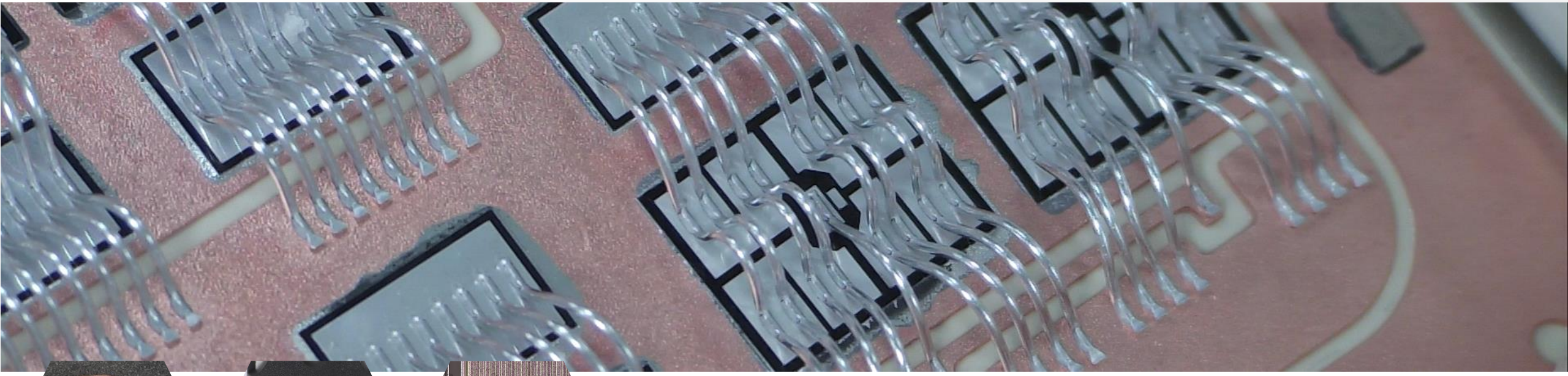


EV/HEV Automotive Power Modules:
Innovations and trends

Elena Barbarini, Phd

IMAPS 2018, 8th November

22 Bd Benoni Goullin
44200 NANTES - FRANCE

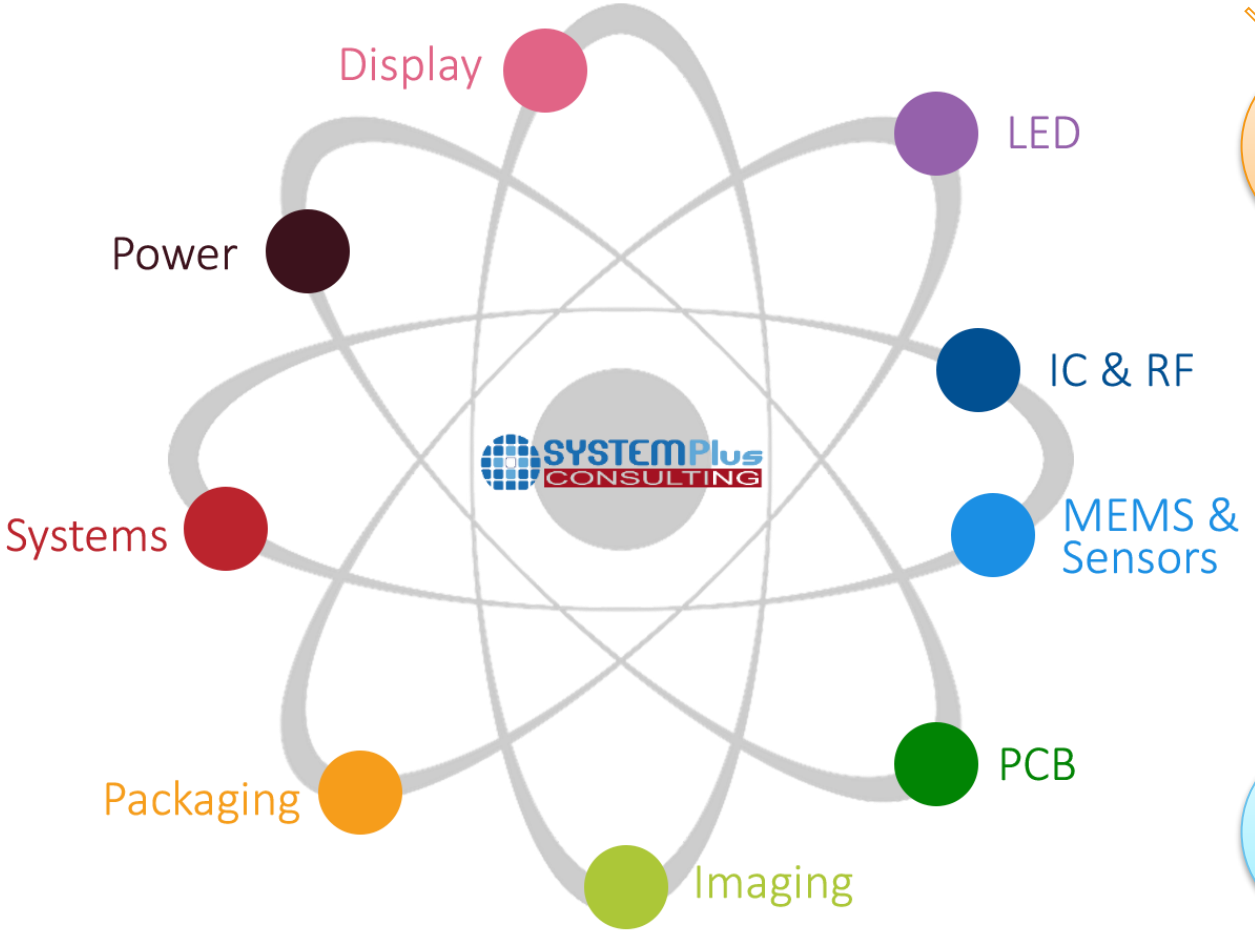
+33 2 40 18 09 16

info@systemplus.fr

www.systemplus.fr

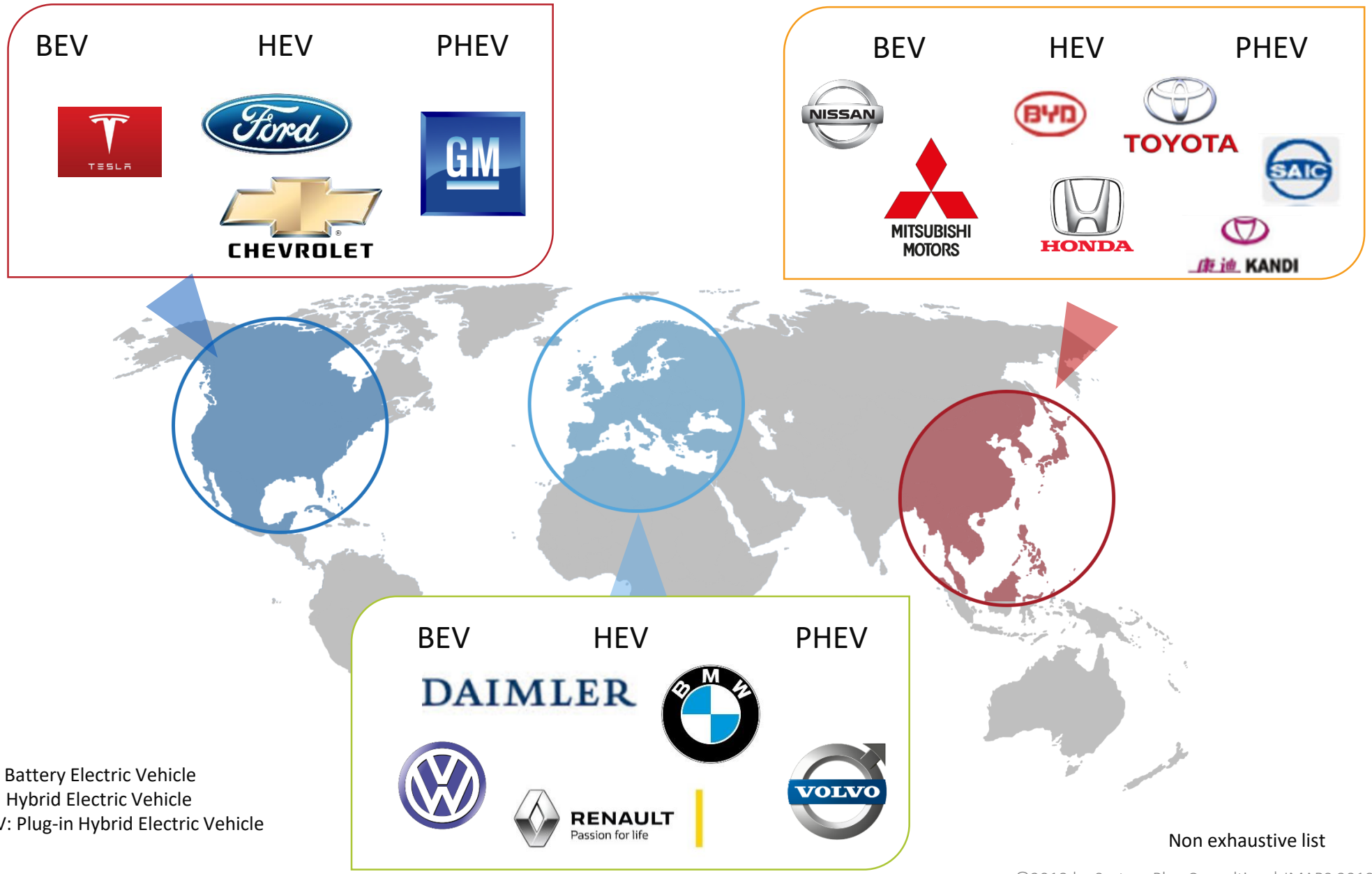
Business Models and Fields of Expertise

SYSTEM Plus CONSULTING mission is to provide decision makers with arguments coming from a bottom-up cost and technology simulation.



EV/HEV Main Manufacturers

Electrification trends depend on the strategy of local car manufacturers, and local governments



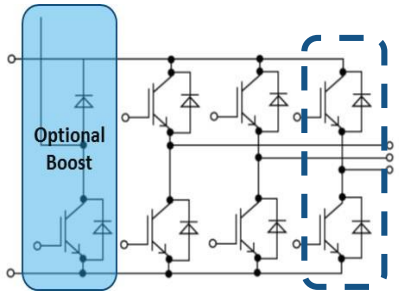
BEV: Battery Electric Vehicle
HEV: Hybrid Electric Vehicle
PHEV: Plug-in Hybrid Electric Vehicle

Non exhaustive list

POWER MODULE Die LEVEL: different integration

To achieve further system cost and package volume reduction, it is common to integrate the electrical motor and the motor drive inverter.
These offer new space saving solutions that require high power density electronics

2-in-1 power module



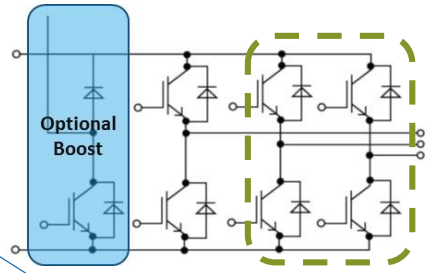
e-up! 2013
Golf 2014

Civic &Fit 2010

Camry 2013
Prius &Mirai 2015

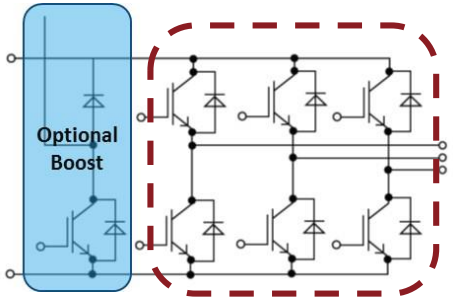
Outlander 2014

4-in-1 power module



C-max 2015

6-in-1 power module

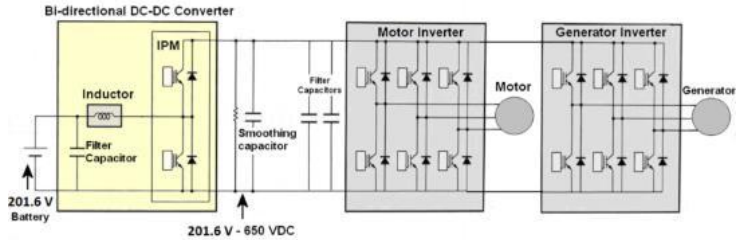


Focus 2014

Leaf 2011
Leaf 2012

Zoe 2013

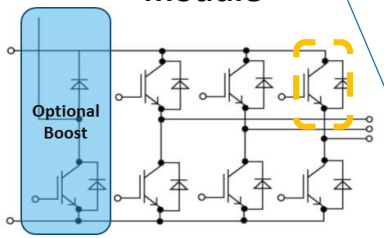
all-in-1 power module



Prius 2004
Prius 2010
Auris 2011
Yaris 2012

Accord 2013

1-in-1 power module



Model3 2017

Volt 2015

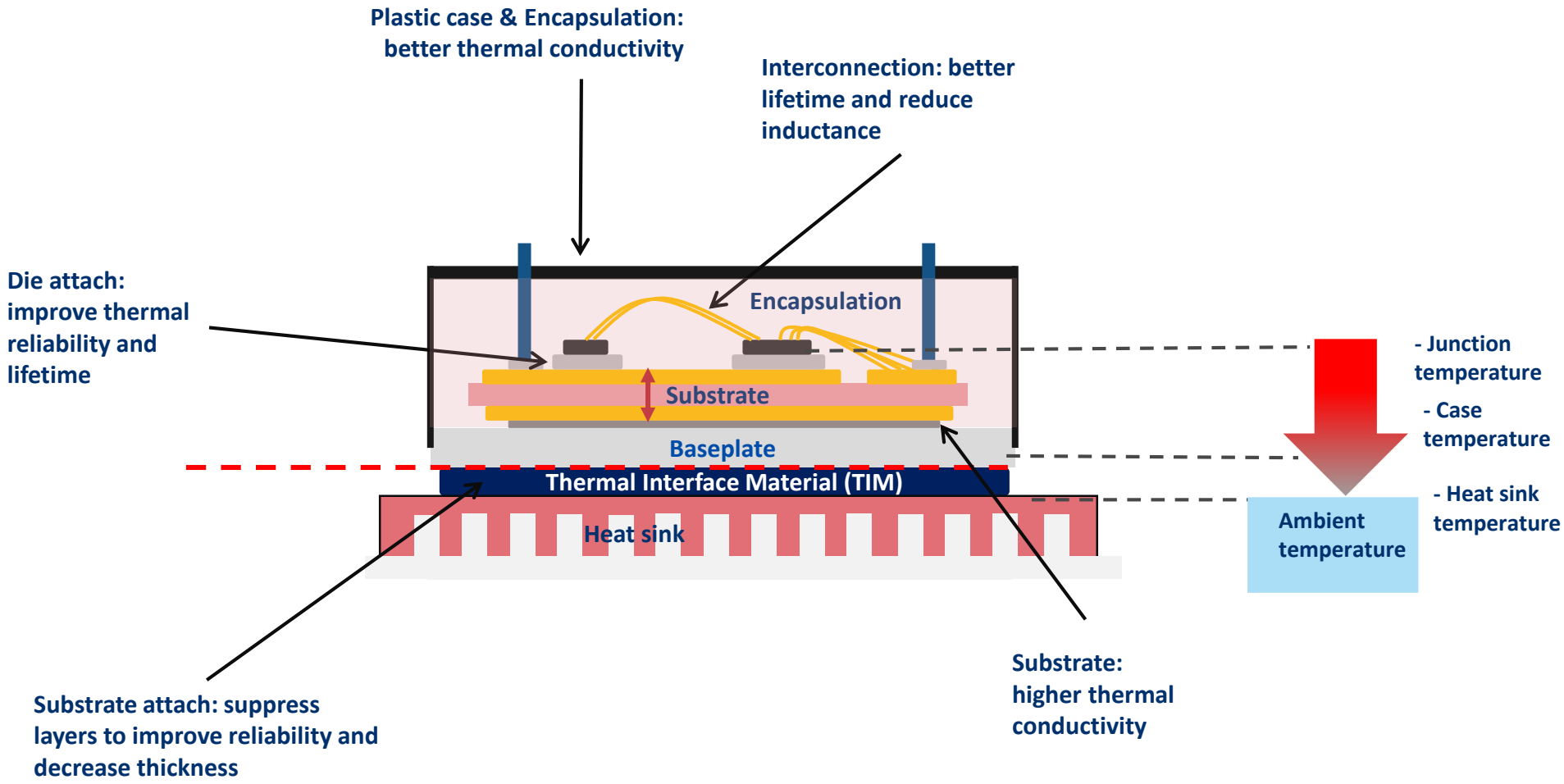
Power Module Issues

In Si modules , mismatching CTE (coefficient of thermal expansion) makes layers detach from one another.

With the introduction of SiC this problem is much more highligted; in fact the main problem of SiC is thermal dissipation because of material density; thus an adapted package and system integration is needed.

Common failure in a power module is caused by thermal cycling.

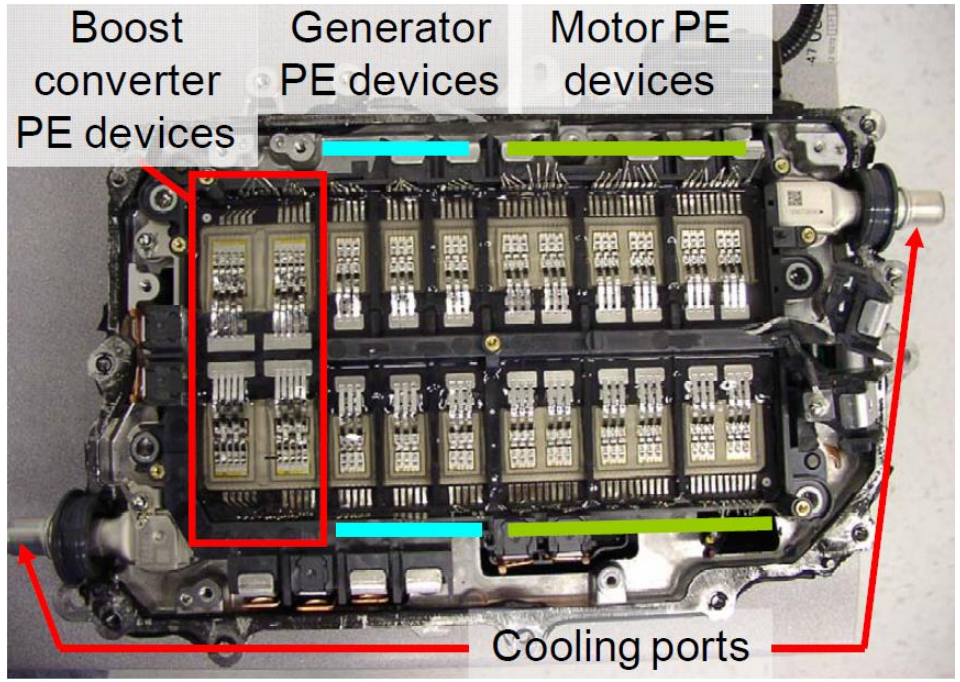
Moreover, module package optimization is necessary to fully benefit of SiC technology advantages against silicon.



Toyota: Interconnections

Toyota Prius:

- ✓ Motor inverter, generator and boost have different die sizes
- ✓ Evolution of IGBT and Diode size and design
- ✓ Decrease of IGBT die size and thickness



Toyota Prius III (2010)

Toyota all-in-1 design:

- ✓ Shared cooling systems
- ✓ Al wire/Al ribbon
- ✓ Reduction of wire connection.

Toyota Prius II (2004):
Al wire

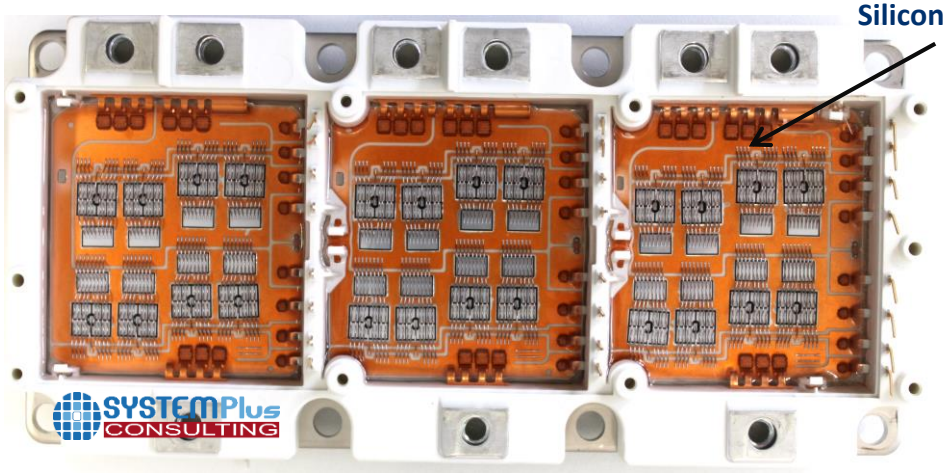
Toyota Prius IIIc (2011):
Al ribbon

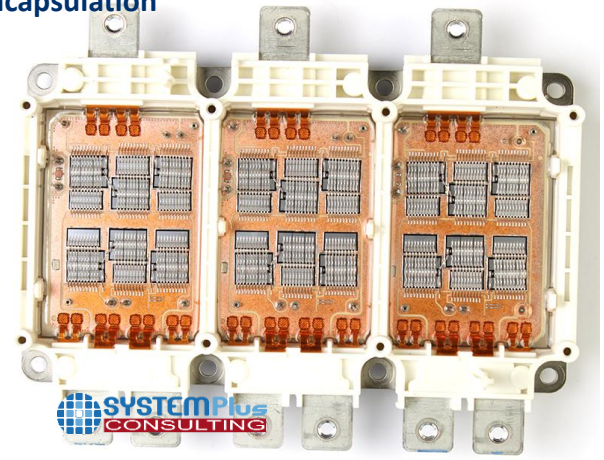
Infineon HybridPACK 2 & Drive

The standard solution for power module is the 6-in-1 module.

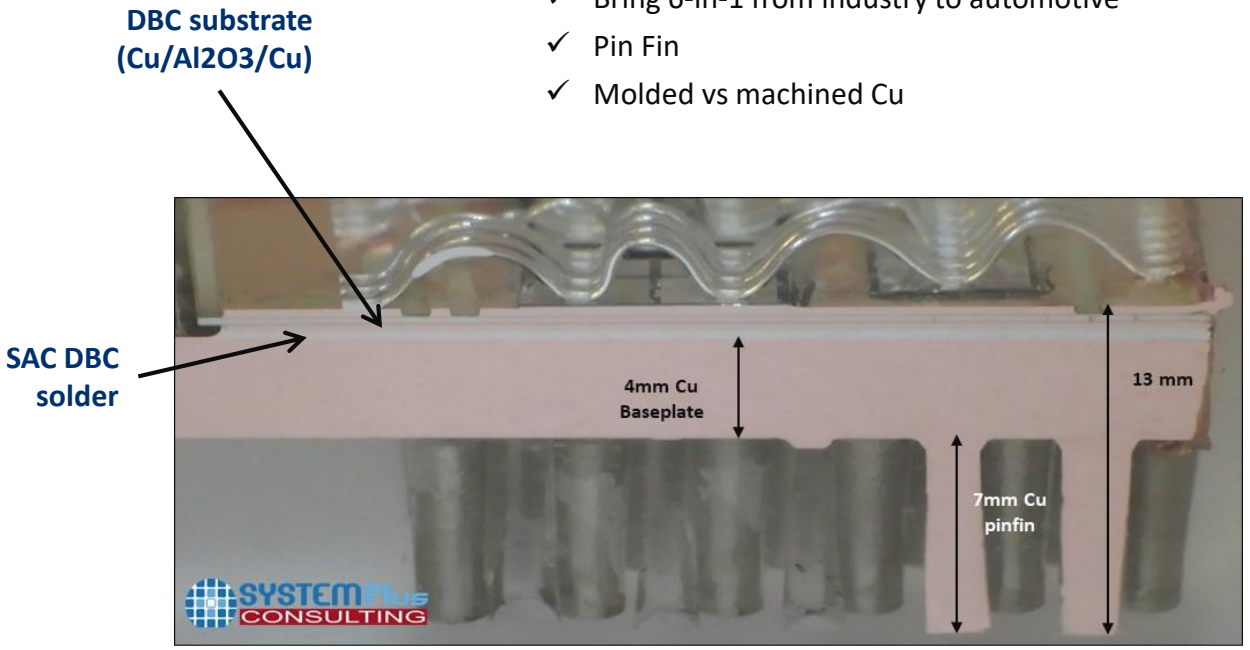
Infineon in 2012 proposed a solution with:

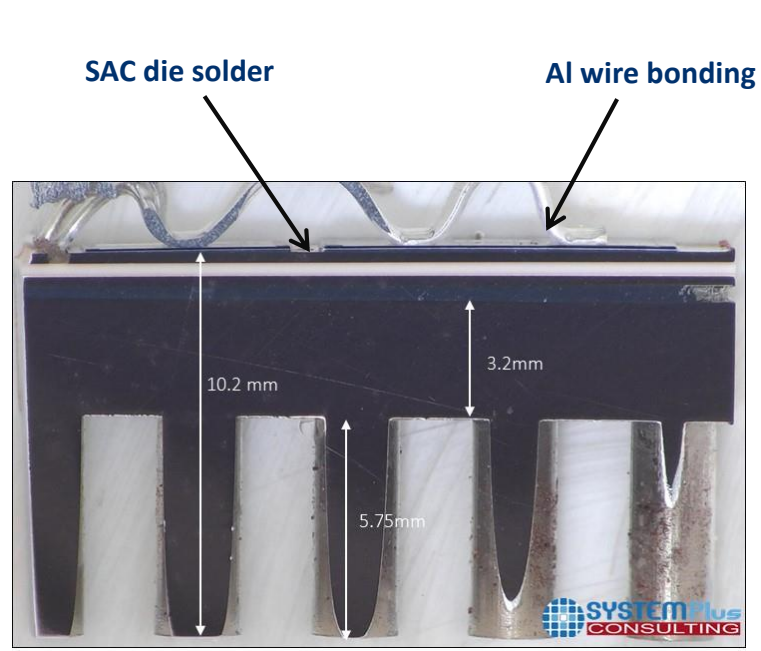
- ✓ 650V/600A
- ✓ Al wire bonding
- ✓ Silicon gel encapsulation
- ✓ Plastic case
- ✓ Cu Pin Fin
- ✓ SAC solder





- ✓ Bring 6-in-1 from industry to automotive
- ✓ Pin Fin
- ✓ Molded vs machined Cu



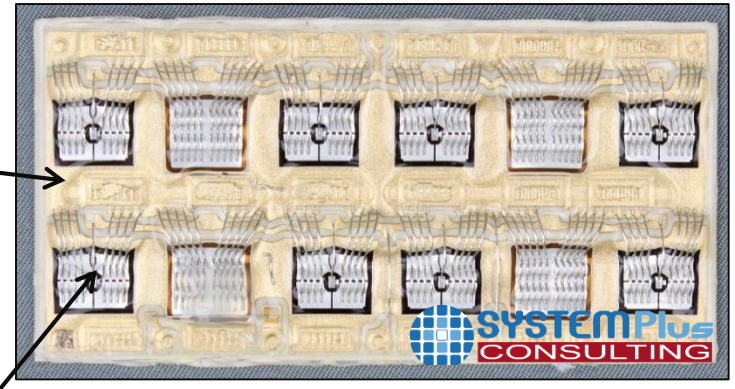


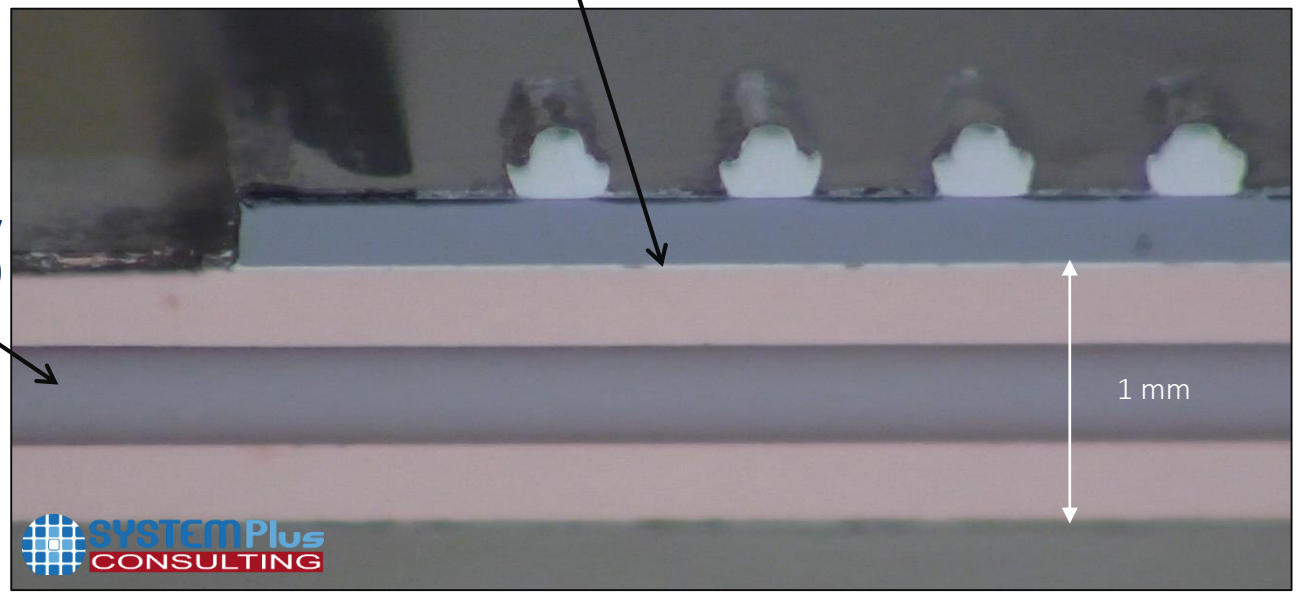
Details DBC substrate: Cross-Section optical view

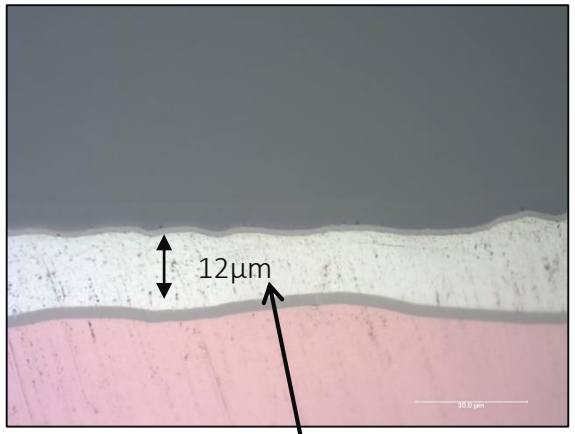
Semikron SKiM

Innovative Semikron solution:

- ✓ 1200V/300A
- ✓ Al wire bonding
- ✓ Central IGBT gate
- ✓ Silicon gel encapsulation
- ✓ Plastic case
- ✓ Ag sintering solder
- ✓ Cu/Al/Cu DBC





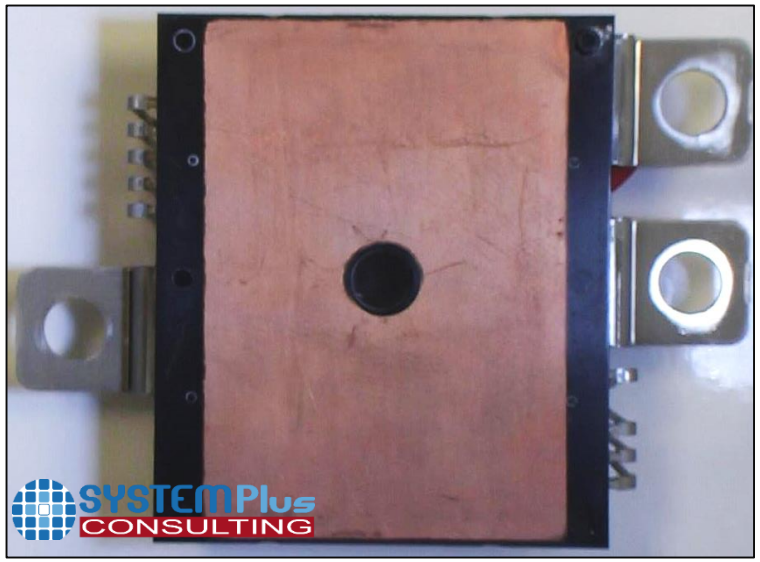


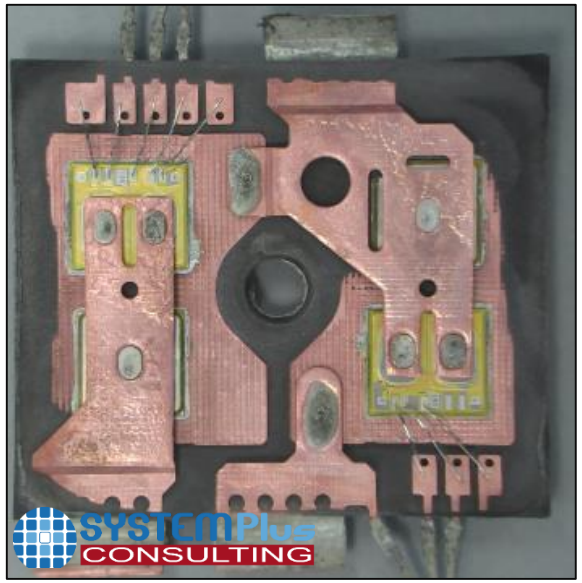
Details DBC substrate: Cross-Section optical view

Mitsubishi for Honda

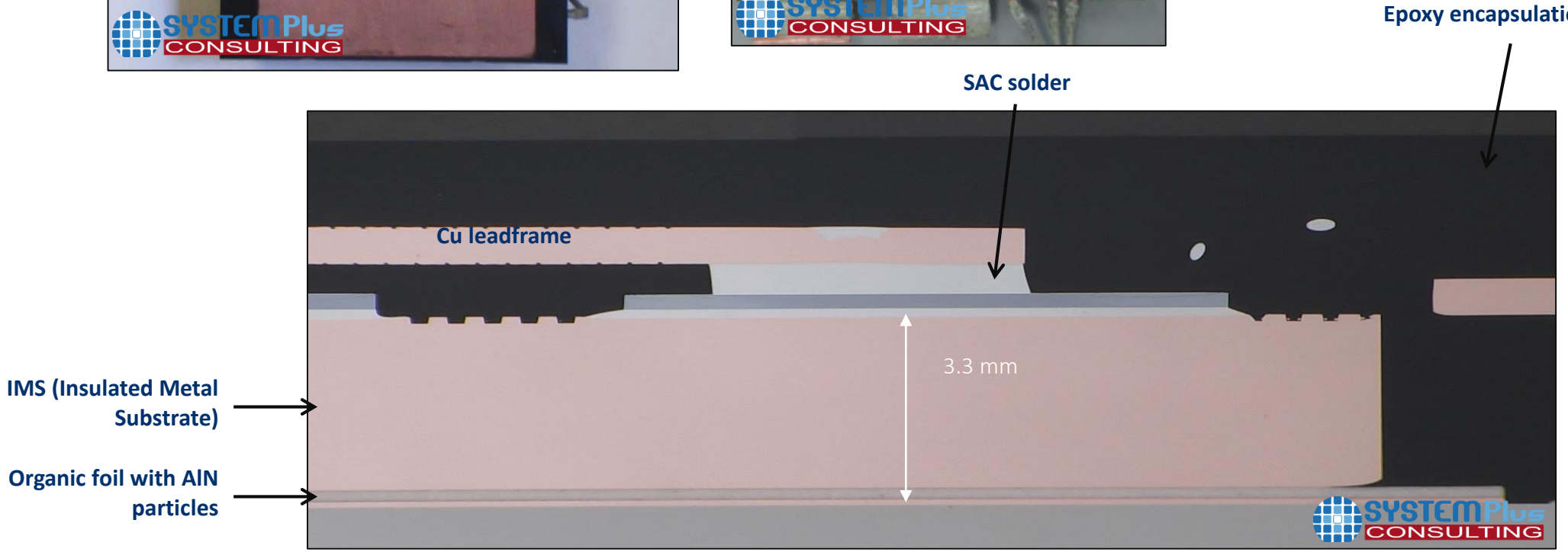
Mitsubishi Electric was one of the first companies to offer molded modules for automotive applications

- ✓ 600V/300A capability
- ✓ Molded package
- ✓ Thick Cu layer of IMS





- ✓ Bring IMS from low power
- ✓ Organic insulator worst thermal conductivity but higher design flexibility

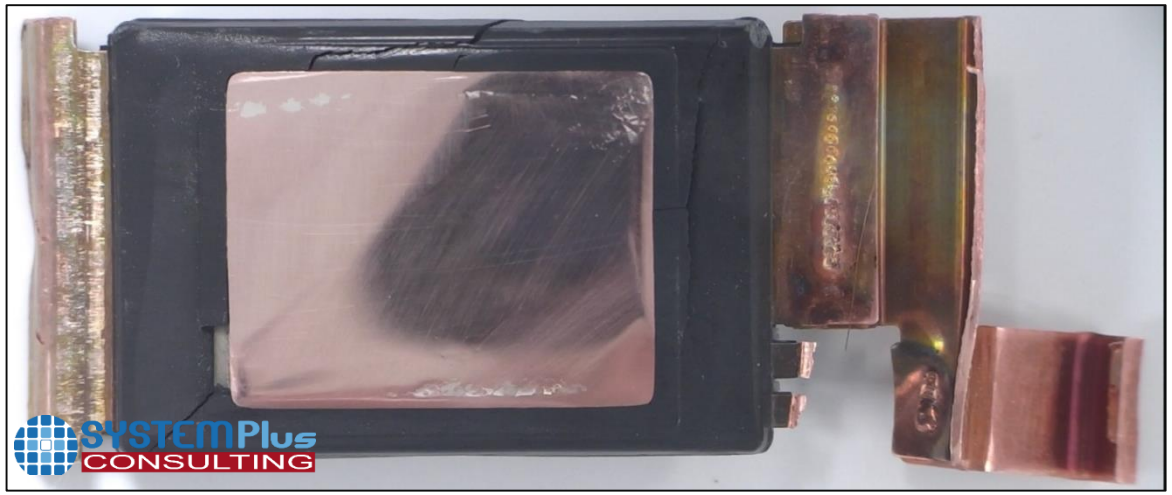


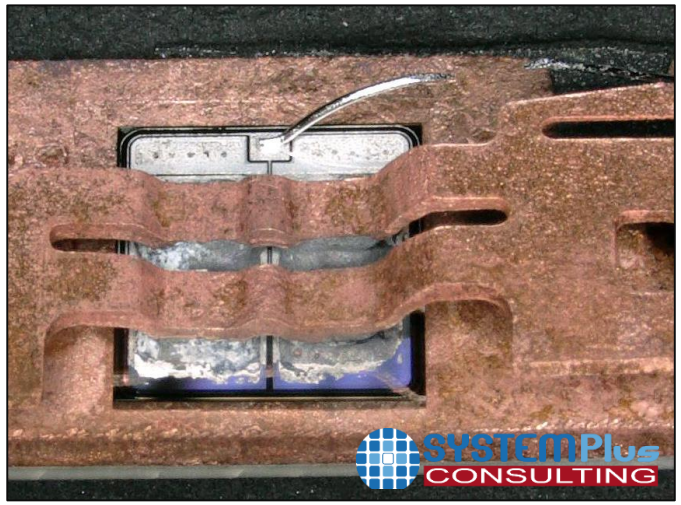
Details substrate: Cross-Section optical view

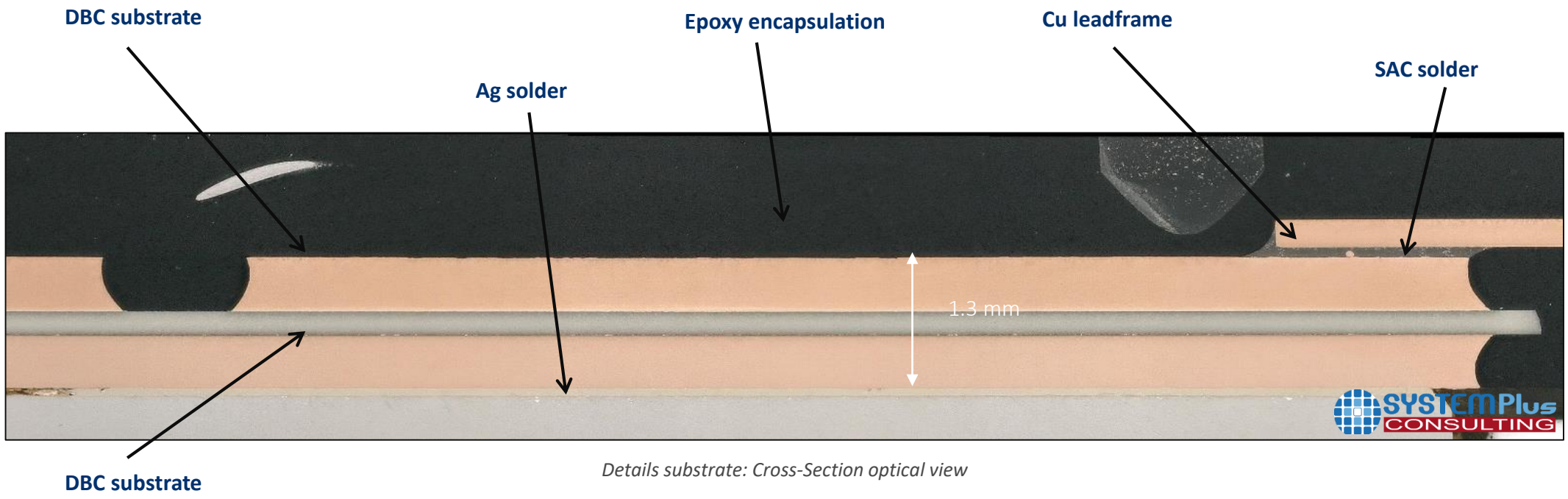
ST for Tesla Module

In 2017 ST proposed a SiC module:

- ✓ SiC MOSFET
- ✓ 650V/300A
- ✓ Epoxy encapsulation
- ✓ Al wire bonding
- ✓ Ag module sintering
- ✓ DBC substrate





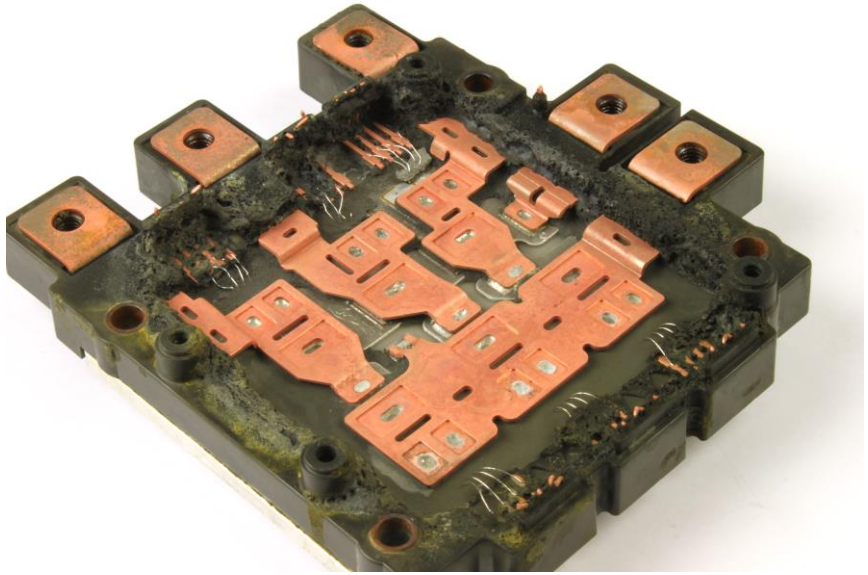


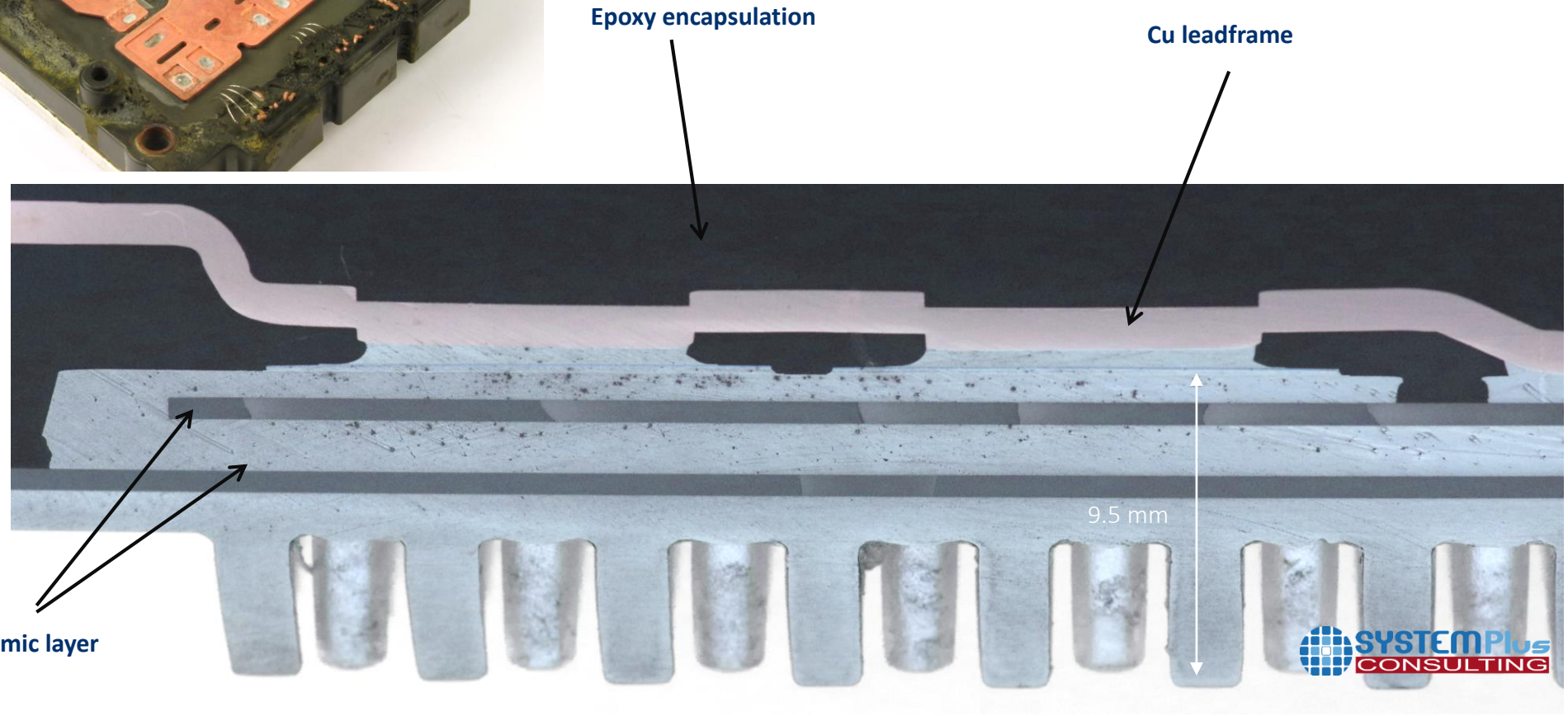
Details substrate: Cross-Section optical view

Mitsubishi J1 serie

Mitsubishi innovates with J1 series:

- ✓ Cu leadframes
- ✓ Epoxy encapsulation
- ✓ Integrated substrate
- ✓ Double Ceramic substrate



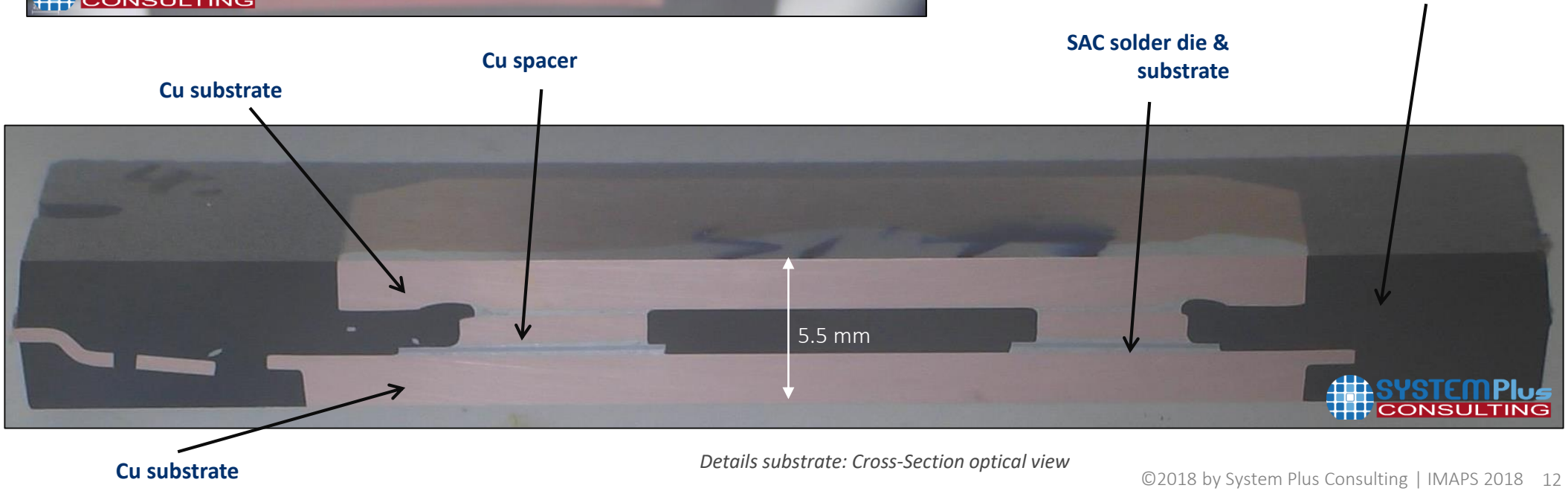


Details substrate: Cross-Section optical view

Toyota Prius IV DSC

In 2015 Toyota changed completely the module design:

- ✓ 750V
- ✓ DSC
- ✓ Epoxy encapsulation
- ✓ Al wire bonding
- ✓ Cu spacer/connection
- ✓ External Isolator

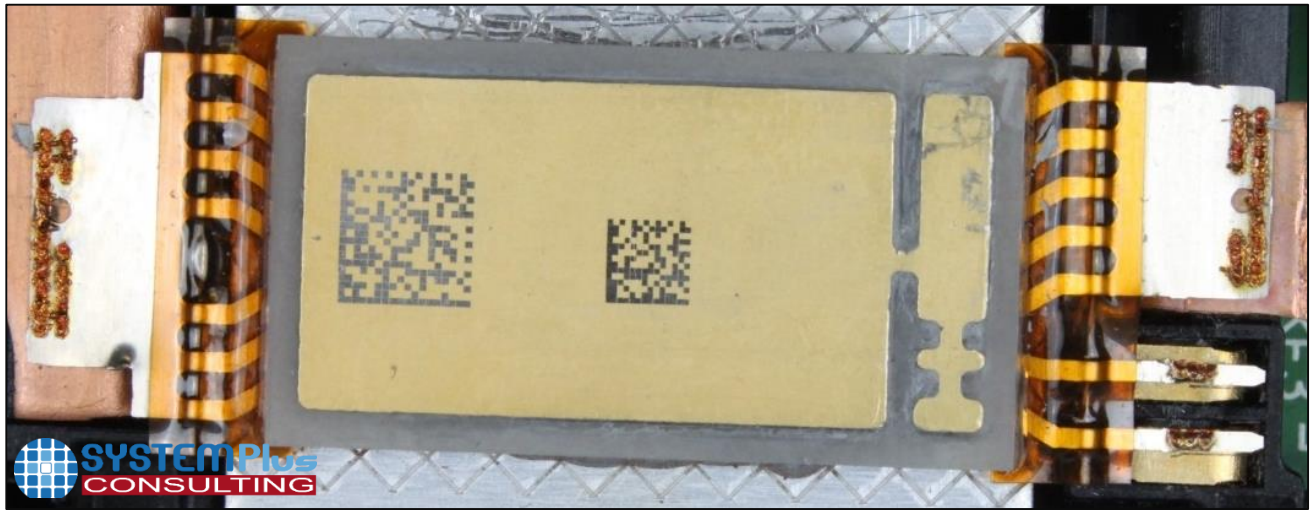


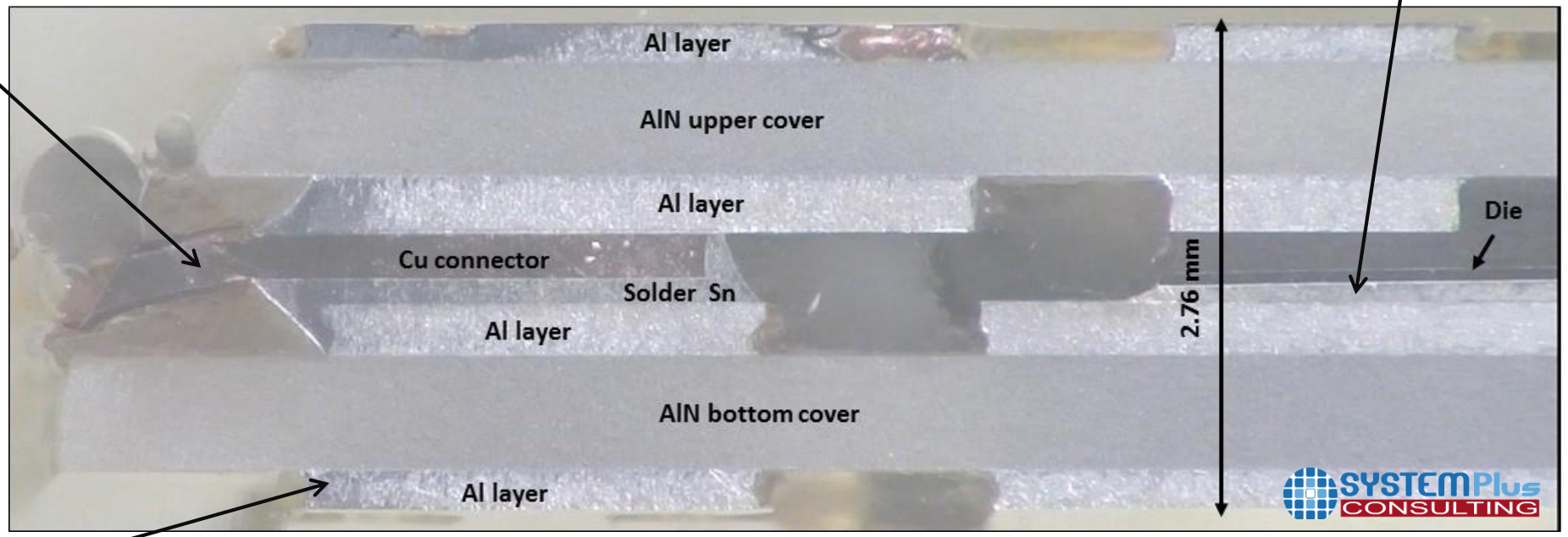
Details substrate: Cross-Section optical view

Viper for Chevrolet Volt

In 2015 Toyota changed completely the module design:

- ✓ DSC
- ✓ No encapsulation
- ✓ Flex connection
- ✓ Ceramic layers



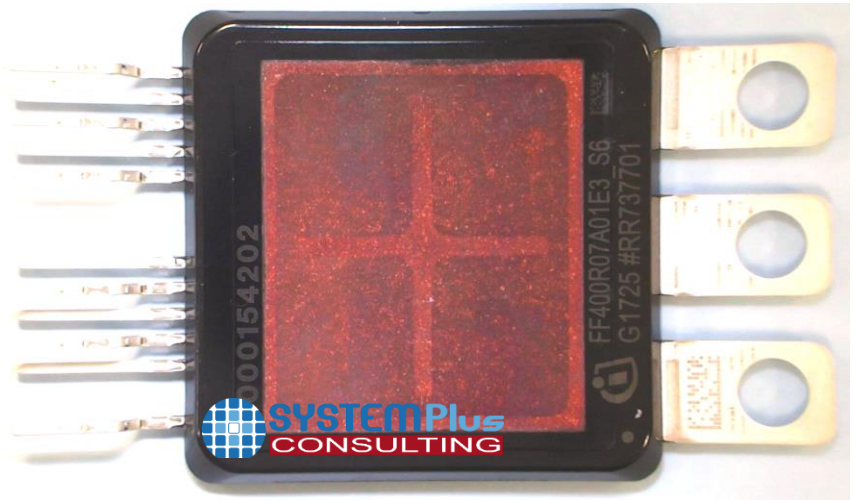


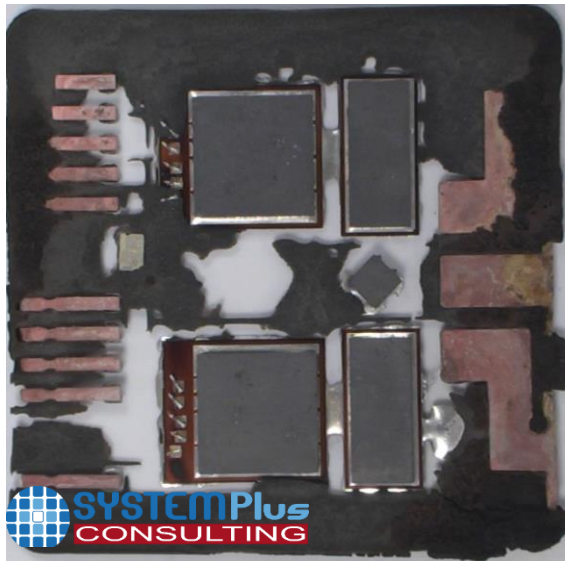
Details substrate: Cross-Section optical view

Infineon HybridPACK DSC

In 2017 Infineon too proposed a DSC:

- ✓ 700V/400A
- ✓ DSC
- ✓ Epoxy encapsulation
- ✓ Al wire bonding
- ✓ Alloy spacer
- ✓ DBC substrate
- ✓ Integrated isolation





Details substrate: Cross-Section optical view

Power Module Solutions

Plastic case

Overmolded

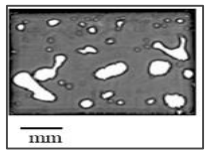
Aluminum wire bonding

Ribbon bonding

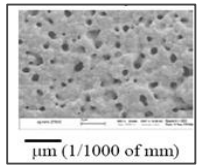
Copper leadframes

Case

Interconnection



Tin soldering



Silver paste or film sintering

Silicone gel

Epoxy

Die attach

Encapsulation

Substrate

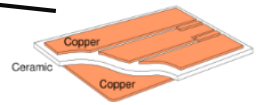
Baseplate

Thermal Interface Material (TIM)

Heat sink

Baseplate + Heatsink

Substrate



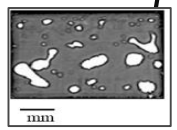
DBC

Double-side cooling with DBC

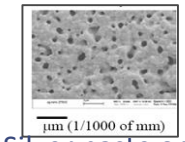
Flat baseplate

Pin-fin baseplate

Substrate attach

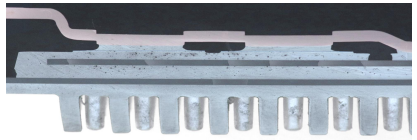


Tin soldering



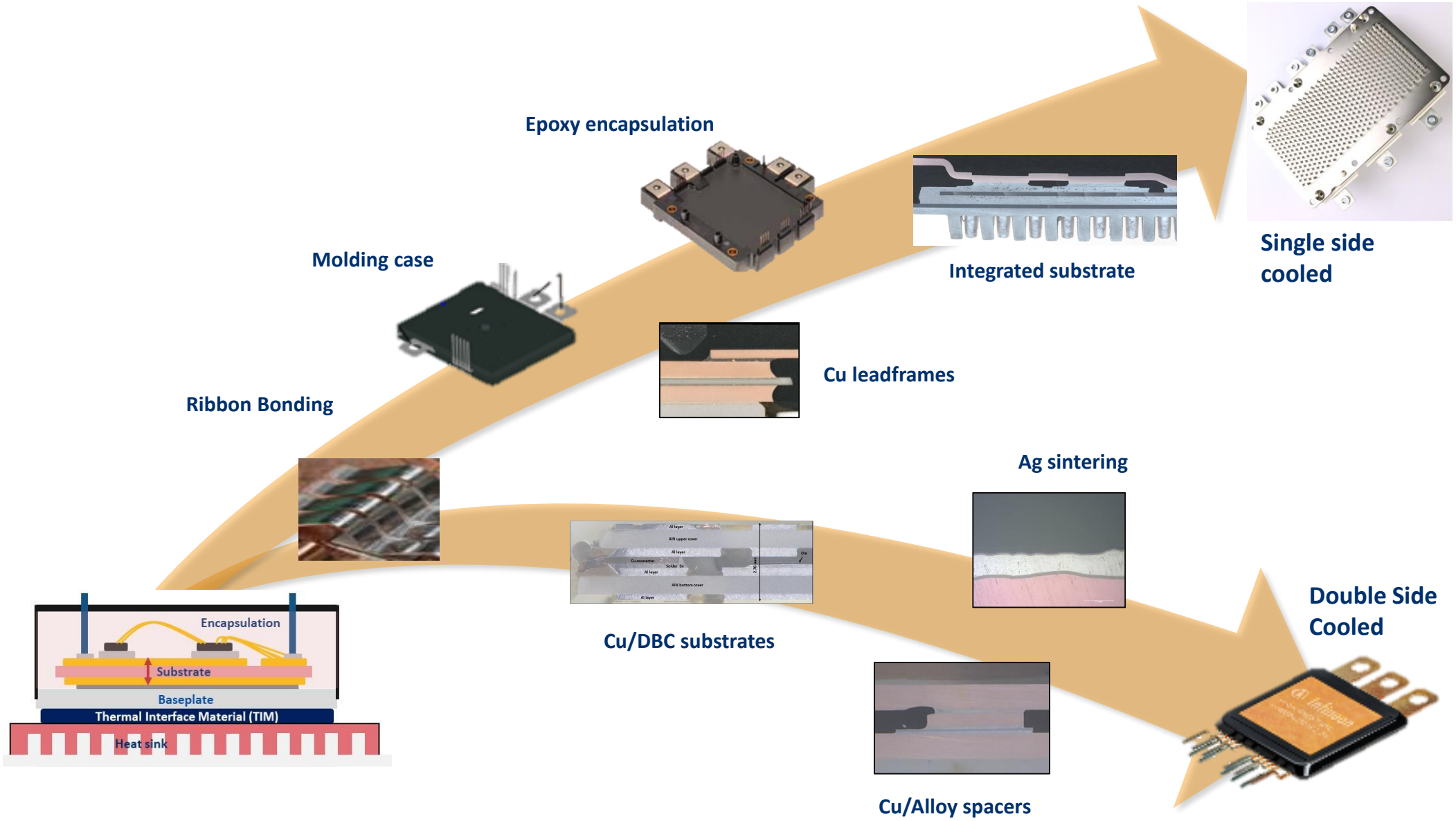
Silver paste or film sintering

Integrated substrate



Main trends

Every manufacturer proposes its solutions; but some main trends are evident.



Contact

Headquarters

21 rue La Noue Bras de Fer
44200 Nantes
FRANCE
+33 2 40 18 09 16
sales@systemplus.fr

Europe Sales Office

Lizzie LEVENEZ
Frankfurt am Main
GERMANY
+49 151 23 54 41 82
llevenez@systemplus.fr

America Sales Office

Steve LAFERRIERE
Phoenix
USA
laferriere@yole.fr

Asia Sales Office

Takashi ONOZAWA
Tokyo
JAPAN
onozawa@yole.fr

Mavis WANG
GREATER CHINA
wang@yole.fr

www.systemplus.fr