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Improving High Voltage Power Modules with New Silicon Snubber Capacitor Technology

Murata Electronics Europe B. V.

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Outline

I. Introduction

II. Review of Automotive use cases with Low ESL requirements

III. Silicon Capacitors: Technology and key features

I. Conclusion

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Facts & Figures

Our Business

We are worldwide leaders in the design, manufacture and supply of electronic components and solutions.
We are Innovators in Electronics.

Our Strengths

- Advanced materials technology and expertise
- Broad product portfolio
- Extensive global manufacturing and sales network

Our Figures

- Established in 1944
- Net sales 1,686,796 million JPY*
- Number of subsidiaries. 87* (30 in Japan, 57 overseas)
- Employees 73,164*

as of March 31, 2023
Murata Manufacturing Co., Ltd. is not included in the number of subsidiaries

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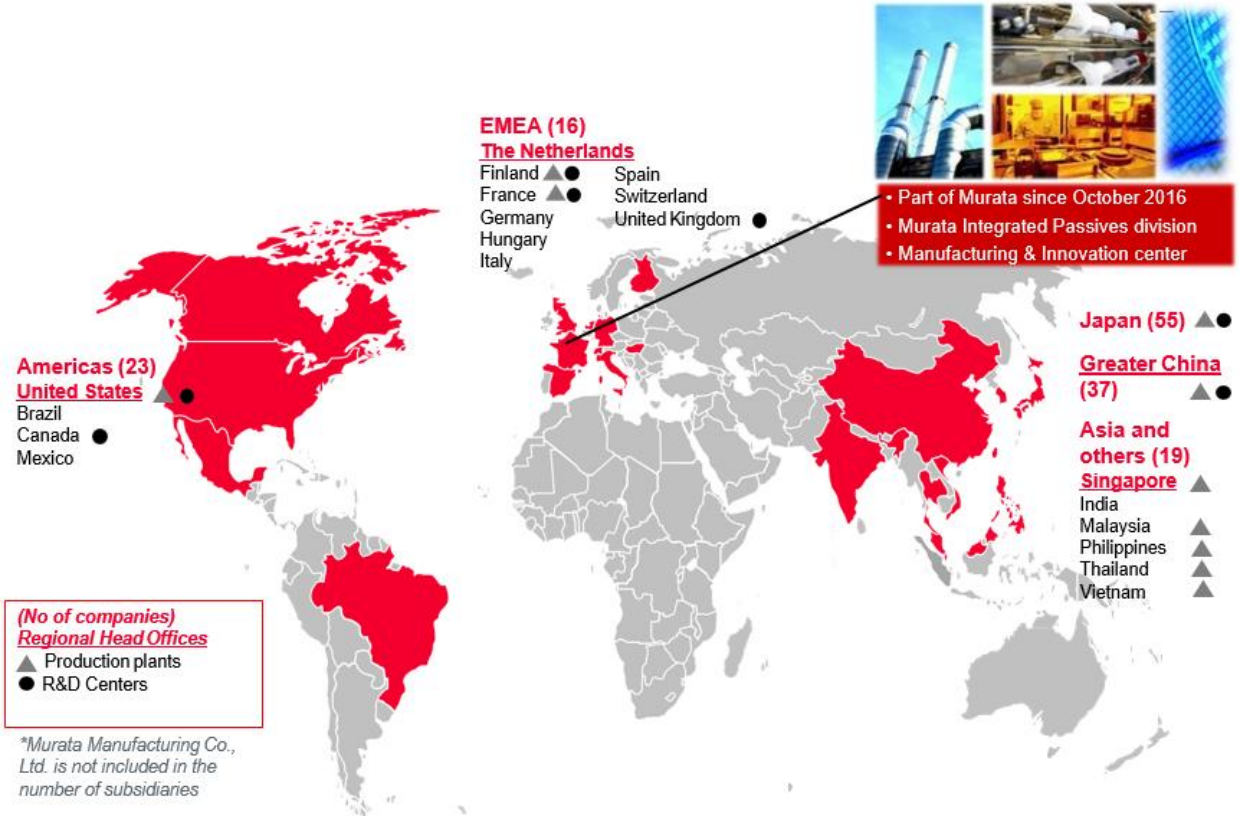
Murata Global locations



- Part of Murata since October 2016
- Murata Integrated Passives division
- Manufacturing & Innovation center

Murata Integrated Passive Solutions S.A.

2016

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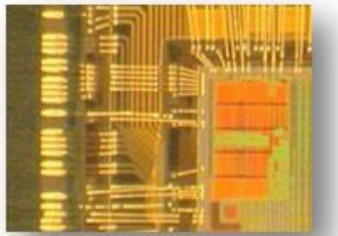
Murata Integrated Passive Solutions

People

- 150 employees / 60 engineers
- High expertise in Microelectronics
- Design – Manufacturing - Support

Manufacturing

- Own wafer fab of 21'000 sqm
- Leading edge Silicon Capacitors and Integrated Passive Devices



Technology

- Patented innovative technology
- Miniaturization and performance
- Recognized Quality

OHSAS 18001:2007 ISO 14001 ISO 9001:2015 IATF 16949 RoHS COMPLIANT

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Murata Philosophy

Founder Akira Murata

社　是

技術を練磨し
科学的管理を実践し
独自の製品を供給して
　文化の発展に貢献し
信用の蓄積につとめ
会社の発展と
　協力者の共栄をはかり
これをよろこび
　感謝する人びとと
　　ともに運営する

We contribute to the
advancement of society
by

Enhancing technologies and skills
Applying scientific approach
Creating innovative products and solutions
Being trustworthy and,
together with all our stakeholders,
thankful for the increase in prosperity.

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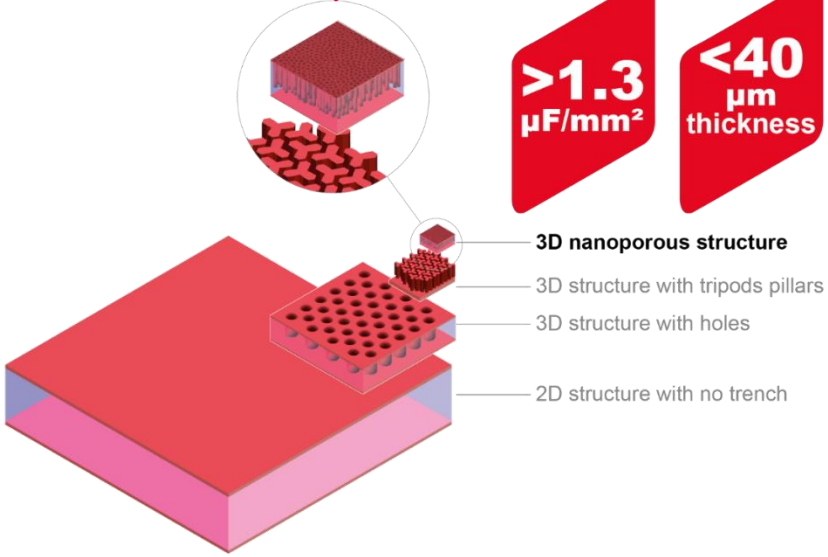
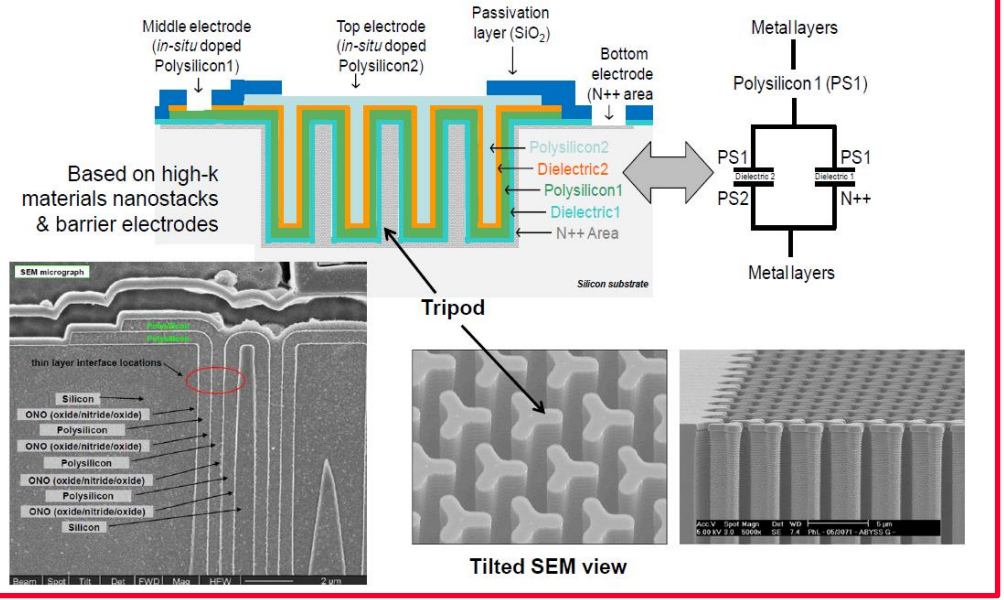
Silicon Capacitors Technology

$$C = \frac{\varepsilon_0 \varepsilon_S \cdot S}{e}$$



2 parallelized capacitors in a MIMIM architecture to increase the capacitance value



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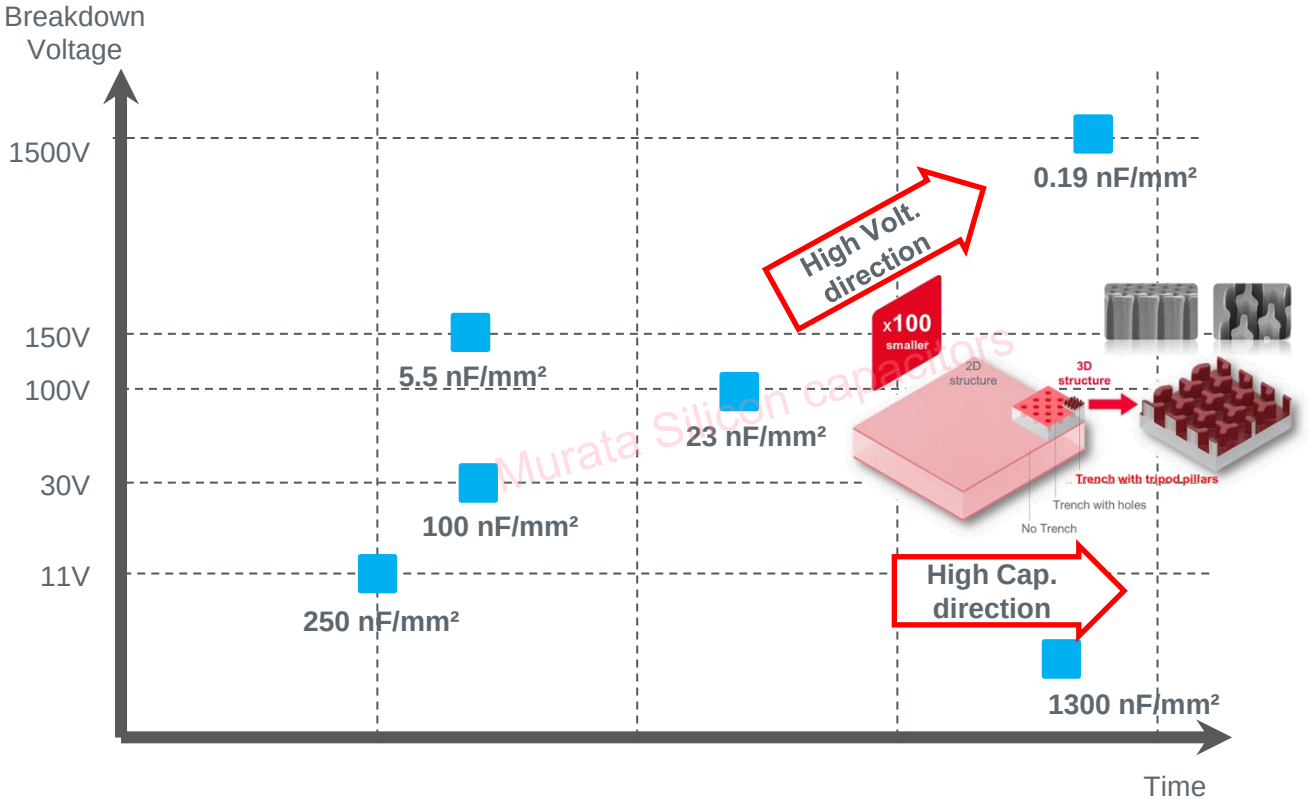
Silicon Capacitor - Technology Road Map



Vehicle electrification

Data centres

Mobile HPC

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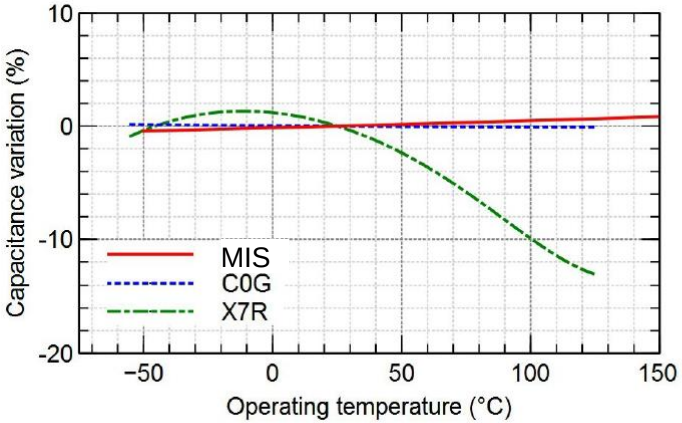
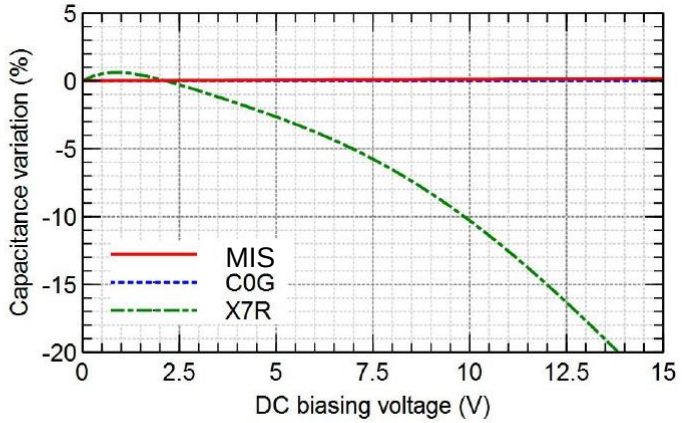
Dielectric materials: High Stability



Capacitance variation vs temperature



Capacitance variation vs DC biasing voltage

- Capacitance stability over Voltage and temperature of MIS SiCap capacitor is a key parameter besides ESL/ESR. Thanks to the nature and the high quality of the mineral dielectric material, there is no derating to take into account that can reduce the effective value of the capacitance
- 470 nF Silicon capacitor has the same effective capacitance than a 1 µF X7R MLLC

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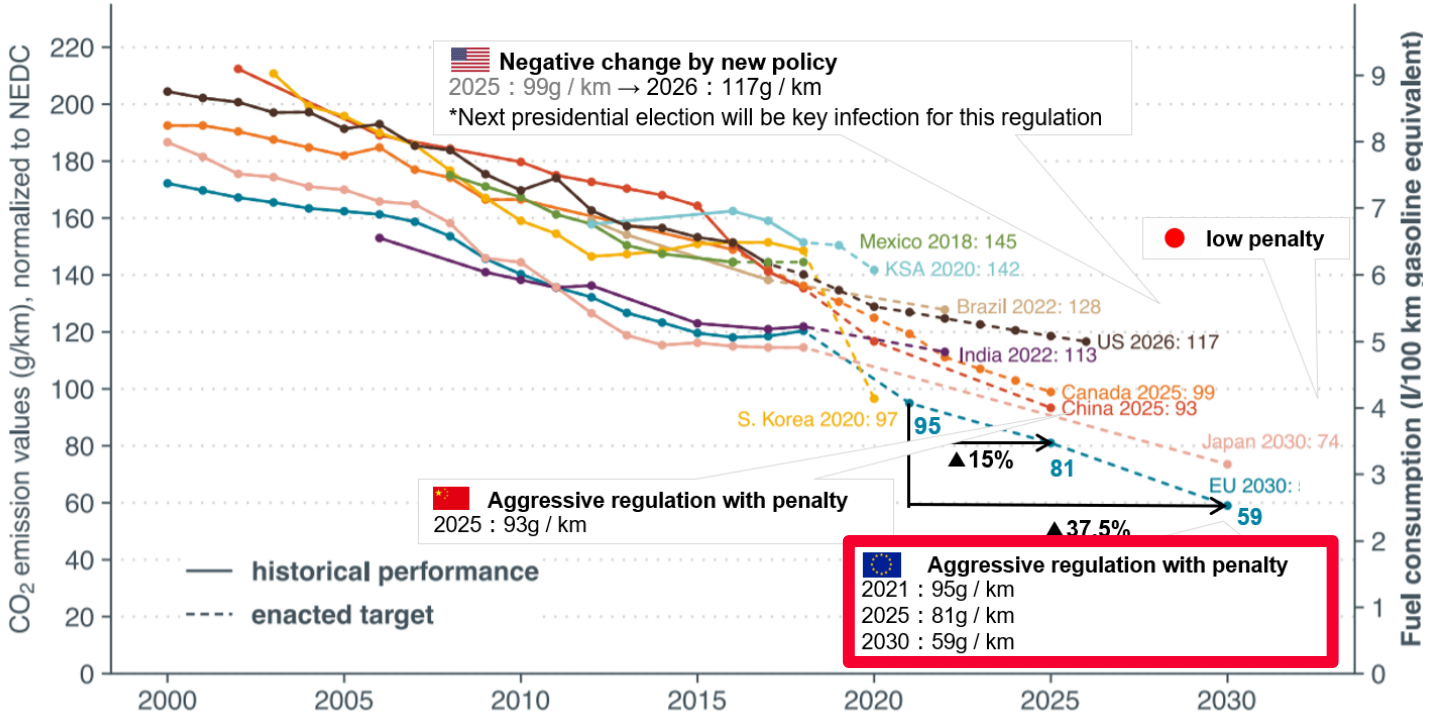
Regulation



EV: 0g/km (WLTP)

PHEV: 16g/km (WLTP)

ICE: 128g/km (WLTP)

- CO2 emission regulations (CAFÉ/GHG) are getting stricter globally.
- **Europe** targets **leading role** to achieve **lowest global CO2 output** in vehicle segment

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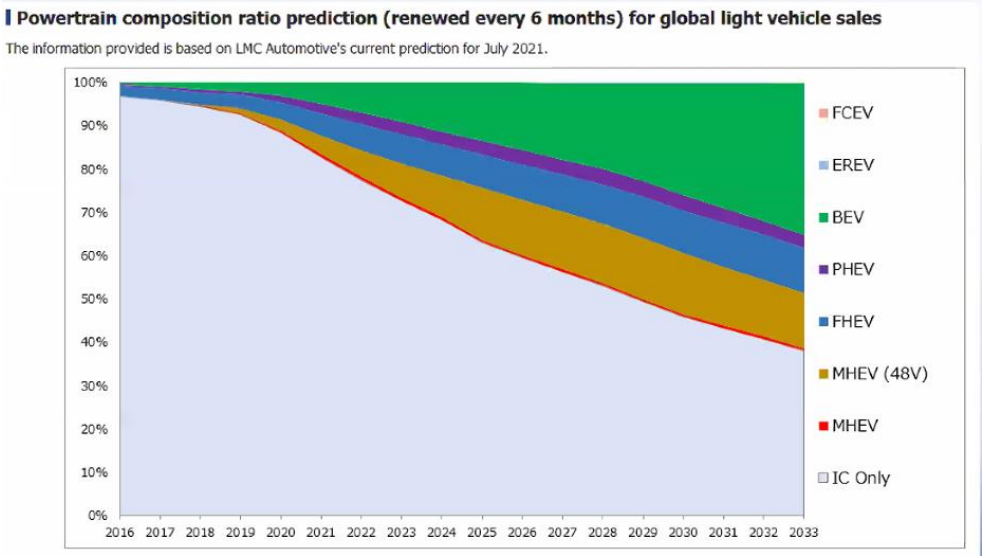
Source: ICCT edited by S9P3

Overall Market Situation

Market information providers predict a **continuous, extraordinary market growth** in segment electrification,

CAGR of **>30%** in **5-7 consecutive years**



Main technologies @ 2030

- BEV: 25%
- MHEV (48V): 17%
- FHEV: 9%
- PHEV: 4%

- **xEV technologies** lead market in **2030 with 55%** against ICE (Marklines)
- xEV share gets to **60+ %** in **2030** (mean value of market research companies and several Tier1s)

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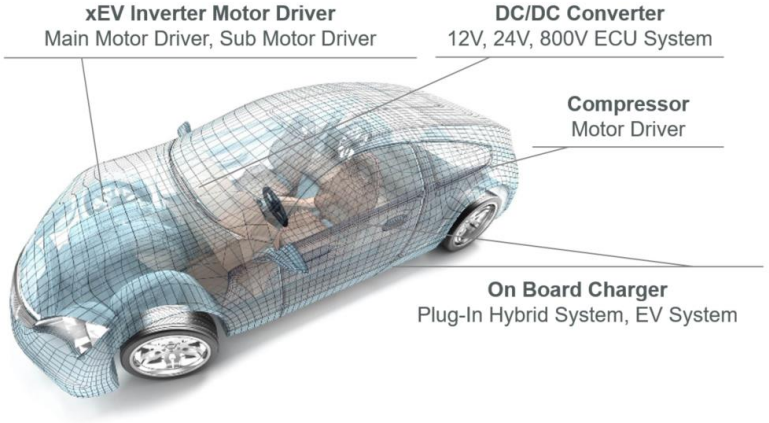
Si-Cap in Automotive Power Electronics

- Automotive grade silicon capacitors exceeding the grade 0 requirements of the AEC-Q100
- Operating temperature up to 200ºC
- Ultra small & thin silicon capacitors
- Suitable for high temperature leadframe mounting
- Dedicated silicon capacitor product line (ATSC)



Trends

- Gradual shift from IGBT technology to SiC
- Later switch to GAN
- Voltages as higher as 800V with SiC
- Powers from 40 to 350 kW

- Multi-phase inverters for large engine
- Increase in DC capacitor temperature
- Rise in Max temperature: increases of active components from 125 °C to 175 °C then 200 °C

- Voltage 400V and 800V
- DC-DC Converters frequency rise
- Improved size and cooling of passive components

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WBG power switching challenges

Market trend

High power density / integration density / efficiency

High temp. operation

High speed switching by using SiC / GaN

High frequency noise

Lifetime & Reliability
- parasistic L on DC bus
- SW junction recovery (IGBT, SiC, GAN …)

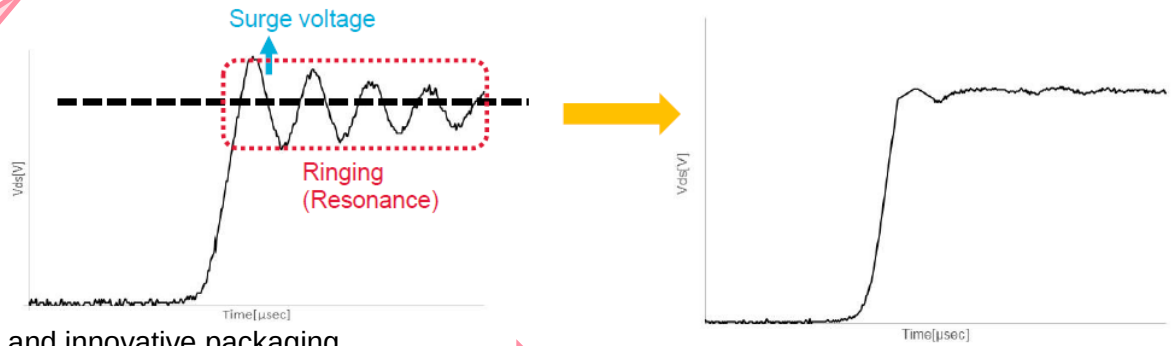
EMI
- complex resonnance of parasitic L and C

Challenge for high speed switching

Parasitic inductance in the circuit cause
1. Surge voltage
2. Ringing

Capacitor Optimization

Damping surges and lowering ringing frequencies



Integration of low ESL components and innovative packaging

Built-in snubber solution for power module

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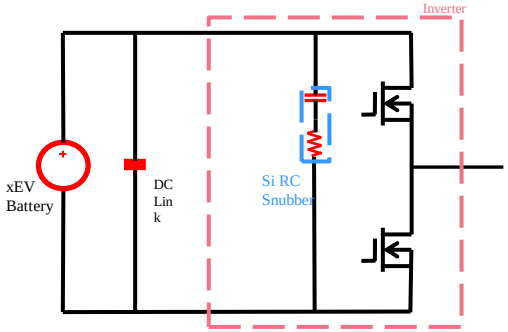
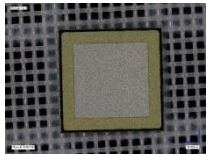
What are we working on ?

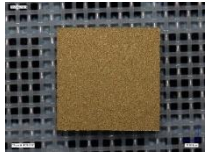
- Si RC Snubber for High Voltage Automotive applications :
  - R+C Passives inside one die of 3.5 x 3.5mm, with a BV of 1500V, made to fit inside High Voltage Power Modules (SiC 1200V)



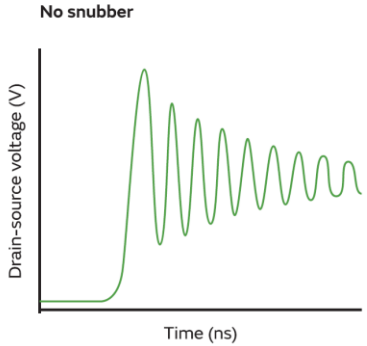
- **Key Benefits :**
- Can be placed near SiC/GaN transistors
- Same assembly method as power transistors
- Ringing suppression maximises inverter efficiency

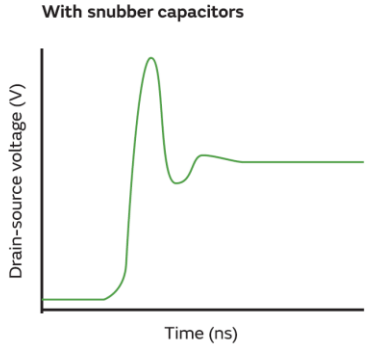


Top view:
Al



Bottom view:
AlTiNiAu





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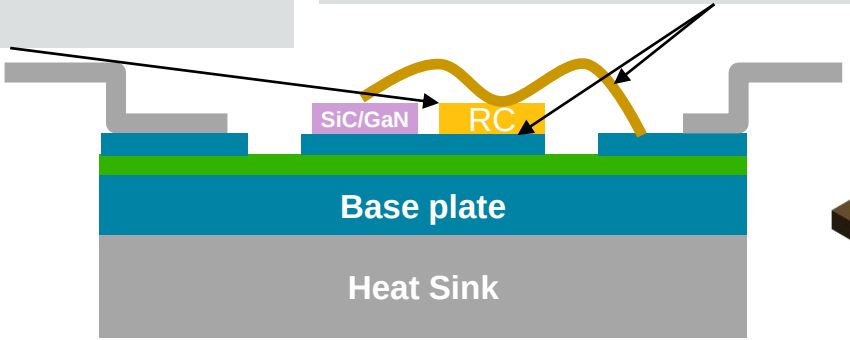
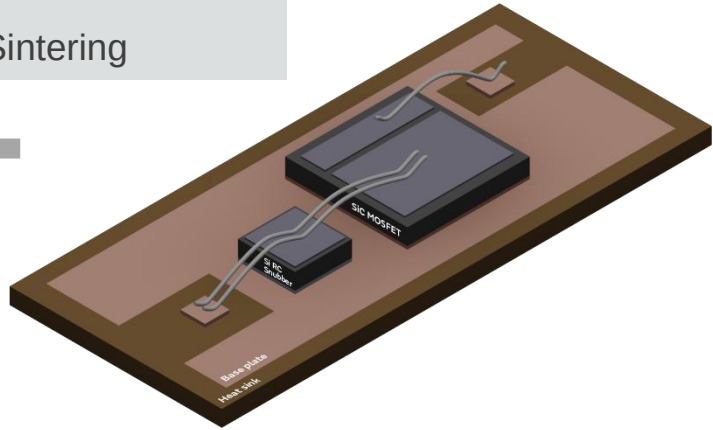
Built-in Snubber Solution

- **The advantage of Si-RC device (Built-in snubber)**

1.High temp. operation (200℃)
Put Si-RC device close to SiC/GaN which operates under high temp.

2. Same mounting method as power device
Ex) Top→ Wire bonding
Bottom→ Soldering and Sintering





3. Function of RC device as 1 chip
Realize downsizing of power module by saving space.
(If you used other capacitors, both capacitors and resistor must be used.)

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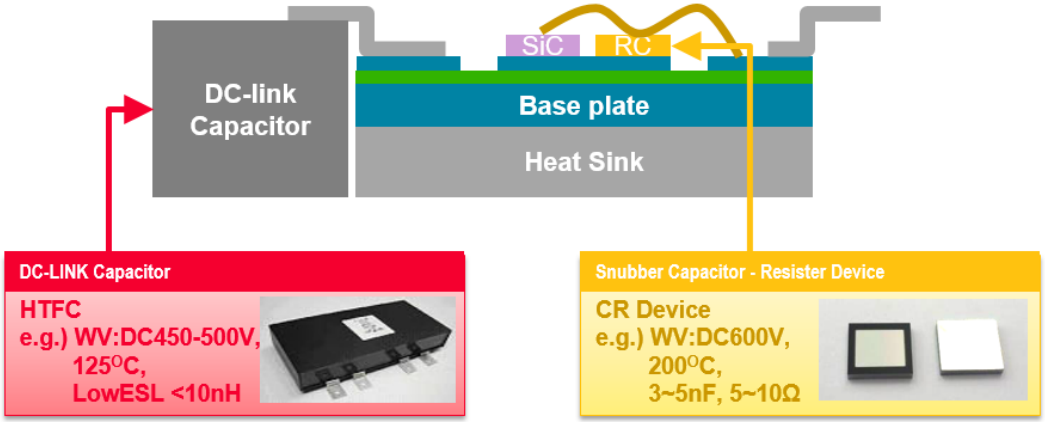
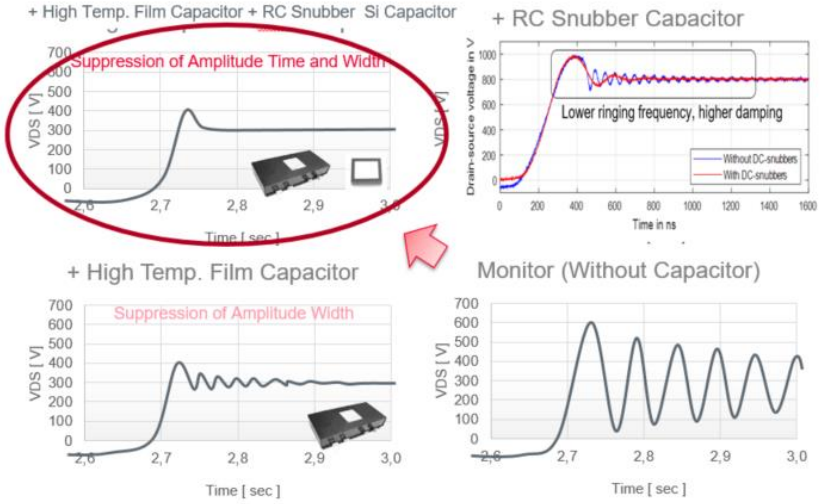
Synergy with Murata Film capacitor

Since it's very important to design both snubber capacitor and DC-link capacitor together to reduce surge voltage and ringing.
Murata can propose the best solution considered combination of snubber capacitor and DC-link capacitor. HTFC is for DC-link and Si-cap is for snubber.



Expected Improvement by New Solutions



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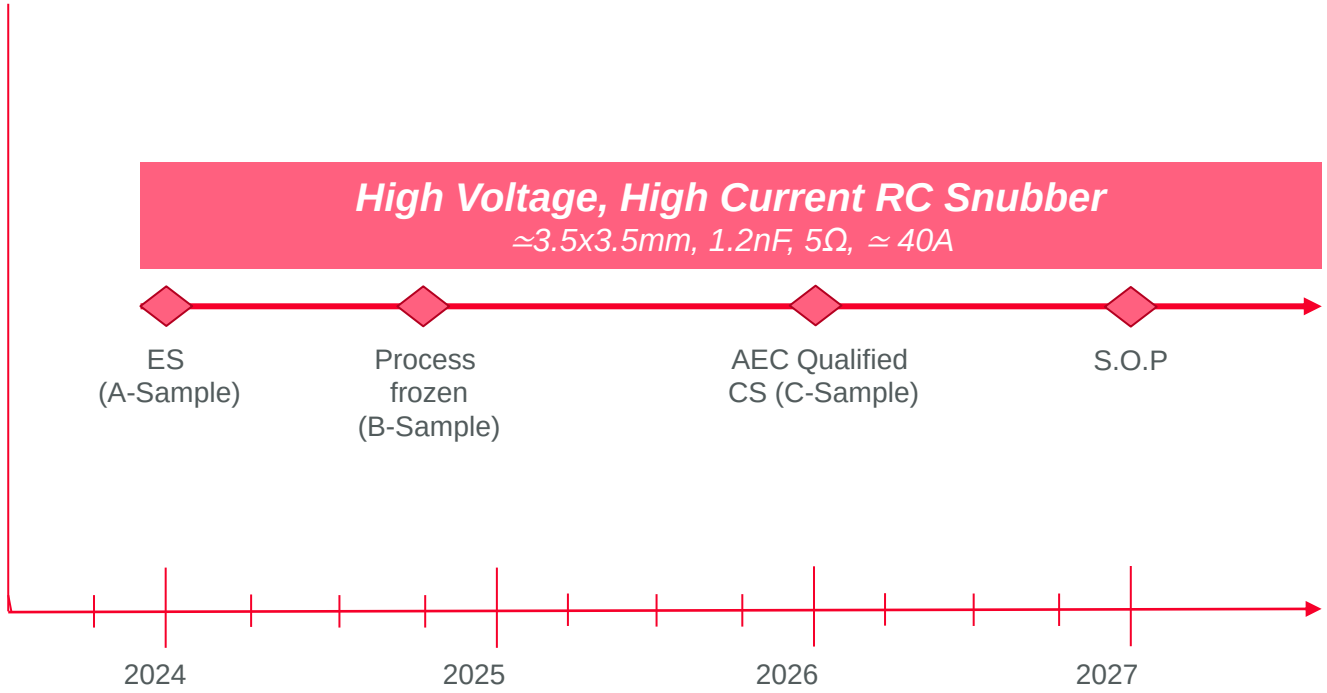
Timeline for BV1500 RC Snubbers



As of Sept. 2023.
Timeline might be changed due to technology development or customer priority

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Conclusion

- Automotive application are pushing passive devices to their technological limits
- Many parameters to take into account: specific to the passive component but also in relation with the surrounding environment (packaging, parasitic)
- Silicon technology presents a good alternative to classical solutions reaching their limits
- Si-IPD technology presents a unique solution to reduce loop inductance
  - High voltage, low ESL loop, Thermal stability
  - Unique design approach → Co-design
  - Silicon capacitive interposer presents innovative solution from electrical and assembly point of view
  - Compliance with automotive reliability (AEC-Q100) and eye safety (IEC 60825)standards
  - Tune our Roadmap in collaboration with Key players in Automotive

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Thanks a lot for your time and attention!

Any questions and/or comments?