

Challenges of implementing capacitor technology in automotive applications

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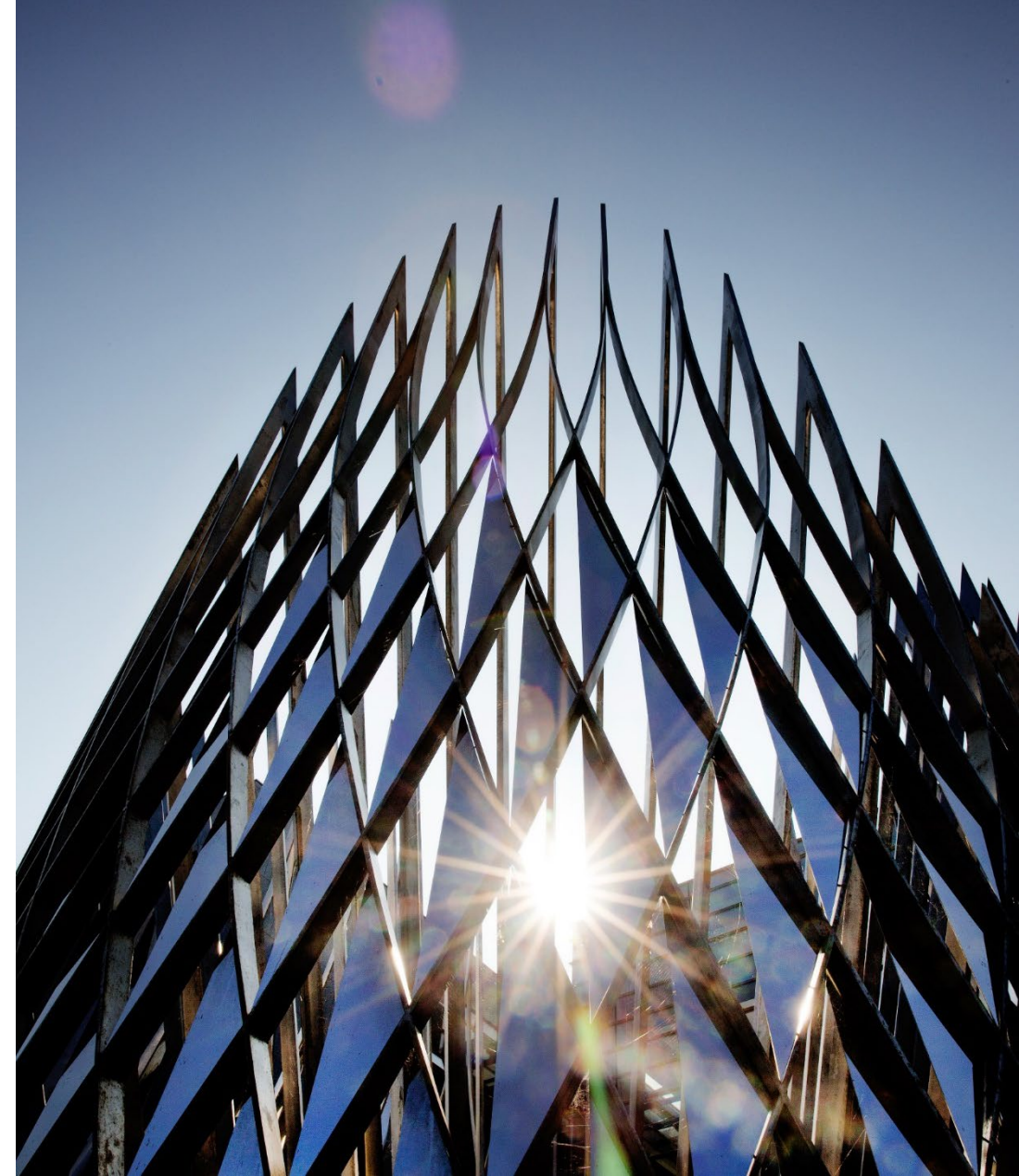
Centre for Industrial Electronics

SDU  Center for Industrial Electronics 

About

The Centre for Industrial Electronics (CIE) was founded in 2017 by an academia-industry-public partnership to

- **Educate** the next generation engineers,
- Conduct world-class **research** and Translate technology into **application** – certain focus drives and passive components – **ECPE competence center – EPCIA member**
- **Testing and Reliability**
CIE collaborates with companies with Service and Consulting activities
- **60 Scientists** (incl. Odense) and **staff** soon work on industrial electronics aspects



Content

- Introduction
- State of the Art Technologies of Aluminium Electrolytic Capacitors for Automotive Use
- Application of Aluminium Electrolytic capacitors in Automotive Applications
- Challenges in Automotive use
- Outlook and future

Introduction

Talk only about **Aluminium electrolytic capacitors**

Aluminium electrolytic capacitors are widely used in automotive applications.

Typically, classical **axial**, **radial** or **SMD** solid **polymer** and **Hybrid** electrolytic capacitors are designed in.

The working voltage of those capacitors varies usually between 14 and 100 V.

The **main applications** are filtering, low power DC-Link in auxiliary drives but also mild hybrid EV inverters in the 14 V or 48 V board net. Typically, classical axial, radial or SMD solid polymer electrolytic capacitors are designed in.

For medium and **high-power DC-Link** applications typically **metalized film** but also **Aluminium electrolytic capacitors are used**. The later usually have a typical working voltage of 350 to 450 V.

For higher DC-link voltages **Aluminium electrolytic capacitors** need to be **connected in series** leading to the well-known issue of voltage balancing.

If the application environment is nearby the combustion motor or the ripple current load is high, **150°C** capacitor types are often selected. Beside the high environmental temperature high ripple current loads and long lifetime expectations of at least **8000 h** are often requested.

So, **external cooling** of the capacitors is sometimes necessary.

In this talk the most important applications of Aluminium electrolytic capacitors in cars are shown.

Discussing the **environmental conditions of the application**, like **vibrational** and **thermal** stress under external and internal load and showing which design in is suitable.

Further a **future outlook** about **new technologies** of Aluminium electrolytic capacitors for the extension of the temperature range, ripple current load, life time and reliability testing and analysis is given.

Note: Certain technology are protected by NDA and could not discussed here.

State of the Art Technologies of Aluminium electrolytic capacitors used in Automotive Application

- Axial capacitors
- Single ended capacitors
- SMD Standard Electrolyte, Polymer and Hybrid Polymer Capacitors
- Radial Capacitors

State of the Art Technologies of Aluminium electrolytic capacitors used in Automotive Application

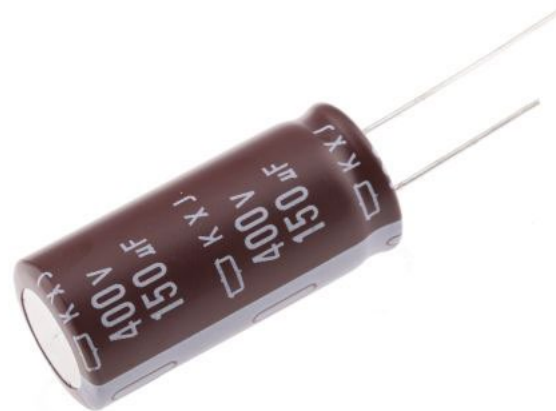
Axial capacitors



Source: Epcos, Kemet

State of the Art Technologies of Aluminium electrolytic capacitors used in Automotive Application

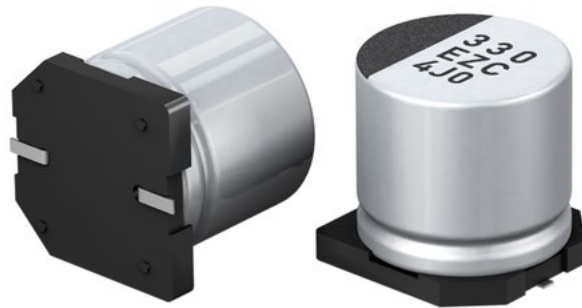
Single Ended capacitors



Source: Nippon Chemicon

State of the Art Technologies of Aluminium electrolytic capacitors used in Automotive Application

SMD Standard Electrolyte, Polymer and Hybrid Polymer Capacitors



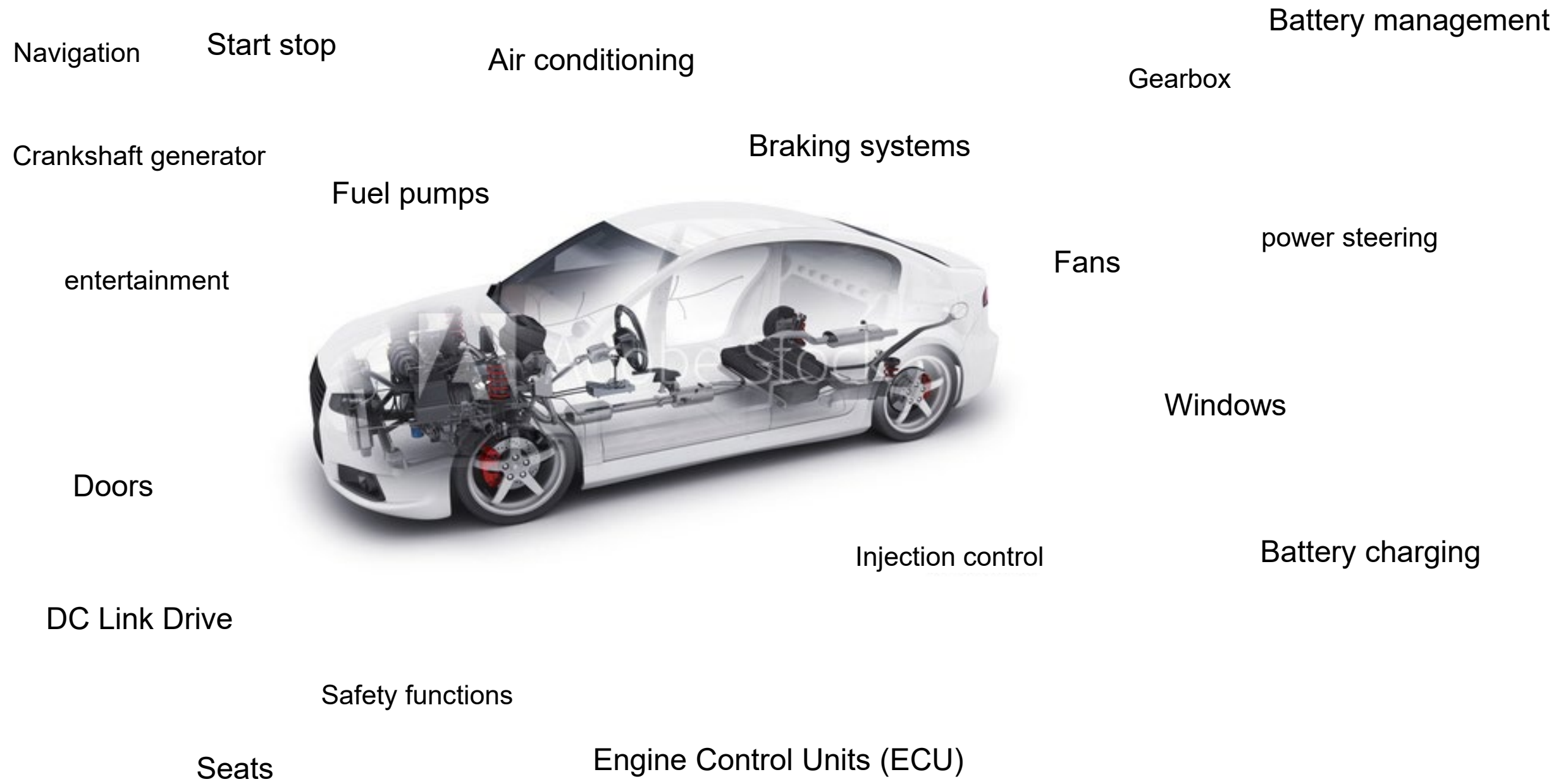
Source: Panasonic

State of the Art Technologies of Aluminium electrolytic capacitors used in Automotive Application

Radial Capacitors



Source: Epcos, Nippon Chemicon, FTCAP





Classical mounting situation of an automotive capacitor

- e.g. Axial construction
- Wires are electrically welded to external terminals
- No isolation necessary because mounting in a plastic case
- Nearly no external cooling possible
- Thermally insulated -> extra stress for capacitor

Challenges in Automotive use

TABLE 3 - TABLE OF METHODS REFERENCED ALUMINUM ELECTROLYTIC CAPACITORS			
Stress	NO.	Reference	Additional Requirements
Pre- and Post-Stress Electrical Test	1	User spec.	Test is performed except as specified in the applicable stress reference and the additional requirements in Table 3.
High Temperature Exposure (Storage)	3	MIL-STD-202 Method 108	1000 hrs. at rated operating temperature (e.g. 85°C part can be stored for 1000 hrs at 85°C. Same applies for 105°C & 125°C). Unpowered. Measurement at 24±4 hours after test conclusion.
Temperature Cycling	4	JESD22 Method JA-104	1000 cycles (-40°C to 105°C) Note: If 85°C or 125°C part the 1000 cycles will be at that temperature rating. Measurement at 24±4 hours after test conclusion. 30min maximum dwell time at each temperature extreme. 1 min. maximum transition time.
Biased Humidity	7	MIL-STD-202 Method 103	1000 hours 85°C/85%RH. Rated Voltage. Measurement at 24±4 hours after test conclusion.
Operational Life	8	MIL-STD-202 Method 108	Note: 1000 hrs @ 105°C. If 85°C or 125°C part will be tested at that temperature. Rated Voltage applied. Measurement at 24±4 hours after test conclusion.
External Visual	9	MIL-STD-883 Method 2009	Inspect device construction, marking and workmanship. Electrical Test not required.
Physical Dimension	10	JESD22 Method JB-100	Verify physical dimensions to the applicable device detail specification. Note: User(s) and Suppliers spec. Electrical Test not required.
Terminal Strength (Leaded)	11	MIL-STD-202 Method 211	Test leaded device lead integrity only. Conditions: A (454 g), C (227 g), E (1.45 kg-mm)
Resistance to Solvents	12	MIL-STD-202 Method 215	Note: Also aqueous wash chemical - OKEM clean or equivalent. Do not use banned solvents.
Mechanical Shock	13	MIL-STD-202 Method 213	Figure 1 of Method 213. Condition C
Vibration	14	MIL-STD-202 Method 204	5g's for 20 minutes 12 cycles each of 3 orientations. Note: Use 8"X5" PCB .031" thick with 7 secure points on one 8" side and 2 secure points on corners of opposite sides. Parts mounted within 2" from any secure point. Test from 10-2000 Hz.

TABLE 3 - TABLE OF METHODS REFERENCED ALUMINUM ELECTROLYTIC CAPACITORS			
Resistance to Soldering Heat	15	MIL-STD-202 Method 210	Condition B no pre-heat of samples. Note: Single Wave Solder. Procedure 1 with solder within 1.5mm of device body for Leaded and 0.75mm for SMD. SMD – remove carrier.
ESD	17	AEC-Q200-002 or ISO/DIS 10605	
Solderability	18	J-STD-002	For both Leaded & SMD. Electrical Test not required. Magnification 50 X. Conditions: Leaded: Method A @ 235°C, category 3. SMD: a) Method B, 4 hrs @ 155°C dry heat @ 235°C b) Method B @ 215°C category 3 c) Method D category 3 @ 260°C.
Electrical Characterization	19	User Spec.	Parametrically test per lot and sample size requirements, summary to show Min, Max, Mean and Standard deviation at room as well as Min and Max operating temperatures.
Flammability	20	UL-94	V-0 or V-1 Acceptable. Test is applicable to components having a resin case.
Board Flex	21	AEC-Q200-005	60 sec minimum holding time.
Terminal Strength (SMD)	22	AEC-Q200-006	
Surge Voltage	27	JIS-C-5101-1	

**NOTE: Pre-stress electrical tests also serve as electrical characterization.
Interval measurements for 1000 hour tests required at 250 and 500 hrs.**

Acceptance Criteria:

Per supplier specification, unless otherwise specified in the user component specification.

Challenges in Automotive use

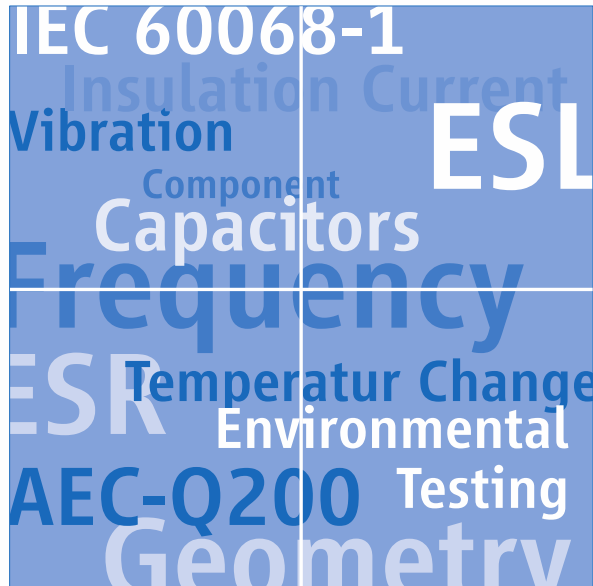
Wide range of **specific** requirements from the OEM Tier 1 e.g. LV124, AEC Q 200, ..

- Capacitances (high)
- Ripple current requirements, frequencies (high)
- Temperature range (wide) – up to 150°C
- Wide voltage range (14 V, 48V, HV board net, multi battery scenarios)
- Mechanical requirements, tolerances, Dimensions
(form function factors – many small caps (SE, SMD) (no space available)
or bigger caps (axial, radial)
- Interconnection, form and material of terminals, case material and thickness, insulation
- Vibration, shock requirements
- Environmental requirements
- Processing requirements
- Quality standard requirements IATF16949...

Challenges in Automotive use

Qualification of DC-Link Capacitors for Automotive Use

General Requirements, Test Conditions
and Tests



German Electrical and Electronic Manufacturers' Association

Source: ZVEI

Content

Electrical Characterisation

- 5.1 E-01 Capacitance
- 5.2 E-02 Insulation Resistance Measurement
- 5.3 E-03 ESR
- 5.4 E-04 ESL
- 5.5 E-05 Insulation Strength against the Environment

Mechanical Characterisation

- 6.1 M-01 Geometry
- 6.2 M-02 Visual Inspection

Environmental and Exposure Tests

- 7.1 B-01 Thermal Shock
- 7.2 B-02 Damp Heat, Steady State
- 7.3 B-03 High Temperature
- 7.4 B-04 Vibration
- 7.5 B-05 Charge/Discharge
- 7.6 B-06 Short-Circuit Test
- 7.7 Acceptance Criteria

Challenges in Automotive use

Quo vadis - capacitor ?

Challenges in Automotive use

Automotive Mobility will change

Self driving cars, Services e.g. Uber,
Climate Change, CO₂, NO_x emission,
E-vehicles

All that will have an impact on the
component level

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Outlook and future

Much higher Life time requirements due to **change in the mission Profile**

8000 h -> up to **30000 h** (80000 h!) under load conditions

Higher switching frequency requirement due to the use of GaN and SiC
- constructions with low parasitic inductances

Higher Temperature requirements up to 200°C due to higher junction temperatures of the Semiconductor like GaN or SiC are discussed

System integration (**Embedded technology**)

CO₂ / Total Energy balance / Recycling will be important - **sustainability**

Outlook and future

- > Higher **Total Reliability** Requirements
- > **Mission Profiles** will change
- > Big impactor for the **processing** of component production
- > Even **higher Quality standards** will be required
- > **Cost**
- > New **Technologies** (Low L, Polymer Caps...)
- > **Material** selection and **testing** (purity of the used raw materials)
- > **System** aspect (**integration** and **simulation**)

Outlook and future



Al electrolytic Capacitor
FTCAP
500 μ F / 425 V 90 A @20 kHz

Printed Embedded Cooling Technology realizing Highest Power Density

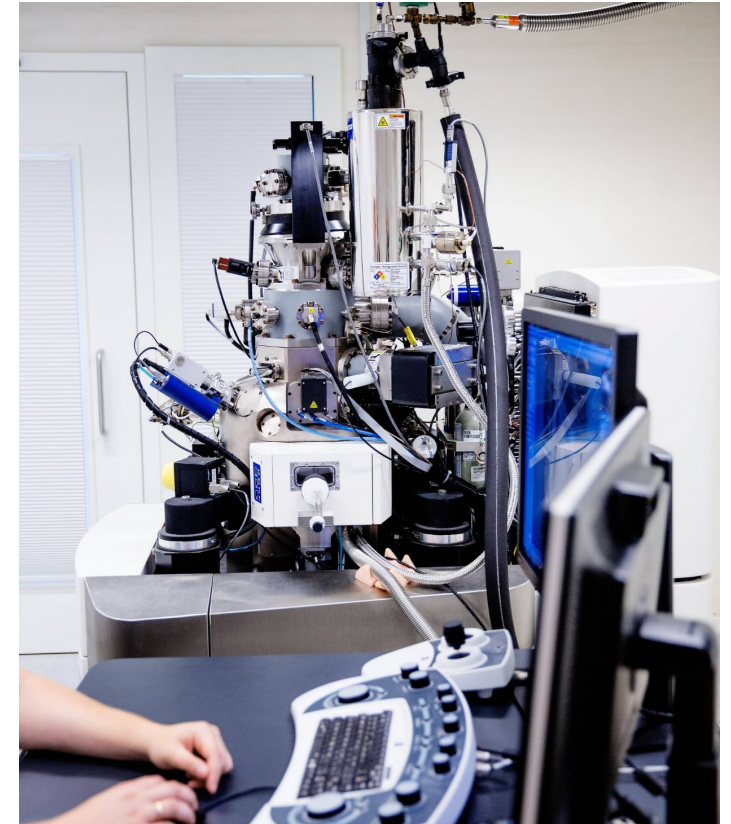
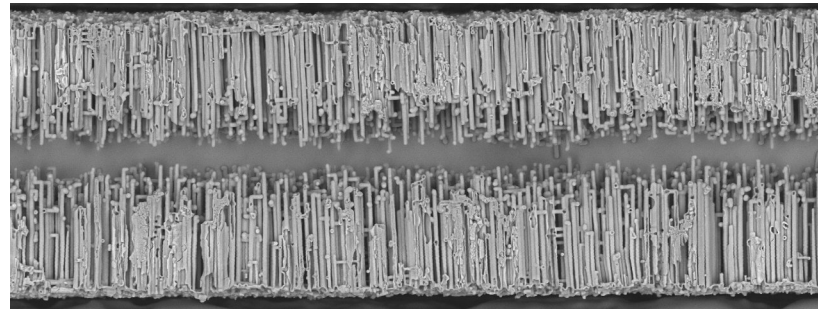
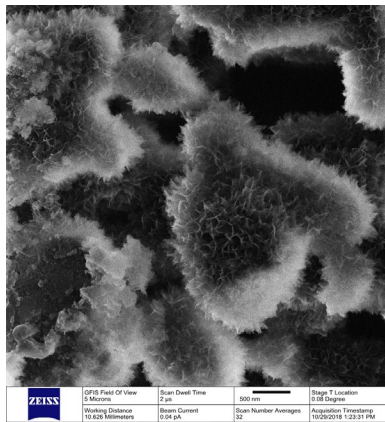
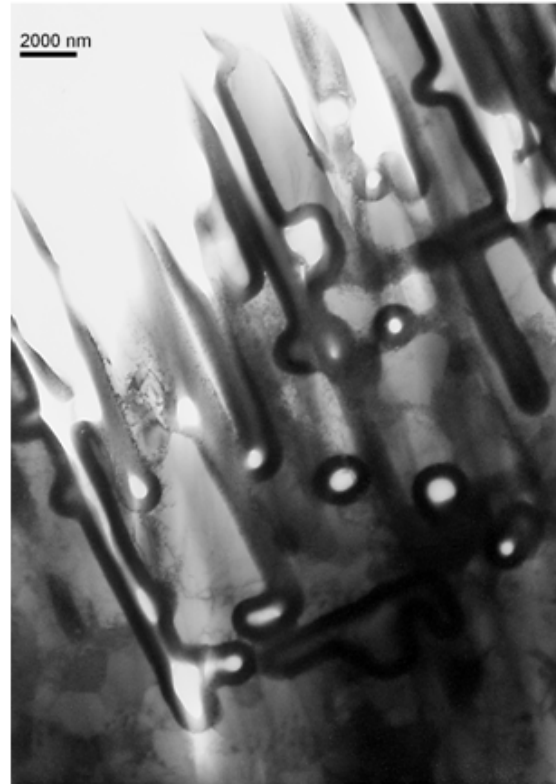
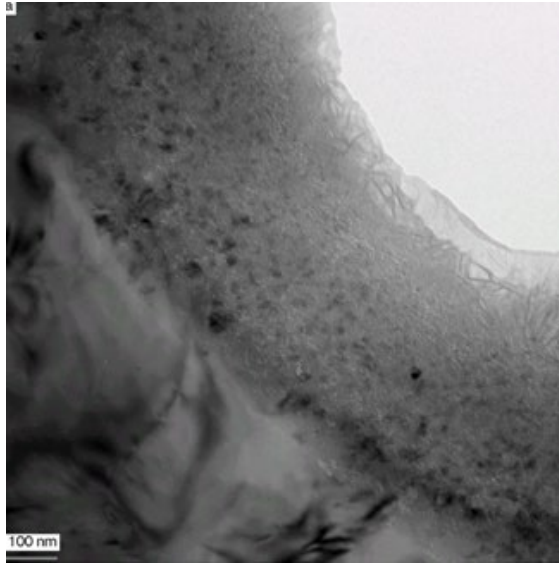
Jasper Schnack ; Dominik Hilper ; Ulf Schuemann ; Ronald Eisele ; Frank Osterwald ; Holger Beer ; **Thomas Ebel**

Abstract:

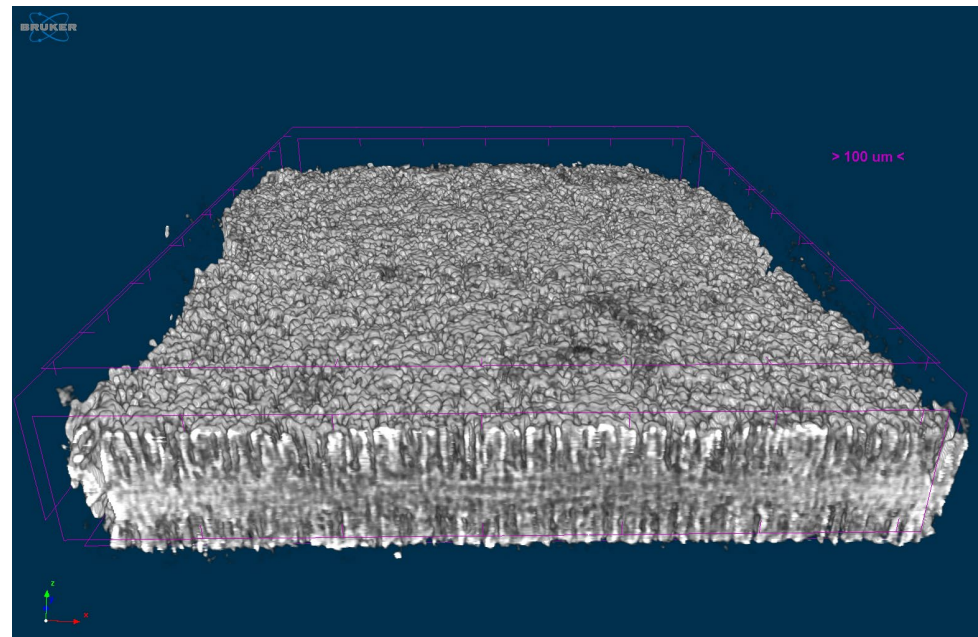
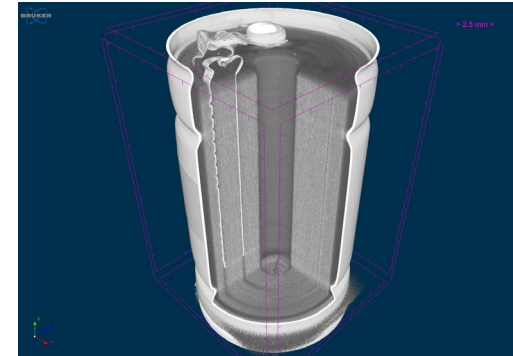
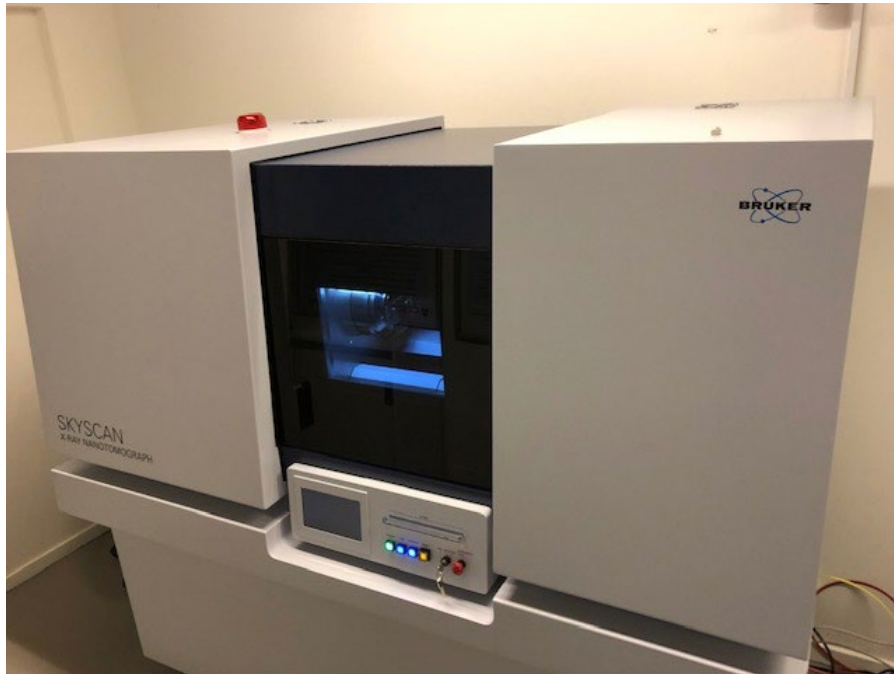
This paper proposes modern approaches for traction inverter concepts in the range of 100 kW/l and more. The development process of a traction inverter with an output power of 80 kW is used to present the results. The paper addresses the realization of cylindrical inverter assemblies for the direct integration into the frame of electrical machines. With the developed 3D-printed embedded cooling system, the concept ensures a very small and compact design. Volume minimization automatically leads to short electrical power lines and small loops guaranteeing a low inductive system. The simultaneous use of electrolyte capacitor technology and the application of silicon power semiconductors shows that common technologies are still in demand. Within the framework of the paper, the innovative strategic approaches for cost-efficient miniaturization of entire inverter concepts as well as the technologies to increase the efficiency are presented.

Published in: [CIPS 2018; 10th International Conference on Integrated Power Electronics Systems](#)

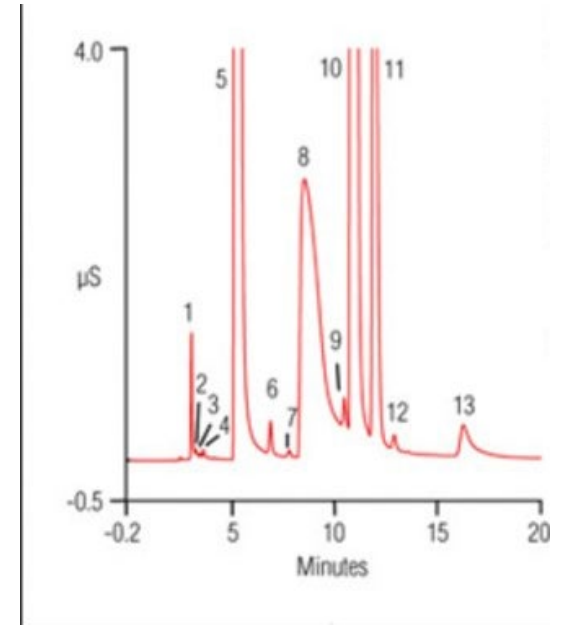
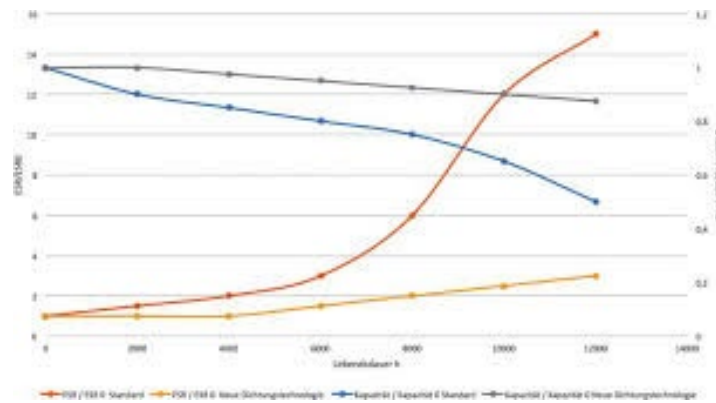
Reliability



Reliability



Reliability



**Thank you for
your attention**