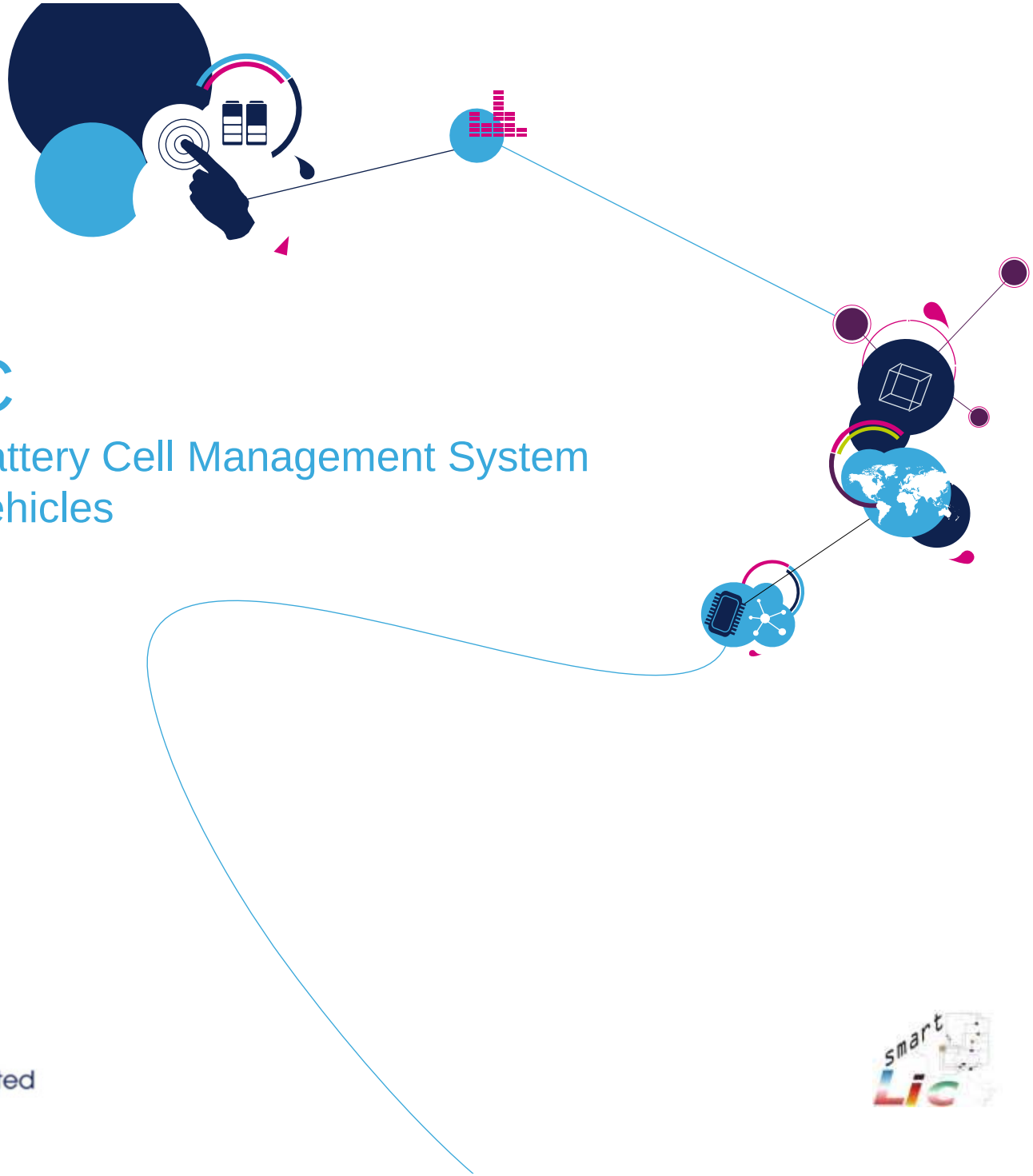

SMART-LIC

Smart & Compact Battery Cell Management System for Fully Electrical Vehicles

Jochen Langheim
STMicroelectronics

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Smart-LIC SUMMARY

Smart-LIC PROJECT	• BMS for Li-Batteries • 36 months (+6) • Started 01.05.2011
PARTNERS	• STMicroelectronics project pilot • 8 Partners
FUNDING	• 5.7 M € project • 3.5 M € funding

SMART-LIC Partners

STMicroelectronics

Berliner Nanotest und Design

Centro Ricerche Fiat

Technische Universität Chemnitz

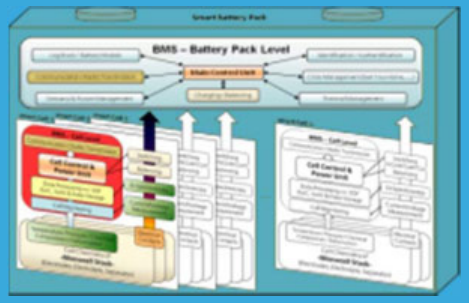
Fraunhofer ENAS

Kemet Electronics Italia

MICRO-Vett

CONTI Temic Microelectronic

Objectives & benefits of 'smart-LIC'

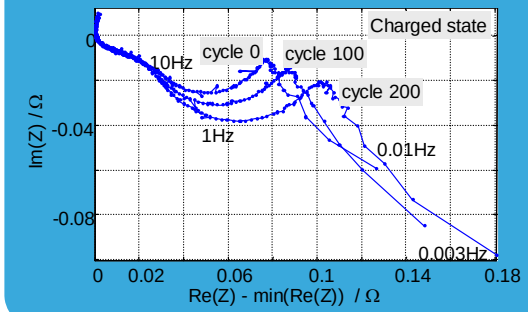


Objective 1: New system architecture

- BMS at cell level, monitoring & controlling of each individual cell, advanced balancing (active & passive)

→ improved performance (charging efficiency, lifetime)

→ reduced cost (simplification, SiP, cost-of-ownership)

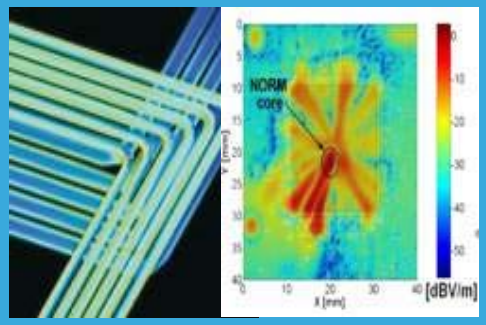


Objective 2: Battery state determination

- Implementation of Electrochemical Impedance Spectroscopy (EIS)
- In-cell measurement of U, I, EIS, T, P…

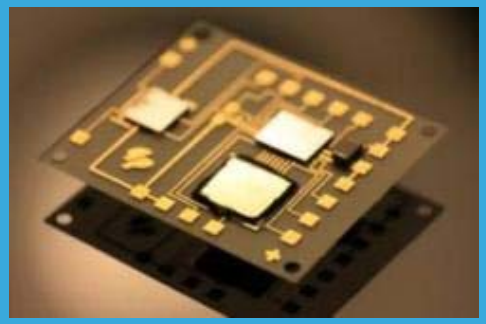
→ More accurate determination of SoC, SoH …SoF

Objectives & benefits of 'smart-LIC'



Objective 3: Communication vs. EMC

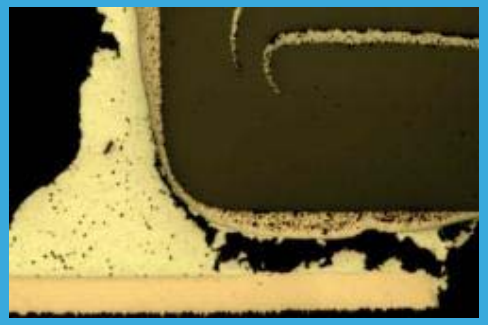
- Addressing & evaluating of wireless and wire based (electr./opt.) communication solutions (to central BMS)
- Consideration of shielding & EMC issues, caused by Signal and Power Integrity (SI/PI)



Objective 4: Packaging/system integration

- Reliable, secure & cost effective packaging of ECU (BMS module) for harsh environment
  → finding of suitable material selection
- Integration of BMS module into Li-Ion cell

Objectives & benefits of 'smart-LIC'



Objective 5: Reliability/safety/plagiarism

- Consideration of reliability & lifetime issues from the beginning of development stage, new lifetime models
- Incorporated safety devices, isolating of individual cell
- Active cell identification & authentication (plagiarism protection)

Objective 6: Testing

- Testing of packaged BMS module (active + passive)
- Demonstrating the functionality of 'smart-LIC' module
- Creating of novel combined testing methods
- Verification of developed lifetime models

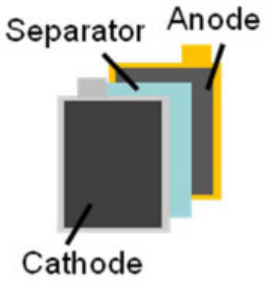
Hierachical structure of battery systems

Cell management — **R&D**

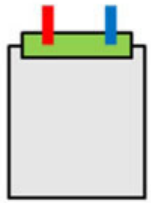
Module management — **Partially implemented**

Battery management — **SoA**

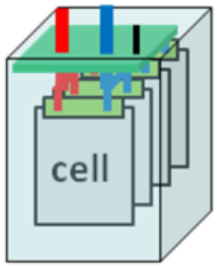
Vehicle management — **SoA**



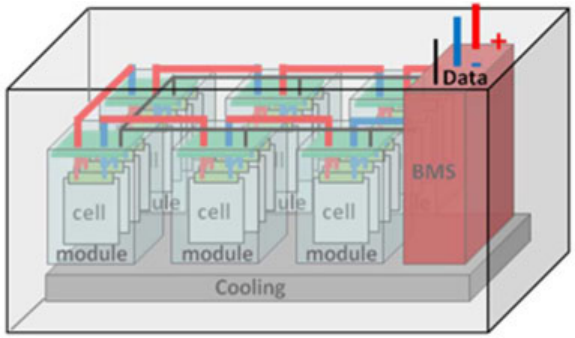
Mono-cell



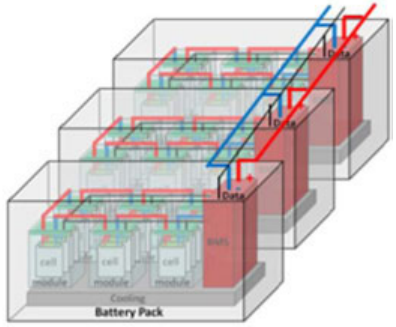
Cell



Module



Battery Pack



Battery System

Performance improvement (more accurate battery state determination, efficient balancing, …)

Optimum?

Management level

Cost improvement (reduced complexity, BOM, …)

Project Smart-LIC: highlights

New system architecture:

- Distribution of BMS functionalities down to cell/macro-cell level
- Advanced balancing (passive + active)
- Consideration of wireless communication strategies between satellite and central BMS (vs. EMC issues)

Improved battery state determination:

- Application of Electro-chemical Impedance Spectroscopy (EIS) for improved on-line determination of SoC, SoH & SoF

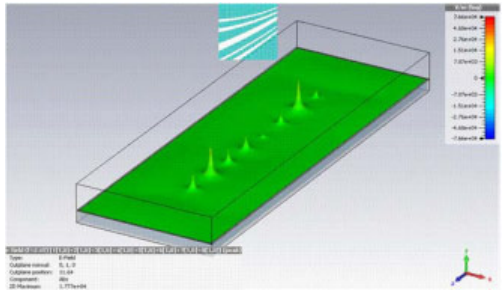
Packaging and Reliability:

- Reliable, secure & cost effective packaging of ECU (BMS module) for harsh environment by overmoulding

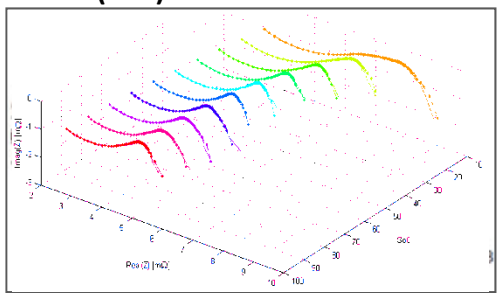
48V application:

- Transfer of Smart-LIC results to 48V applications

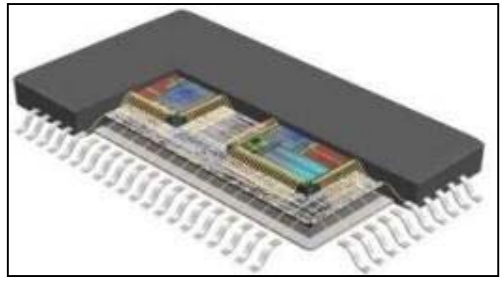
Electrical Field Distribution at XZ-Plane:



EIS = f (SoC):



Moulded ECU with leadframe contacts:



Exposure and controllability, ASIL determination

		Exposure E * Controllability C					
		1	0.1	**0.01**	**10E-3**	**10E-4**	10E-5
Severity	S1 - slight and moderate injuries (very low speeds)	ASIL B	ASIL A	QM	QM		QM
	S2 - serious, including life-threatening, injuries, survival probable	ASIL C	ASIL B		QM	QM	QM
	S3 - life-threatening injuries (survival uncertain) or fatal injuries	ASIL D	ASIL D	**ASIL C**	**ASIL B**	**ASIL A**	QM

Evolution of safety requirements over the years

OEM 2012

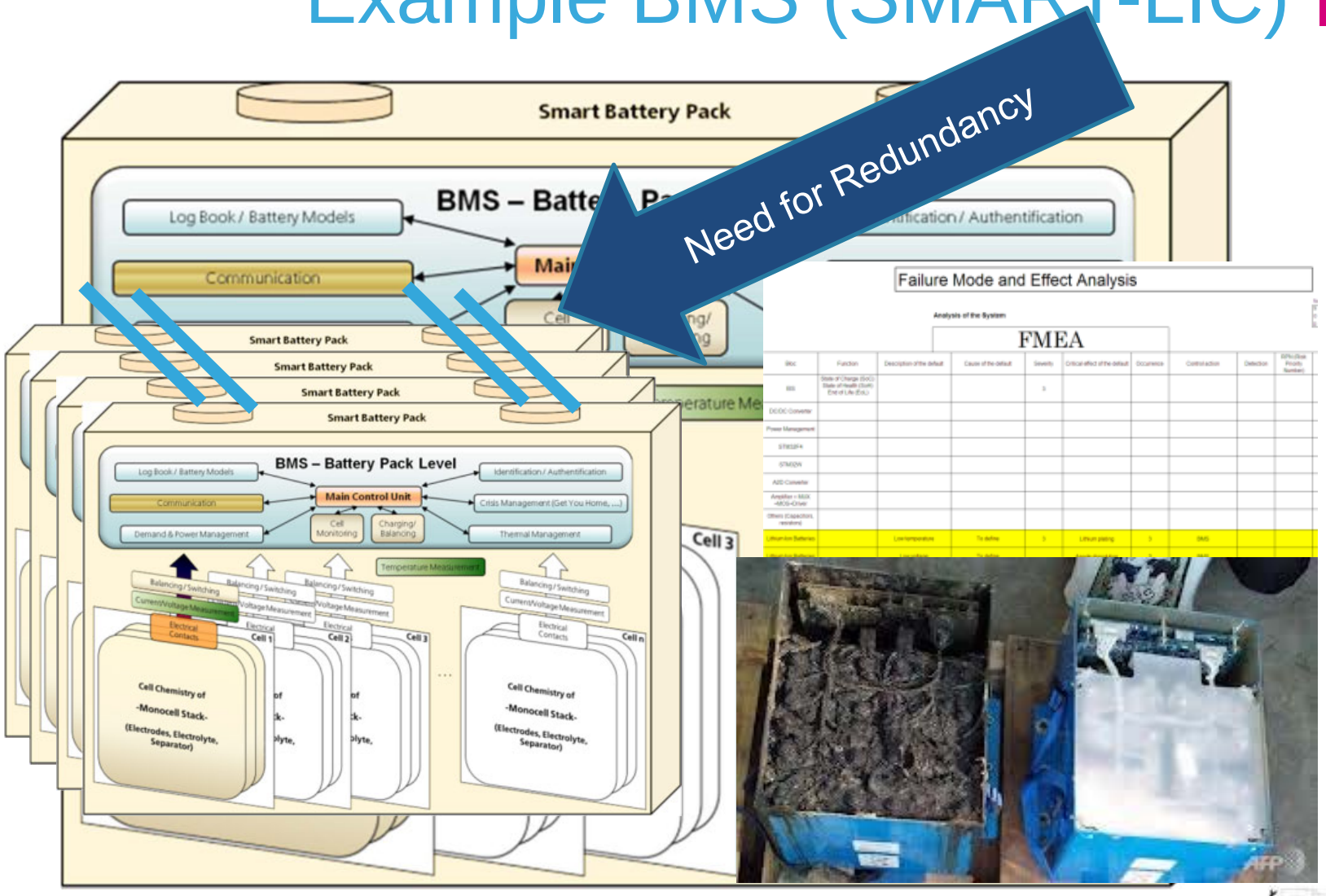
Batt B 2012

SBLiMotive 2012

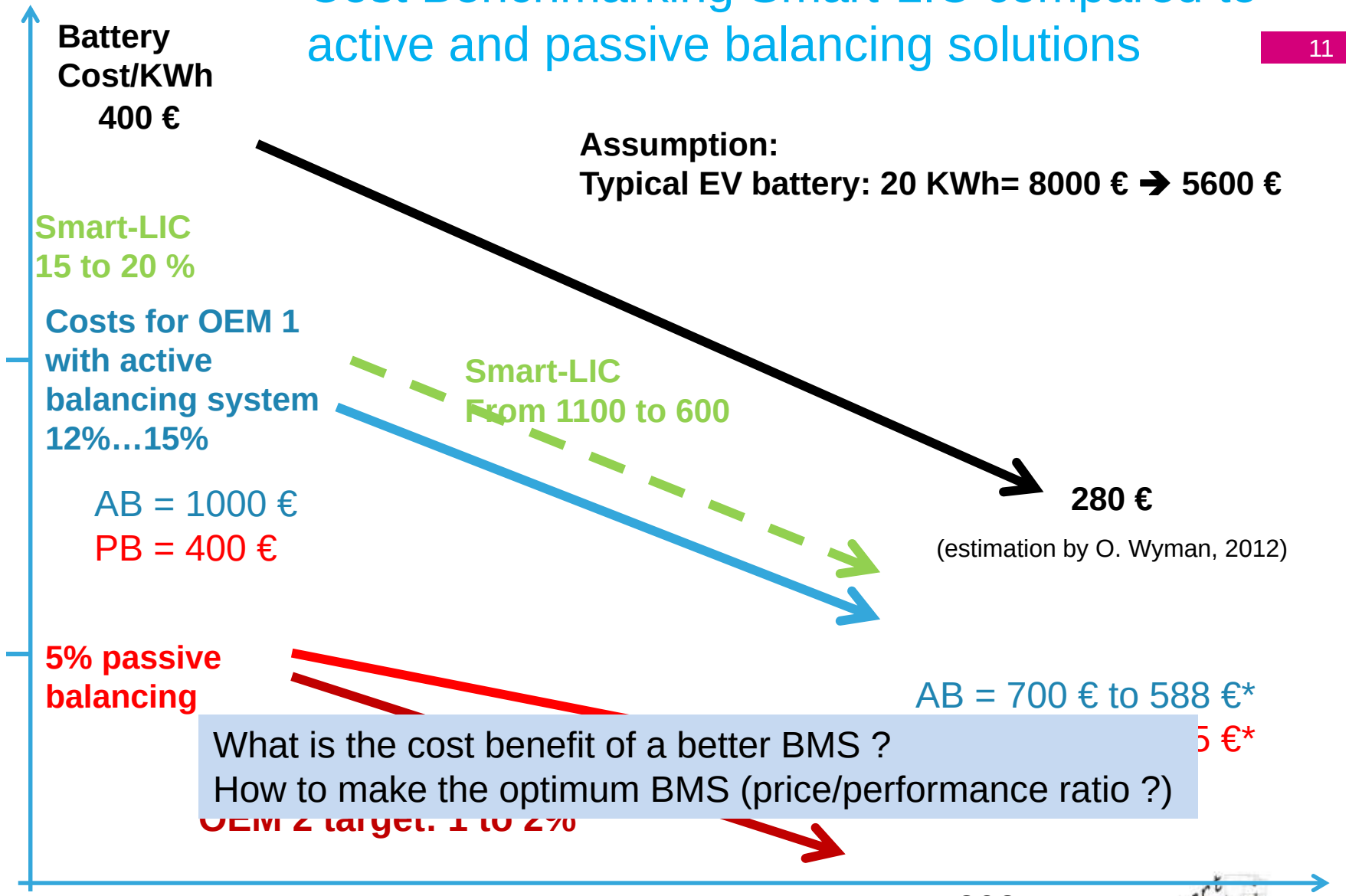
E3Car A 2010

E3Car B 2009

Example BMS (SMART-LIC)

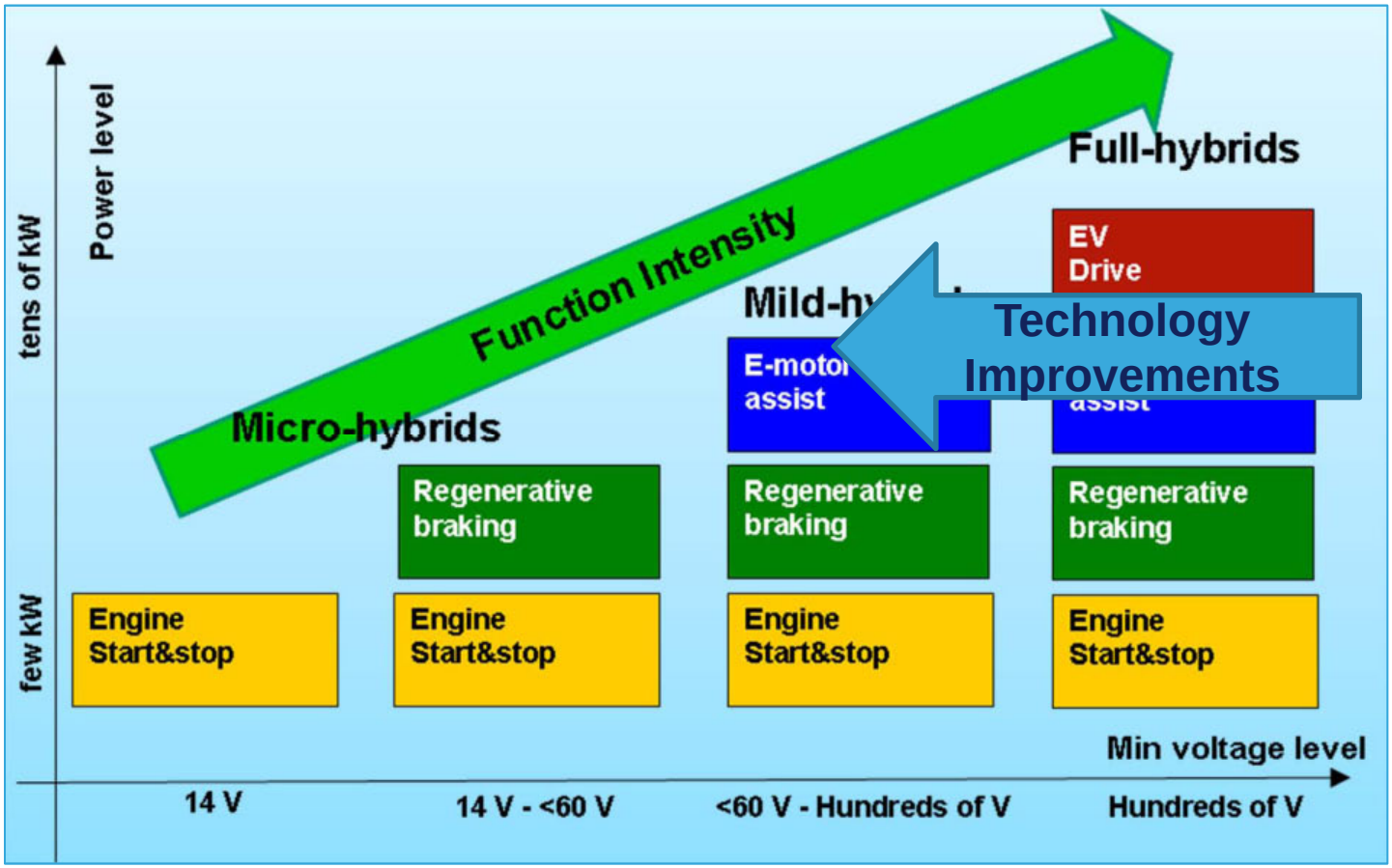


Cost Benchmarking Smart-LIC compared to active and passive balancing solutions



*) With productivity 4% / year (imposed by Car Maker) :

Vehicle Electrification is 100V becoming the new trend?



The road to EV is clear
(also due to standardisation in power electronics)

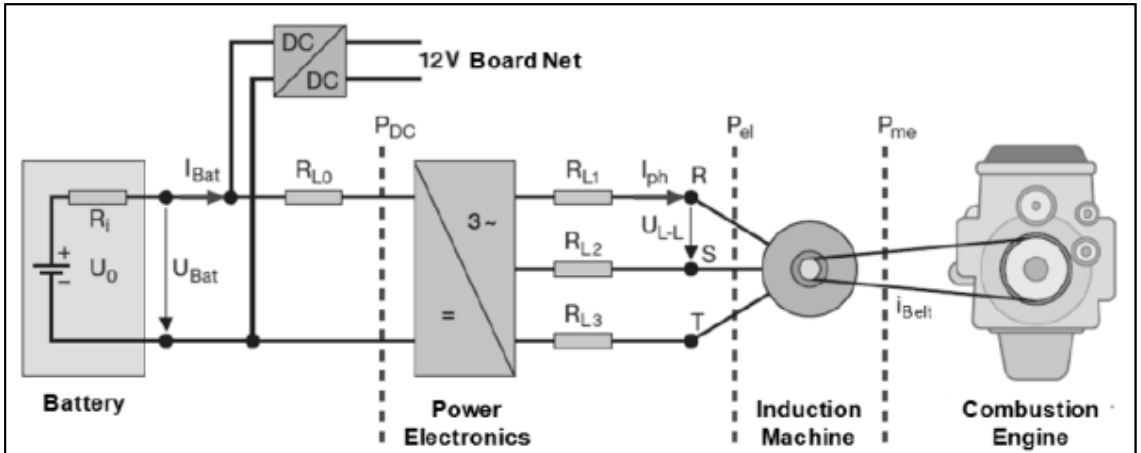


Figure 4: 48V-BSG-System Topology

Example 48 V system
(source: CONTINENTAL @ APE 2013)

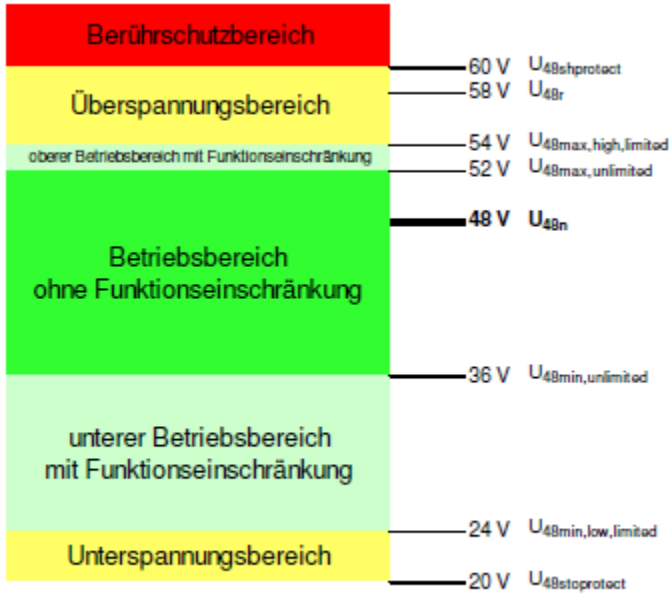
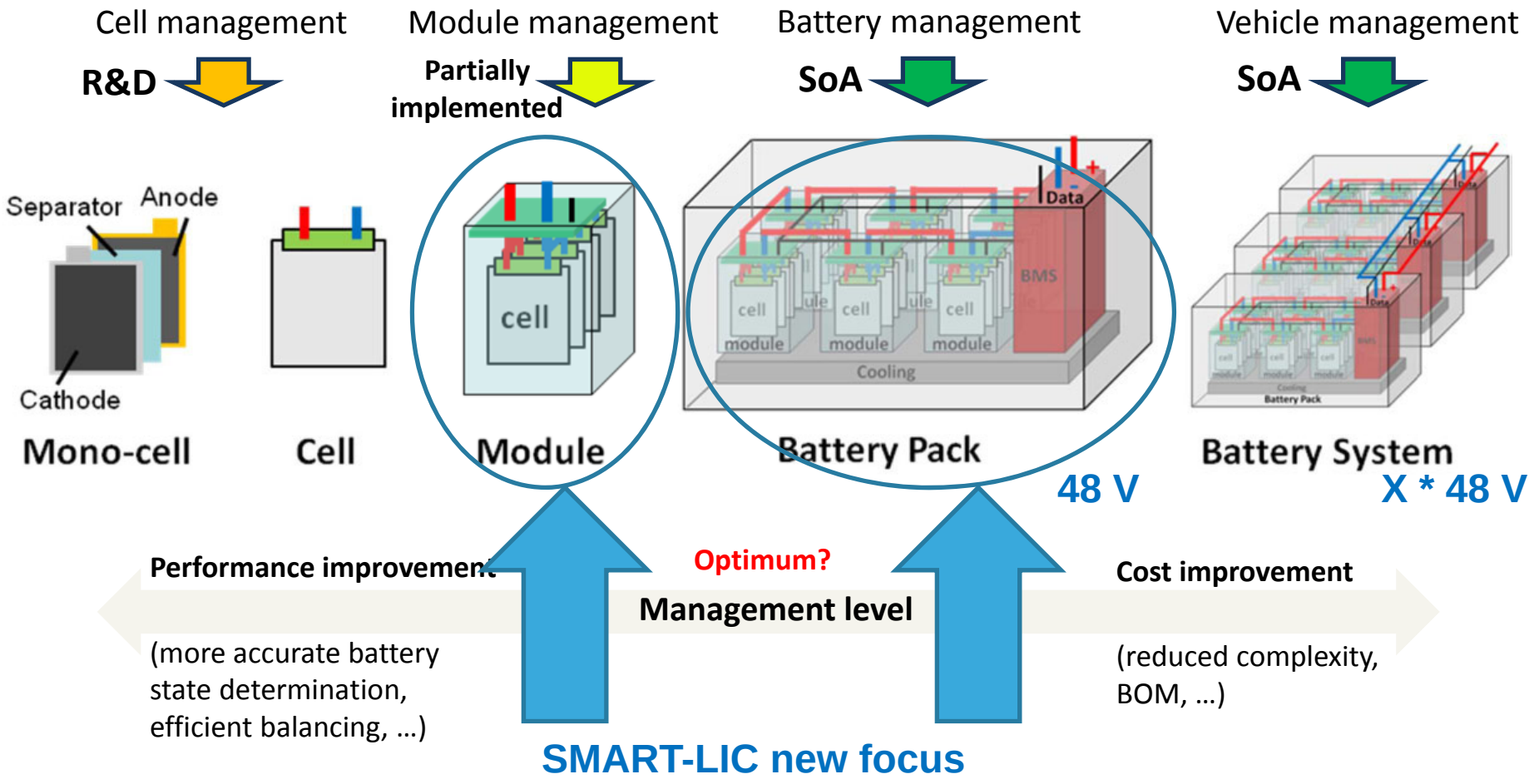


Figure 1: Definition of static voltage-ranges

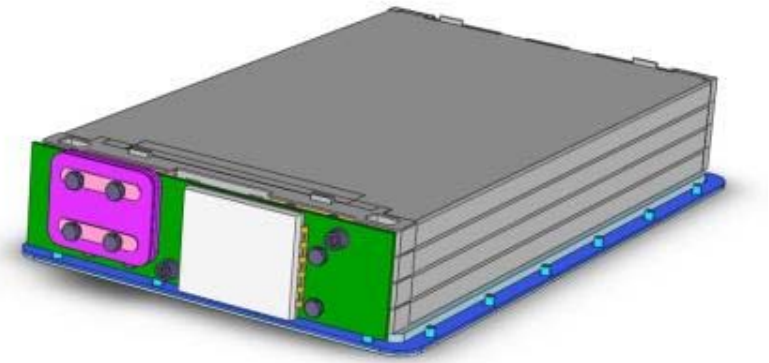
Consequences for SMART-LIC

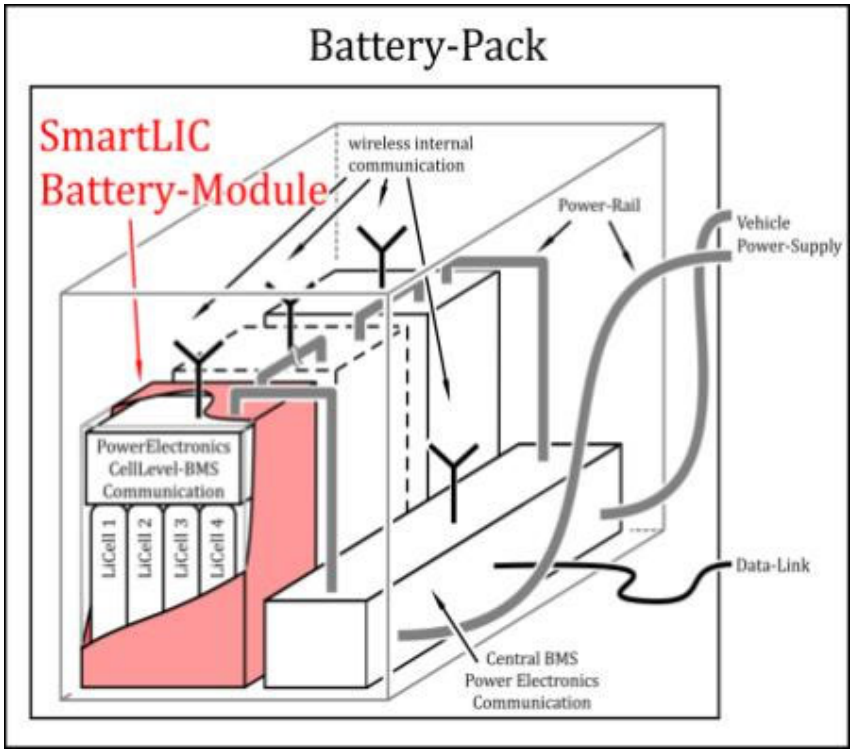


Project Smart-LIC: realization

1st demonstrator - Smart-LIC macro cell:

- Sealed metal case containing 4 Li-ion cells being connected in series
- 14,4V, 20Ah, 288Wh (based on EiG NCM cells)
- Maximum current: 100A (5C)
- Dimensions: H=260, W=148, L=38 [mm]

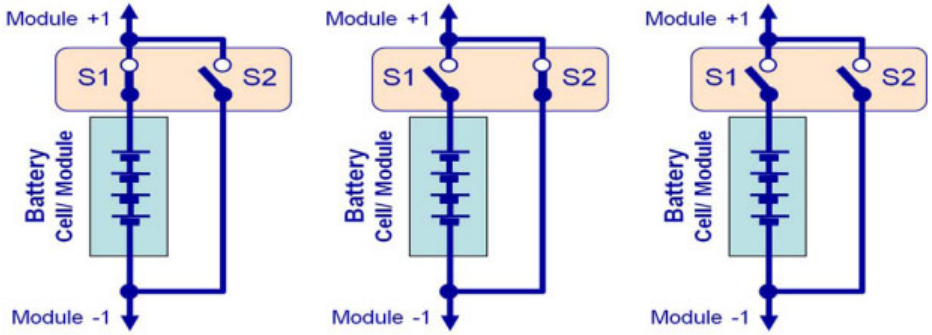




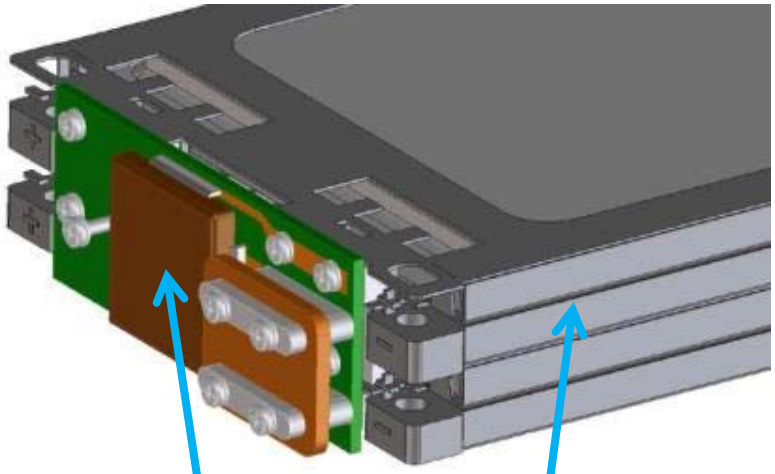
Power module: Main tasks

Main tasks of power module:

- **Safety switching**, e.g. isolation of individual macro-cells in case of malfunction
- **Active balancing** between macro-cells
- Deactivation of macro-cell for **'Electro-chemical Impedance Spectroscopy'** analyses
- **Shut down** of the **high-voltage of the battery** to increase safety e.g. of the rescue team
- Realization of a **'Limp Home' functionality**

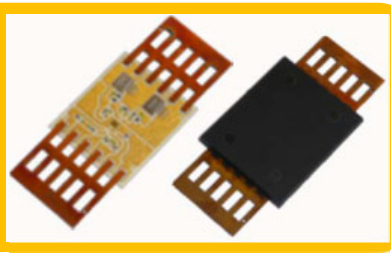


Regular Mode **Limp Home Mode** **Safety Mode**



Smart-LIC macro-cell

Power module:
based on DCB substrate



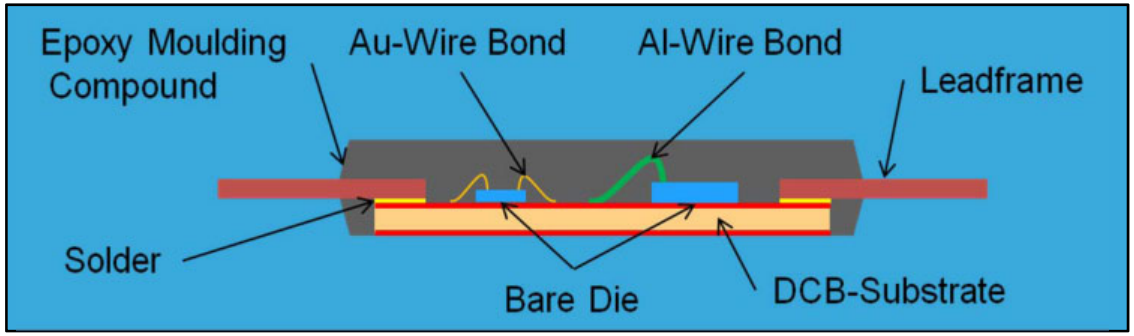
Power module: Reliability considerations

Challenges:

- Demand for high safety, low contact resistance ⇒ High relevance of reliability & lifetime
- Influence factors: temperature cycles, vibration, humidity, **chemicals (electrolyte)**, …

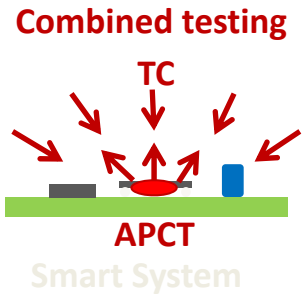
Approach:

- Overmoulding of whole BMS electronic module(s)

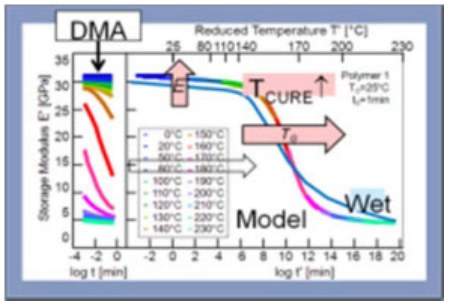


Reliability assessment:

- Combination of FE simulation and reliability testing
- SoA reliability testing: APCT
  → demand for combined testing
  (= passive TC + APCT + Vibration, …)



Comprehensive material characterization for FE modeling:



ST circuit development

- ASIC development together with industrial partner
- First silicon already in the market
- Second silicon: some optimisation based on SMART-LIC

Lithium ION Battery Management IC

Datasheet v1.0

Features

- 3 to 12 cell Li- Ion battery cell control & monitoring
- Passive balancing
  - External balancing switch for increased balancing currents
  - Integrated driver for external balancing switch
- Daisy chain vertical differential communications interface, stackable to 32 nodes

Body: 10 x 10 x 1.4mm

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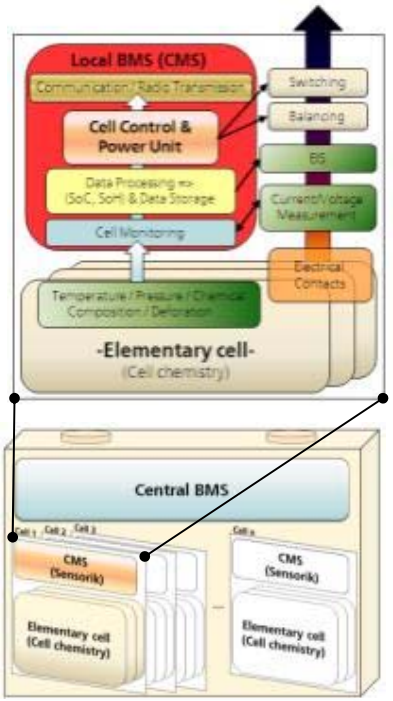
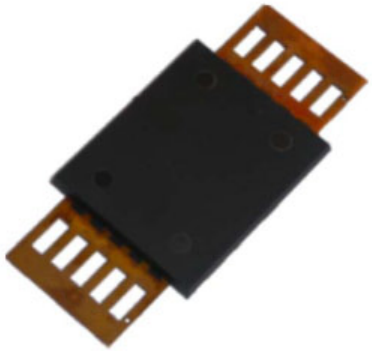
Summary & Conclusion



Distribution of BMS functionalities down to (macro-)cell level brings …

- ❑ Higher efficiency due to **local control** at (macro-)cell level
- ❑ Increased precision in determining SoC, SoH, and SoF due to implementation of a **new cell / battery model** based on electrochemical impedance spectroscopy (**EIS**)
- ❑ Increased safety so that cells can perform at **maximum rating** without thermal risks due to redundant sensors and HT joints
- ❑ Reduced cost of ownership for the end user due increase in battery lifetime caused by the **smart battery management** **(if battery technology and market evolution is well considered)**



Next steps ...

- ❑ Proof of concept for power module functionalities (safety switching, balancing, ...)
- ❑ Proof of concepts for electronic / power module reliability improvement due to overmoulding by means of various (combined) APCTs

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