WORLD MATERIALS FORUM

Silicon Carbide Power Devices Enabling Mobility Electrification

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life.augmented

STMicroelectronics

- Among the world's largest semiconductor companies
- Serving over **100,000** customers across the globe
- 2018 revenues of **$9.66B,** with year-on-year growth of **15.8%**
- Listed: NYSE, Euronext Paris and Borsa Italiana, Milan
- Signatory of the United Nations Global Compact (UNGC), Member of the Responsible Business Alliance (RBA)

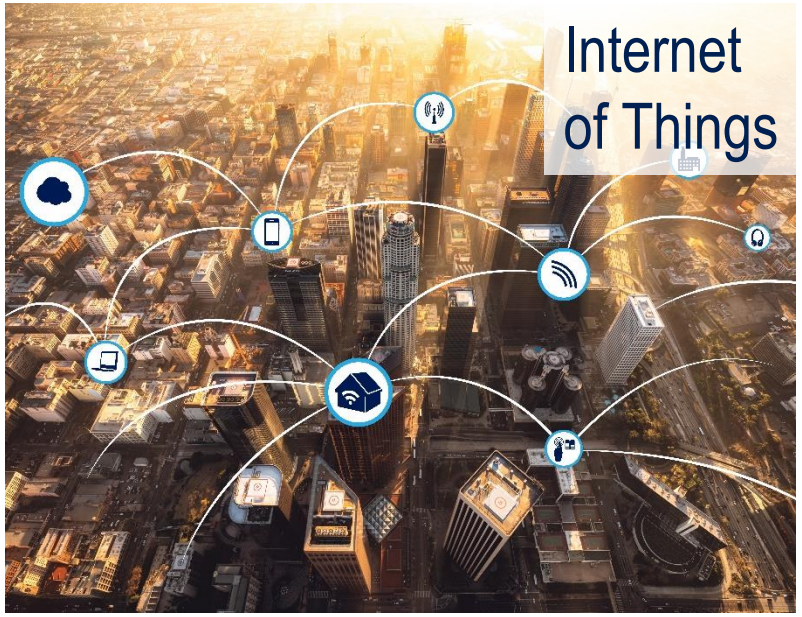
- **~46,000** employees worldwide
- **~ 7,400** people working in R&D
- **11** manufacturing sites
- Over **80** sales & marketing offices

As of December 31, 2018

Enabling Strategic Electronic Demand Trends

ST provides innovative solutions help our customers make driving **safer, greener and more connected** for everyone

ST technology and solutions enable customers to increase **energy efficiency** everywhere and support the use of renewable energy sources



ST provides **sensors**, **embedded processing solutions**, **connectivity**, **security and power management**, as well **tools and ecosystems** to make development fast and easy for our customers

Electrification Reshaping Avionics Industry

Last 60 Years of Avionics Architecture remained unchanged Constrained by Traditional ICE Engine

Alouette II 1955

Bluecopter 2015

A300 1970

A350 2017

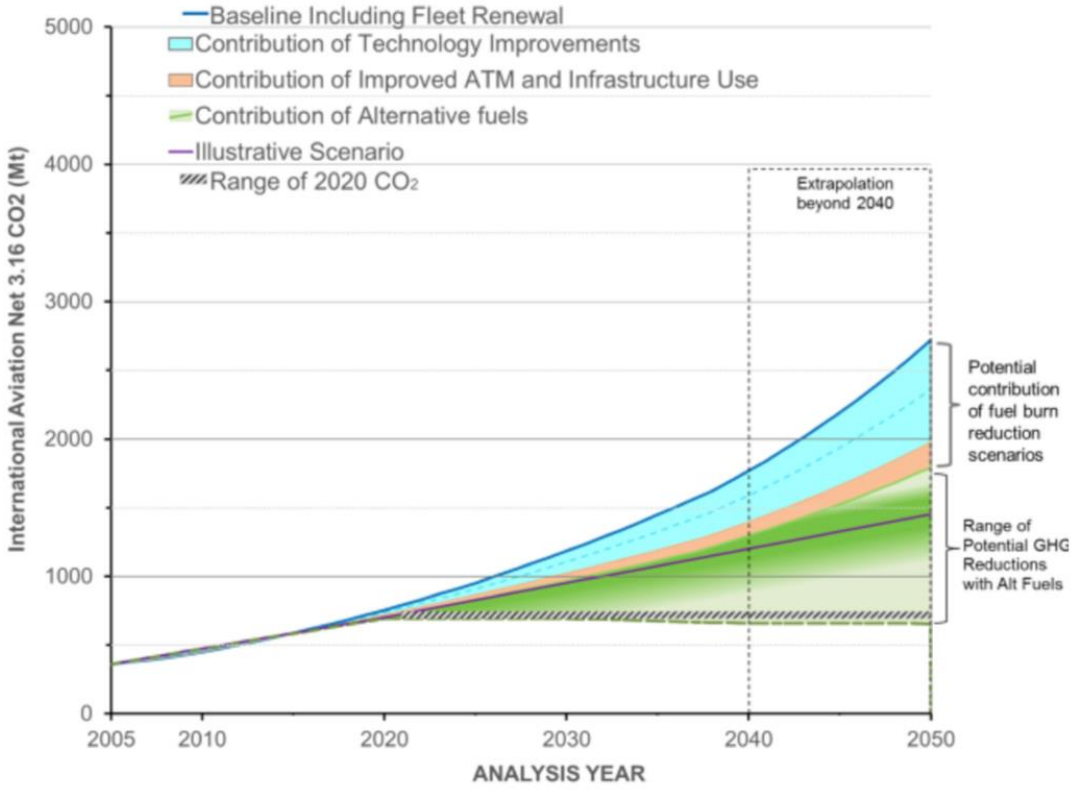
Powertrain Electrification Opens Disruptive Architecture Changes

With significant advantages in terms of **Safety**, **Reliability** and **Total Cost of Ownership**

Avionic Electrification

Key Advantages & Industry Challenges

Increasing Emissions



Source: ICAO 2016 Environmental Report

Key Advantages

Pollution Reduction

Consumption Reduction

Low Cost Transportation

Goods Deliveries with Autonomous Helicopters

Key Challenges

Battery Size

Up to 2~20 MW Power Needed

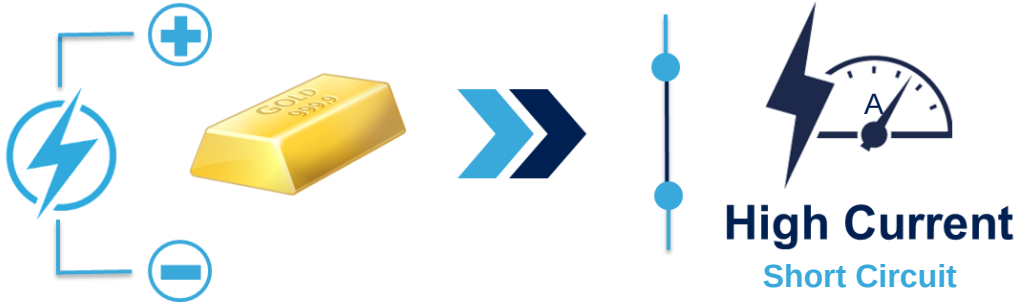
Power Management handling with Predictive Maintenance system

Power Energy Conversion Efficiency is a Must to Enable Electric/Hybrid Aviation

What is a Semiconductor?

Insulated Material

Conductive Material



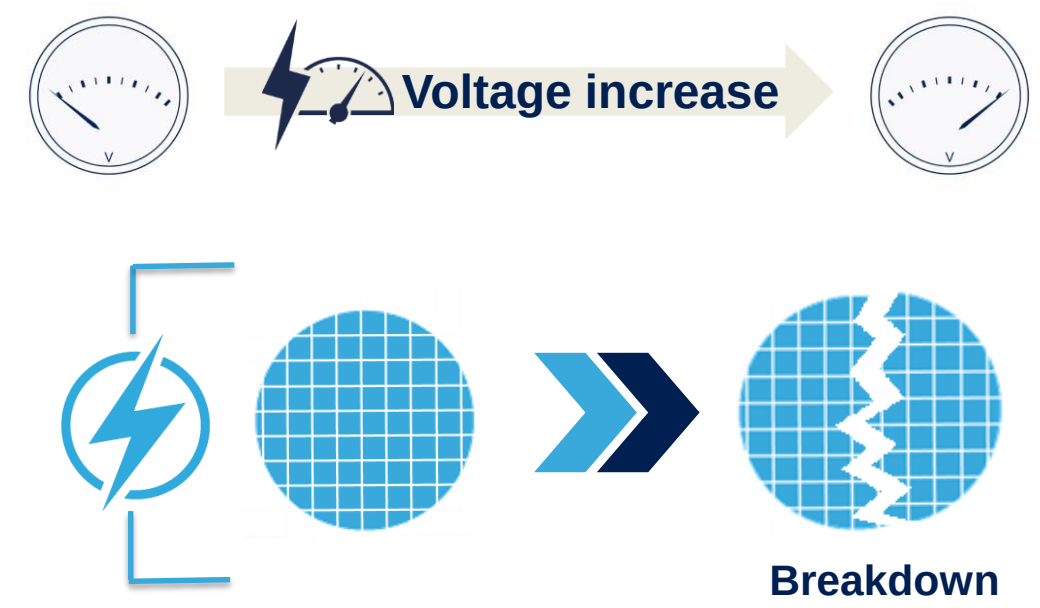
Semiconductor Material

Based on the External Electric Field behaves as:

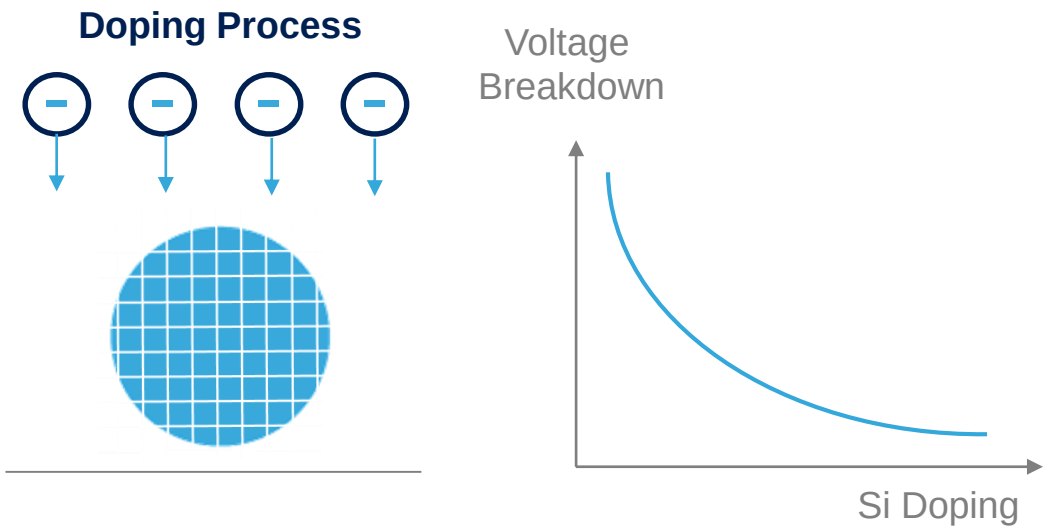
Variable Current

Exploiting Silicon Characteristics

Depending on material type, there's always a **Breakdown Voltage Threshold** beyond which the material behaves as an Open Circuit



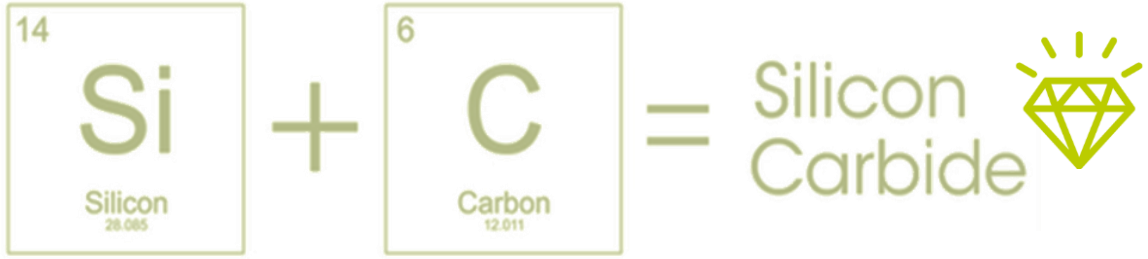
Bare Silicon is **Doped** with other elements in order to further increase **Conductivity Level**



The higher is the Silicon doping, the lower is the Breakdown voltage

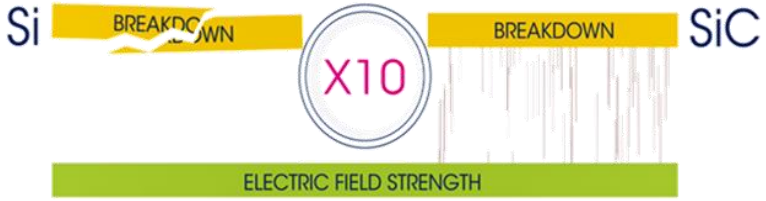
What is Silicon Carbide?

Silicon & Carbon combination give rise to a semiconductor with Enhanced Electrical Performances



Silicon Carbide shows higher **Energy Conversion Efficiency**, allowing Power Devices to go beyond the limits of Silicon

Compared to Silicon, Silicon Carbide shows intrinsic higher breakdown threshold….

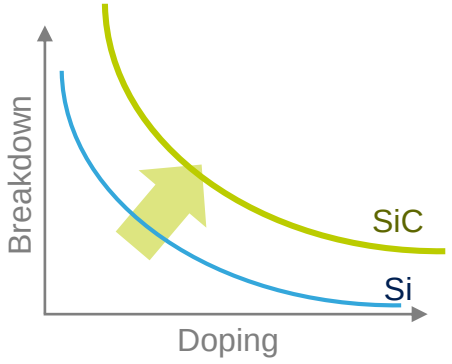


Achieving:

Higher Breakdown Voltage

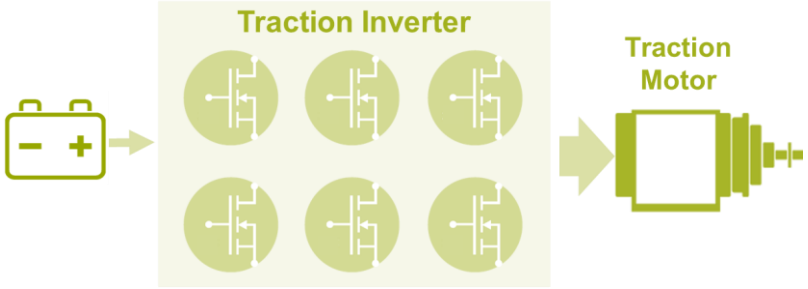
Increased Doping level

Better Conductiviy



SiC PMOSFET Advantages in Automotive

Electric Engine heart is the **Traction Inverter** that convert the Energy stored into the Battery pack in **Electric Motor Actuation**



…Energy conversion always implies some power losses…

This is the reason we need a **High Efficient** Power Semiconductor Device

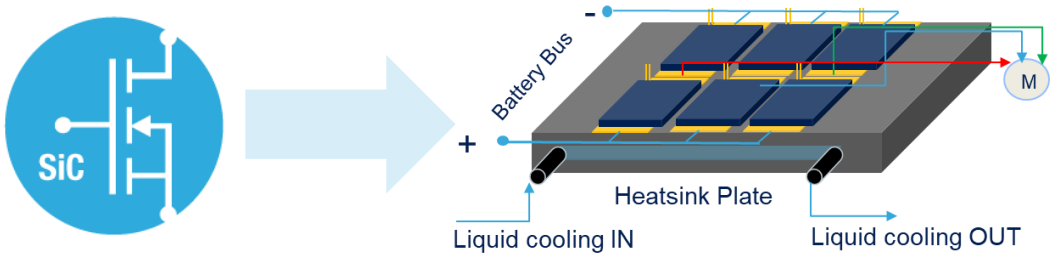
SiC PMOSFET better **conductivity** and **faster switching frequency** drastically reduce power losses

Faster Energy Commutation

Less energy is lost as heat!

SiC PMOSFET Energy Conversion Higher Efficiency **increase** heavily the overall **Electric Vehicle Mileage**!!!

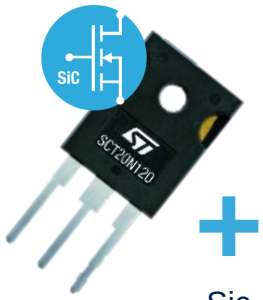
SiC PMOSFET Traction Inverter



Application Saving

Independent Analyst Estimation

Electric Vehicle



+300$
Sic Additional Cost

~2000$
Estimated Saving

Main Saving Contributors

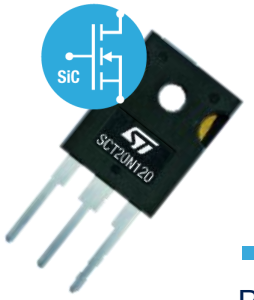
Battery Cost: up to 600$

EV-Space: up to 600$

Cooling: up to 1000$

…and 50% Charging time reduction

Solar Inverter



x5
Switching Frequency

-50%
Power Losses

-20%
System Cost Saving

Main Saving Contributors

Footprint: up to 70%

Weight: up to 80%

Installation Cost: 50% cut

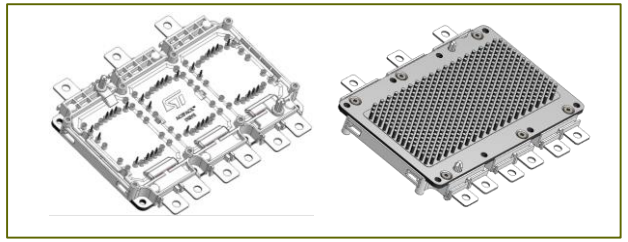
…100% adoption in 10 years

Source: Goldman Sachs, Nov 2018

SiC PMOSFET Manufacturing Process

Raw Material

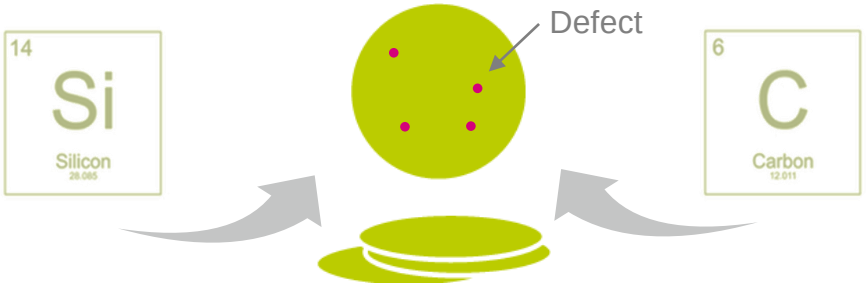
SiC Product



Silicon Carbide PMOSFET

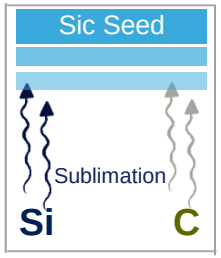
Manufacturing Challenges vs Silicon Process

SiC has higher intrinsic material defectiveness that propagates during substrate manufacturing…



…leading to a more complex manufactuing flow to grant quality and reliability

SiC Ingot Manufacturing

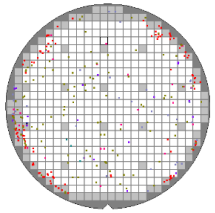


Seed Defectiveness propagation

Sawing Process

Phisical Defects Mapping at Wafer level

SiC Wafer Testing

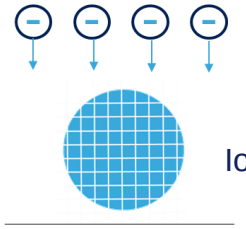


Electrical Testing to verify Mapped Defectiveness Area

Silicon Carbide is a “Harder” Material and requires a more sophisticated manufacturing process at certain key diffusion Steps

>1700°C

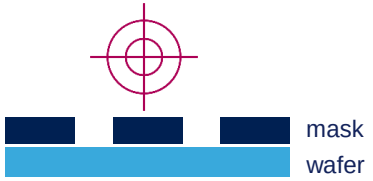
Annealing
(Vs. 800° Si)



500°C

Ion Implantation
(Vs. 25° Si)

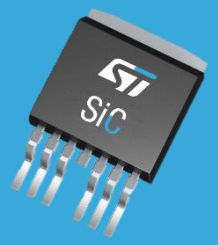
Harder Etching Phase
(similar to diamond)



More accurate Photolithography to define dopant shape

R&D and Manufacturing close synergy to materialize SiC material advantages…

Takeaways



- **SiC** is an outstanding material to meet the needs of **energy saving** in multiple market domains
- **SiC** PMOSFET gives great benefits in terms of **performance** and cost, every time high power energy conversion is needed
- **SiC** is a difficult material to master in order to reap all the benefits coming from its intrinsic properties
- **ST** has the **know how**, the **partnerships**, the **commitment** and the right intimacy between **R&D** and **Manufacturing** to master SiC PMOSFET technology