



ASE GROUP

Automotive IC Packaging: Evolving Power Solutions

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- October 2019



What We Will Cover:

- **Automotive Market Trends & Evolution**
Market Growth & Key Package Enablers
- **Automotive Package Options/Roadmap**
- **Next Generation Power Enablers:**
Direct Cu-to-Cu Interconnect

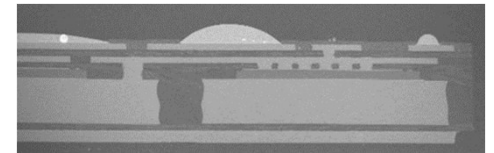


GM

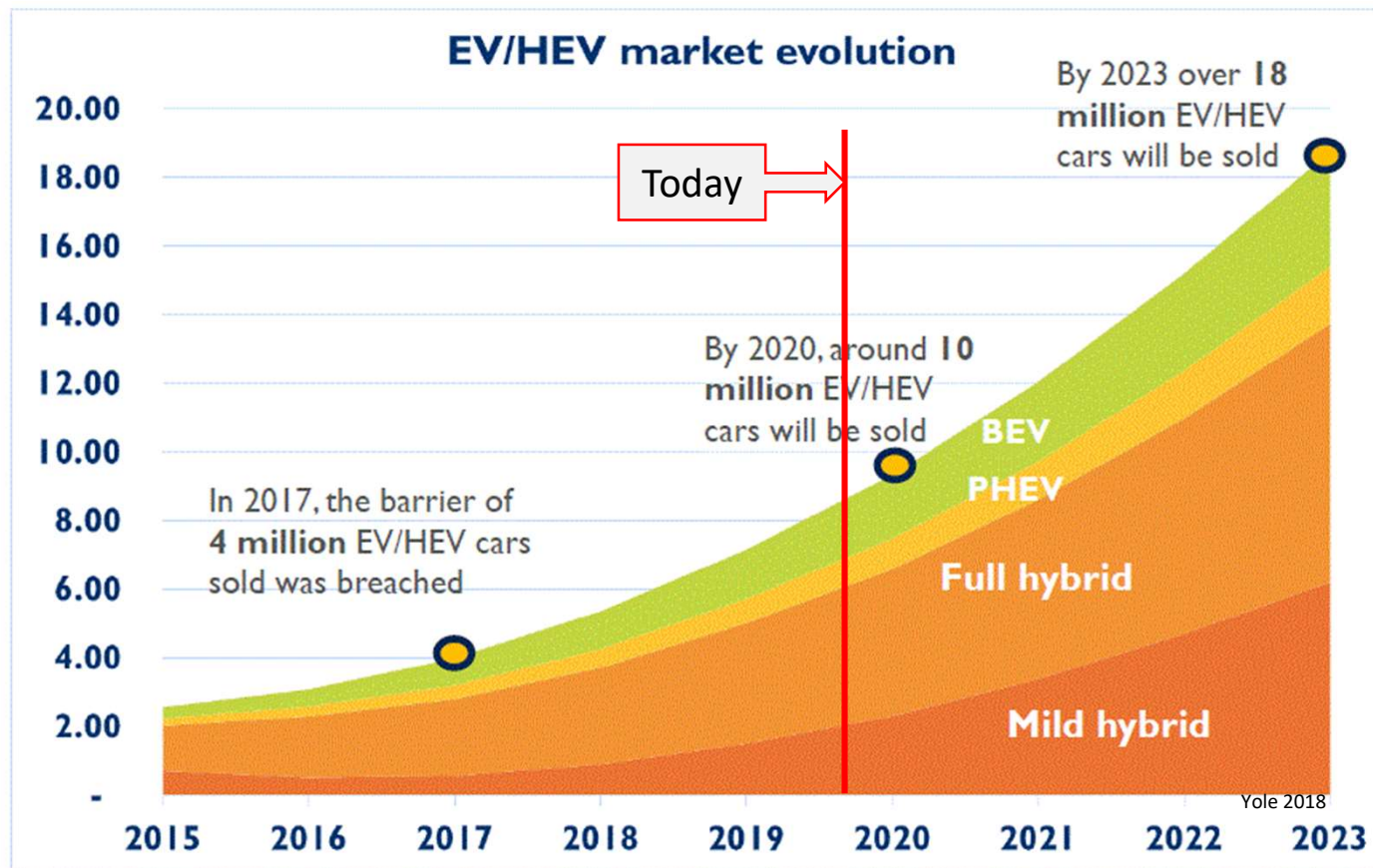


Automotive Market Trends & Evolution

Market Growth and Key Focus



EV/HEV Market Forecast

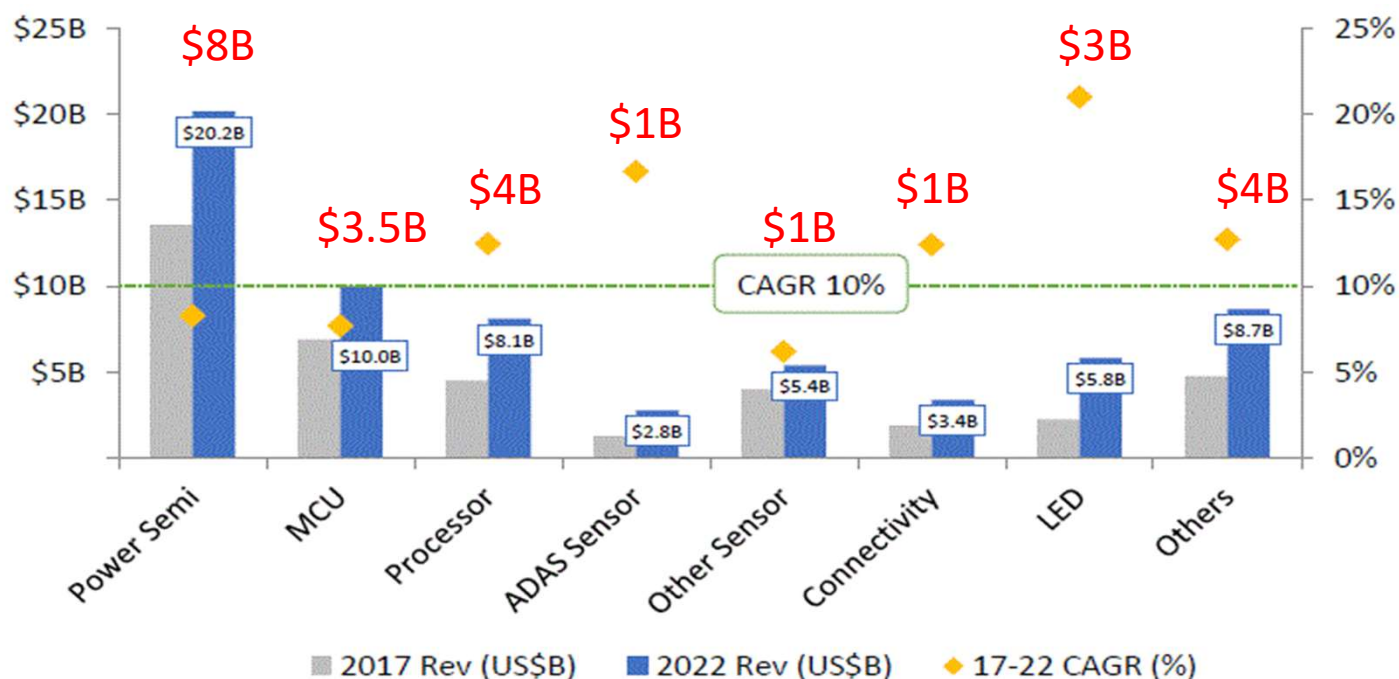


BEV: Battery Electric Vehicle
PHEV: Plug In Hybrid Electric Vehicle

EV/HEV Power Modules Market Data

- **Each EV/HEV Car Requires 5 Power modules**
 - 50kW to 300kW: Inverters
 - 10kW to 40kW: Starter- Generators
 - 4kW to 20kW: Battery Chargers
 - 2kW-8kW: Battery DC-DC Converters
 - 500W – 3kW: Power Steering, Water Pump, Climate Compressor
- **EV/HEV accounts for half the WW power module market value in 2017, and 80% of the produced power module units**
- **EV/HEV only accounts for 4% of new cars in 2018**
- **Forecasts ranges for EV/HEV in 2030 is between 40% and 80% of all new annual vehicle sales**
- **EV/HEV cars will grow from 4Mu in 2018 to between 50Mu and 100Mu in 2030 (10x-20x Growth)**

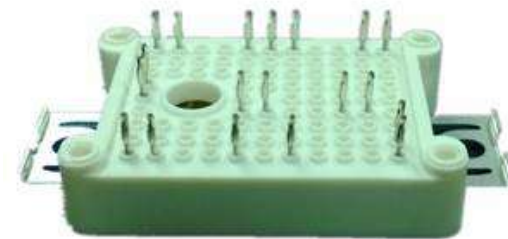
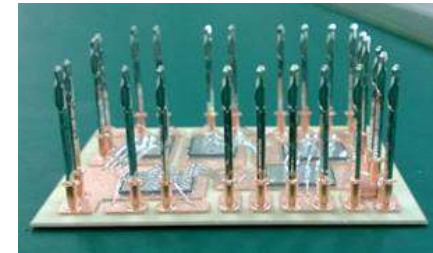
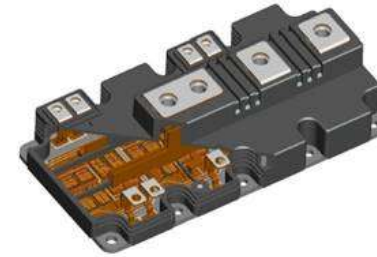
Automotive Semiconductor Content By Device



Source : Gartner, Jul 2018/IHS, 2018

Conventional/Traditional Type of High Power Modules

- Singulated Processing
- Large All-In-One Modules
- Specific Expensive BOM (DBC Ceramic Subm,, GEL Filling, Plastic Housing, Large Silicon Dies)
- SnPb Die Attach (With Lead)
- Vacuum Soldering
- Bottom Side Cooling Only
- Complex structure with cleanable baseplate for over 30yr useage
- Ok for trains, Windmills, Power, Power Stations, Solar Panels
- Not Suitable for high volumes (x10's from today)

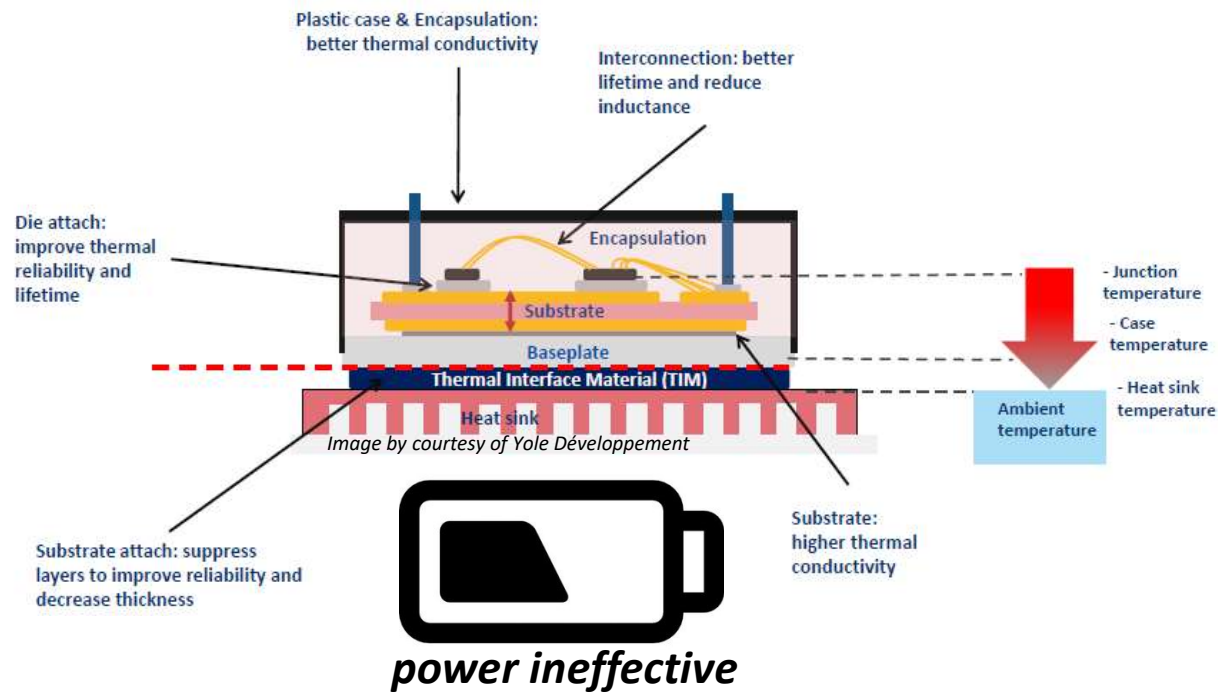


A 30-year Old Technology Designed For The Conservative Industrial World



expensive

A Conventional Power Module



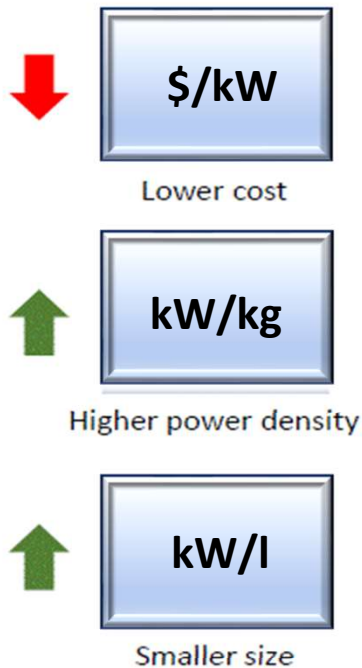
heavy



power ineffective

Technology Trend for Power Electronics in EV/HEV

Objective



System Level

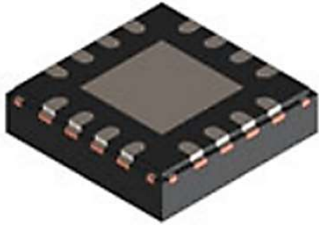
- More integration like motor + inverter
- High Temperature Capacitors, Laminated busbars
- Enhanced cooling of the power converter, Double-sided cooling

Module/Packaging Level

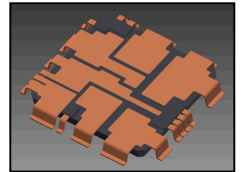
- Double-sided cooling
- Use epoxy resin as encapsulant
- Silver Sintering is promising die attach material for power packaging

Device Level

- Wide band gap material will emerge (SiC, GaN) as new material for power semiconductor

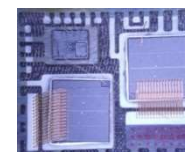
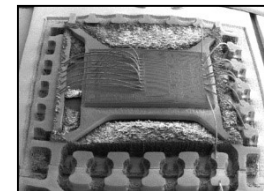
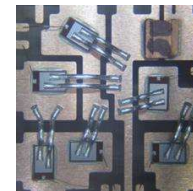
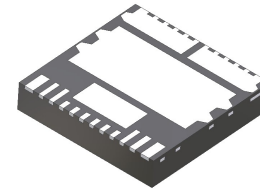


Power Package Options (Automotive)

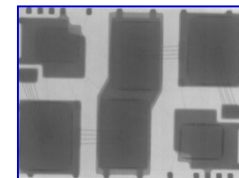


Power & Module QFN

- **Power QFN development**
 - High Thermal requirement
 - 20 mil thick LF: Under mass production
- **Integrated L/F power module development**
 - 6-MOSFET + 1 shunt resistor
 - High Pb solder D/A
 - Al wedge bonding (3mil Gate / 20mil source)
- **Module QFN**
 - Component integrated
 - HV / LV MOSFET + control chip
 - Half-bridge application as 2 HV MOSFET + 2 LV MOSFET + 2 control chips

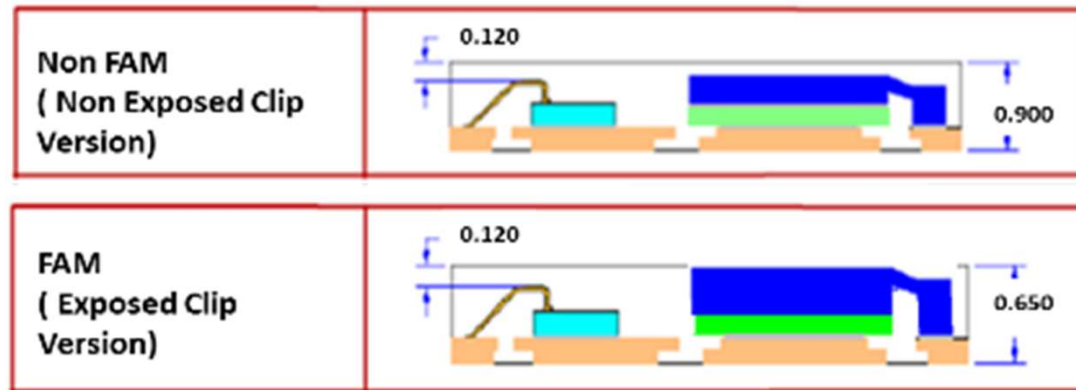


Half Bridge Power QFN

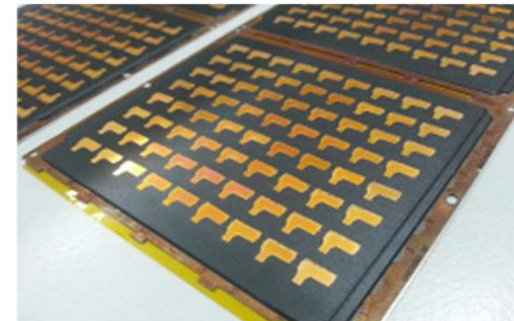


Full Bridge Power QFN
With wettable flank

PQFN with Cu clip – Package Structure



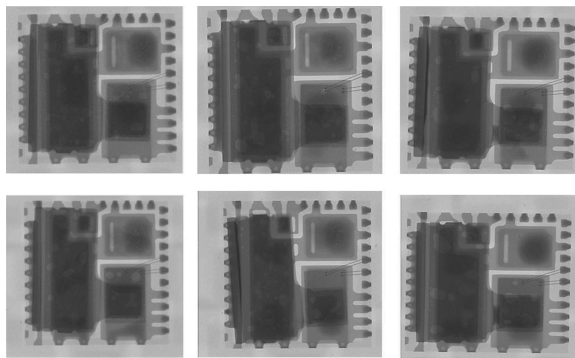
After Molding



After Sn
Plating



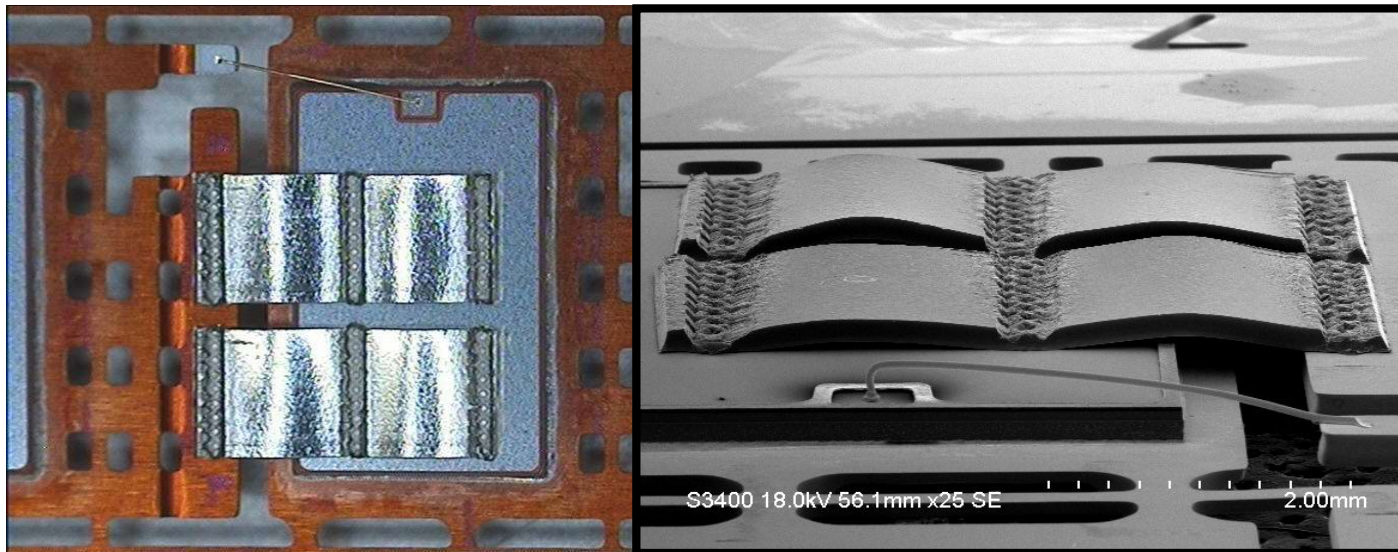
X-Ray



Wettable 7x8PQFN with Al Ribbon - AEC Q101

- Package structure & BOM

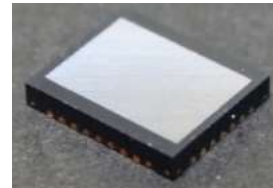
DFN 11L 8X7 BODY
DIE SIZE : 235X143MIL



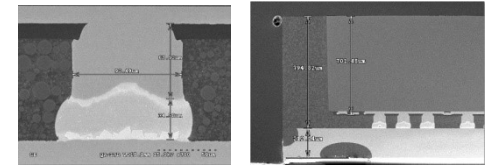
Flip Chip QFN (FCQFN)

• FCQFN Structure & Benefit

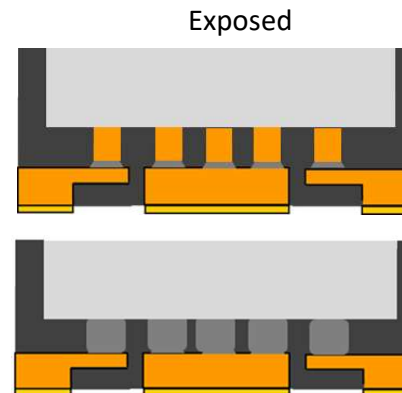
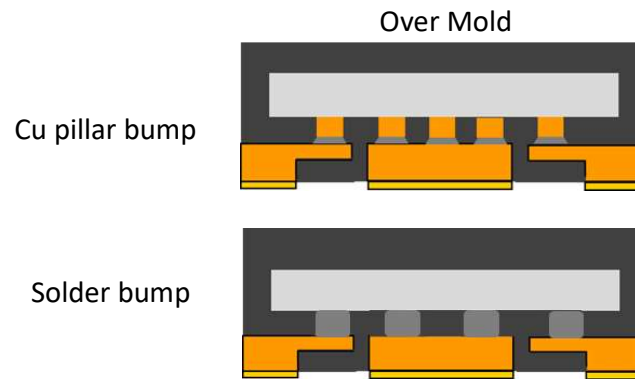
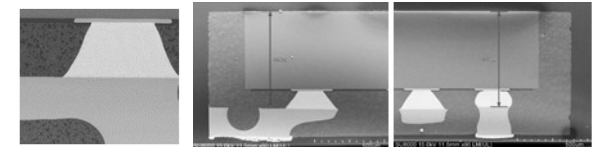
- Low Rds-on for power management device by reducing wire trace to have lower power consumption
- High Current solution for Power device/ Low IR Drop
- High Thermal solution
- Short process flow & CT
- W/ & W/O die exposed solution
- Low cost compared with FC CSP



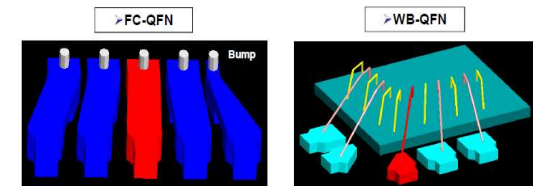
Cu pillar bump



Solder bump



IR Drop Evaluation for WB-QFN and FC-QFN

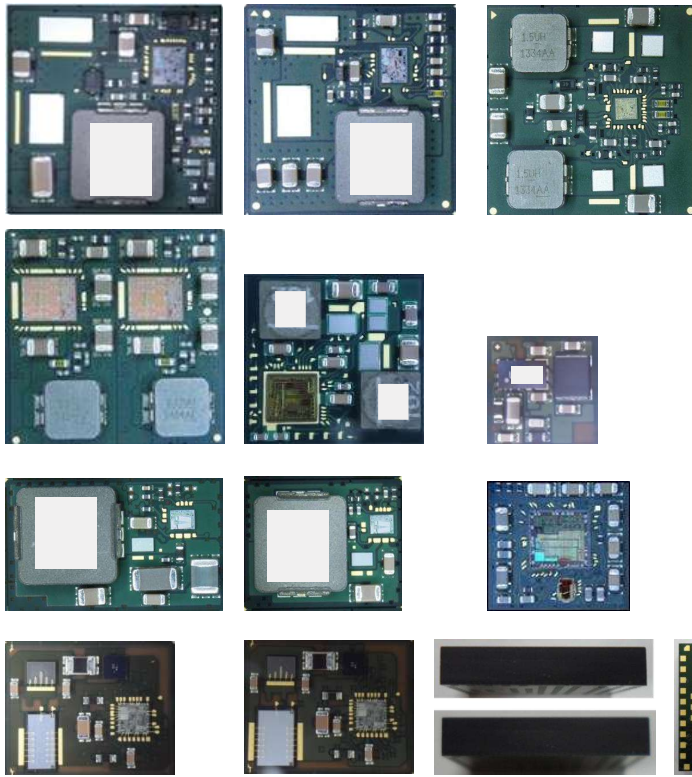


Resistance simulation by ANSYS Q3D

PKG Type	PKG Size (mm ²)	Resistance (mOhm)	
		Max	Min
FC-QFN	5 X 5	6	5
WB-QFN	5 X 5	65	55

➤ According to the resistance evaluation, it has about 90% resistance reduction from WB-QFN design to FC-QFN design. Thus, there is about 90% IR-drop improvement.

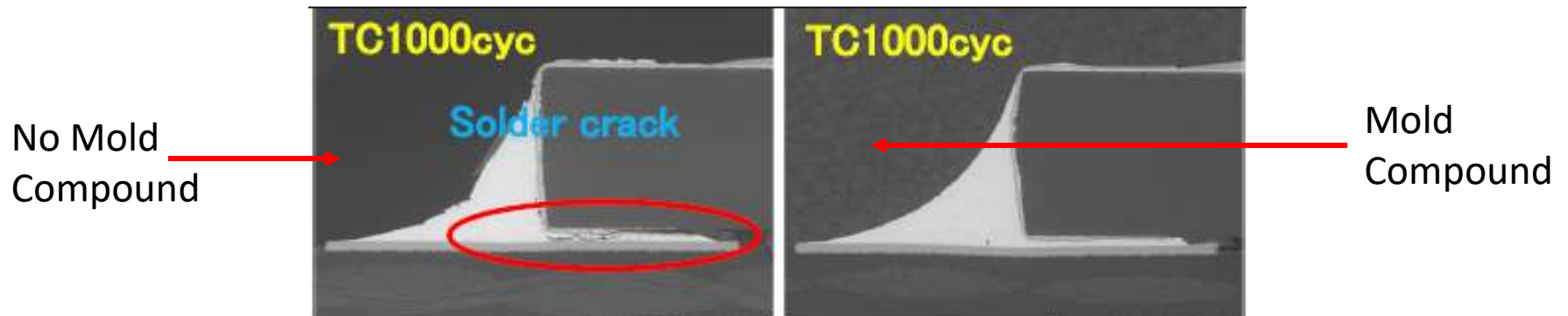
uPower Module



- Application: DC-DC Converter / Smart Voltage regulator
- Requirements:
 - Solder D/A and epoxy D/A
 - R/L/C & Inductor (or diode, transformer) handling (Max. 7x7.6x2mm)
 - Flip-chip, Multi die and multi wire handling
 - High Reliability for automotive application
 - Thick mold cavity (Max. 4mm)
- Status:
 - Started Vol. Production from Dec '13
 - Automotive uPower Module production from Oct'14

Benefits of Molding: Molded SiP vs PBA (System on Board)

- Improved thermal cycling compliance
- Higher immunity to vibrations

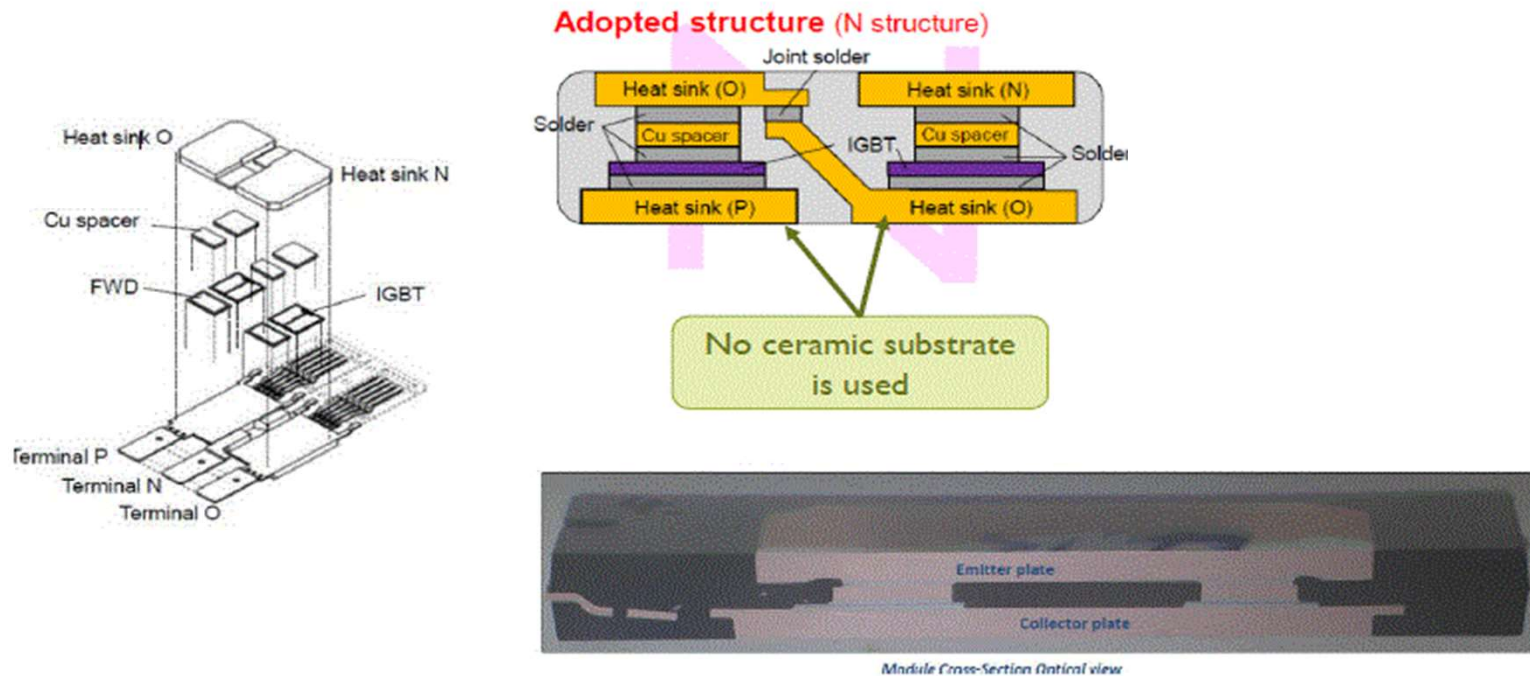


Good protection ECU with direct molding, while solder crack occurs at solder joint of the chip resistance without mold

By courtesy of Sumitomo Bakelite

Other Industry Solutions – Improved Thermal

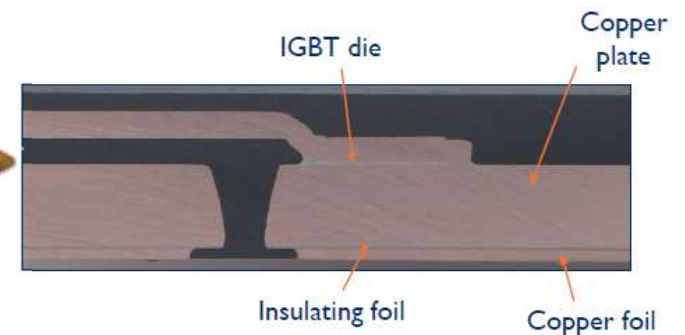
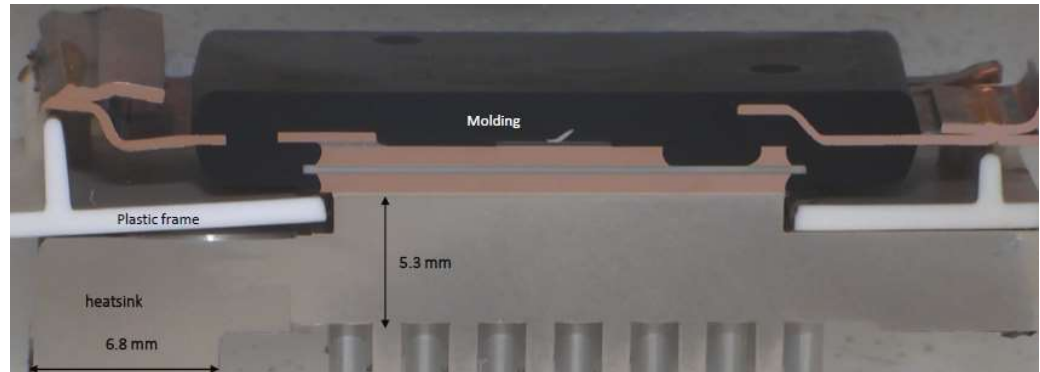
Toyota Prius Fourth Generation – Double Sided Cooling Power Card



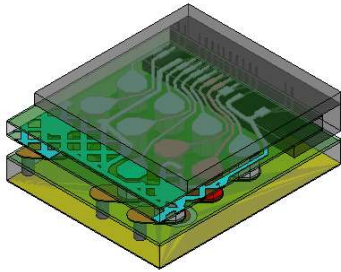
Source: System Plus Consulting

Other Industry Solutions – Improved Thermal/Electrical

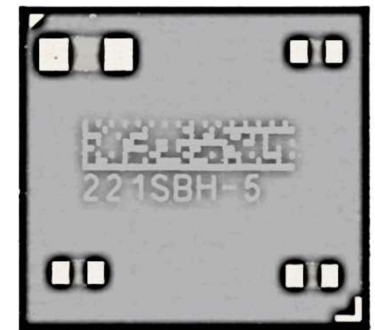
- Custom Leadframe Tooling
- Batch Processing (strips, panels)
- Modularized (multiple packages in module)
- Semiconductor -like BOM & structure (leadframe, embedding, overmolding)
- Smaller SiC and GaN dies
- Lead-free die attach (TLPB, Ag sintering)
- Reflow with (limited) pressure



Cross-section of a Bosch 2-in-1 module showing IMS technology
Courtesy of System Plus



Next Generation Power Enablers: Direct Cu-to-Cu Interconnect



Power Discrete & SiP – How packaging is evolving.....

Leaded
Package

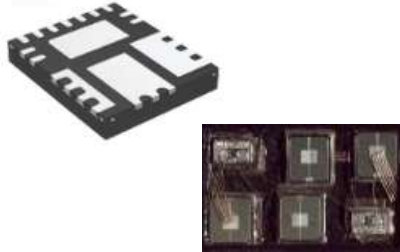


TO220

Workhorse for
Power discrete
Inductance from
wires & leads



Leadless Package
(surface mount)



Power QFN

No-leads
Integrate
multiple die



Embedded Die



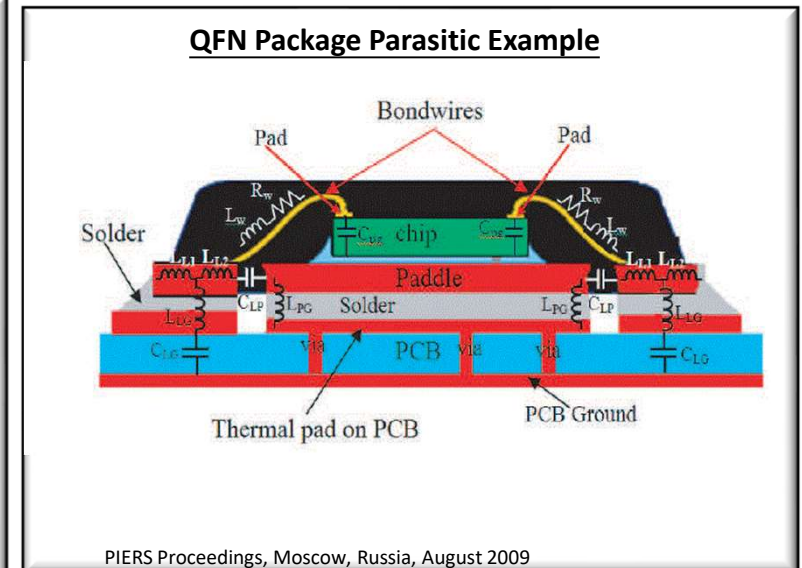
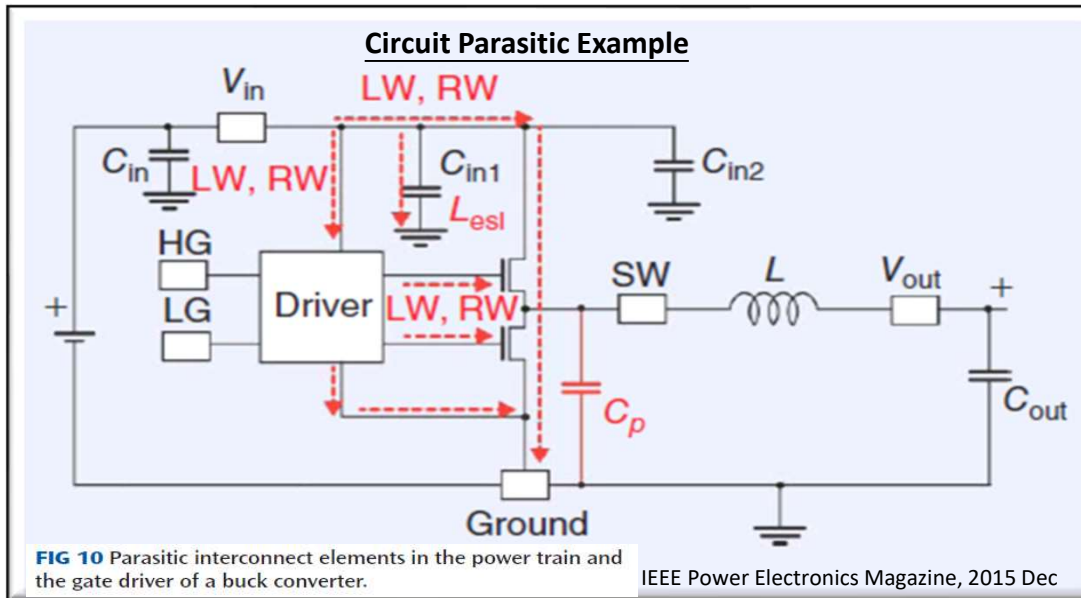
aEASI/SESUB

No-leads
Direct connection
Integrate multiple
components

Electrical Considerations of Embedding



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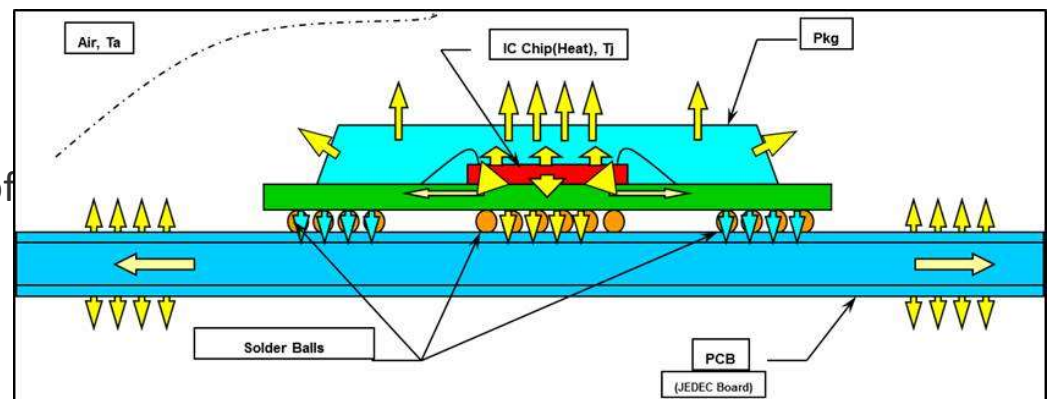
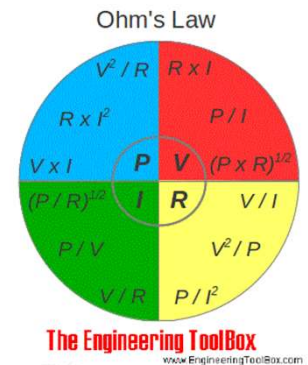


- Ⓢ High Capacitance Can Create Parasitic Crosstalk and Inductance Drives Power Loss

Understanding Ohms Law for Packaging



- Ohm's Law : Power Loss = Current Squared x Resistance
(Double the Current give you 4x the Power Loss)
- Physical Explanation – The voltage difference along a wire depends on the current – More current flowing with resistance mean more voltage (pressure of electricity if you like) is built up.
- Practical Explanation – Power measured in watts is equal to $I^2 \times R$ along the path of circuit. If you keep resistance small, you **minimize power loss as HEAT!!**

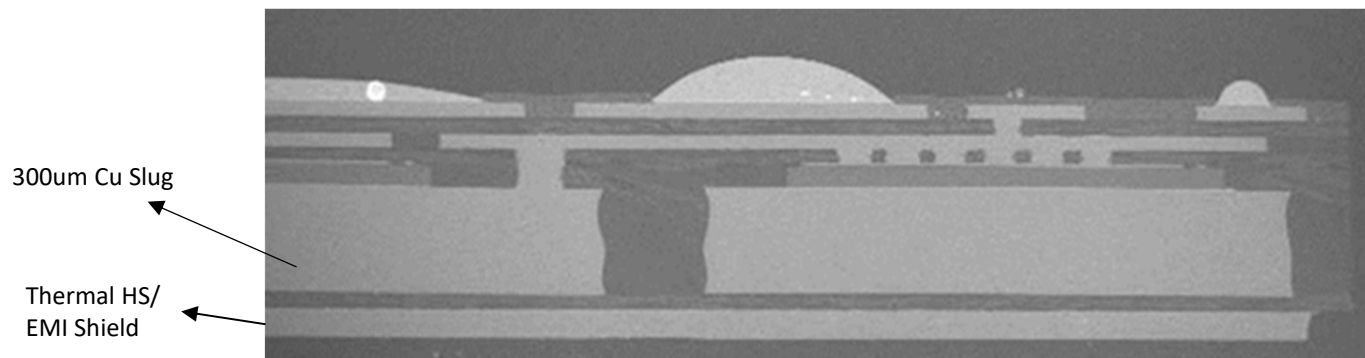


**Physics Forum 2008

What's **a-EASI**?

aEASI = Advanced Embedded Active System Integration

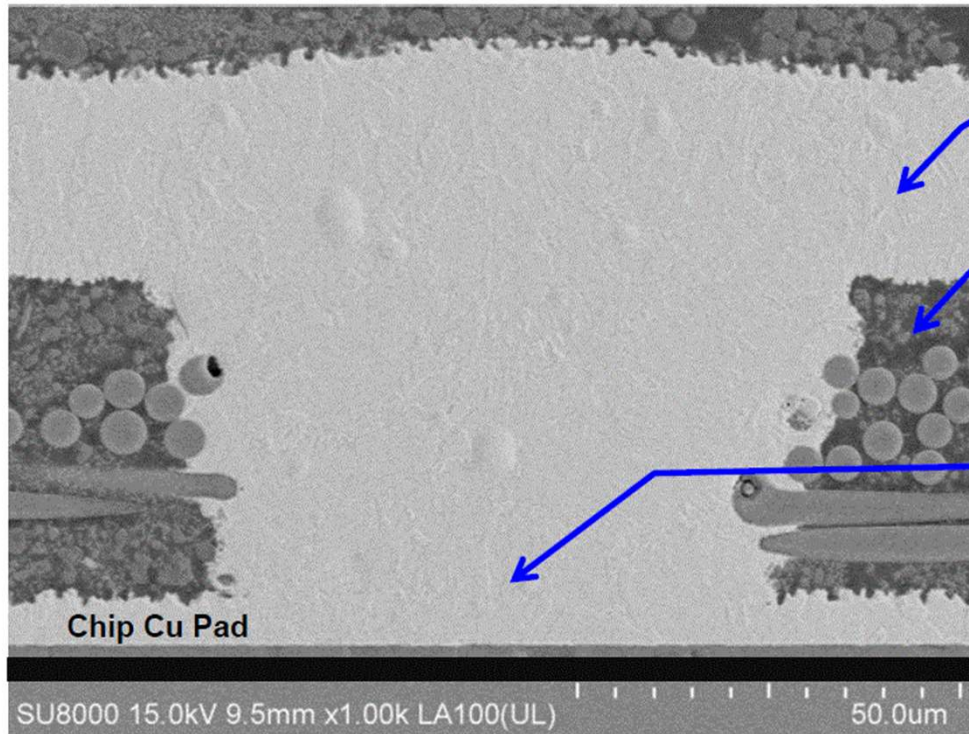
- Utilizes Mature Organic Substrate Process Modified to Meet High Power Applications
- Hybrid Power Package Combining Lead frame & Substrate Technologies
- Good Current Capability- ~60A (Integrated Power Stage Example), ~ 1.9W/mm²
- 300um thick Copper Heat Spreader/Electrical Pad (Back of Die)
- Deep Full Filled Vias to Die ~ 130um Diam
- Ultra Low Resistivity Die Attach Interface



P1 Example

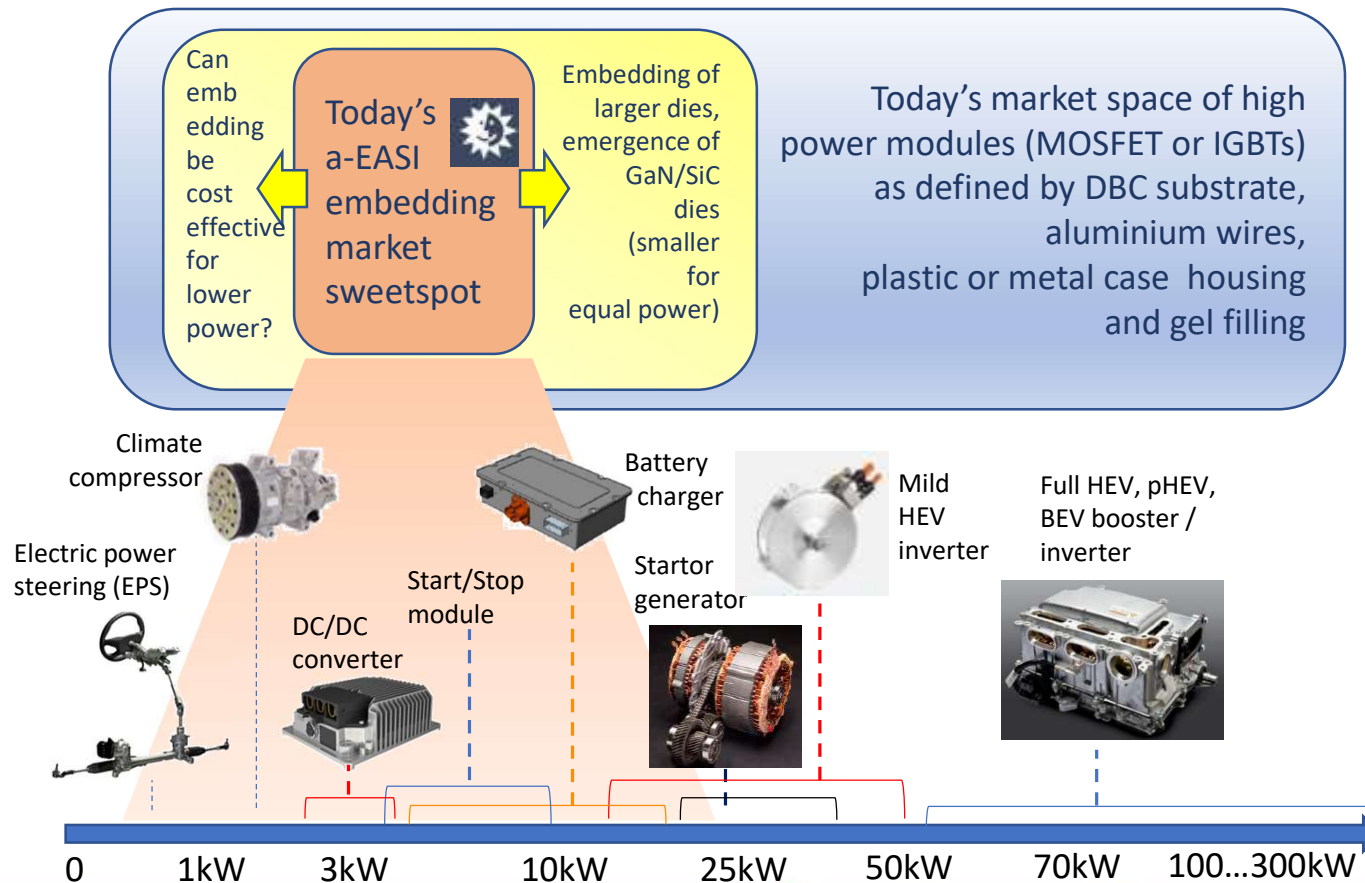
aEASI P1 Package to Die Interconnect Highlights

* Design for power devices

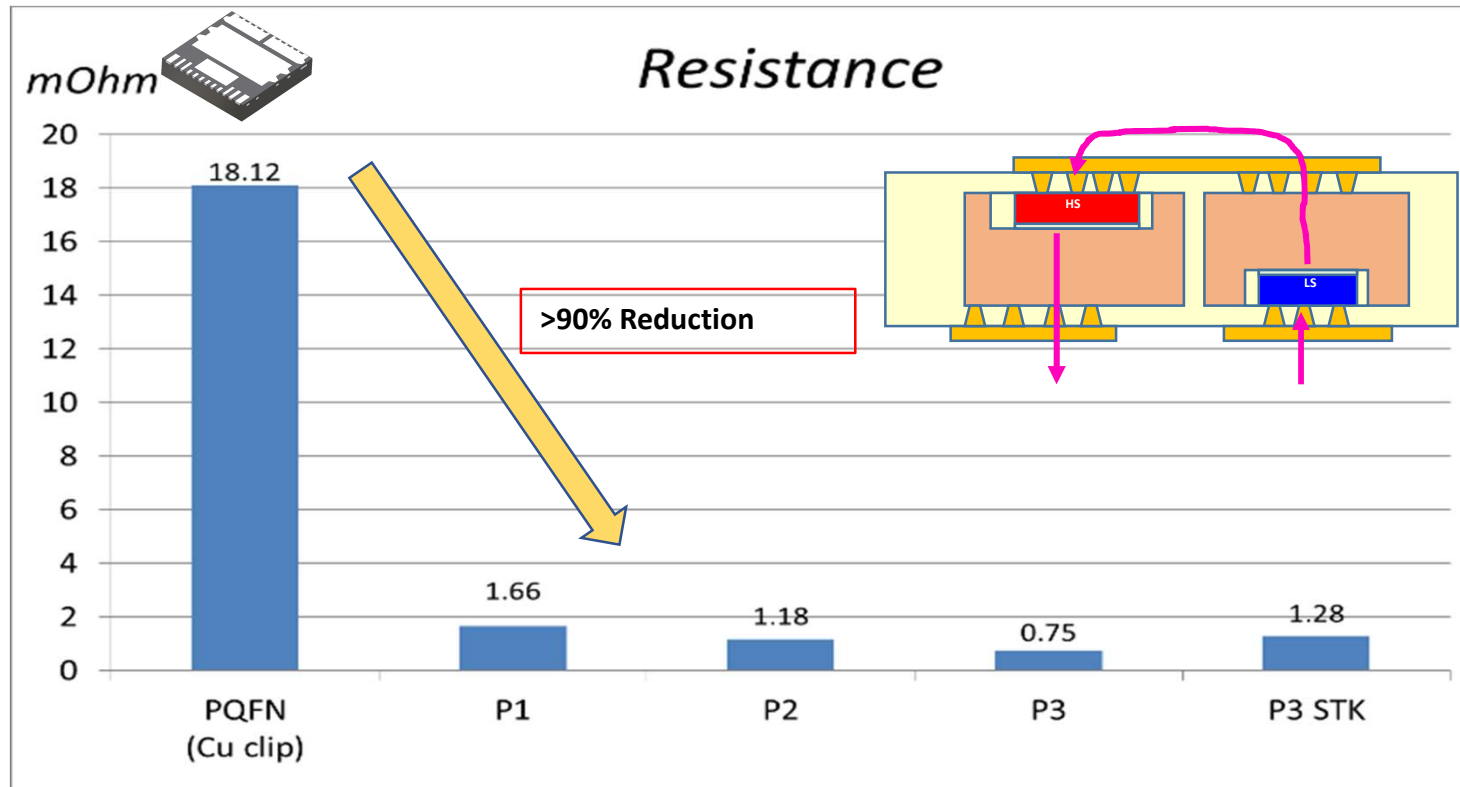


- Thick Cu RDL (32 um).
Minimize turn on resistance.
- Prepreg material provide
>2.5KV breakdown voltage
- 50um via diameter (Equal
to 4 x 1 mil wire bond in
conductor area)
- Cu to Cu interface.
Minimize reliability risk in
high current density
condition

a-EASI Embedded Market Application in Electrified Cars



aEASI Electrical Performance Comparison



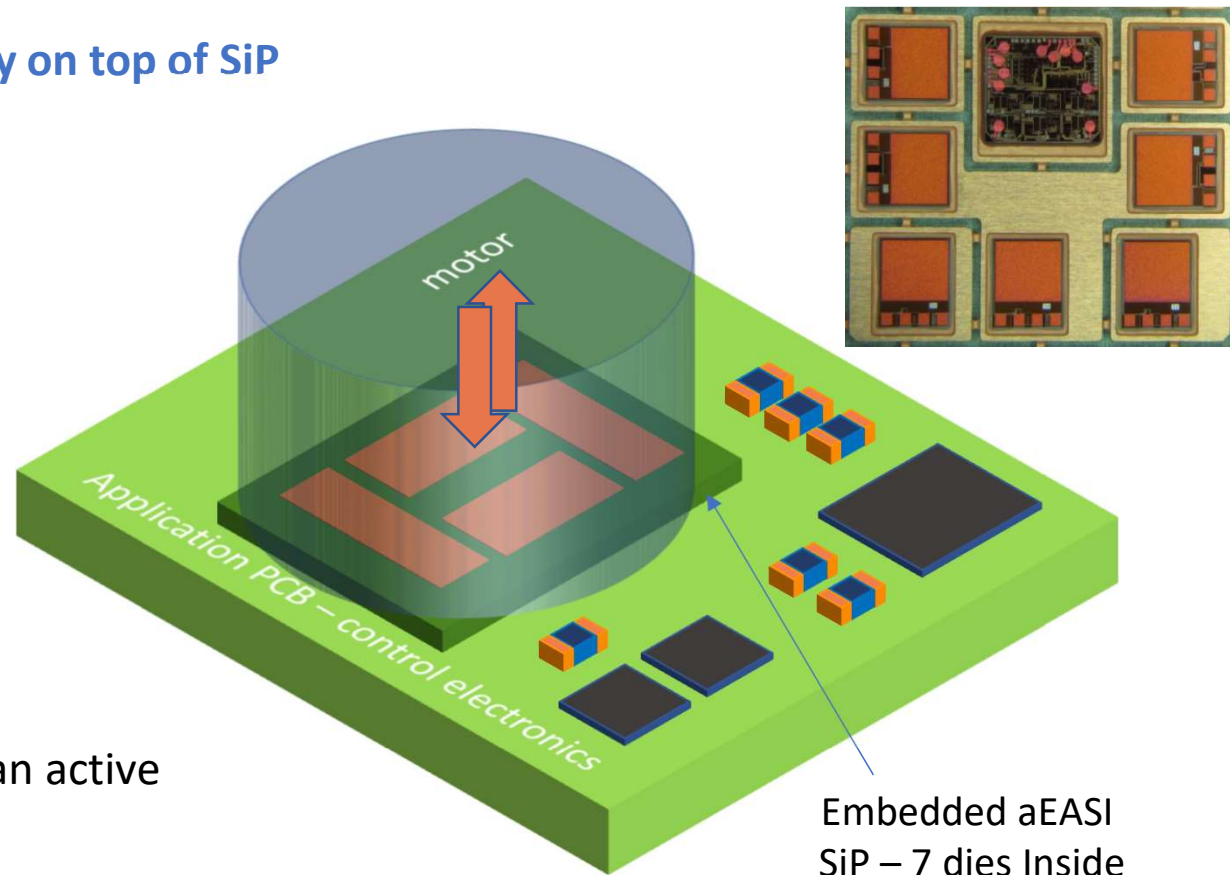
High Efficiency Electric Motor Pump in EV/HEV cars

Motor mounted directly on top of SiP

- SiP with top side cooling and vertical current flow

Benefits

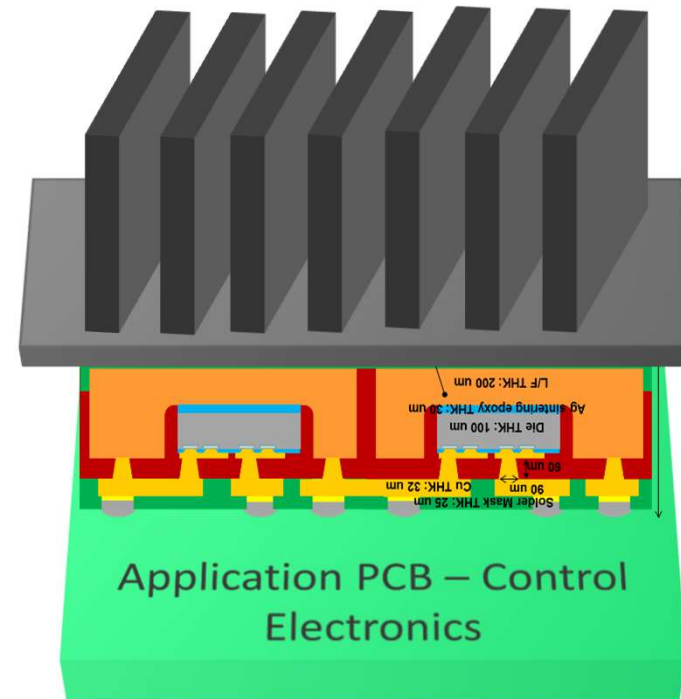
- Shortest current path maximizes power efficiency
- The motor is used as an active fan for the power SiP!



Application to DC/DC Converter for Automotive

Embedded aEASI SiP:

- Reduce Parasitic Inductance
- Enable higher frequency of operation (250kHz instead of 80KHz)
- Enable Big Reduction in Passives (L & C) in buck/boost circuit
- Reduce total size & cost of the converter module

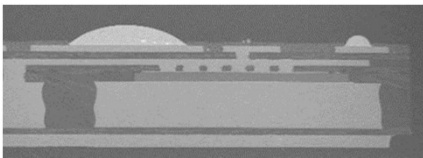
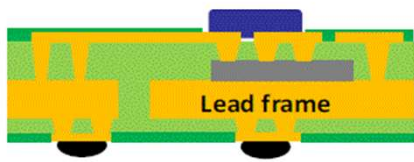


Thank You

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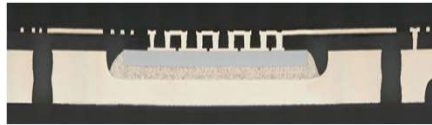
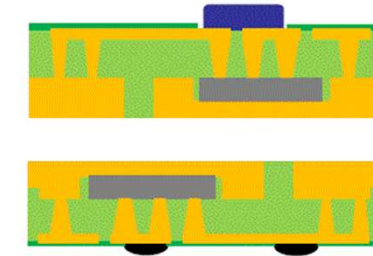
aEASI Package Portfolio



P1

Production

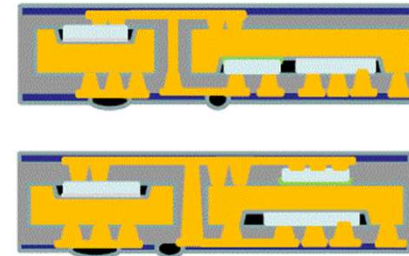
- Good Baseline Miniaturization
- Good Electrical and Thermal



P2

Production

- Superior Thermal w/ Cavity Exposed Pad
- Thinner Solution
- Double Sided Thermal Capability



P3

Qualified

- Multiple Vertical Current Flow Die Stack
- Higher Level of Integration Options