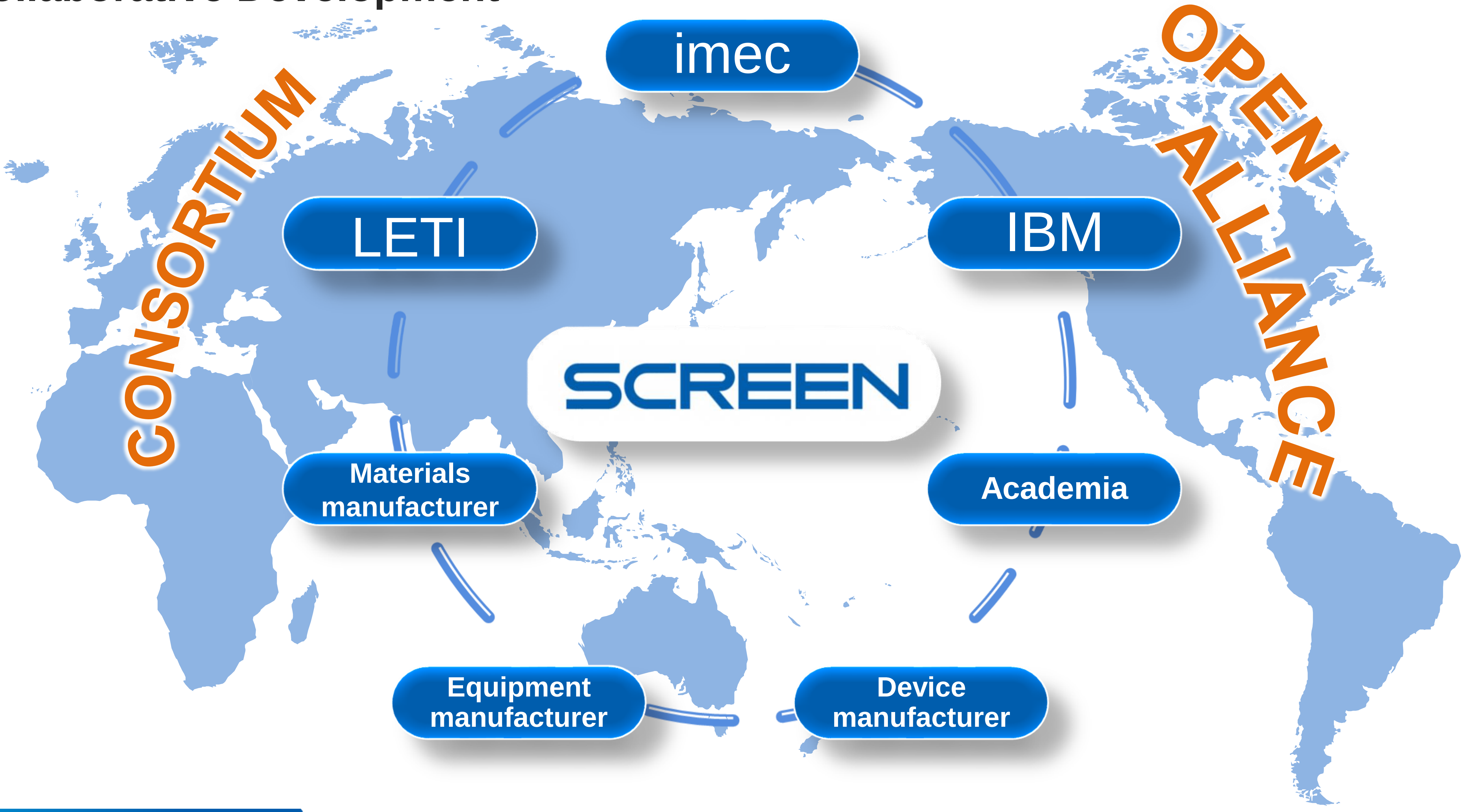
● Other Office

SCREEN SPE Germany GmbH

Laser Systems & Solutions of Europe (LASSE)

- Headquarters: Paris (France)
- Development and manufacturing of laser annealing equipment
- Employees: 60+
- Clean Room Area: 2500 m²

Collaborative Development

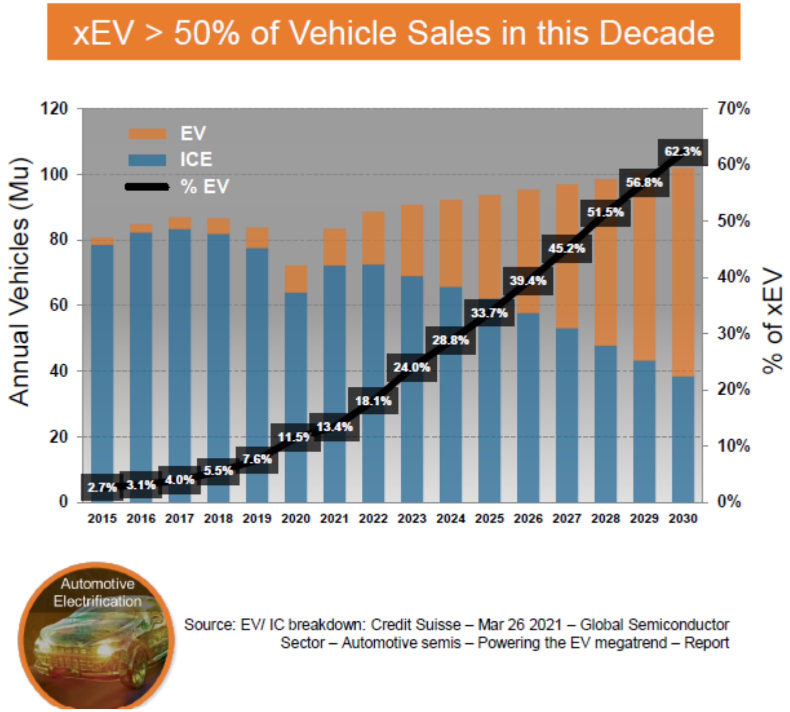


Silicon Carbide :

Market evolution and futures challenges

Electrical Cars Market Evolution

The production of **Electrical Vehicle (EV)** is expected to drastically **increase** within this decade to fulfill countries engagements in their **greenhouse emissions** reduction policy.



Source: EV/ IC breakdown: Credit Suisse – Mar 26 2021 – Global Semiconductor Sector – Automotive semis – Powering the EV megatrend – Report

Electrical Cars Market Evolution

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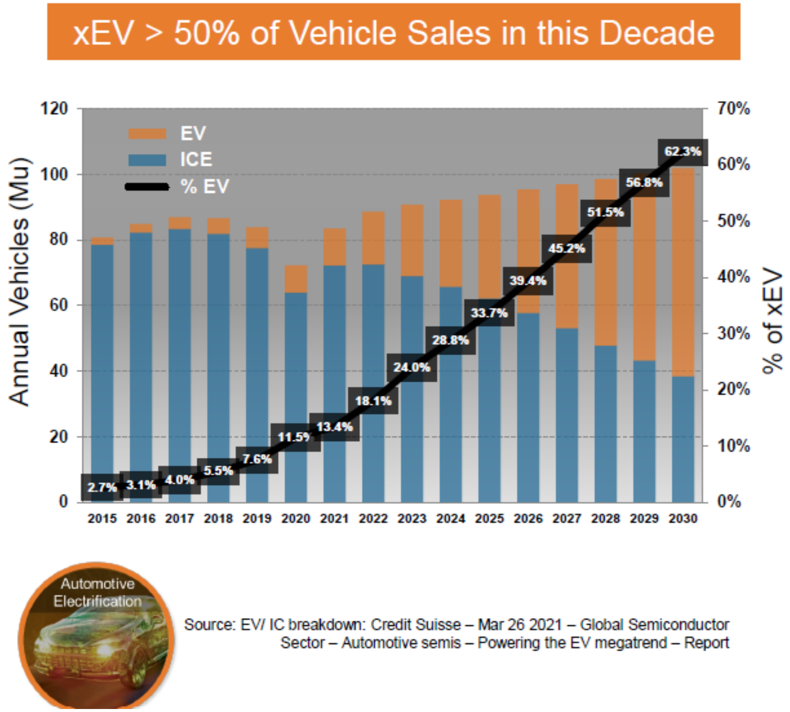
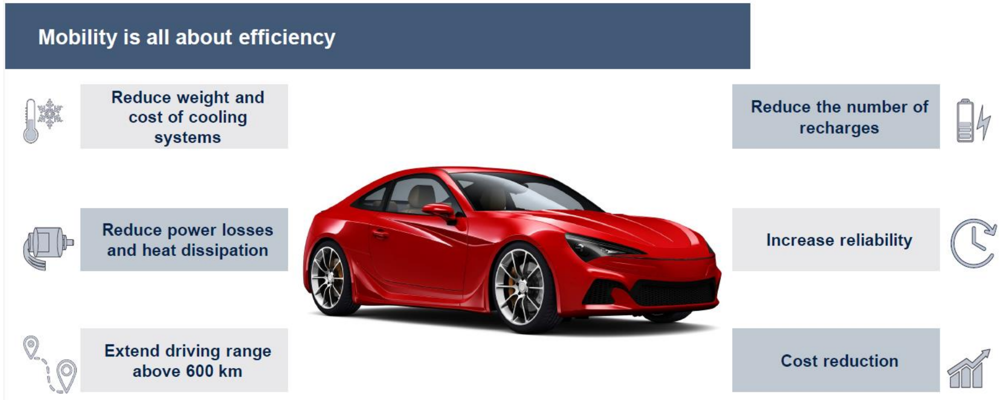


Source: EV/ IC breakdown: Credit Suisse – Mar 26 2021 – Global Semiconductor Sector – Automotive semis – Powering the EV megatrend – Report

However, mass-scale adoption of EV remains challenging due to their high costs and limited performances in term of autonomy.

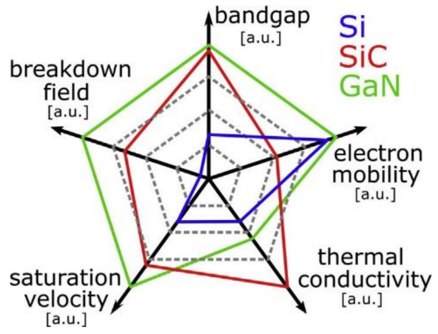
➔ **Trade-off Performance/Cost**



Source : Silicon Carbide offers high hopes for EVs, but can they meet stringent automotive quality levels ?, F. Di Giovani, STM, CSE23

What are the solutions to face EV mass-adoption challenges ?

Silicon Carbide



Intrinsic properties
- Three times the thermal conductivity of silicon.
- Three times wider bandgap than silicon, allowing a breakdown field ten times higher.

Device performance
- High current density
- Fast switching
- High temperature operation
- Low Rdson

System benefits
- Simpler cooling systems
- Smaller passive components
- Higher efficiency
- Reduction of conduction and switching loss

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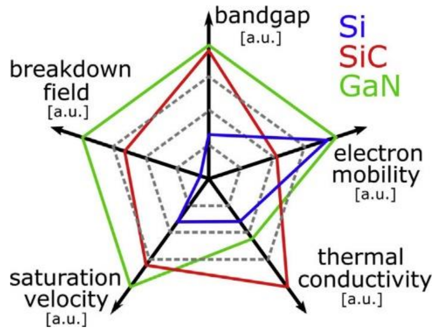

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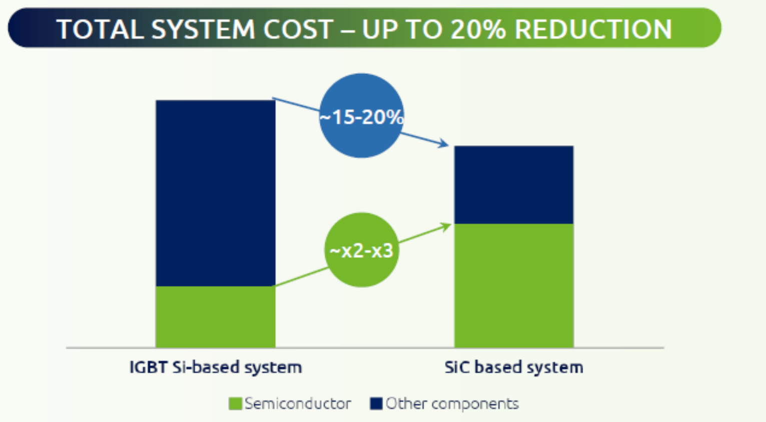


Shorter charge time 800V	~50% faster
Increase battery range	5% – 10% more range
Reduce system / battery costs	$500 – $1,000 savings

Source :SmartSiC™ from SOITEC a greener, faster and better technology for SiC , E. Sabonnadière, SOITEC, CSE23

However, manufacturing of high performances SiC devices at reduced costs remain challenging...

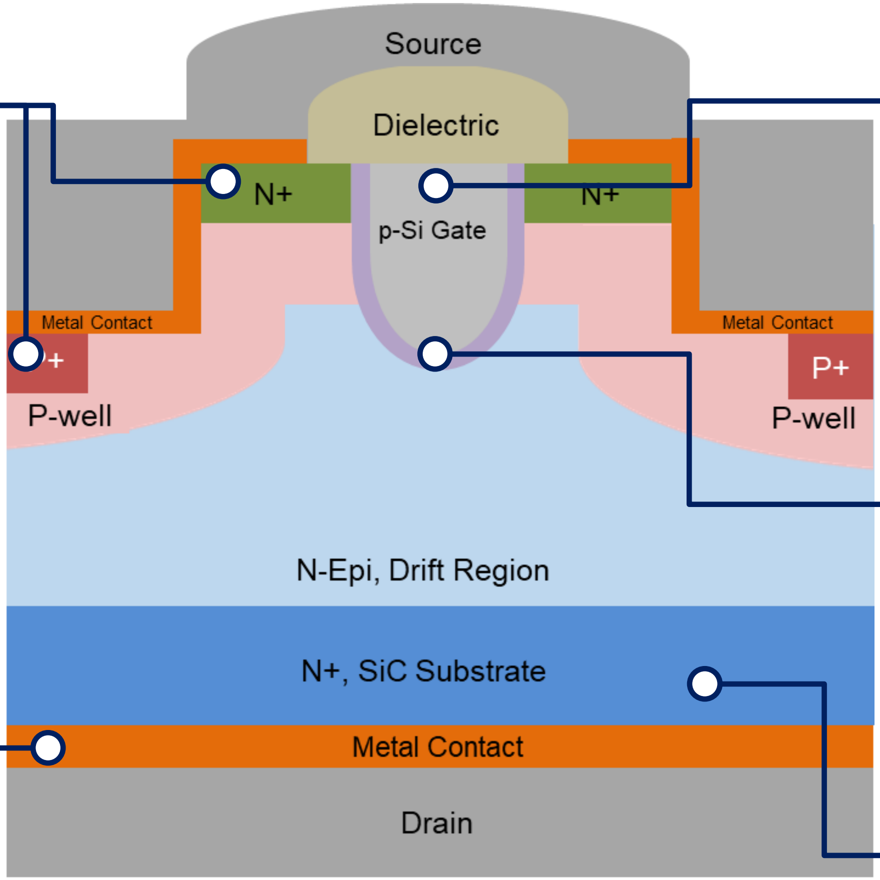
SiC – Technical Challenges

Dopant Activation

- Costly and complex for limited activation ratio.

BS Metal Contact Formation

- Risky and complex integration (double flip).



Trench Formation

- Complex and expensive (multiple cycles Implant/etch).

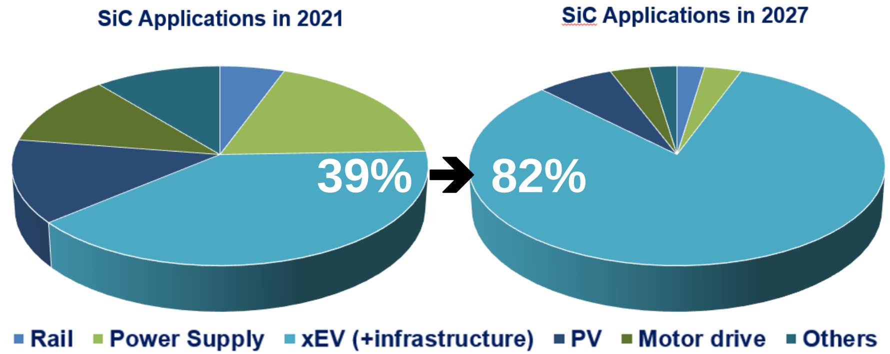
Gate Stack Reliability

- Traps at the SiO_2/SiC reduces carriers mobility.

Substrate Quality

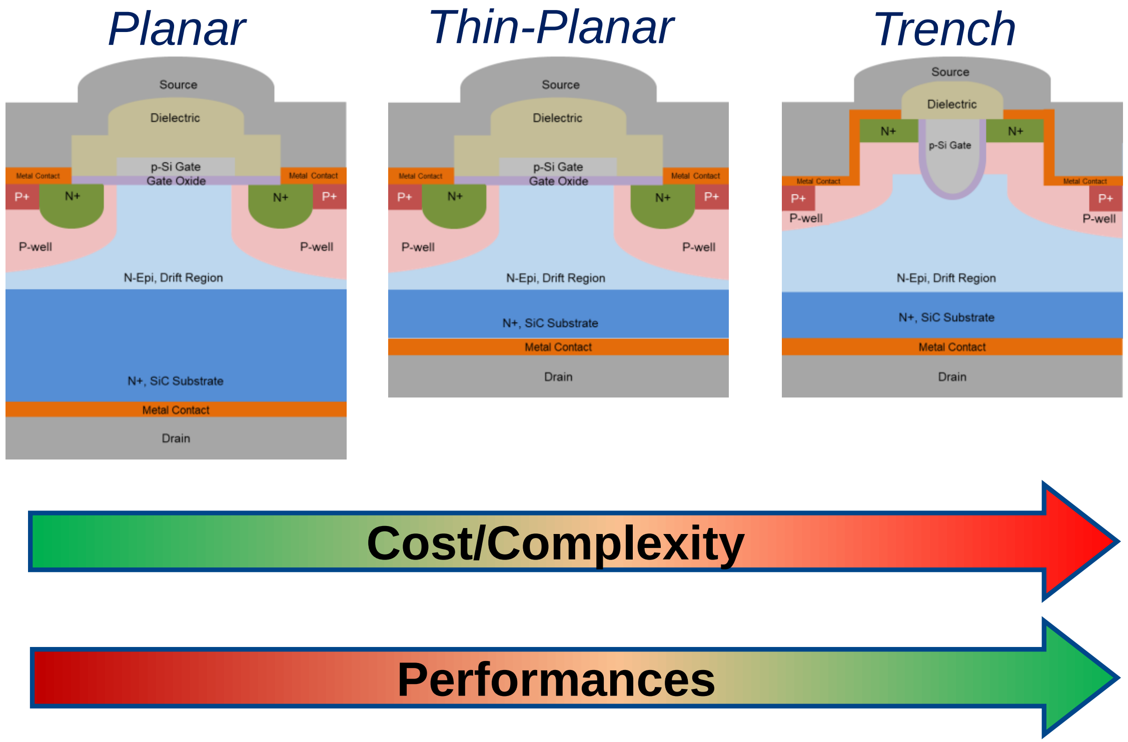
- Important substrate defectivity reduces overall performances.

SiC Market Evolution – Summarize



Source : Yole development

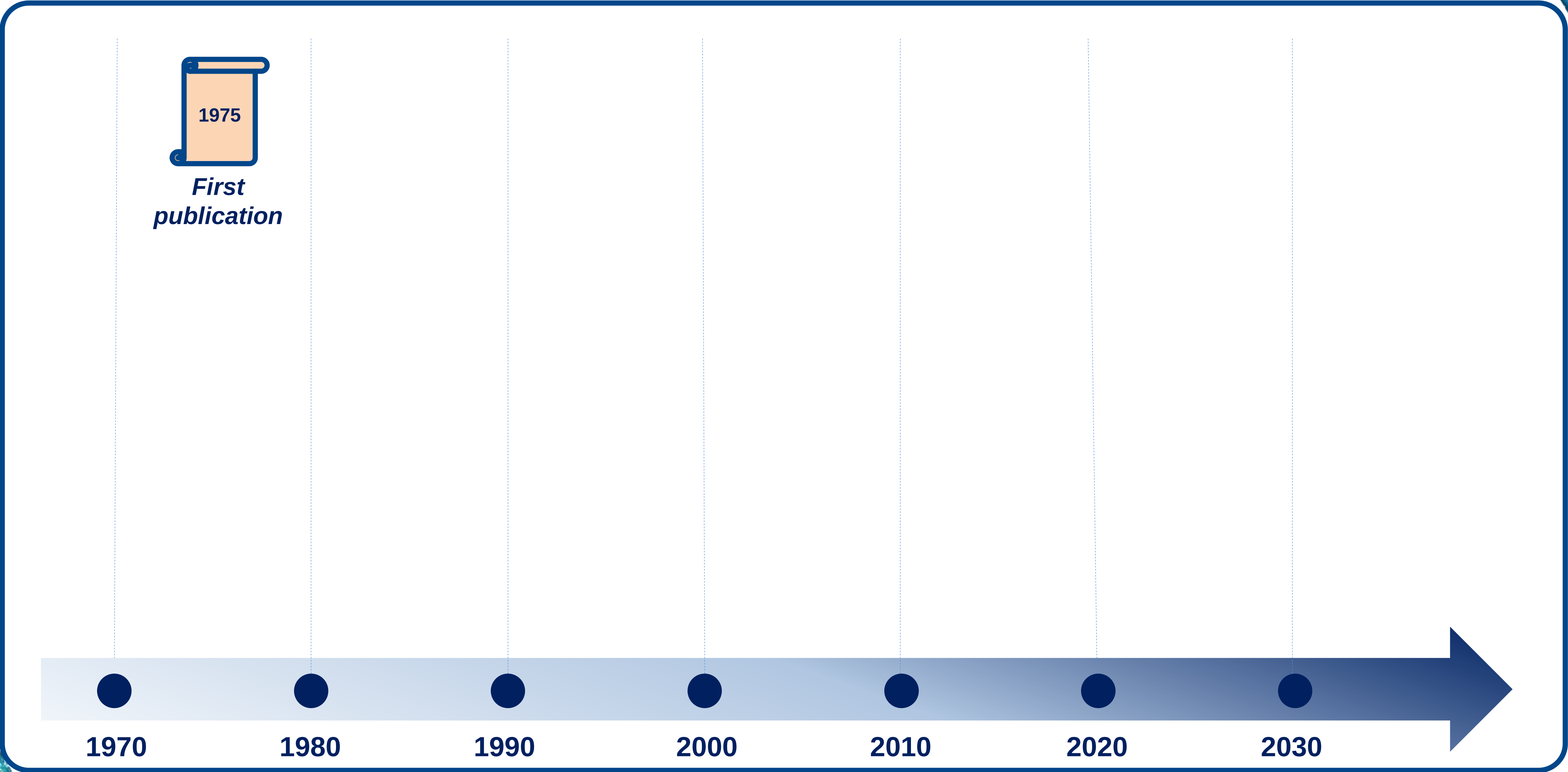
Evolution of SiC MOSFET-based devices



Main guidelines for SiC Market		
Improve devices performances	Reduce manufacturing costs	Transposable solutions from 6” to 8”

Laser Annealing for the semiconductor industry

Laser Annealing for the Semiconductor industry

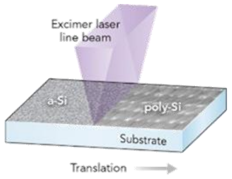


Laser Annealing for the Semiconductor industry

SCREEN

1975

First publication



Flat Panel

1970 **1980** **1990** **2000** **2010** **2020** **2030**

Laser Annealing for the Semiconductor industry

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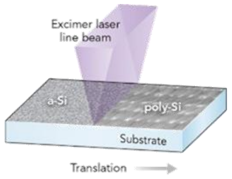

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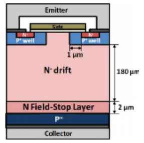

Si IGBT

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Laser Annealing for the Semiconductor industry

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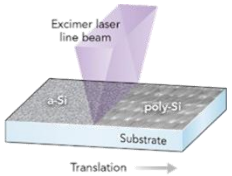

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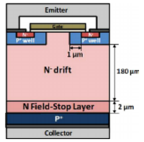

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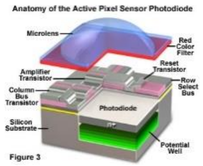

CIS

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Laser Annealing for the Semiconductor industry

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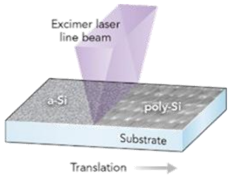

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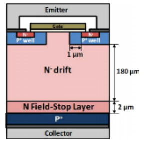

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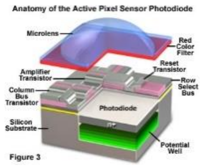
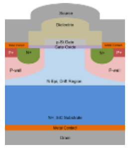


CIS



SiC MOSFET/Diodes

1970 | 1980 | 1990 | 2000 | 2010 | 2020 | 2030

Laser Annealing for the Semiconductor industry

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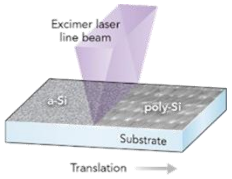

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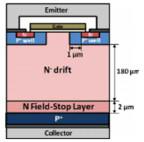

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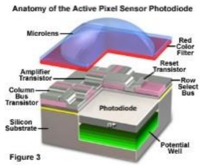

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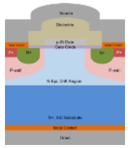
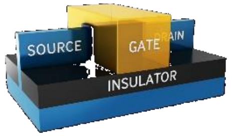


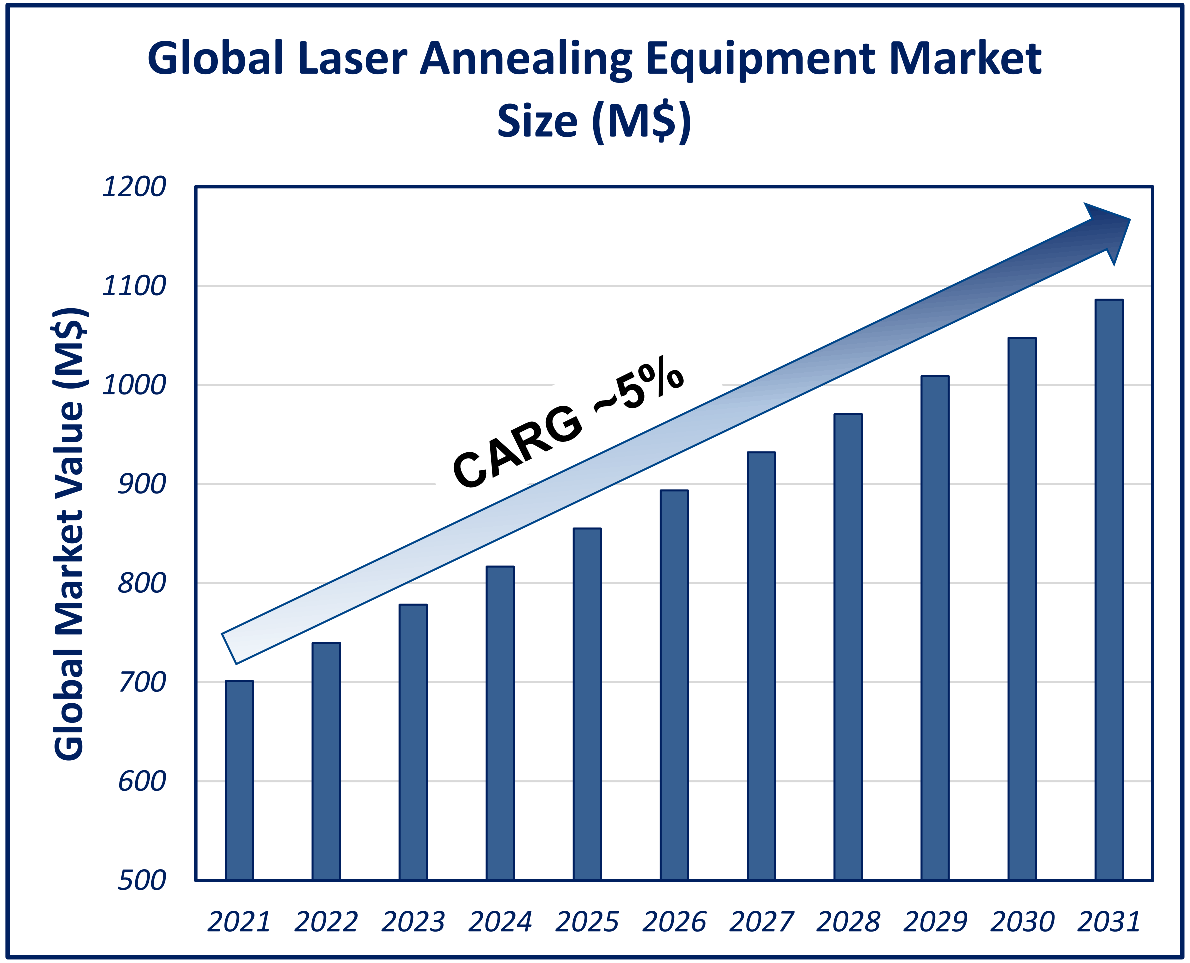
SiC MOSFET/Diodes



Advanced IC

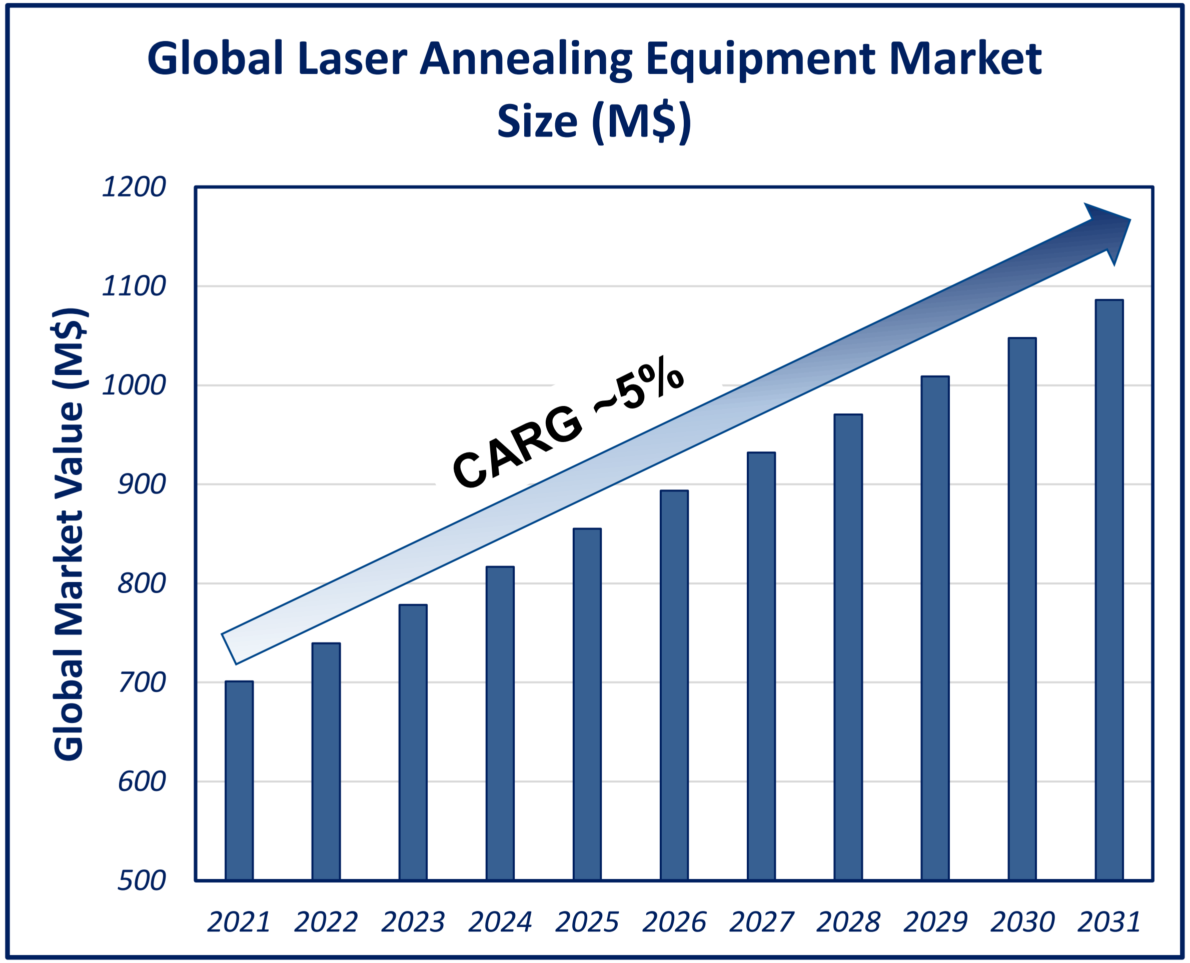
1970 | 1980 | 1990 | 2000 | 2010 | 2020 | 2030

Laser Annealing – Market Evolution



Source : www.businessresearchinsights.com

Laser Annealing – Market Evolution



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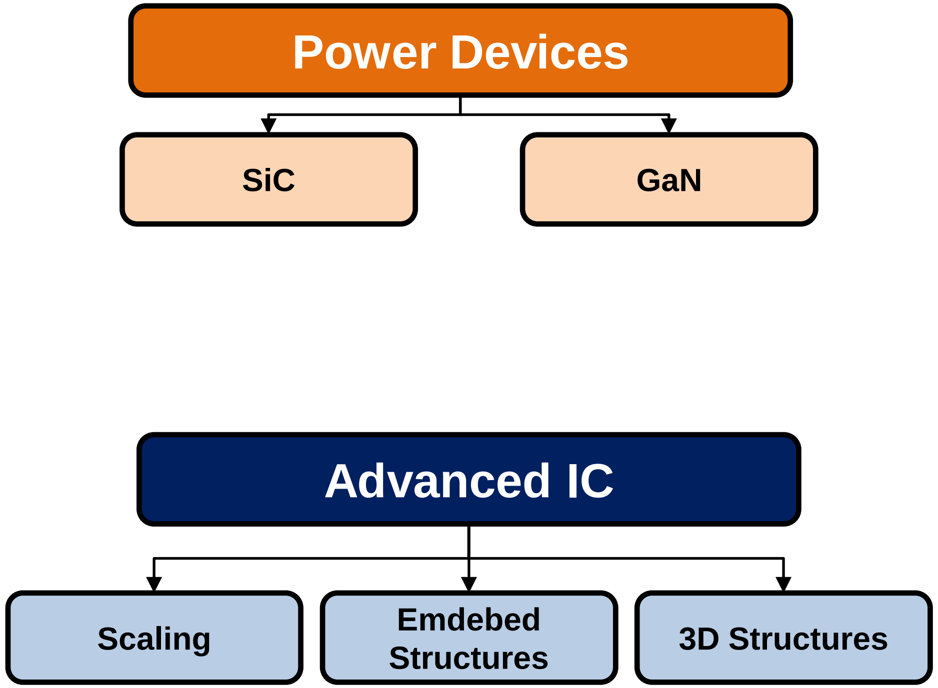
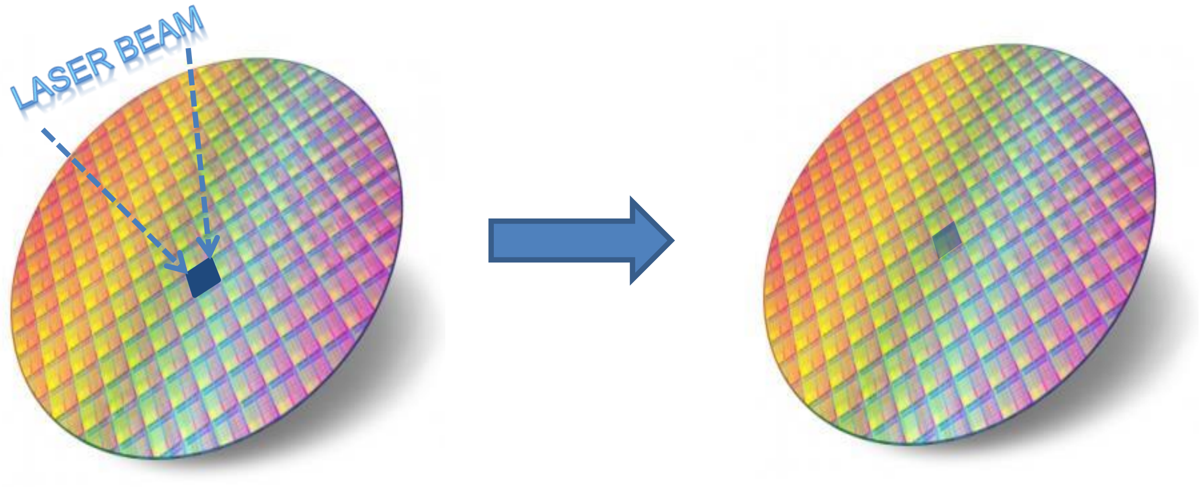
Main Drivers :



Product Presentation :
LT-3100

LT-3100 : Product Presentation

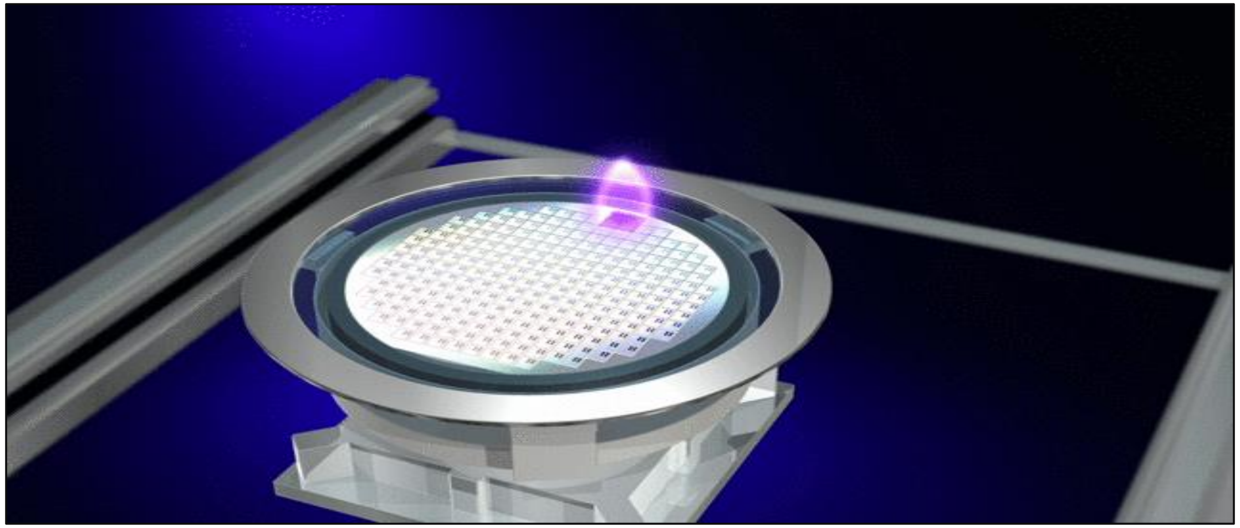
The LT3100 is a step and repeat high energy UV laser annealing tool.				
160 ns pulse	**308 nm wavelength**	**Up to 9J/pulse**		**Adjustable size**
Short time annealing	Shallow annealing	High temperature annealing (up to melt)	One or several dies simultaneous annealing	Adjustable to the shape of the die



For more information *: https://www.screen.co.jp/spe/en/products/lt-3100*

LT-3100 : Product Presentation

Step & Repeat



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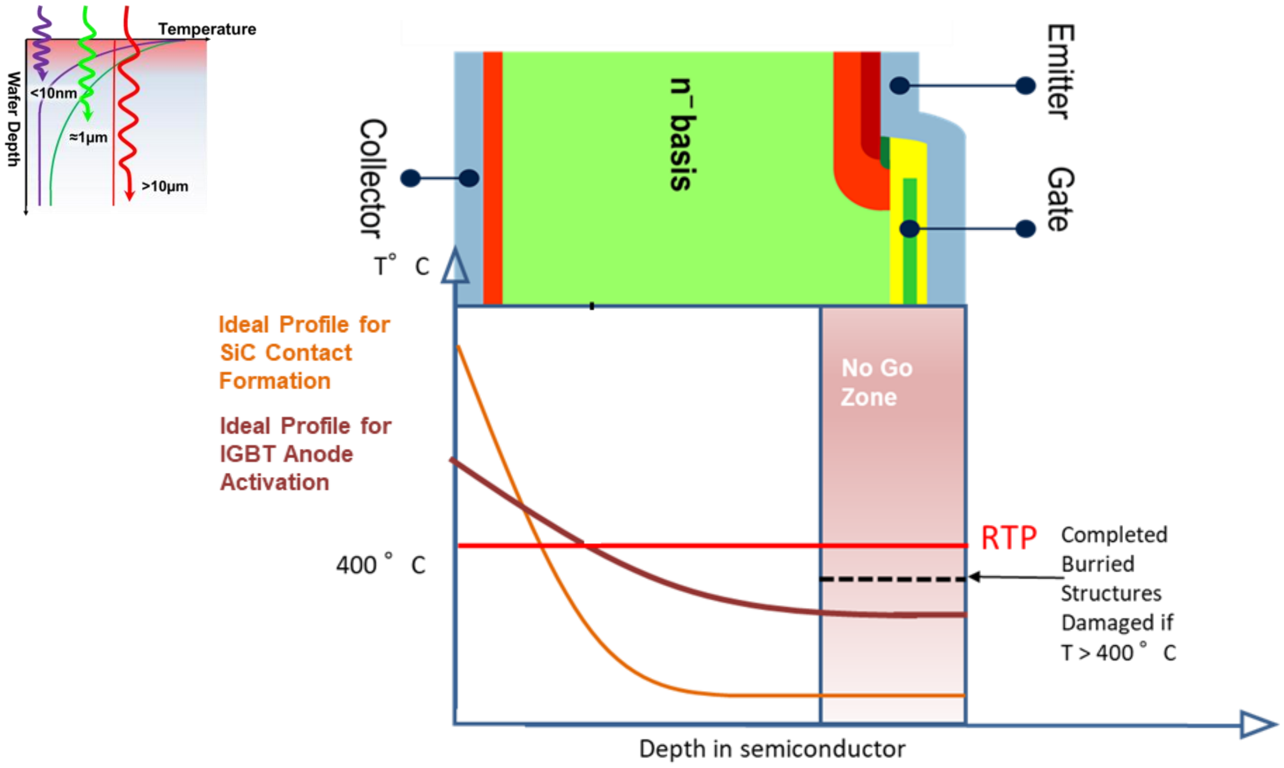
UV + nanosecond anneal ➔ Ultra Low Thermal Budget



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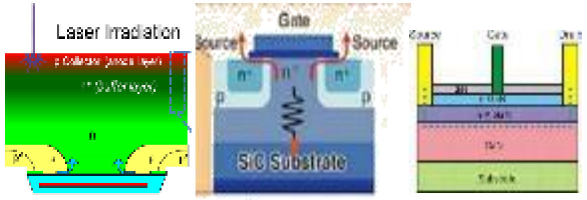
LT-3100 : Product Presentation

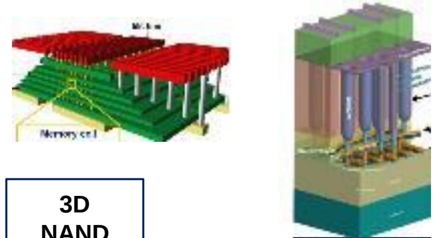
Compatible with a wide range of technologies !

Power Devices



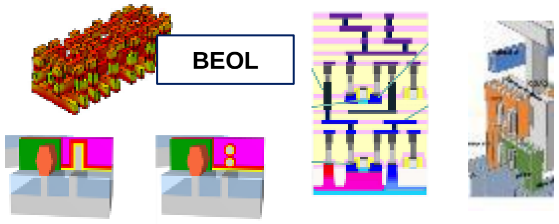
Si *IGBT* | **SiC** *MOSFET* | **GaN** *HEMT*

Memory



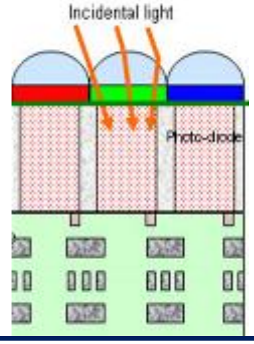
3D NAND | **DRAM**

Advanced Logic



BEOL | **FinFET** | **GAA** | **3D** | **CFET**

Imaging Sensor



BSI-CIS

For more information *: https://www.screen.co.jp/spe/en/products/lt-3100*

LT-3100 : Product Presentation

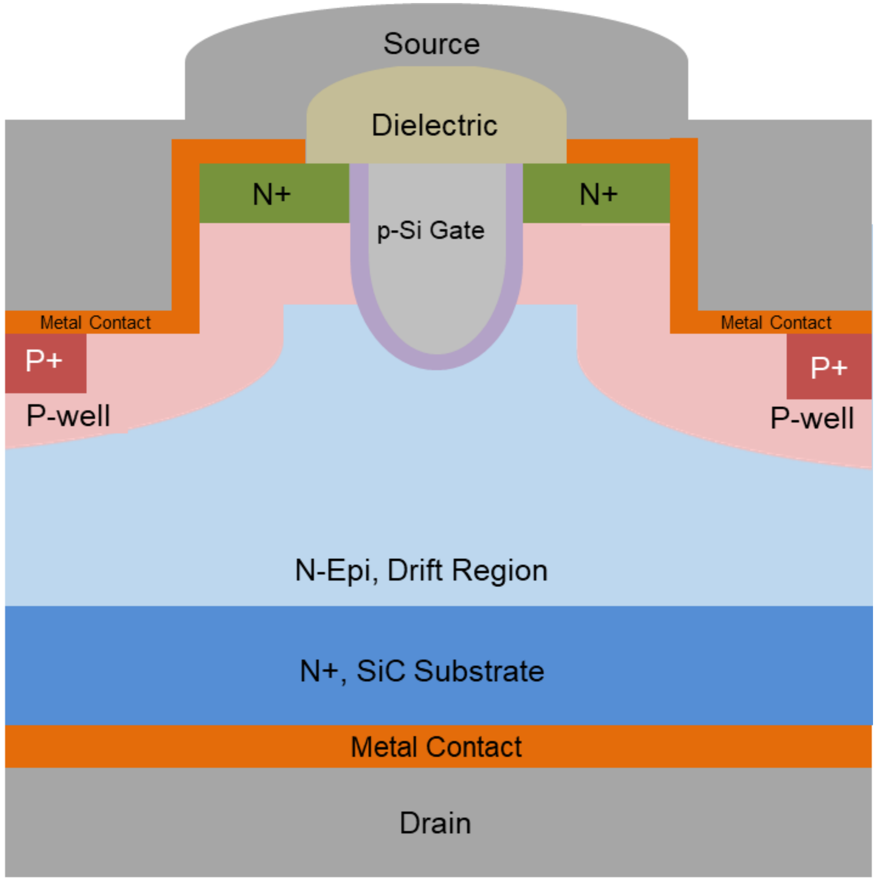
Highlights

- ➔ **Ultra Low Thermal Budget**
- ➔ **High Productivity**
- ➔ **All wafers sizes/type compatible**
- ➔ **Compatible with existing and next power devices generation**
- ➔ **Industry Oriented**

For more information : *https://www.screen.co.jp/spe/en/products/lt-3100*

Backside Ohmic Contact Formation with LT-3100

Challenges for SiC Backside Ohmic Contact Formation



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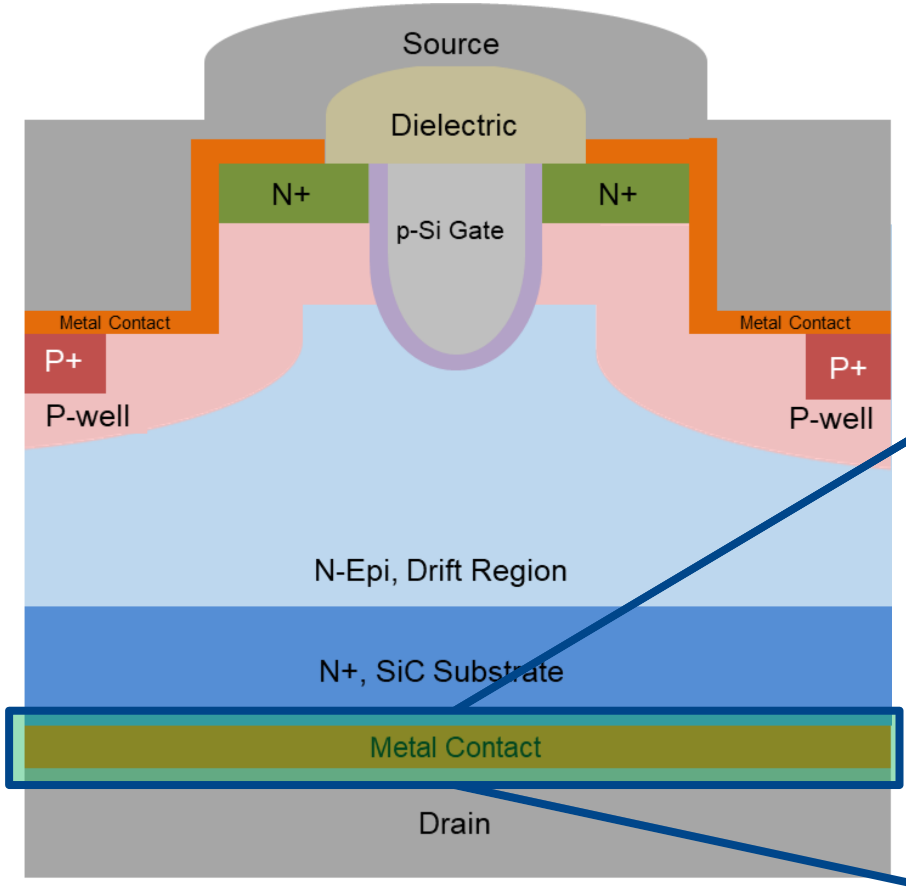
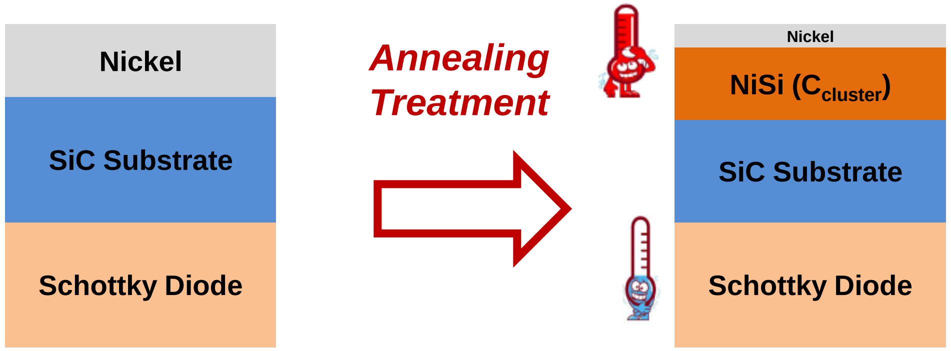
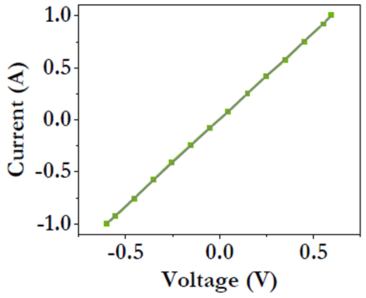


"Silicidation of SiC with Ni"



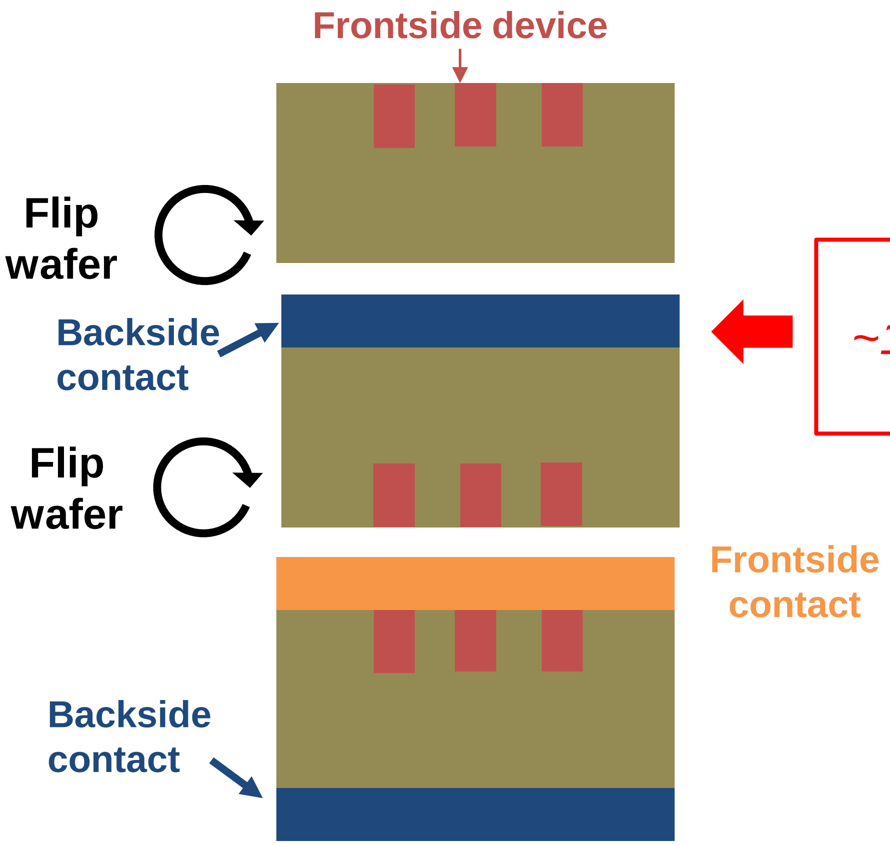


Requirements :

1. Ohmicity of the contact
2. Formation of NiSi phase
3. No/Limited remaining Ni
4. No degradation of frontside
5. Cost-friendly

Challenges for SiC Backside Ohmic Contact Formation

Standard Flow with furnace anneal forming backside ohmic contact

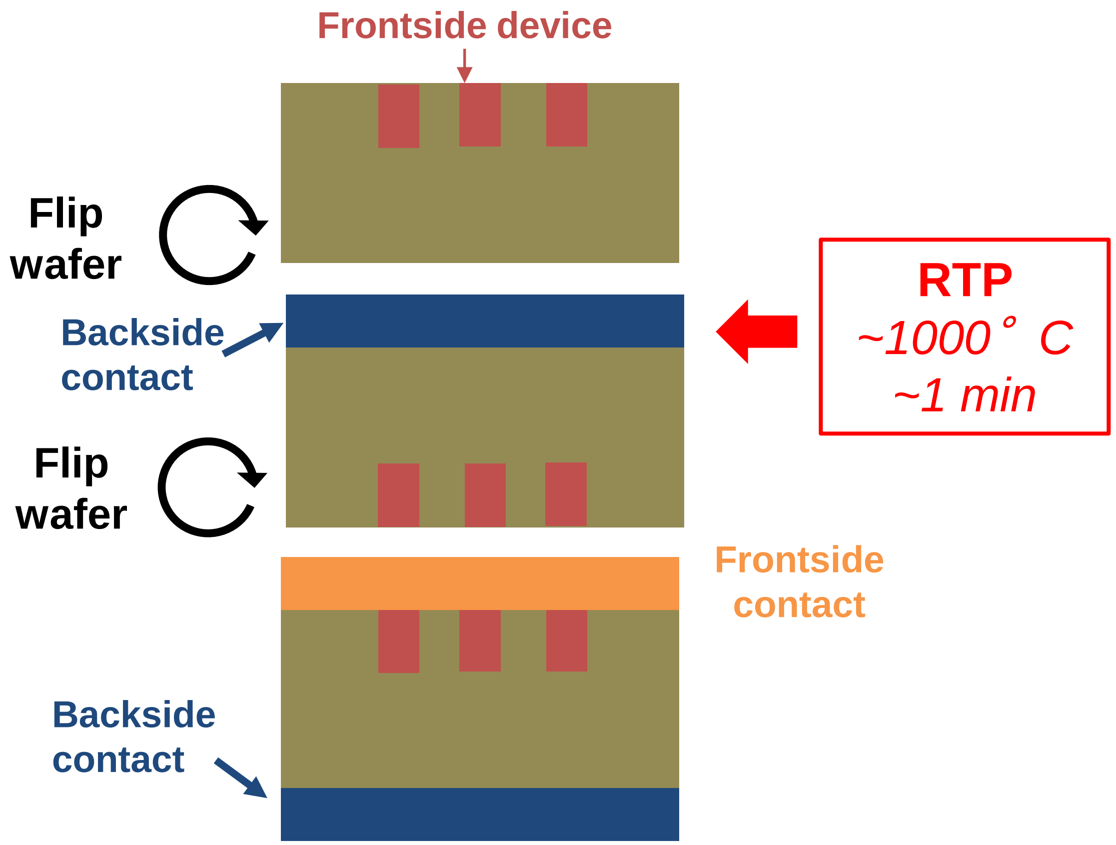


RTP
~1000° C
~1 min

Double flip (FEOL ➔ BEOL ➔ FEOL) ➔ costs and complexity increase

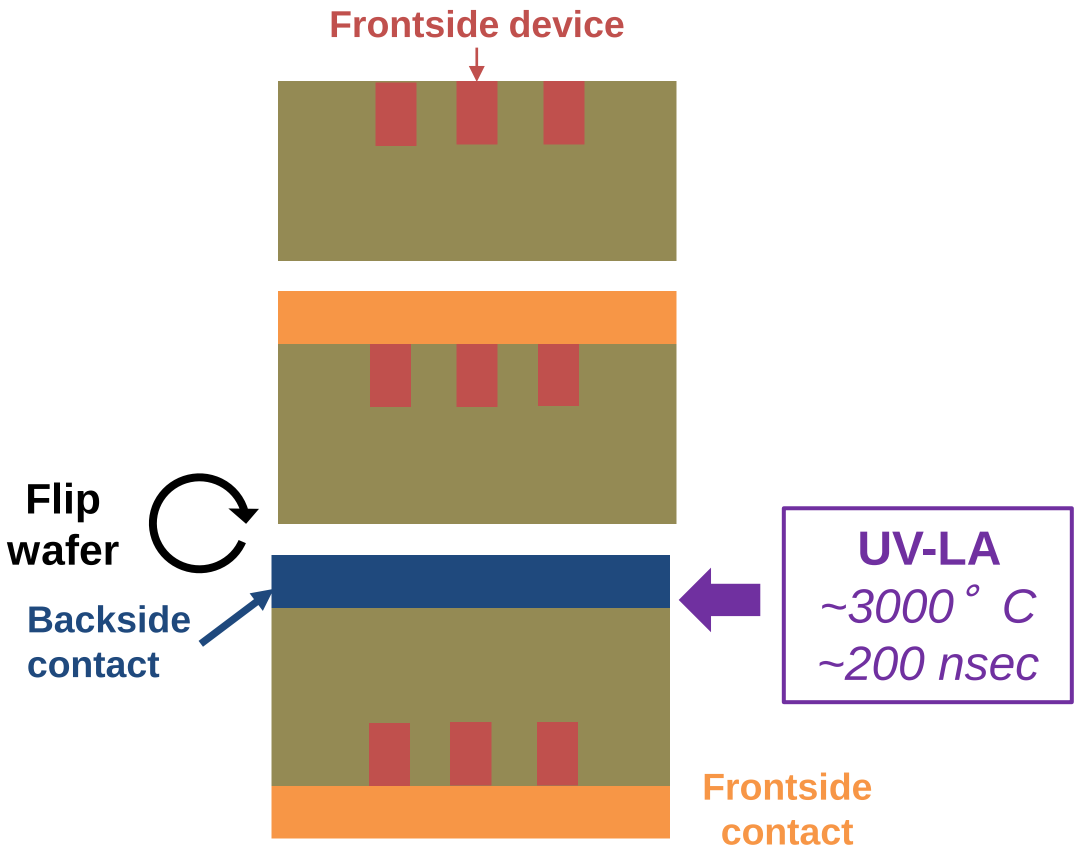
Challenges for SiC Backside Ohmic Contact Formation

Standard Flow with furnace anneal forming backside ohmic contact



Double flip (FEOL ➔ BEOL ➔ FEOL) ➔ costs and complexity increase

Flow with Laser Anneal forming backside ohmic contact

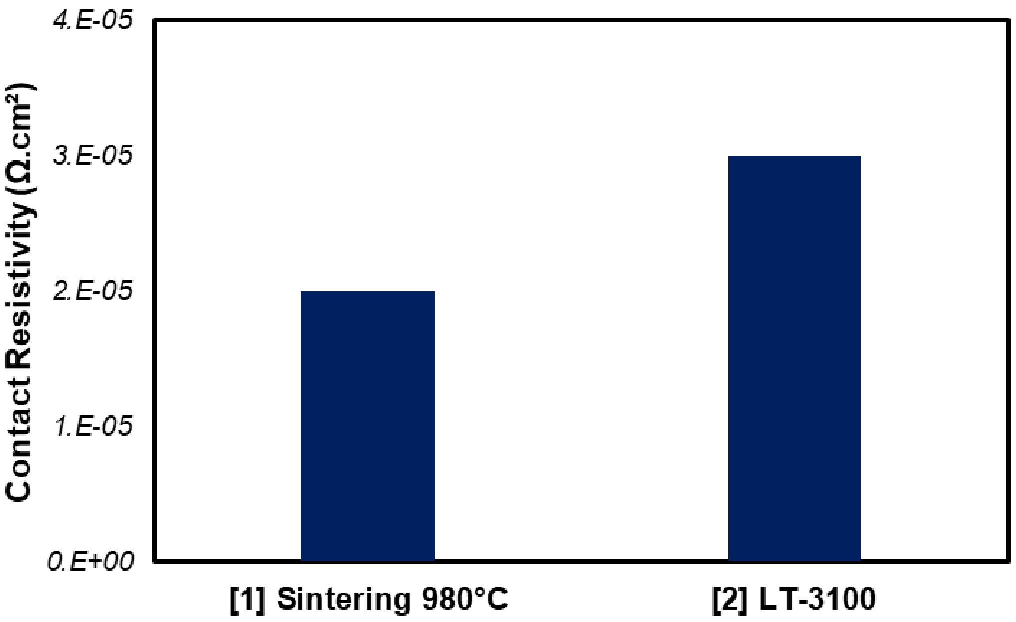


Single flip (BEOL ➔ BEOL)

Experimental Results

Requirement	Measured
1. Ohmicity	➔ ρc ~3E-05 Ω.cm² *With Nd 6E18at/cm3*
2. Formation NiSi Phase	
3. No remaining Ni	
4. No thermal degradation of Frontside	

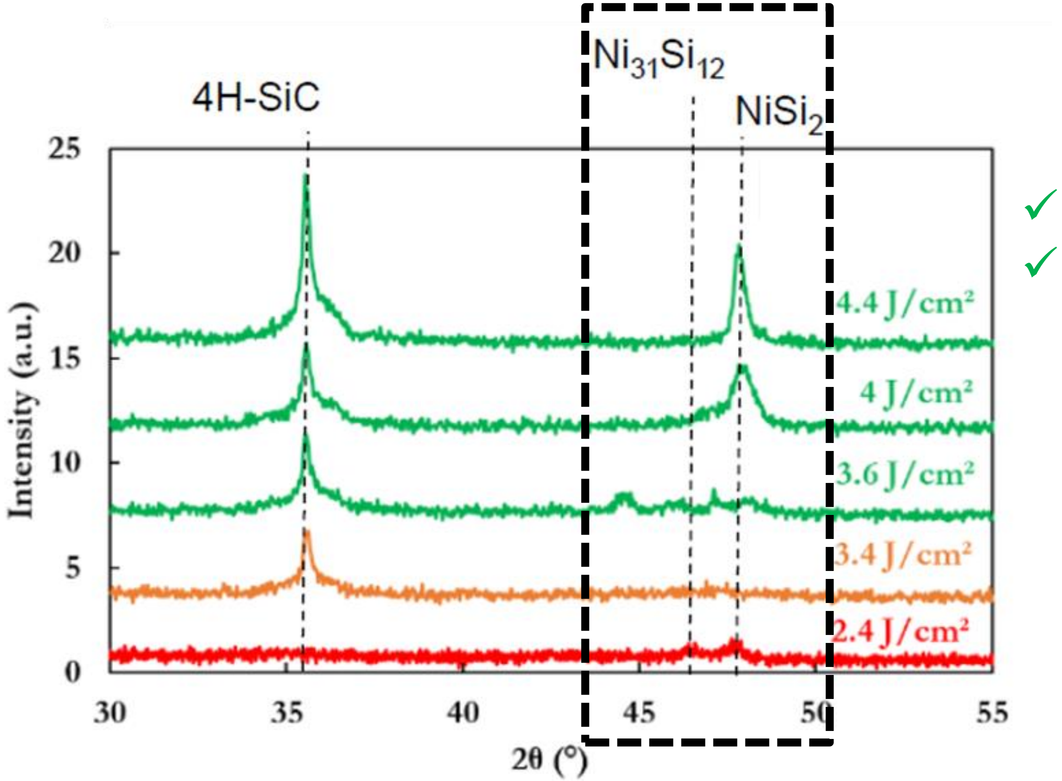
Comparison of Contact Resistivities between RTP (950° C) and Laser Annealed Ni/SiC TLM Samples



✓ Ohmic contact formed
✓ ρ_c comparable to RTP

[1] Liu et al. Appl. Phys. Lett. 114
[2] M. Opprecht, ICSCRM23

Experimental Results

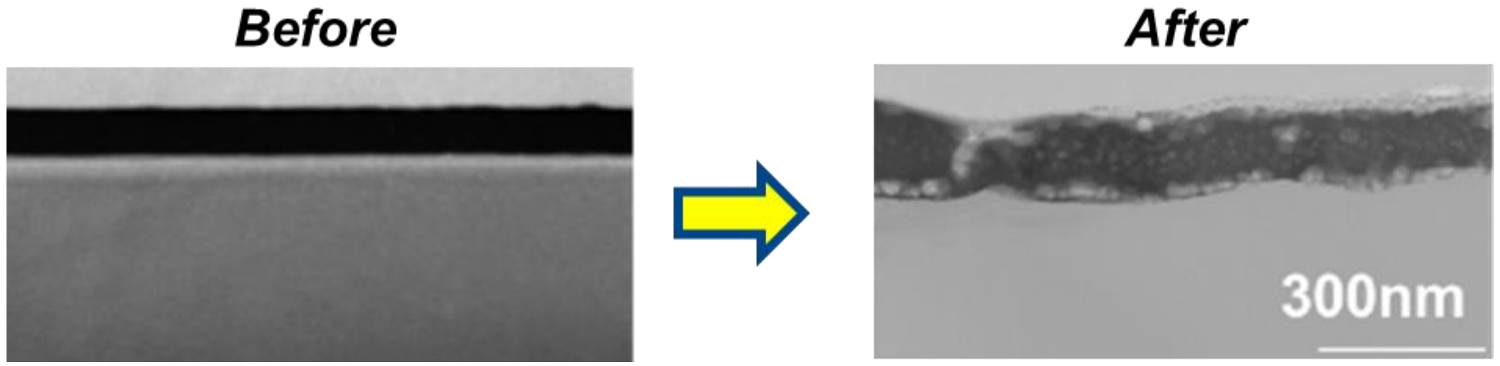
Requirement	Measured
1. Ohmicity	➔ Progressive formation of NiSi2  ✓ $NiSi_2$ phase formed ✓ Phase Control possible
2. Formation NiSi Phase	
3. No remaining Ni	
4. No thermal degradation of Frontside	

[1] Liu et al. Appl. Phys. Lett. 114
[2] M. Opprecht, ICSCRM23

Experimental Results

<table>
<tr><th>Requirement</th><th>Measured</th></tr>
<tr><td>1. Ohmicity</td><td rowspan="4">

➔ All Ni has reacted

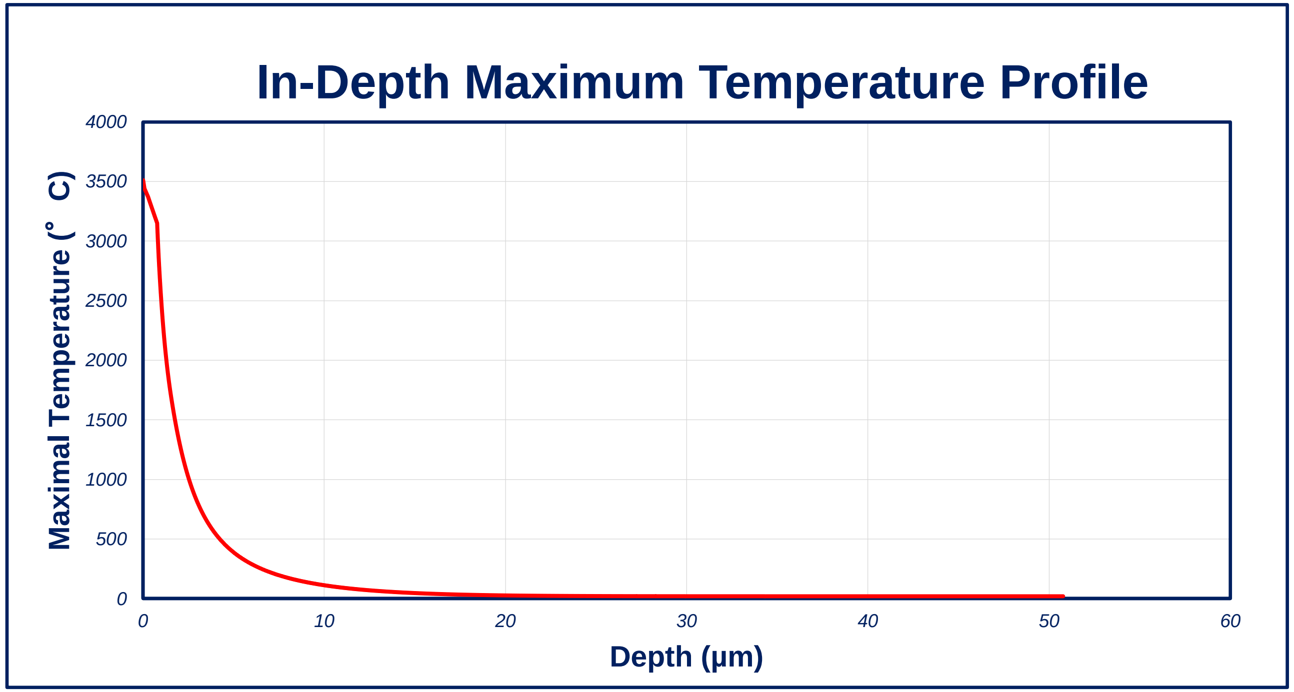


✓ No visible remaining Ni
✓ Uniform Layer of NiSi

</td></tr>
<tr><td>2. Formation NiSi Phase</td></tr>
<tr><td>3. No remaining Ni</td></tr>
<tr><td>4. No thermal degradation of Frontside</td></tr>
</table>

[1] Liu et al. Appl. Phys. Lett. 114
[2] M. Opprecht, ICSCRM23

Experimental Results

Requirement	Measured
1. Ohmicity	➔ MaxT < 25° C @20 μm
2. Formation NiSi Phase	
3. No remaining Ni	
4. No thermal degradation of Frontside	 ✓ Temperature at Frontside <25° C

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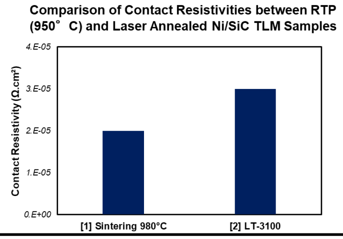
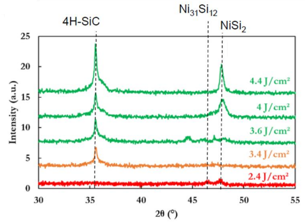
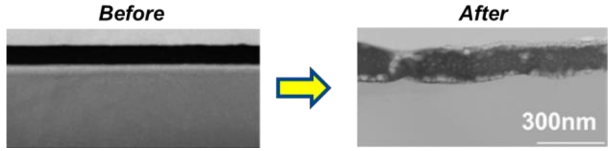
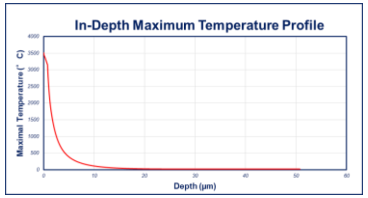
Experimental Results

Requirement	Measured	
1. Ohmicity	 ➔ ρc ~3E-05 Ω.cm² *With Nd 6E18at/cm3*	✓ Ohmic contact formed ✓ ρ_c comparable to RTP
2. Formation NiSi Phase	 ➔ Progressive formation of NiSi2	✓ $NiSi_2$ phase formed ✓ Phase Control possible
3. No remaining Ni	➔ All Ni has reacted 	✓ No visible remaining Ni ✓ Uniform Layer of NiSi
4. No thermal degradation of Frontside	 ➔ MaxT <25° C @10 µm	✓ Temperature at Frontside < 25° C

[1] Liu et al. Appl. Phys. Lett. 114
[2] M. Opprecht, ICSCRM23

LT-3100 has been adopted as Process of Reference for backside ohmic contact formation by Tier 1 SiC Manufacturers thanks to its high productivity and excellent process uniformity.

Extending UV- Laser Annealing applications for SiC Devices

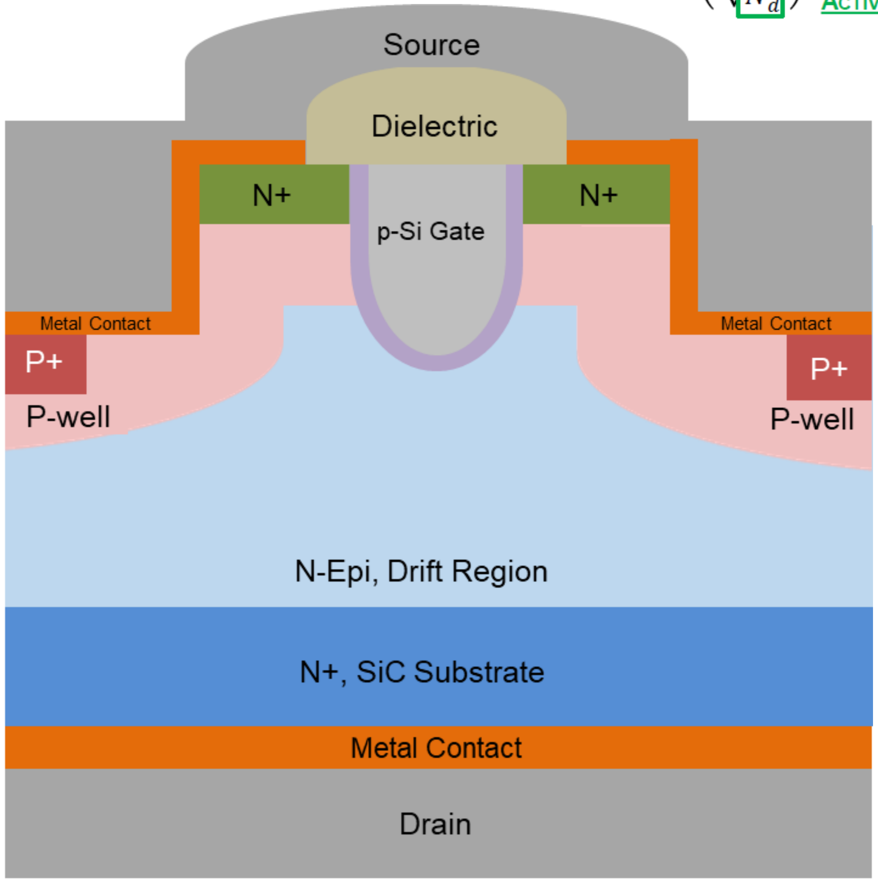
Optimization of SiC p-type and n-type contacts

On-going development

$$\rho_C \sim exp\left(\frac{C \cdot \boxed{\emptyset_b}}{\boxed{\sqrt{N_d}}}\right)$$

Schottky Barrier Height ϕ_b

Active Interface Dopants N_d



Optimization of SiC p-type and n-type contacts

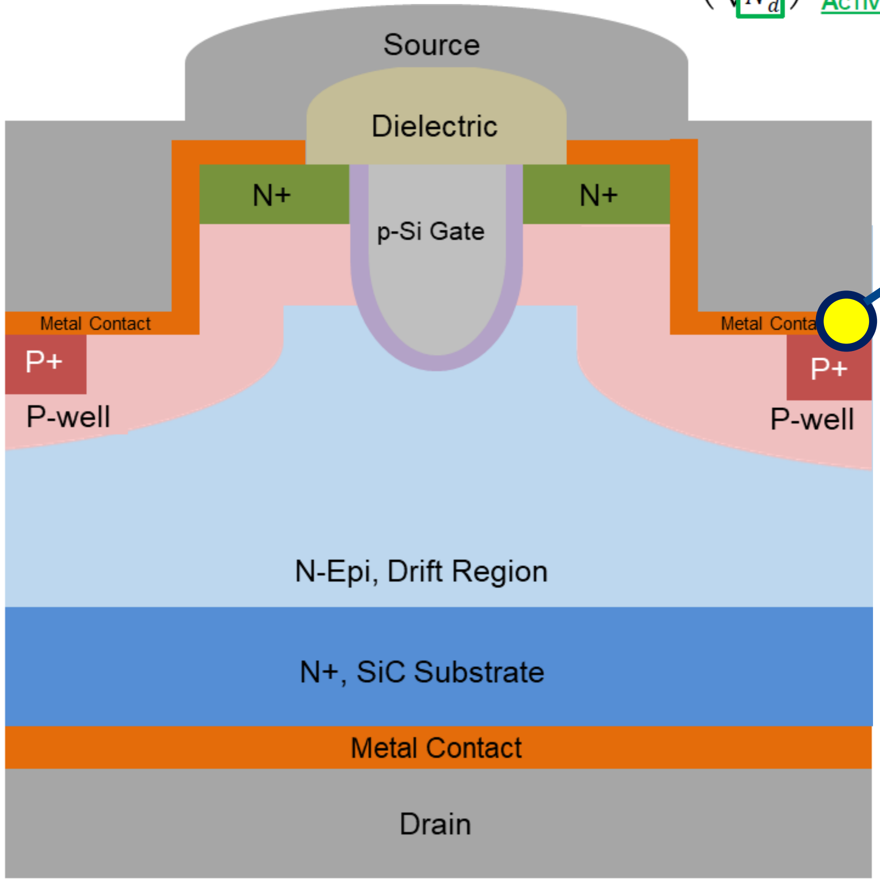
On-going development

SCREEN

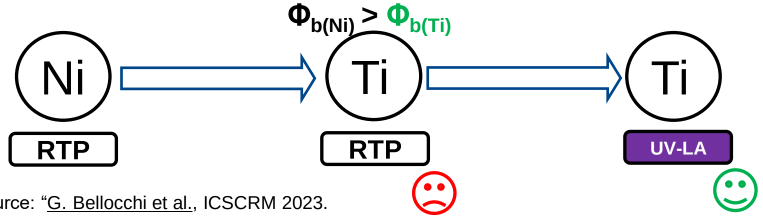
$$\rho_C \sim exp\left(\frac{C \cdot \boxed{\phi_b}}{\boxed{\sqrt{N_d}}}\right)$$

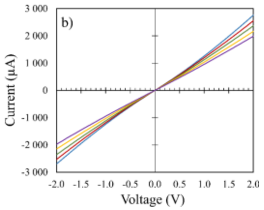
Schottky Barrier Height ϕ_b

Active Interface Dopants N_d



"Reduce Schottky Barrier Height by forming Ti_3SiC_2"





Source: "G. Bellocchi et al., ICSCRM 2023.

Optimization of SiC p-type and n-type contacts

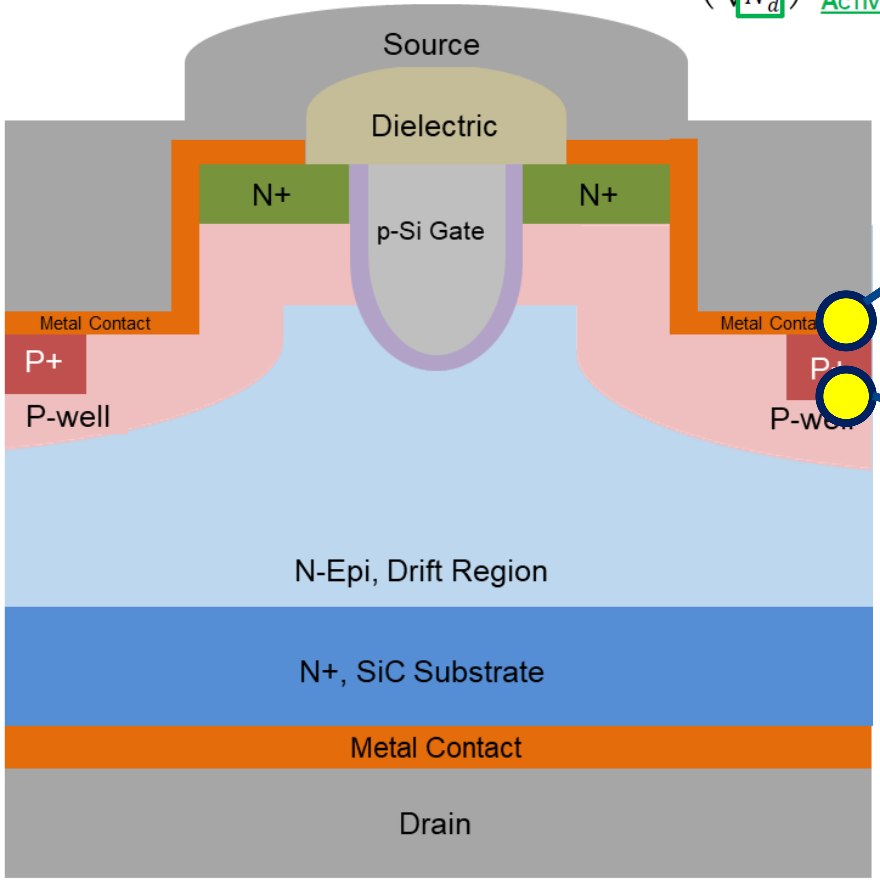
On-going development

SCREEN

$$\rho_C \sim exp\left(\frac{C\cdot\boxed{\phi_b}}{\sqrt{\boxed{N_d}}}\right)$$

Schottky Barrier Height ϕ_b

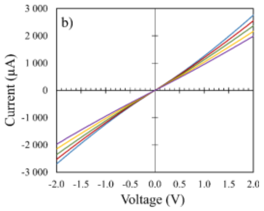
Active Interface Dopants N_d



"Reduce Schottky Barrier Height by forming Ti_3SiC_2"

$\Phi_{b(Ni)} > \Phi_{b(Ti)}$

Ni (RTP) → Ti (RTP) → Ti (UV-LA)

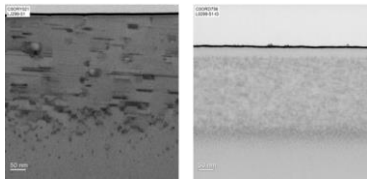


Source: "G. Bellocchi et al., ICSCRM 2023.

"Increase p-type Active Interface Dopants Level"

Furnace

UV-LA



- $[Al]_{implanted}$ >1E21 at/cm³
- 6 times more activation (Rs)
- No thermal extended defects
- Crystal fully cured after I/I

Source: "F. Mazzamuto et al., ICSCRM 2023.

Optimization of SiC p-type and n-type contacts

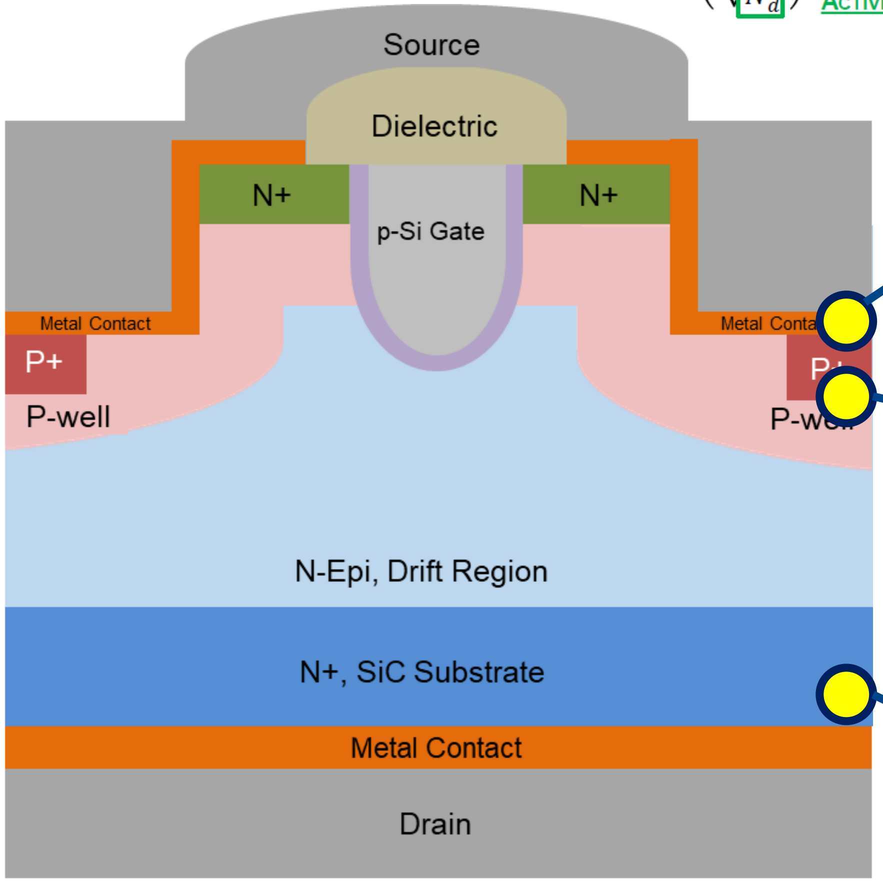
On-going development

SCREEN

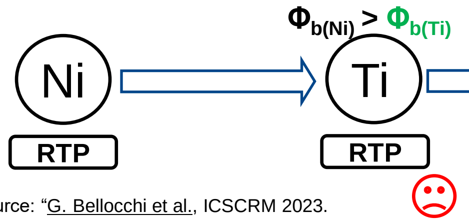
$$\rho_C \sim exp\left(\frac{C \cdot \boxed{\phi_b}}{\boxed{\sqrt{N_d}}}\right)$$

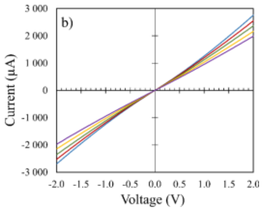
SCHOTTKY BARRIER HEIGHT ϕ_b

ACTIVE INTERFACE DOPANTS N_d



"Reduce Schottky Barrier Height by forming Ti_3SiC_2"





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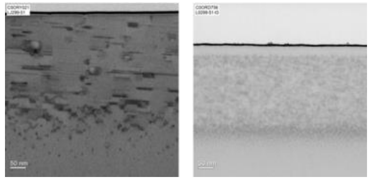
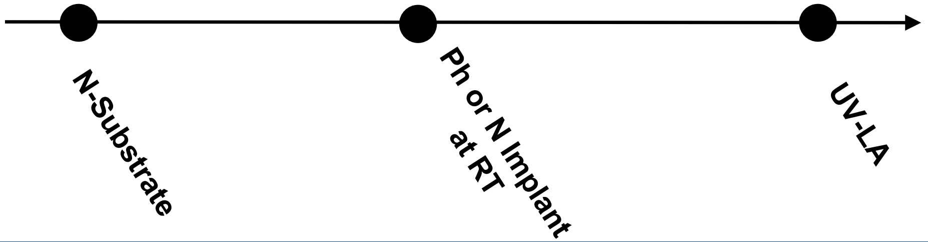
"Increase p-type Active Interface Dopants Level"



- $[Al]_{implanted}$ >1E21 at/cm³
- 6 times more activation (Rs)
- No thermal extended defects
- Crystal fully cured after I/I

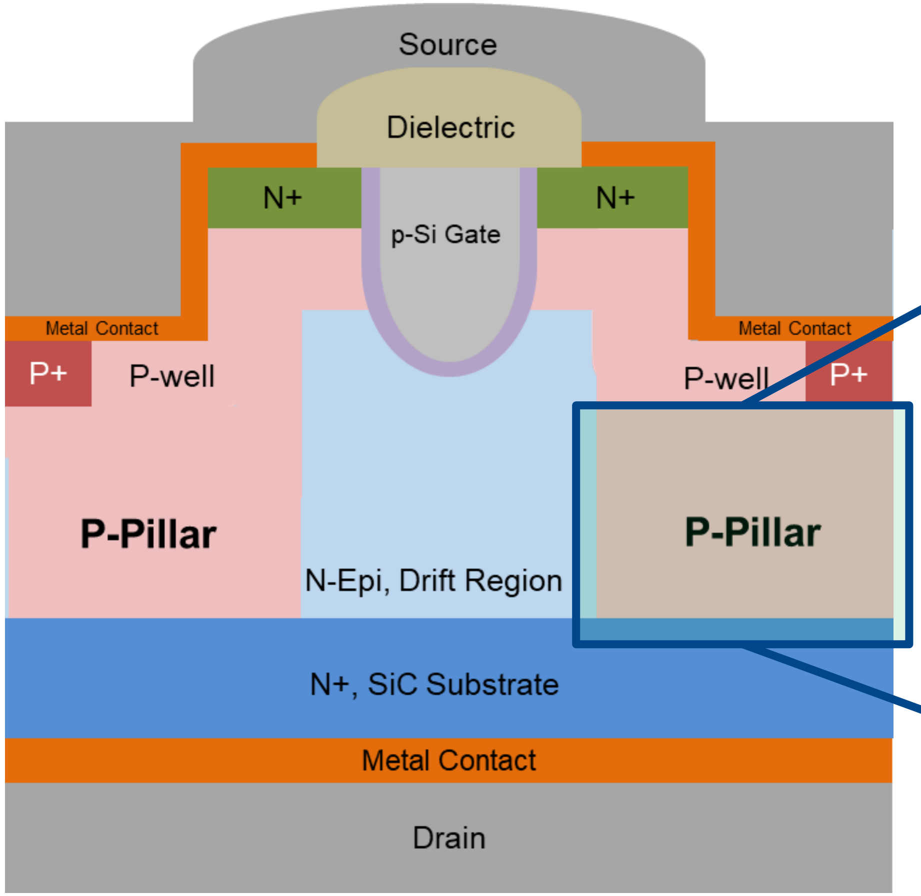
Source: "F. Mazzamuto et al., ICSCRM 2023.

"Increase n-type Active Interface Dopants Level"



Formation of Super-Junction for next generation of SiC

On-going development



"Deep Activation of p-dopant for SJ Formation"

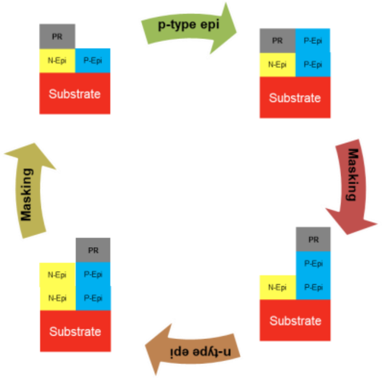
Actual

Multi-epitaxial approach

Complex

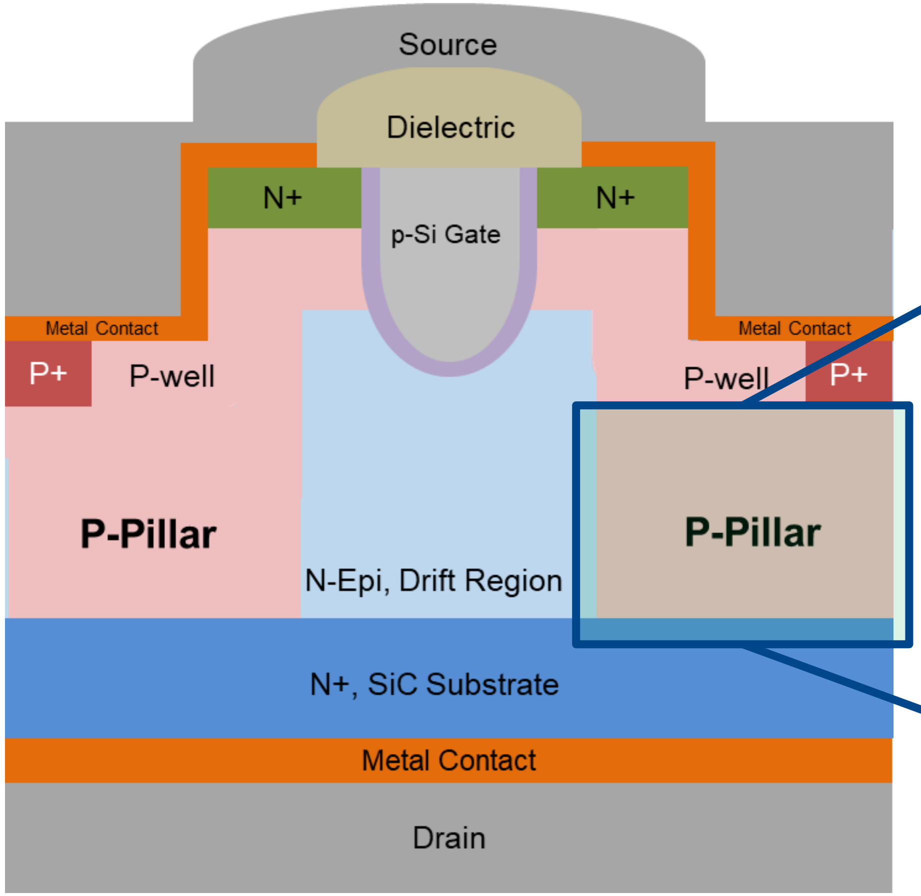
Expensive

Low-Quality SJ



Formation of Super-Junction for next generation of SiC

On-going development

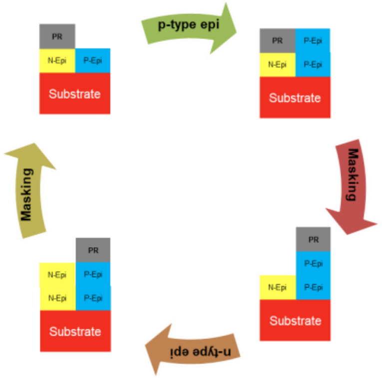


“Deep Activation of p-dopant for SJ Formation”

Actual

Multi-epitaxial approach

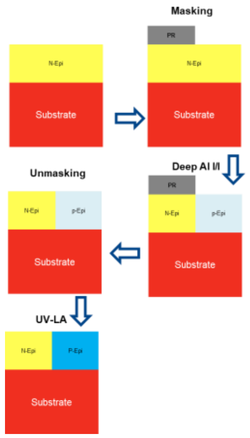
Complex · **Expensive** · **Low-Quality SJ**



Proposed

Deep Implant + UV-LA

Simpler · **Cheaper** · **High-Quality SJ**



Conclusion

Conclusion

- Industrials need to develop new technological solutions to face the important demand of Electrical Cars (EV).
- Silicon Carbide emerges as a promising candidate to reduce overall cost and improve performances of EV.
- However, development of low-cost and high-performances SiC devices faces some technological challenges.
- Laser Annealing Technologies have been widely adopted by semiconductor industry for more than 4 decades including SiC markets.
- **LT-3100 is today considered as POR for the formation of backside Ohmic contact by Tier 1 SiC players.**
- Moreover, it is expected that UV-LA will be a major actor to face other technical challenges of SiC device manufacturing.

ADVANCING
TECH & INNOVATION

SCREEN Semiconductor Solutions Co., Ltd.

Innovation for a Sustainable World

SCREEN