DIE VERÄNDERUNG DER DEUTSCHEN AUTOMOBILINDUSTRIE DURCH DEN EINFLUSS DER DIGITALISIERUNG SOWIE DIE ROLLE VON NANOMATERIALIEN ALS MÖGLICHE SCHLÜSSELTECHNOLOGIE FÜR DIE ERFOLGREICHE GESTALTUNG DES WANDELS

FachDialog Chancen und Risiken der Anwendung von Nanotechnologien im Automobilbereich

27.September 2017

Ivica KOLARIC Fraunhofer IPA

Fraunhofer IPA
Technology consultant and innovation driver since 1959

- Operational budget of 70.8 million euros
- 25.8 million euros in industrial revenues
- More than 1,000 employees

New technical center "Gebäude D" in Stuttgart

Fraunhofer Institute Center in Stuttgart

Note: key figures for 2016; IPA Stuttgart including locations in Rostock, Mannheim, Bayreuth and Vienna

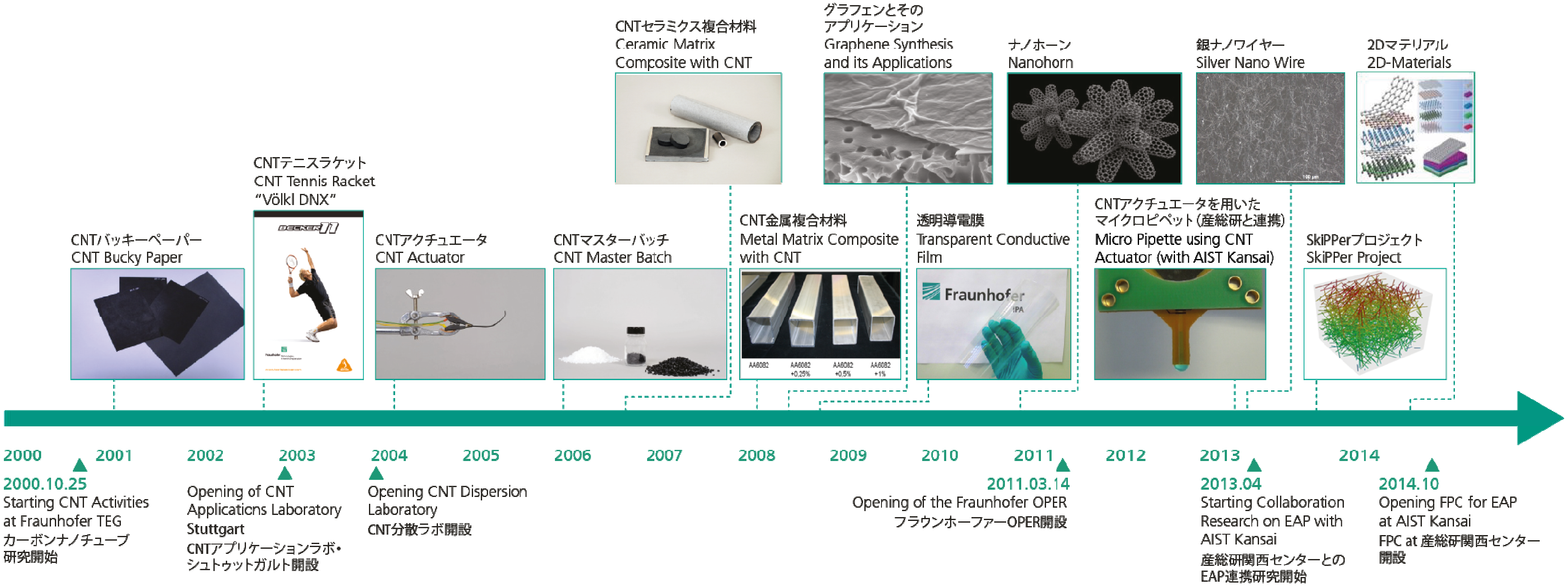
Fraunhofer IPA Functional Materials
One Stop Shop in Printed Functionalities

Synthesis and functionalization	Dispersion Technology	Application Technology

Data management & Simulation

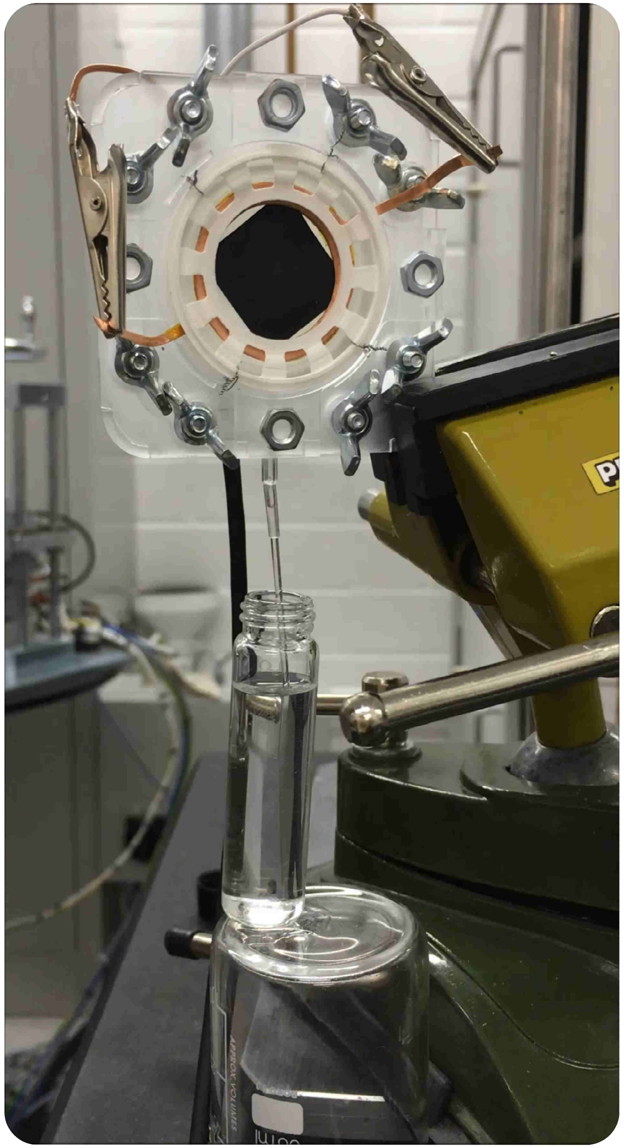
Efficient management of resources

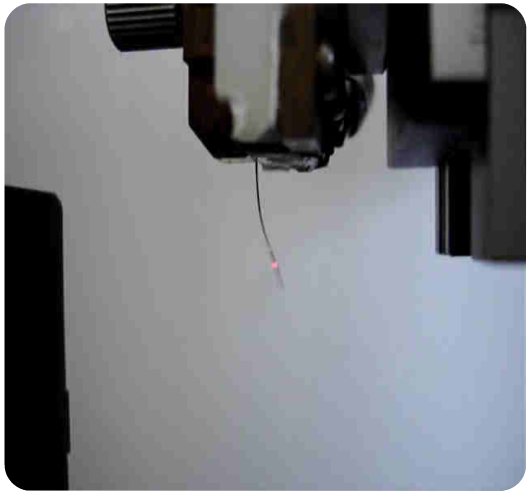
History of Fraunhofer IPA's Research on Functional Materials

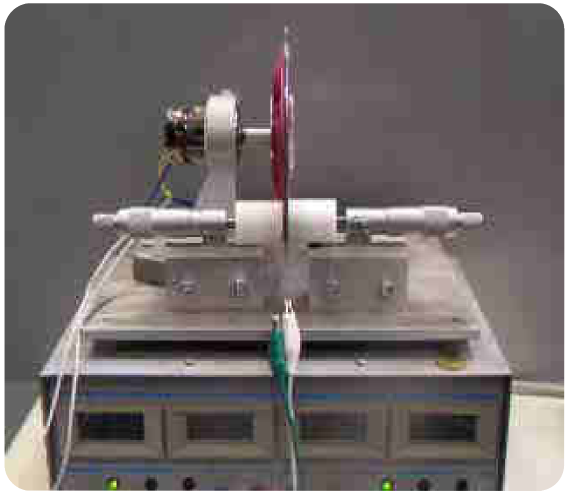



Technology in Society, for Society

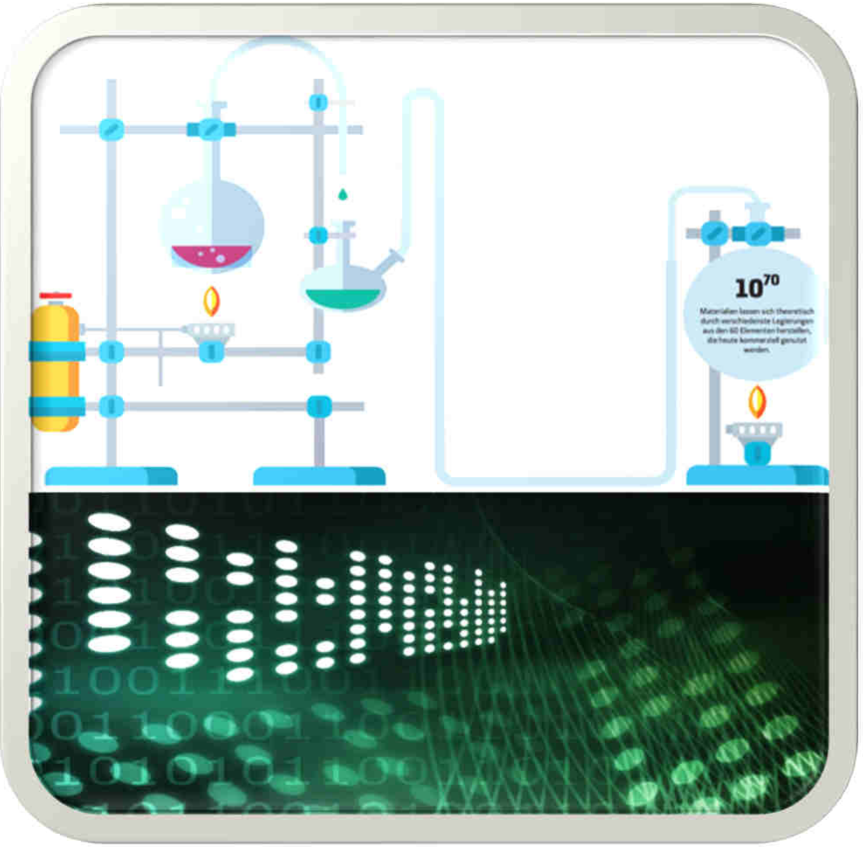

AIST
Material
Simulation
Integration
Application
& Production
Fraunhofer
IPA







The Future of Materials
New super alloys and electronics



- **Rising demand for electronics**
  - sensor materials
  - conductive materials
  - materials for semiconductors
  - High capacity materials
- **High productivity mining**
  - Lithium
  - Phosphor
  - Indium
  - … …
- **New Super Alloys**
  - 60 Materials used => 10 Exp 70 potential alloys

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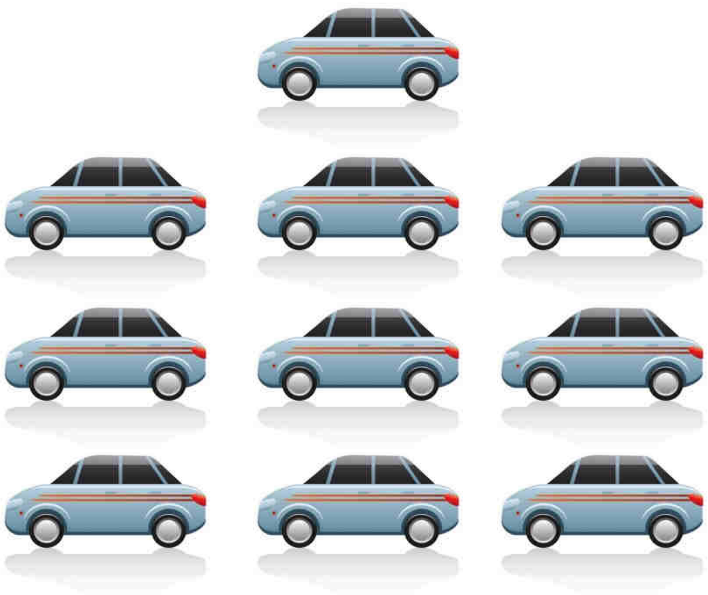
Stuttgart, Germanys Center of Automotive

- 1.366 bill.€ turnover worldwide
- 76 mil. cars sold worldwide
- Annual turnover of German OEMs: 412 bill. € (German GDP: 3,000 bill.€)
- Every 6th €-earned in Germany is related to cars
- Every 4th job in Baden-Württemberg
- Every 2nd in Stuttgart area
- 80% of Germany Automotive Production 200km around Stuttgart

Fraunhofer IPA

TODAY



TOMMOROW

TODAY

17.100.000 T / p.a

Source (Handelsblatt „Stahl bleibt wichtigster Werkstoff“ September 2005

TOMMOROW

1.710.000 T / p.a

- 15.000.000 T/p.a

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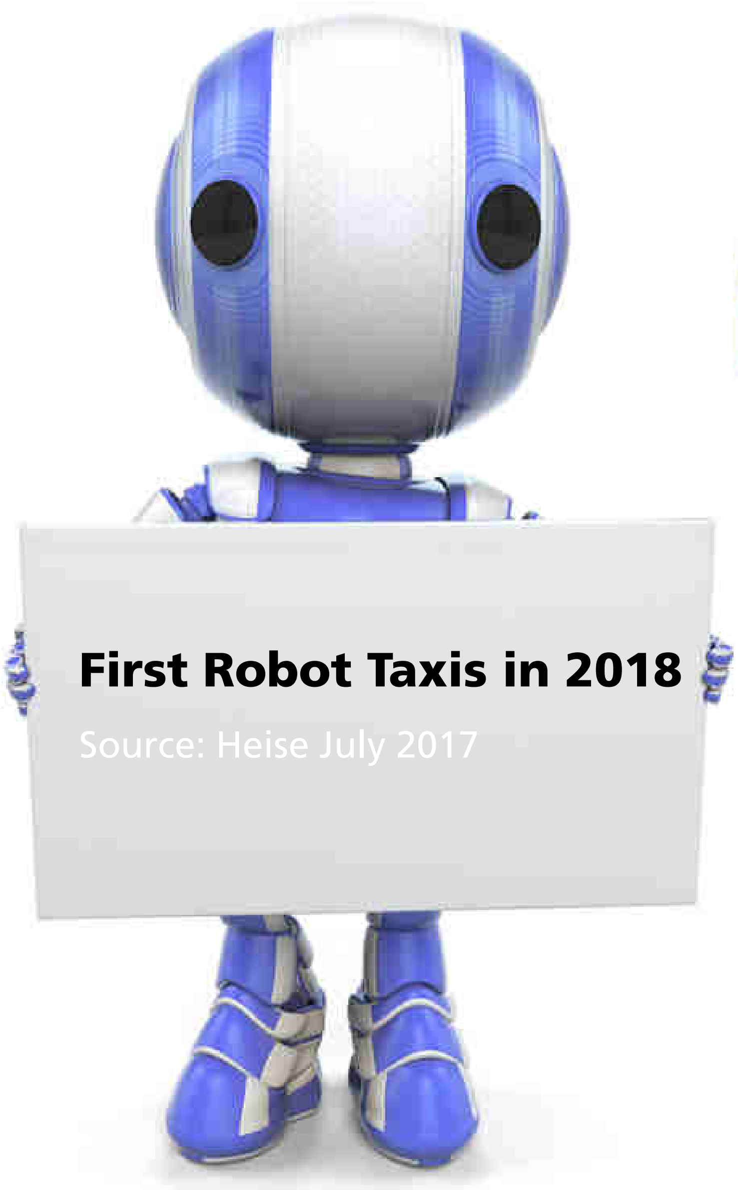


Mercedes-Benz

BOSCH

Nano Materials in Automotive Industries
Future Spheres of Activity of Nanomaterials

// PRODUCTION //

// LIGHTWEIGHT DESIGN //

// ENERGY STORRAGE //

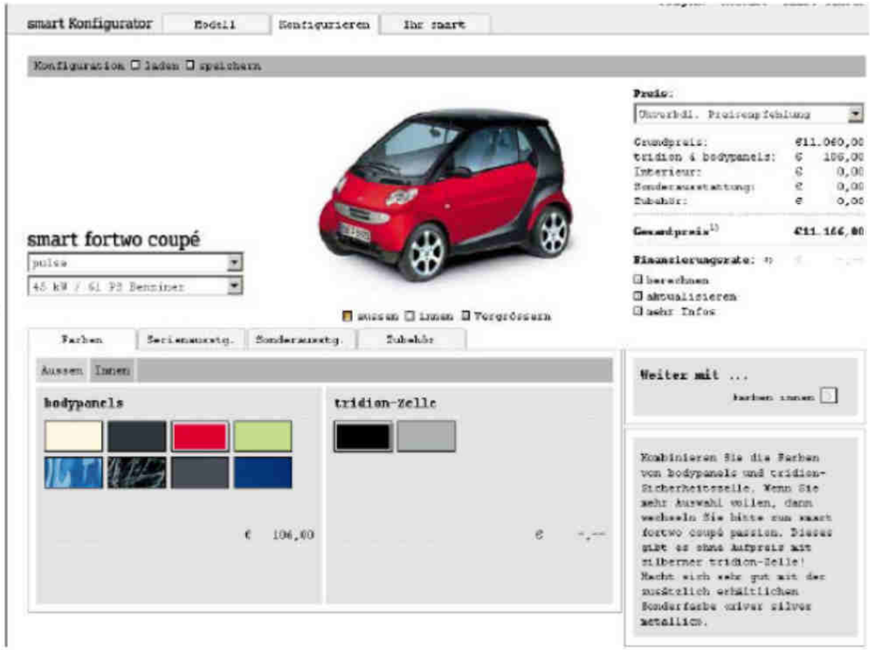
// HUMAN MASCHINE INTERFACES //

Fraunhofer IPA

Gestern

Heute

„any colour you want, as long as it´s black“



Make to stock

1 Variante

Online Konfigurator

Rechnerisch:
32.000 Türinnenverkleidungen (Audi A8)
10^8 Varianten Gesamtfahrzeug

Source : BVL

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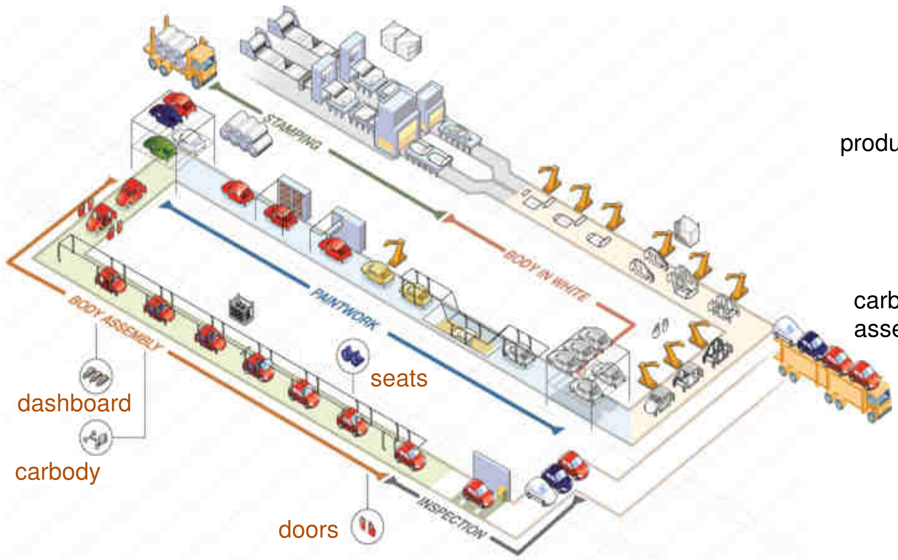
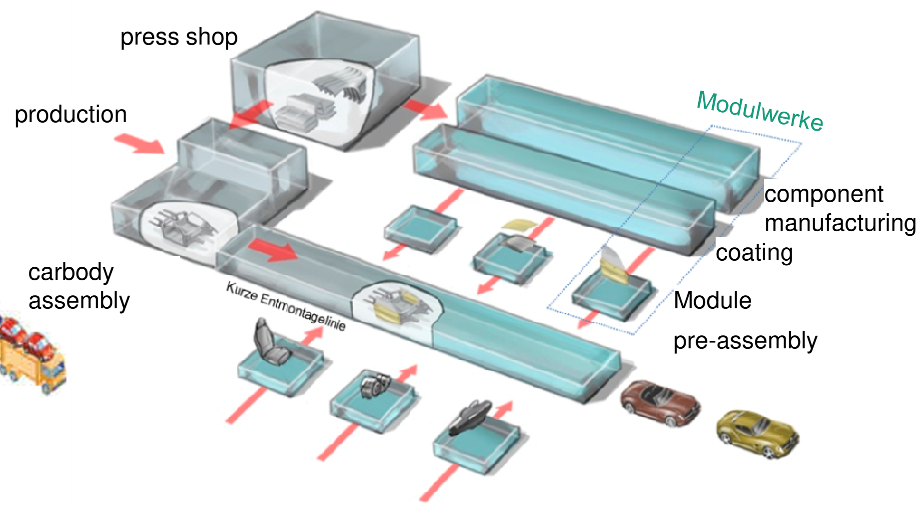
ARENA2036

Freely Accessable Process Modules for (Automotive)Production of the Future

Today



Arena 2036



Challenge

- Decomposing traditional processing line without the disadvantages of classical workshops
- Changeability creates additional complexity

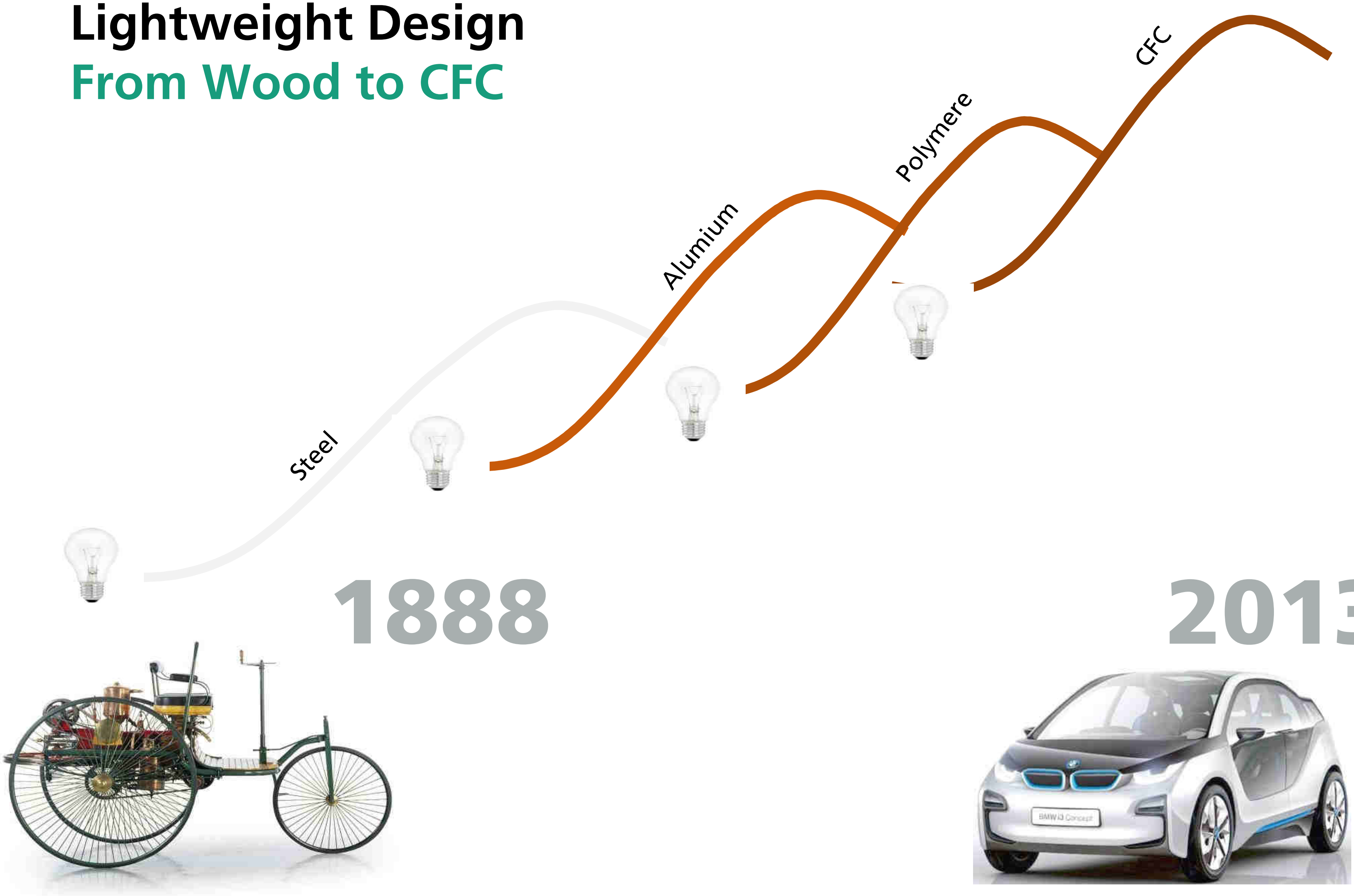
Objects in a Factory will become smart and very agile

Example: swarm intelligence for logistics

source: Fraunhofer IML, Prof. Dr. Michael ten Hompel

LIGHT WEIGHT DESIGN

Lightweight Design
From Wood to CFC



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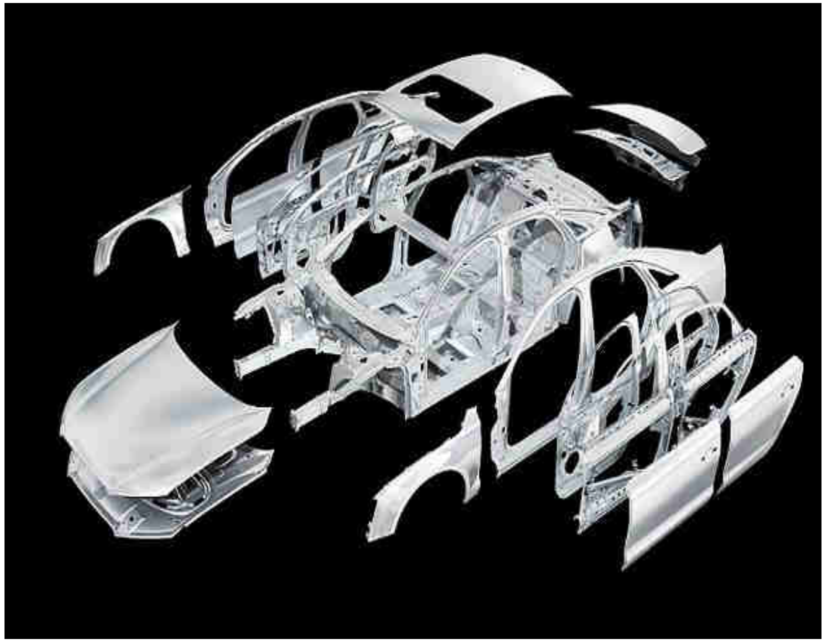
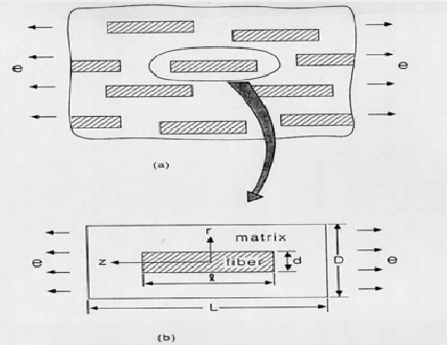
Lightweight Design
Multimaterial Space Frame (MSF) by Audi

- Connection of metal (Al / Steel) and / or Carbon (CFK) structures
- Better mechanical structure and better deformation behavior
- Connection of both materials, form- or force fitted
- Development of new processes, like RTM: Resin Transfer Moulding


Source: AUDI AG

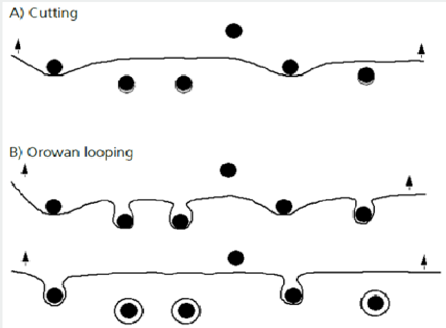
Lightweight Design
Principles of Nano reinforcement

Thermal mismatch*1



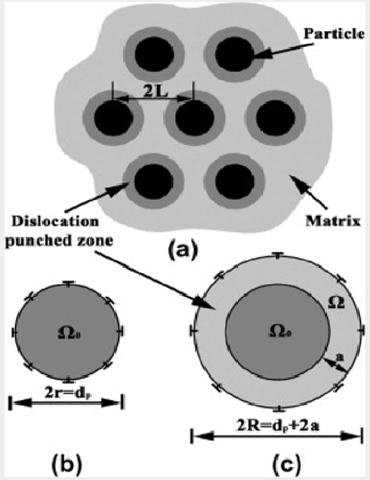
- Hardening of the matrix
- Al matrix high, CNT low
- Prismatic punching of dislocations

Orowan looping*2



- Increase in yield strength
- Stop dislocation movement

Shear lag*3



- Increase in stiffness (E Mod)
- Transfer of load from the matrix to reinforcement

*1: Arsenault RJ, Shi N. Mater Sci Eng 1986;81:175.
*2: Orowan E. Z, Phys 1934;89:634
*3: Clyne TW, An Introduction to Metal Matrix Composites. Cambridge University Press; 1995. p. 26

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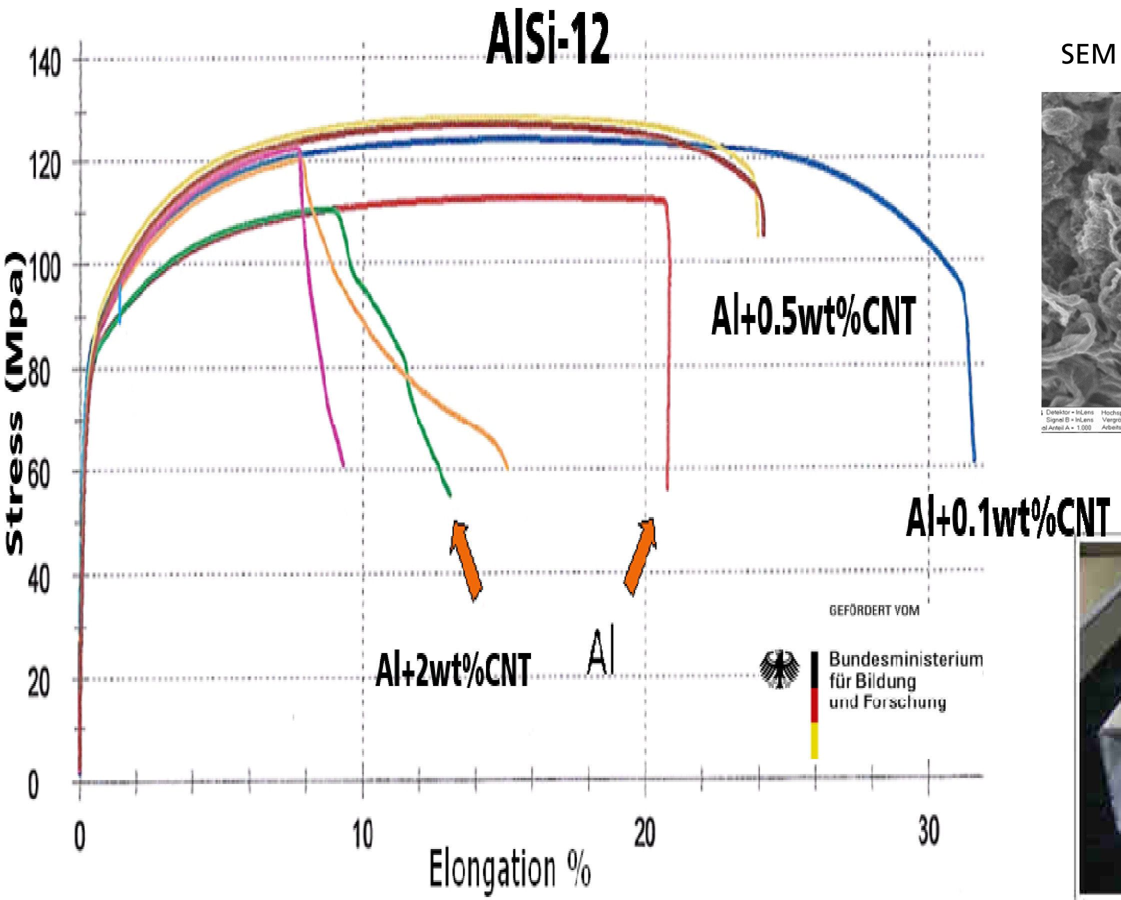
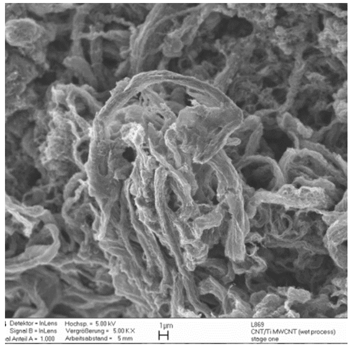
Nano Fiber reinforced Metal
CNT ALSi-12 Composite

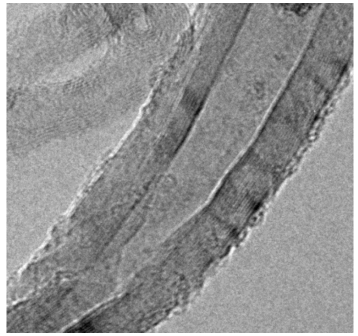


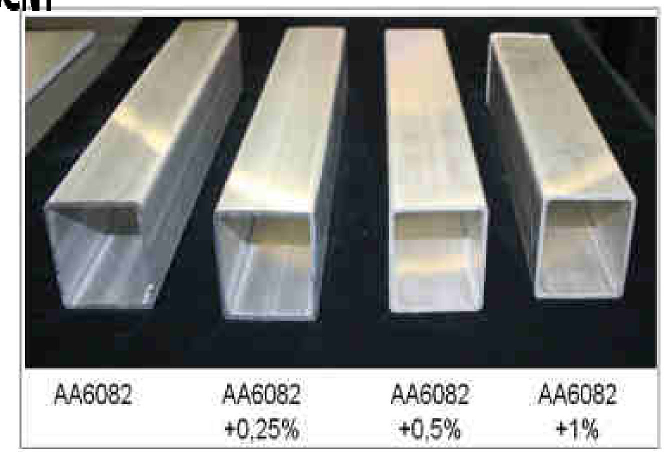
Source: Kolbenschmidt - Projekt Canamat

SEM Picture

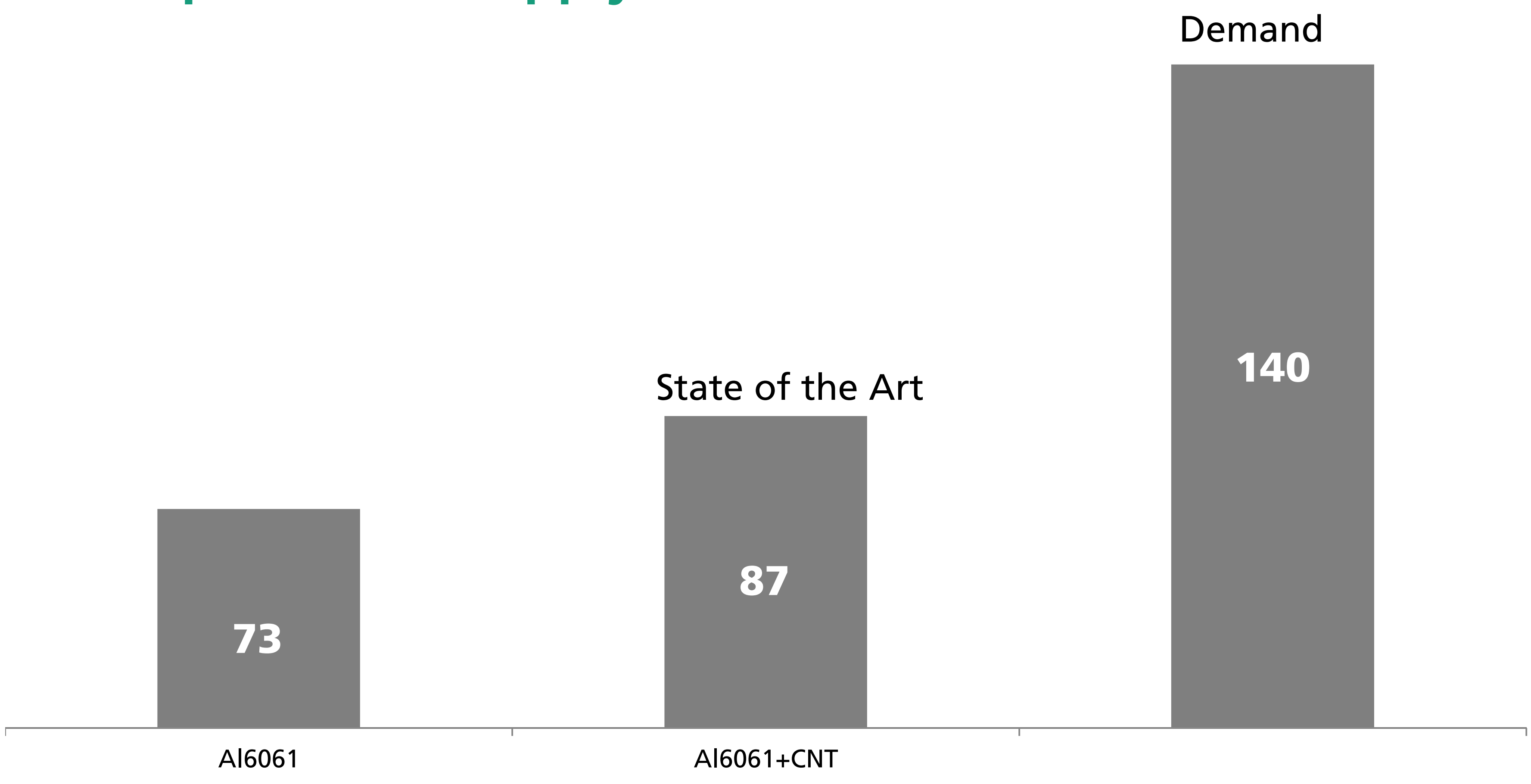


TEM Picture





Nano Fiber reinforced Metal
Comparison of Supply and Demand



E Modul in GPa

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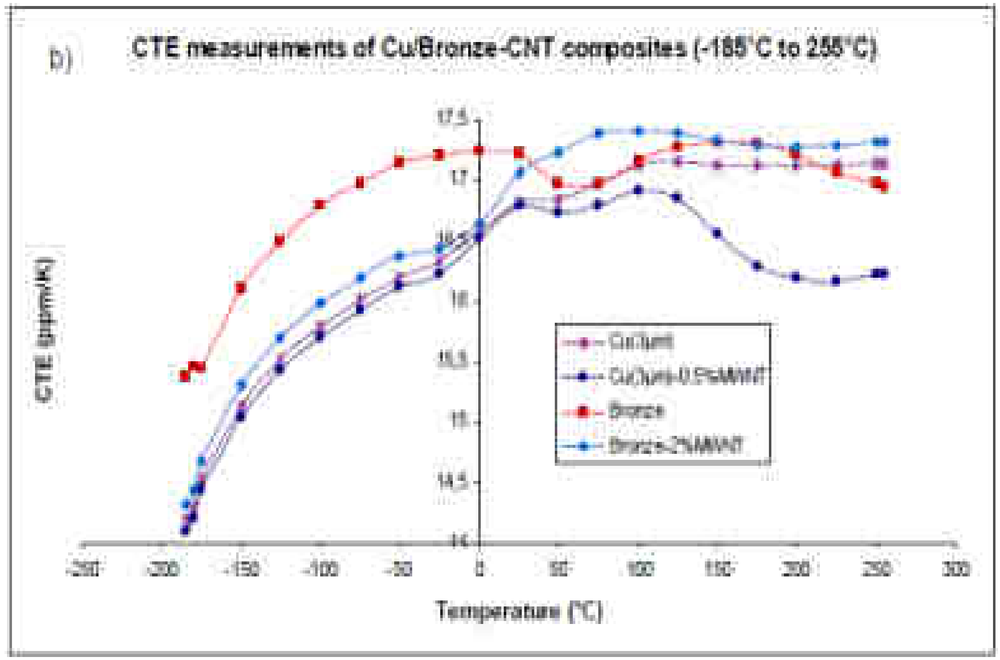
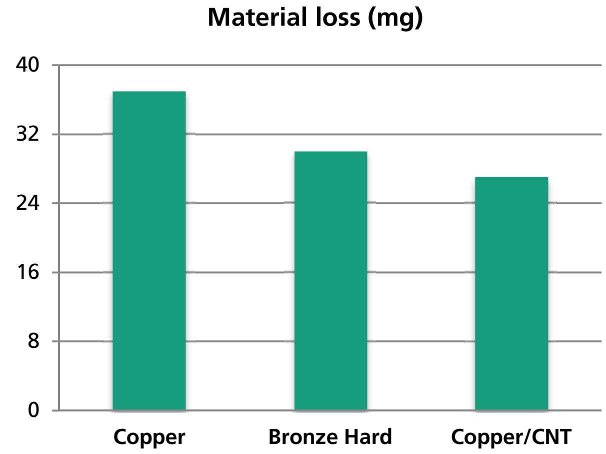
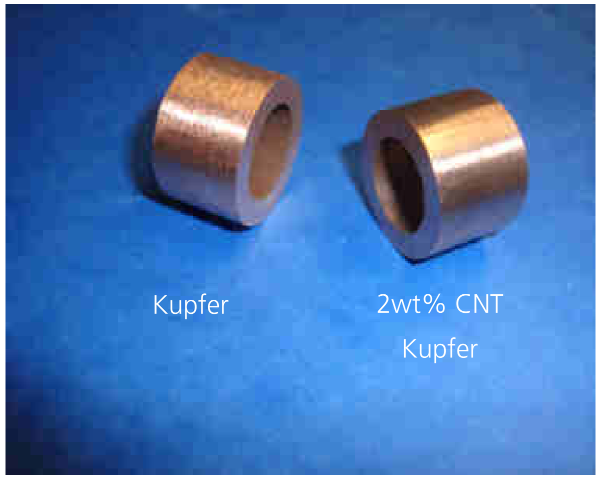
Nano Fiber reinforced Metal

Copper Bearings







Additive Manufacturing
Lightweight design and construction

Used Materials

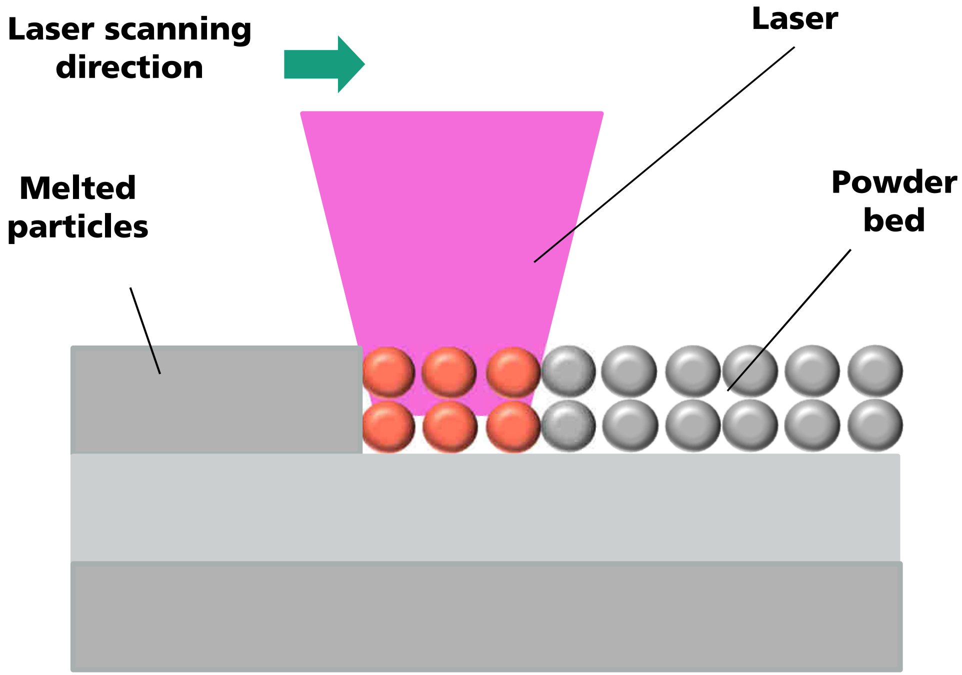
- Scalmalloy®
- Stainless Steel 1.4404
- Stainless Steel 1.4540
- Stainless Steel 1.4542
- Steel 1.2709
- Titanium Ti6Al4V
- Aluminum Alloy ALSi10Mg

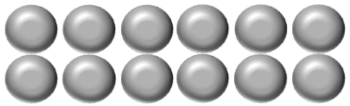
Source: AP Works

Additive Manufacturing
SLM Steering Knuckle

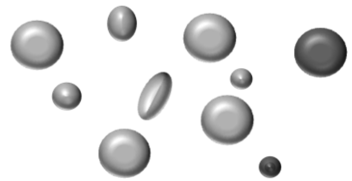
Source: Fraunhofer ILT

Material adaptation for additive manufacturing processes
Industrial challenge / problem setting





Ideal:
Homogeneous powder particles



Real:
Inhomogeneous powder particles

Homogeneous powder base for efficient additive manufacturing,
In titanium, for example, this homogenization is still the problem

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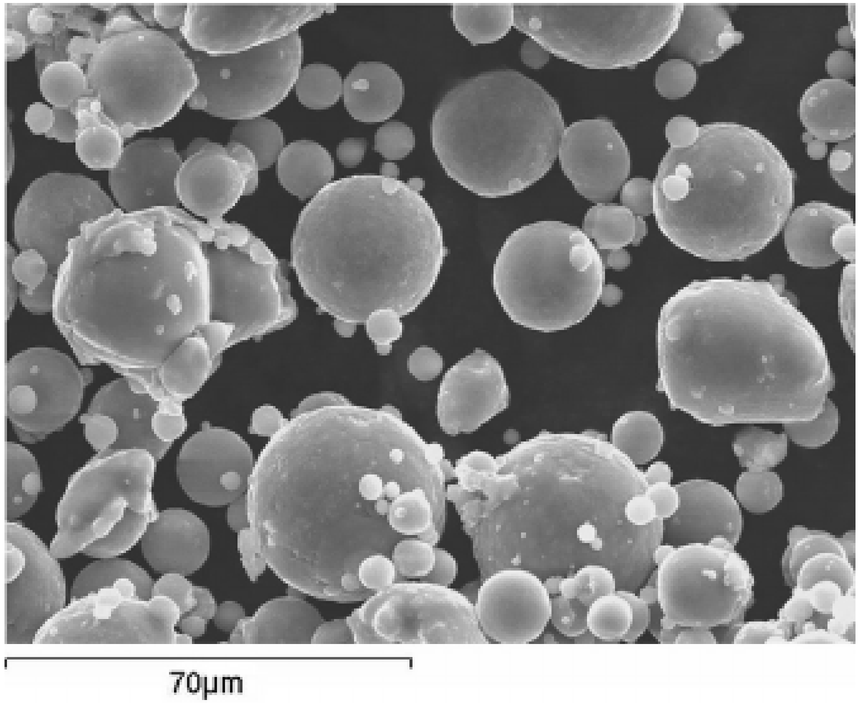
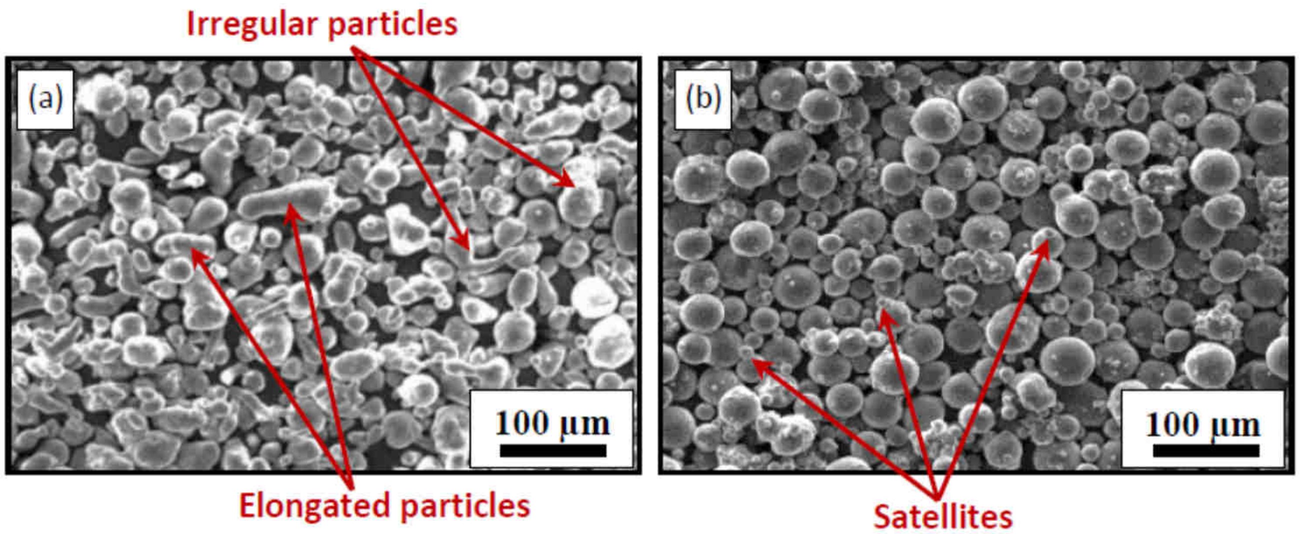
Inhomogeneous geometry of metal powder

SEM Image AlSi10 Mg



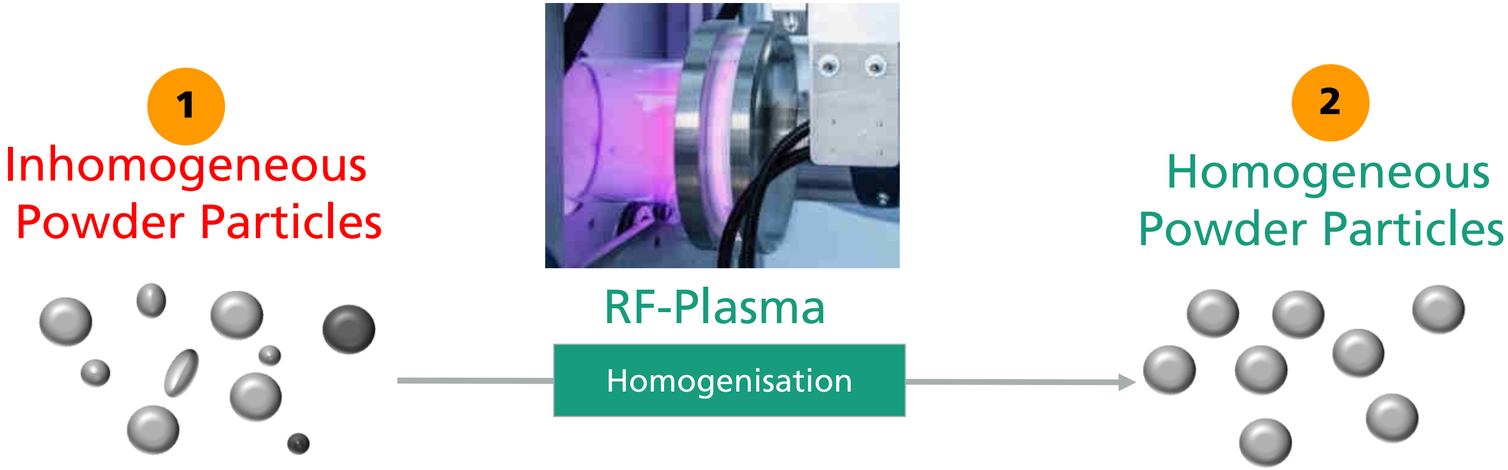
Source: Yan , et. al. ; Materials Science and Engineering A 628 · March 2015

Inhomogeneous geometry of metal powder
SEM Image AlSi10 Mg



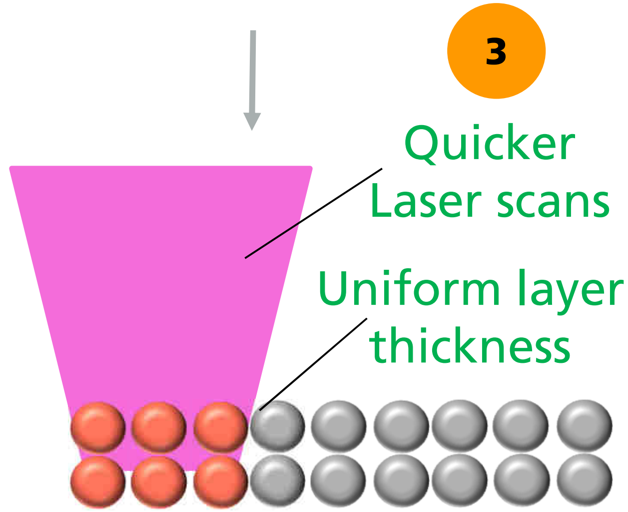
Source: Aboulkhair , et. al. ; Lasers in Manufacturing Conference 2015

Adaption of Materials for Additive Manufacturing
Industrial approaches to solution



Homogenity of the powder particles refers to:

- Shape of particles
- Size or Particle Size Distribution
- Surface properties (Chemical Composition)



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RF Plasma Spheroidization
Main challenges / Productivity

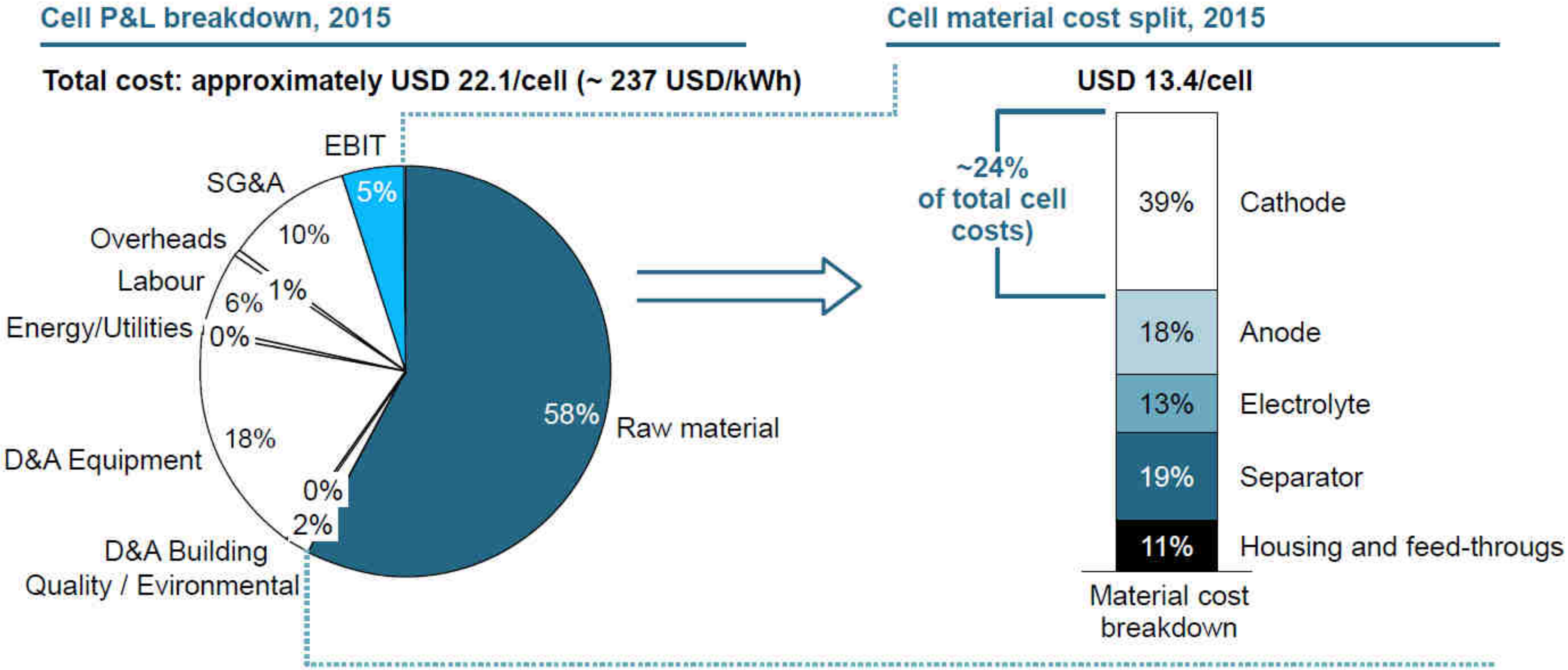
Challenges

- Ex Schutz
- Automatization potential
- Handling and Manipulation
- Occupational safety
- Total running cost

Roland Berger Strategy Consultants

Price levels around 200 EUR/kwH (approx USD 250) in 2015 do not provide sufficient EBIT to finance cost of capital

Typical 96 Wh PHEV cell – Cell cost structure 2015



1) Including carbon black content, foil and binder cost

Source: Roland Berger LiB Value Chain Cost model 2011

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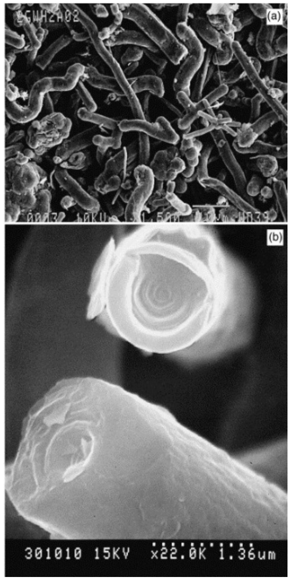
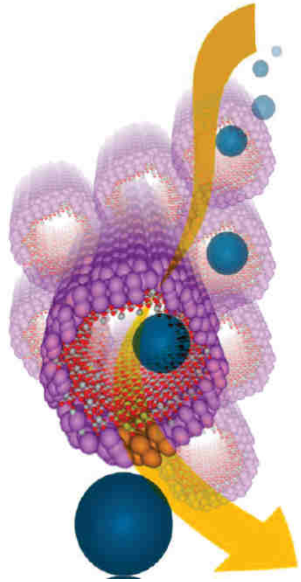
Prof Morinobu Endo

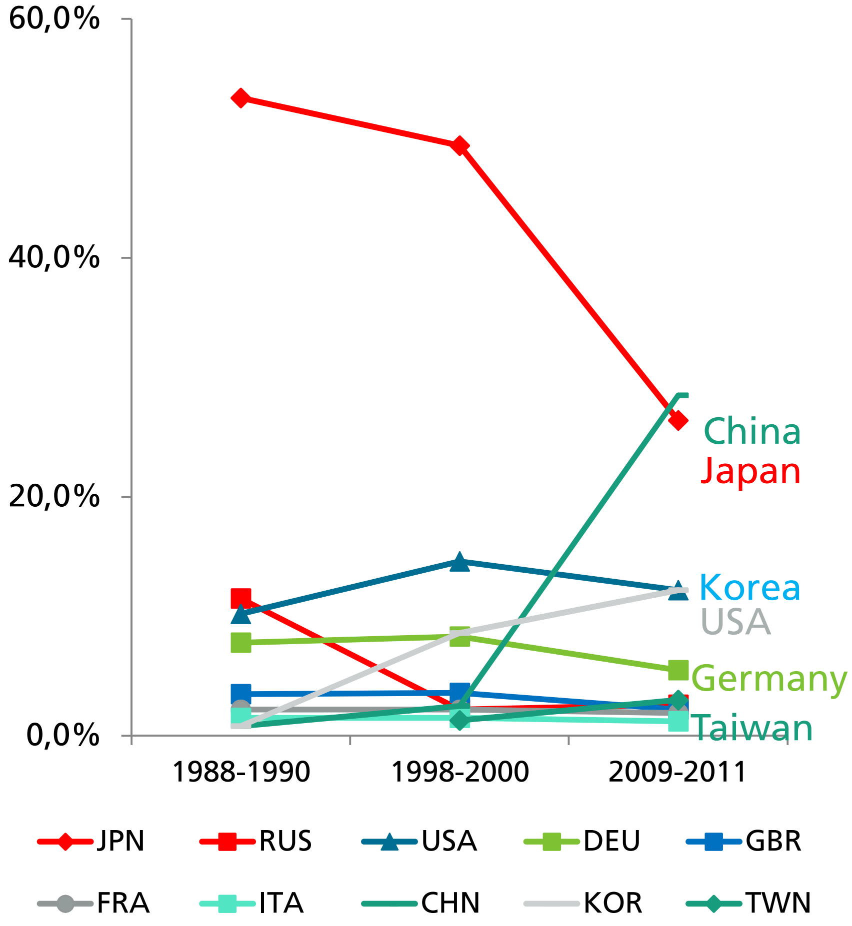


1) H. Abe 1998



2) Park 2009

Patent and Patent Family Applications (in %)



		Country	No.	%
1988-1990	1	Japan	319.854	53,4%
	2	Russia	68.864	11,5%
	3	USA	61.057	10,2%
	4	Germany	46.486	7,8%
	5	UK	20.895	3,5%
1998-2000	1	Japan	353.942	49,4%
	2	USA	104.660	14,6%
	3	Korea	61.476	8,6%
	4	Germany	59.234	8,3%
	5	UK	25.571	3,6%
2009-2011	1	China	284.869	28,5%
	2	Japan	264.374	26,4%
	3	Korea	122.459	12,2%
	4	USA	122.369	12,2%
	5	Germany	54.944	5,5%

Source: NISTEP „Japanese Science and Technology Indicators 2014“

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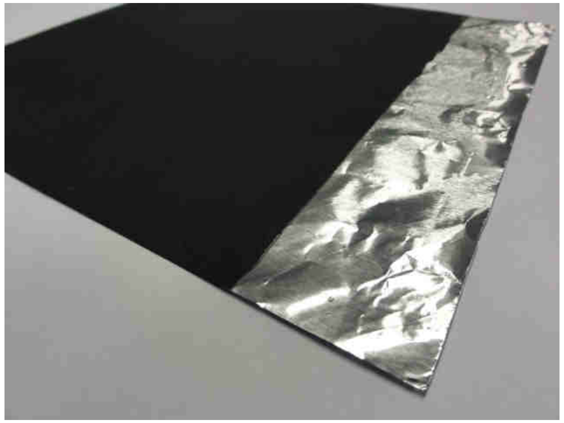
Reference Project : ElectroGraph

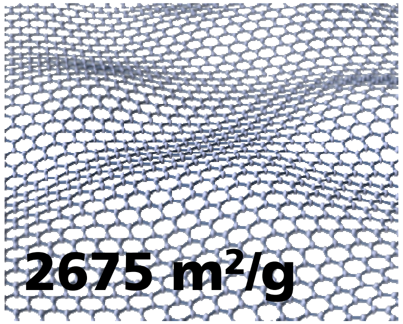
Graphene based electrodes for application in supercapacitors

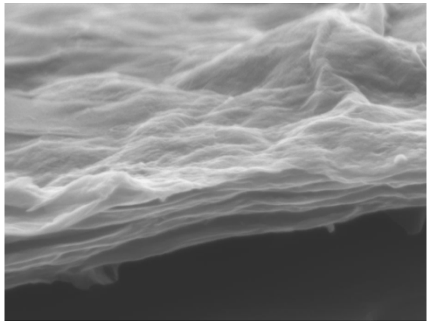
Development of materials and production technology for electrodes



Integration in a rear view mirror with PV module for energy self-sufficient mirror adjustment

High surface = high capacity





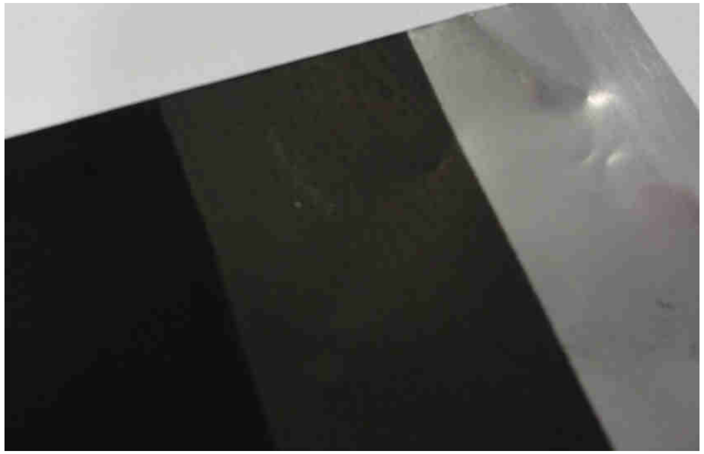
product development

Electrode SuperCap E-Auto

GNP based electrode Vs. commercial electrode

Sample	Specific capacitance [F/g] Cyclicvoltammetry (25mV/S)	Specific capacitance [F/g] Galvanostatic charge/discharge (0.25 A/g)	ESR [Ω]	P_{spec} [kW/kg]	E_{spec} [Wh/kg]
GNP based electrode	70	**61.6**	21.5	5.45	13
Commercial electrode (Activated carbon)	40	**21**	9.2	11.7	4.47

- Electrodes consist of active materials coated on aluminum current collectors.
- Measurement with 2-electrode EC-cell
- Size of electrodes A3
- Increasing of active (useful) surface



Demonstrator – Autonomous External Rear view mirror

Integrated graphene-based supercapacitor

and Photovoltaic Cells (PV) for Lancia Delta external rear-view mirror

FINAL GOAL

Cable removal by contactless remote control, solar cells and supercaps based power supplying.

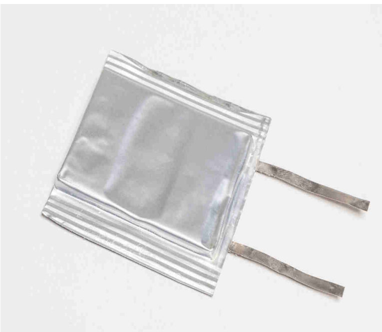
Project example:

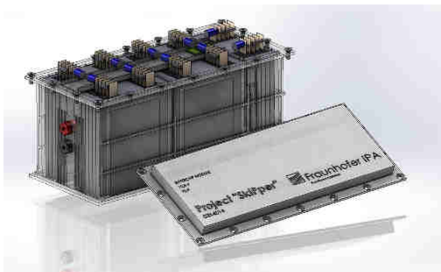
SkiPper - Supercapacitor as buffer system for storage of electric energy in automotive applications

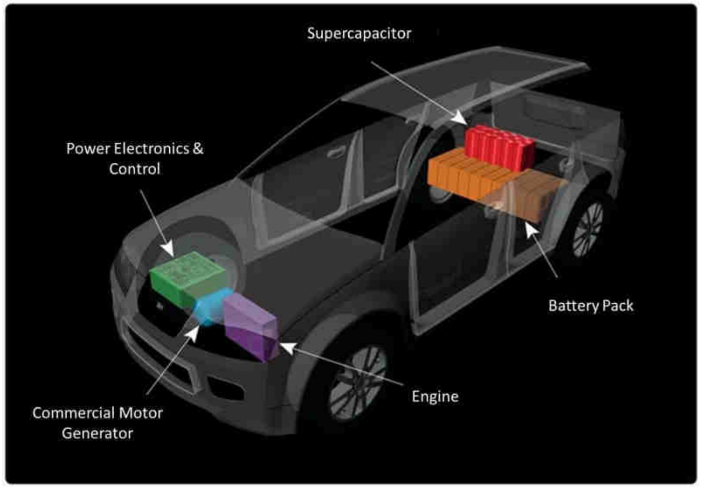
Nanocarbon-based electrodes for electro mobility

- Buffer system for energy storage, compatible with long-time storage such as Li-batteries
- System integration, module development
- With AIST Kansai, National Institute of Advanced Industrial Science and Technology (AIST)

- Rapid-charging
- Long lifetime
- Power density superior to battery systems
- Vehicles for decentralized energy storage







Integration of supercapacitor in automotive application - here as support of battery pack

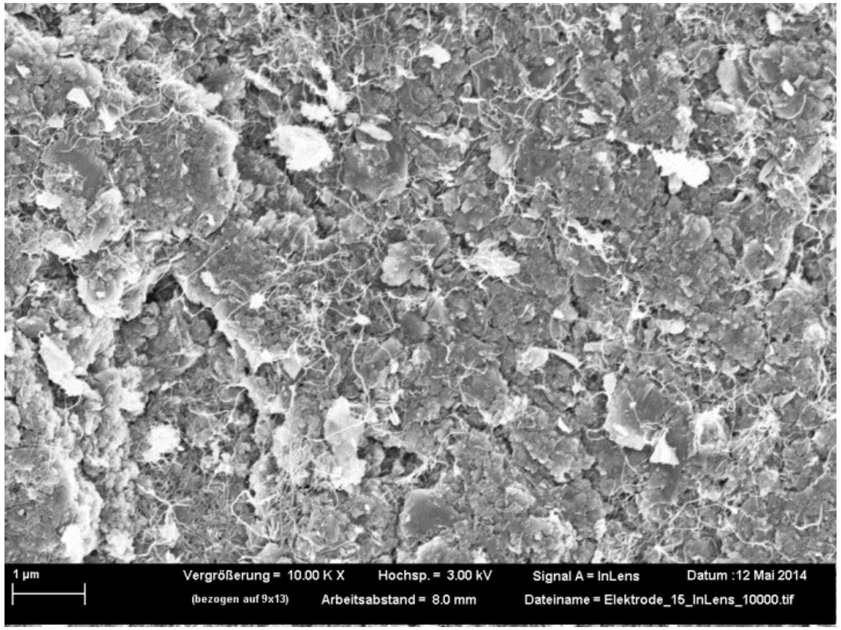
Project example:
Power Industry – Storage Systems for Electric Power FastStorage BW

- **Task**
  - Development of novel high-performance and high-power storage cells (power caps) with a long service life and ultrafast charge, which is highly secure; development of the respective production processes
  - Defining application fields for energy recovery and efficiency increase in industry and e-mobility
- **Services provided by IPA**
  - New production methods for nanomaterial (graphene nanoplatelets) and electrodes with high potential for power storage
  - Development of a innovative, solvent-free dry coating method for better processing
  - Up-scaling wet chemical dispersion and application technology for a higher energy density

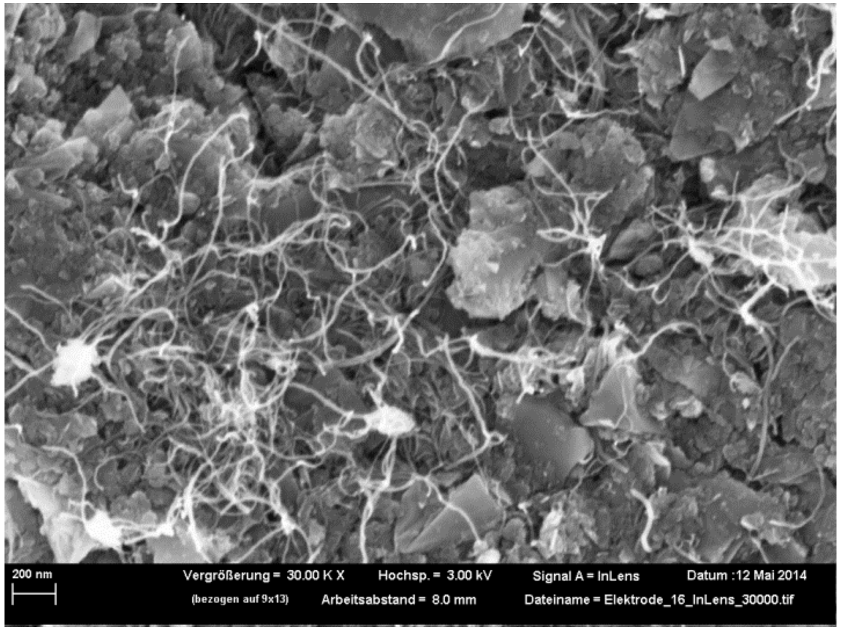
SEM of Composite Electrodes
Binder Substituion via Nano Carbons

Baden-Württemberg
MINISTERIUM FÜR FINANZEN UND WIRTSCHAFT

- CNTs replace the binder material
- CNT mesh keeps active material on electrode



(10.000 x magnification)



(30.000 x magnification)

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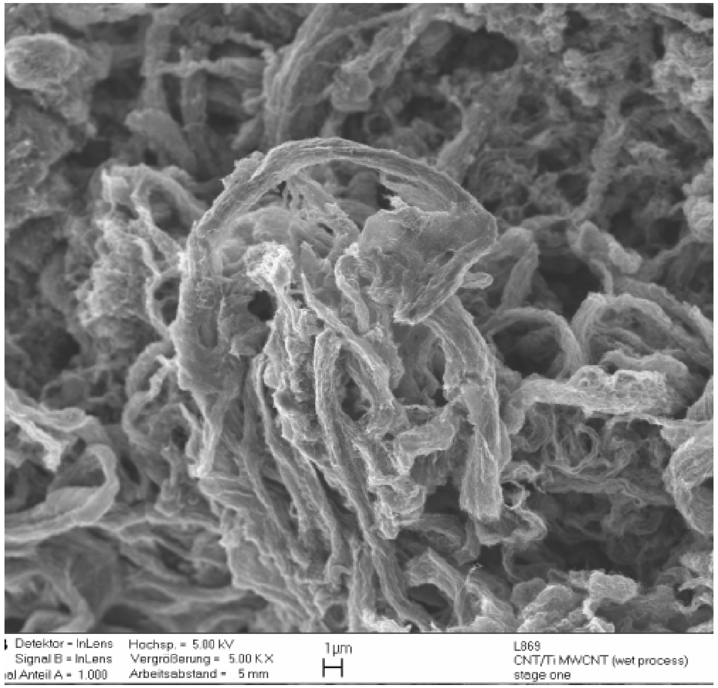
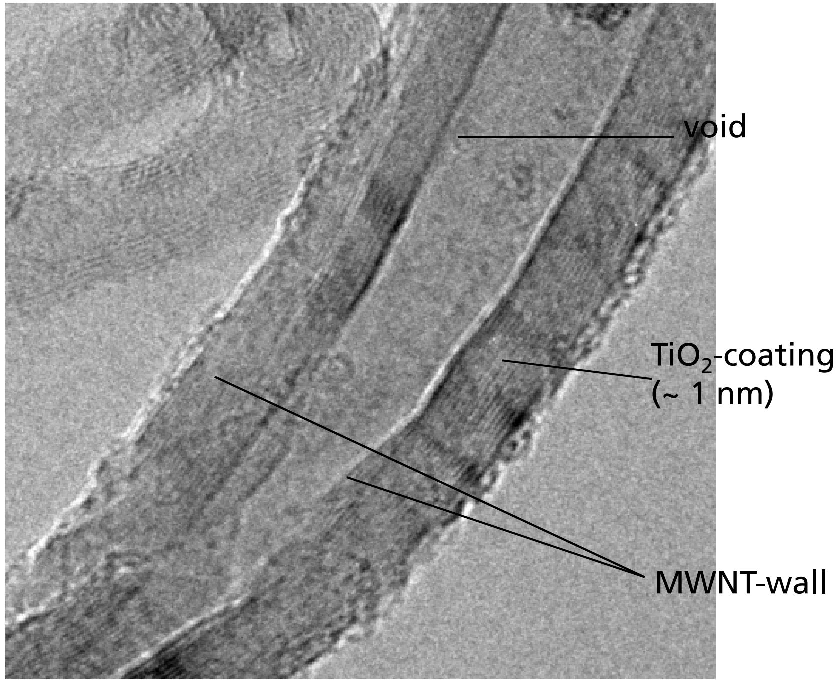
Synthesis and Functionalization
Hybrid Particles

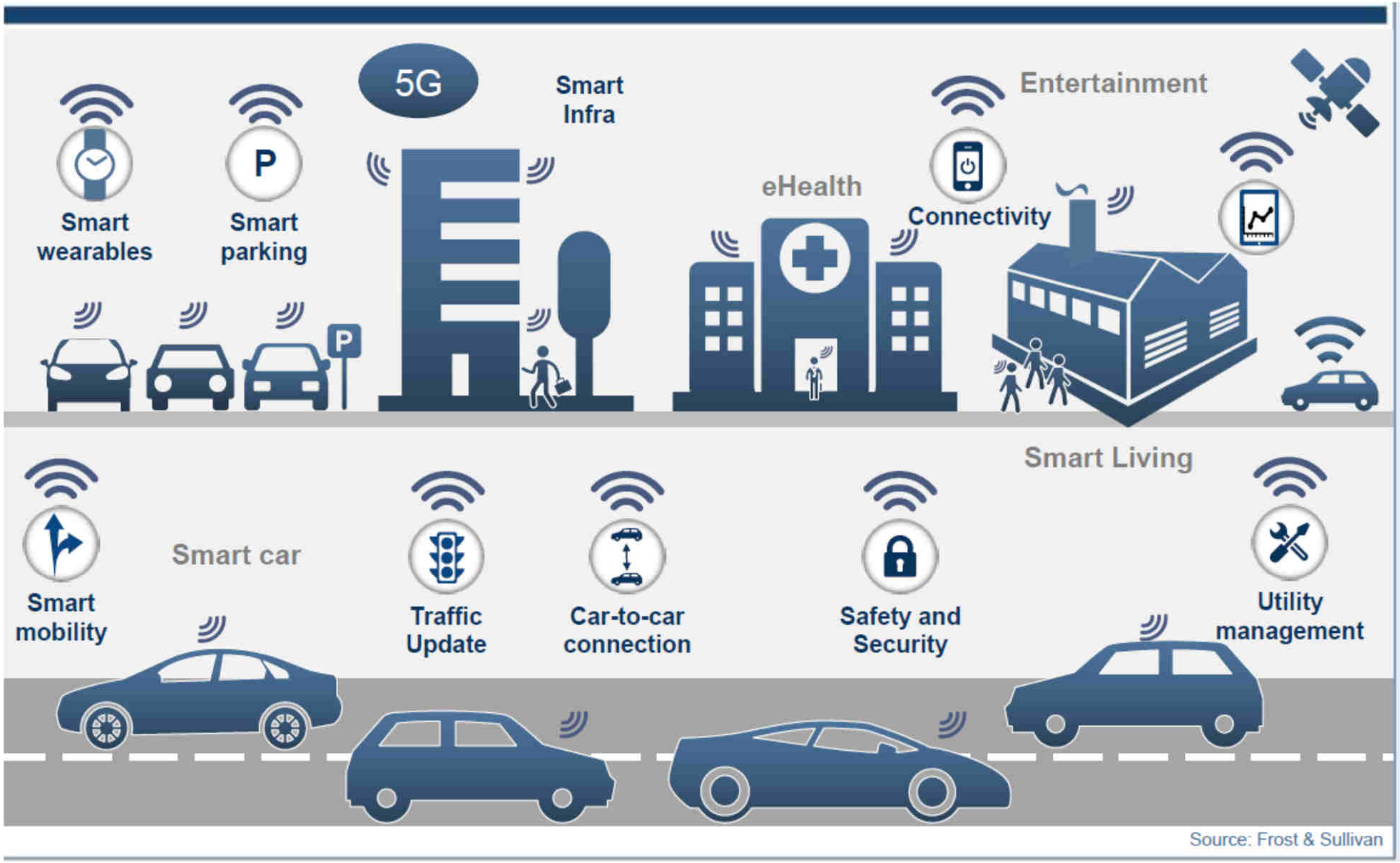
TiO_2 coating of CNTs (Sol-gel procedure)

SEM

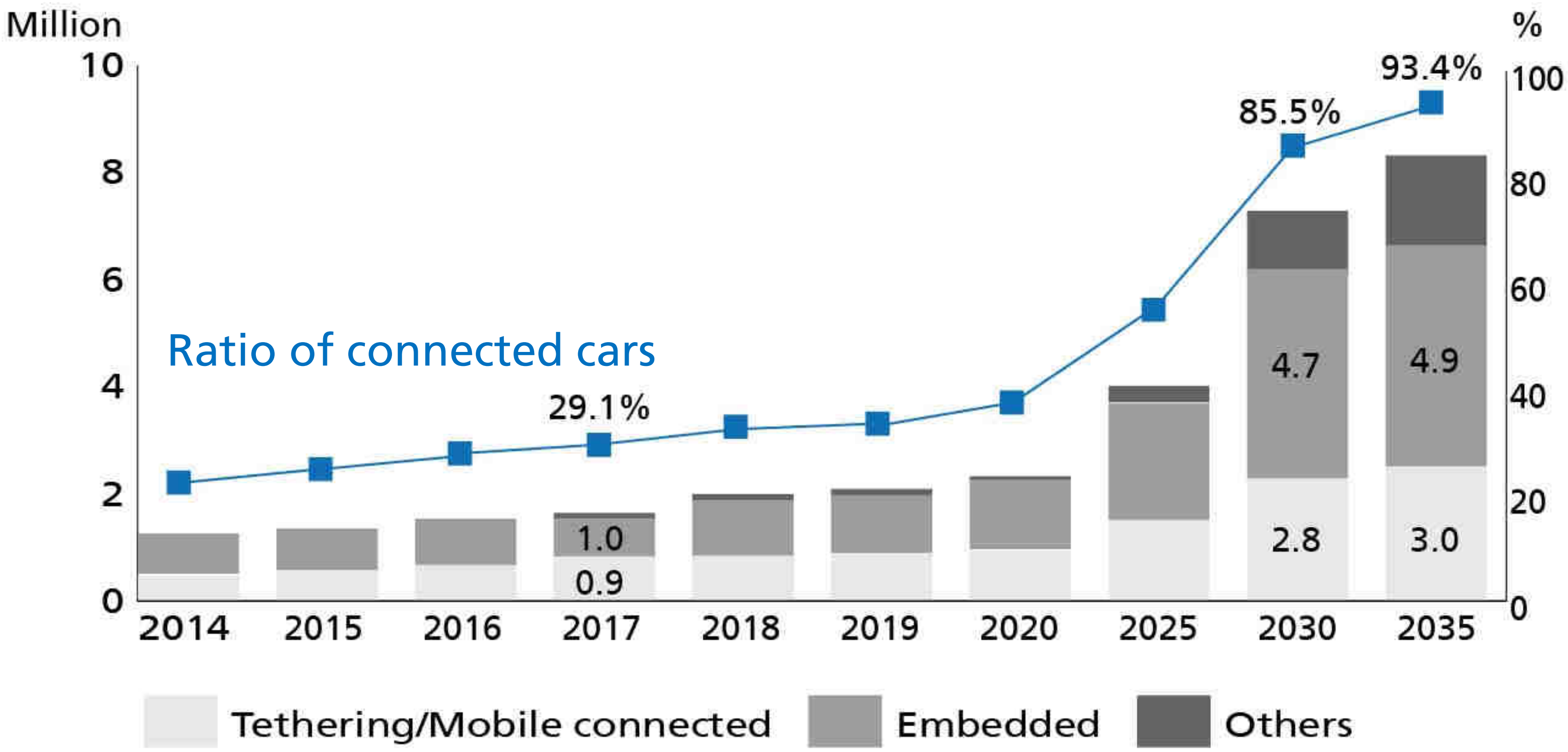


TEM




5G
Smart Infra
Entertainment
Smart wearables
Smart parking
eHealth
Connectivity
Smart Living
Smart mobility
Smart car
Traffic Update
Car-to-car connection
Safety and Security
Utility management
Source: Frost & Sullivan

Connected car world market forecast (2035) (based on new auto sales)



Source: Fuji Keizai, March 2017

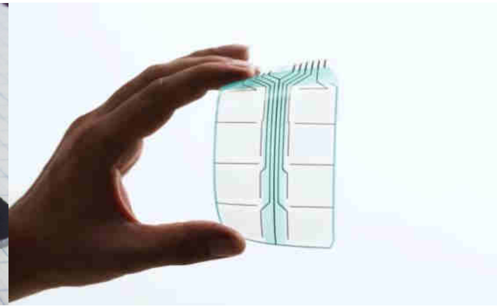
Fraunhofer IPA

„Printed HMI“

The Need for Change – Advantages of Printed HMI

©BMW AG (background picture)

©DesignHMI



- **Advantages:**
  - Integration of sensor/actuator applications in curved, complex 3D surfaces
  - Personalized design & positioning of sensoric/actoric surfaces
  - Saving of material by selective sensor integration (compared to off-the-shelf components and according to desired degree of variation)
  - Better recyclability of printed HMI parts due to non-critical disposal of sensor-integrated polymeric parts (no rare metals etc…)
  - Reduction of metallic material use due to nanocarbon-based conductive inks/polymers. -> Better recycling and resource efficiency
  - Cost optimization due to simple & automated sensor integration/assembly.

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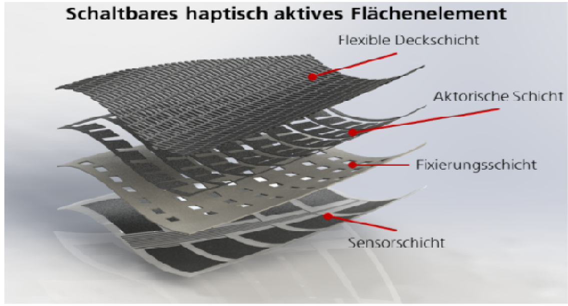
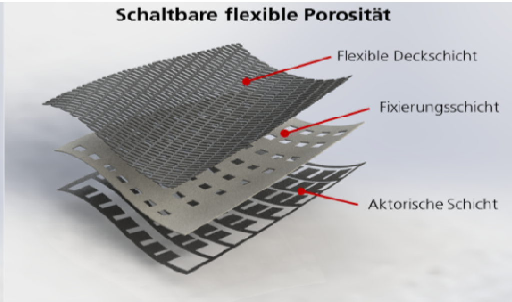
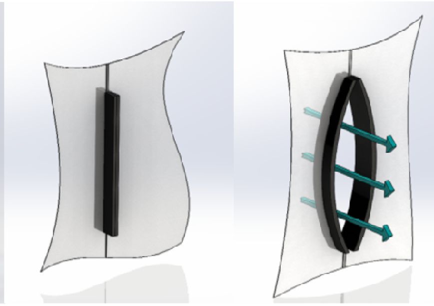
Structured Active Surfaces

Printed Actuator Arrays for SFB1244 (Project Start in 2017)



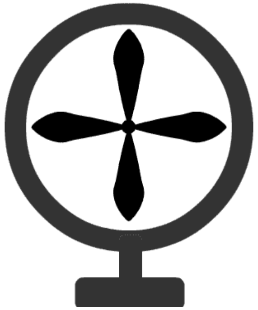


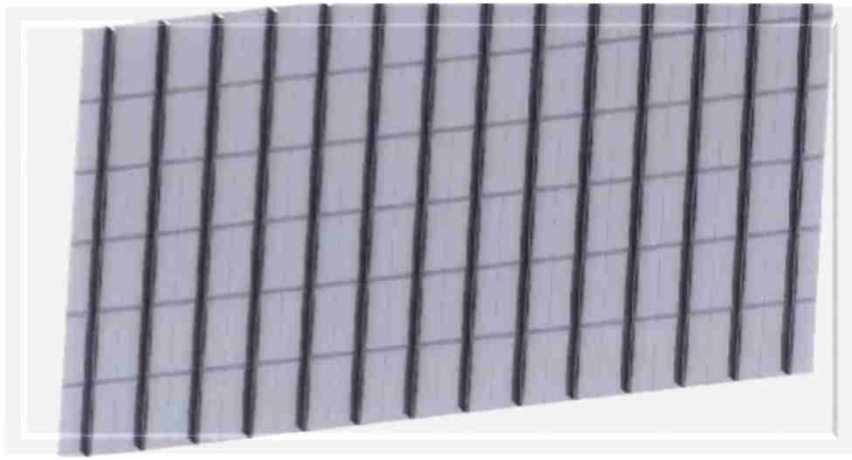


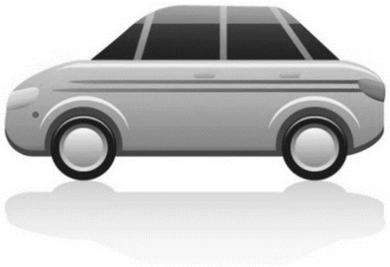
- **Approach:**
  - Utilizing intrinsic action modes of electroactive polymer actuators (EAPs) for adaptive functionalities in buildings
  - Optimizing reliability and reproducibility by using uninterrupted manufacturing concepts e.g. roll-to-roll printing
- **Value proposition:**
  - Noise-free, continuous, intrinsic actuation of soft, flexible surfaces
  - Innovative manufacturing methods with printed structures for actuator fields

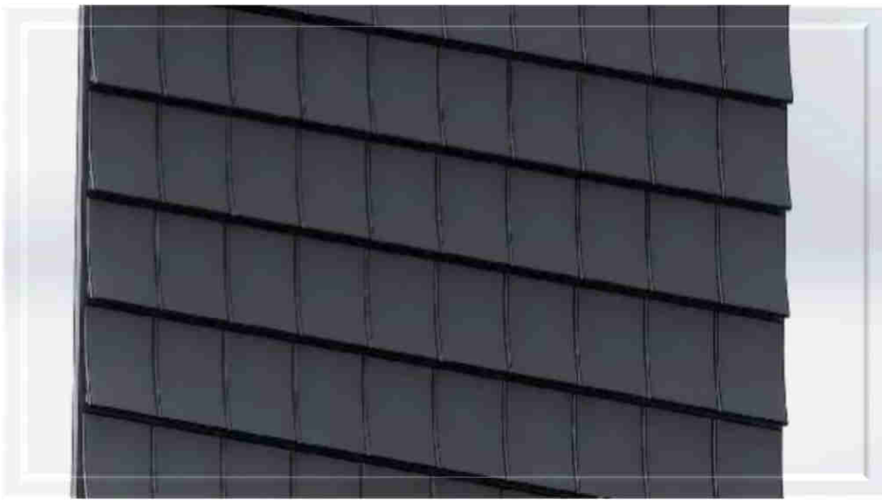
Fraunhofer IPA

Smart Skins For Thermal Managment
Adaptive Flow control Management Systems



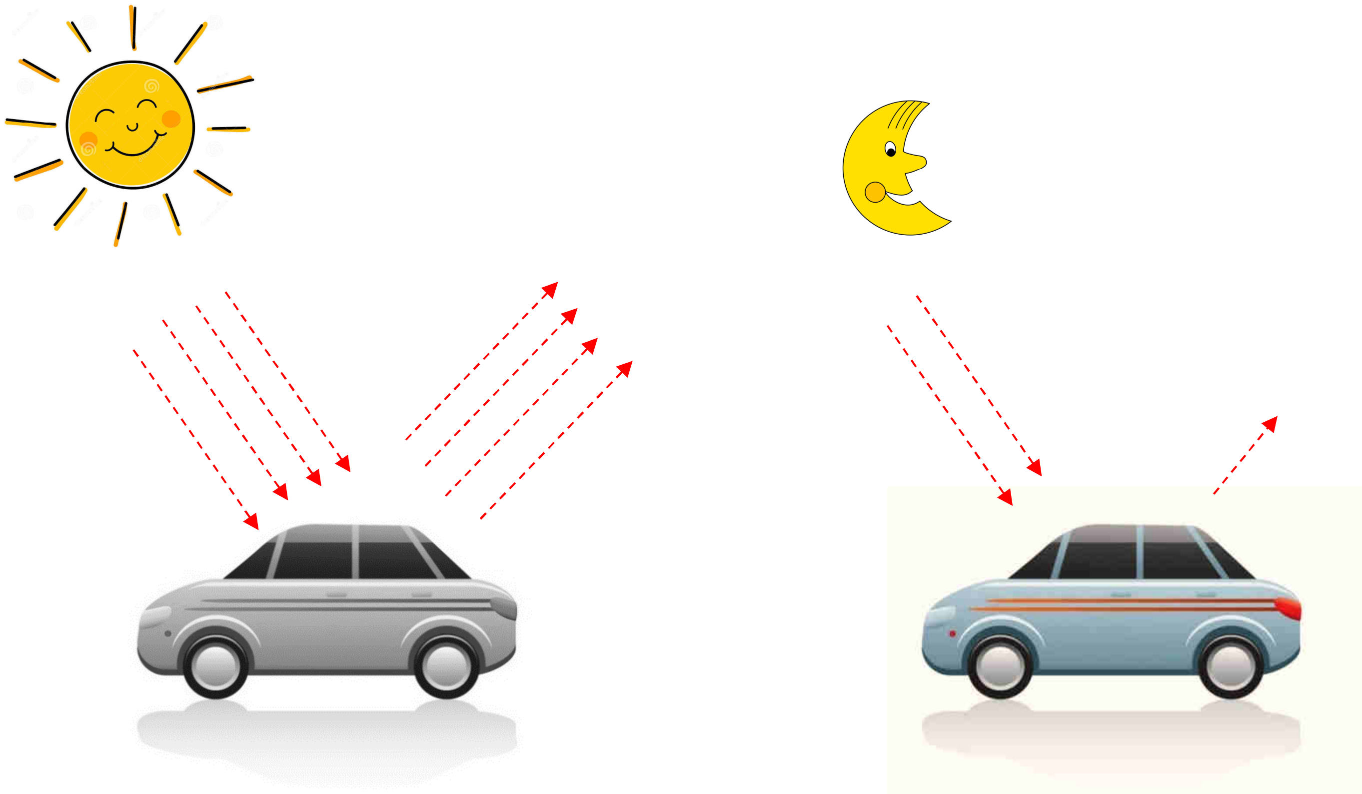






Smart Skins For Thermal Managment

Color Change Materials



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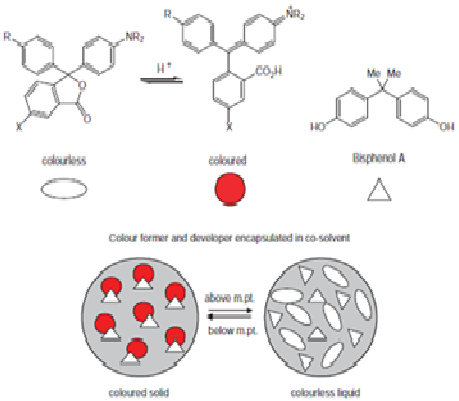
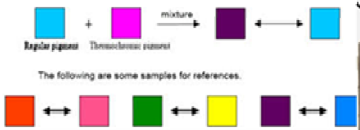
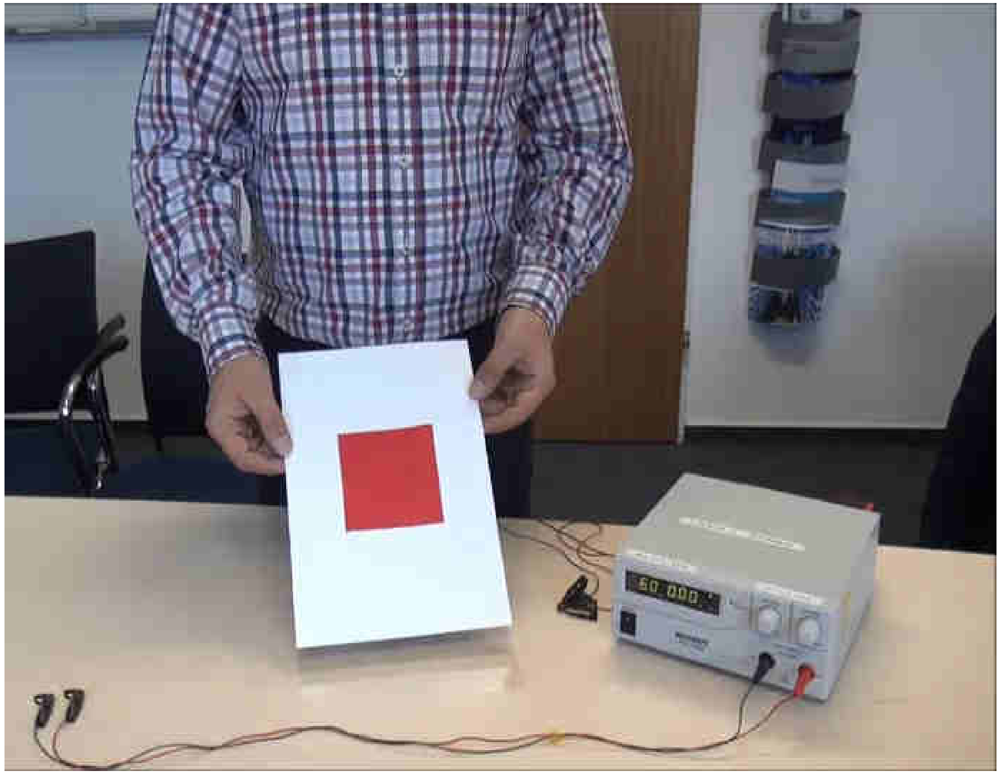
Smart Skins For Thermal Managment
Color Change Materials

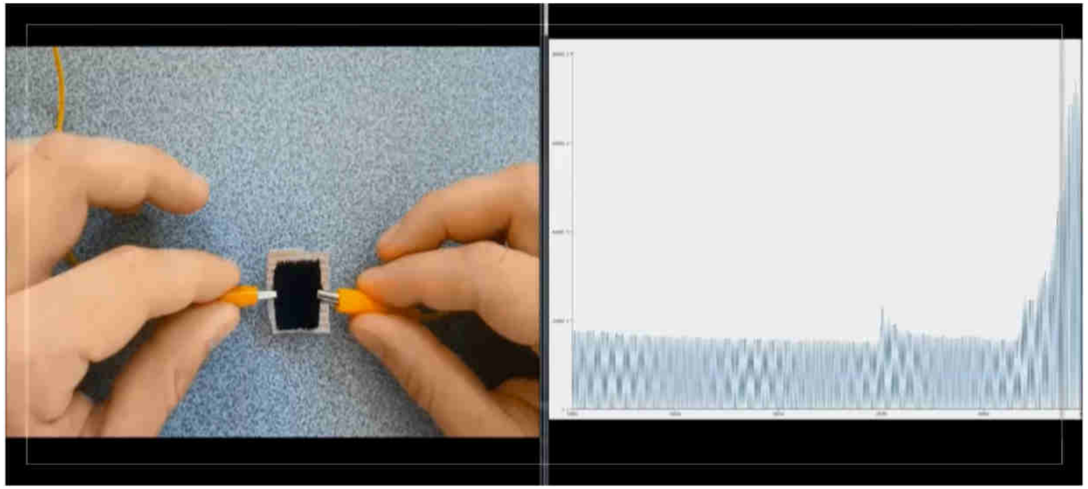


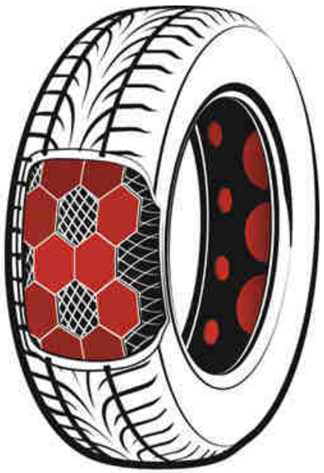


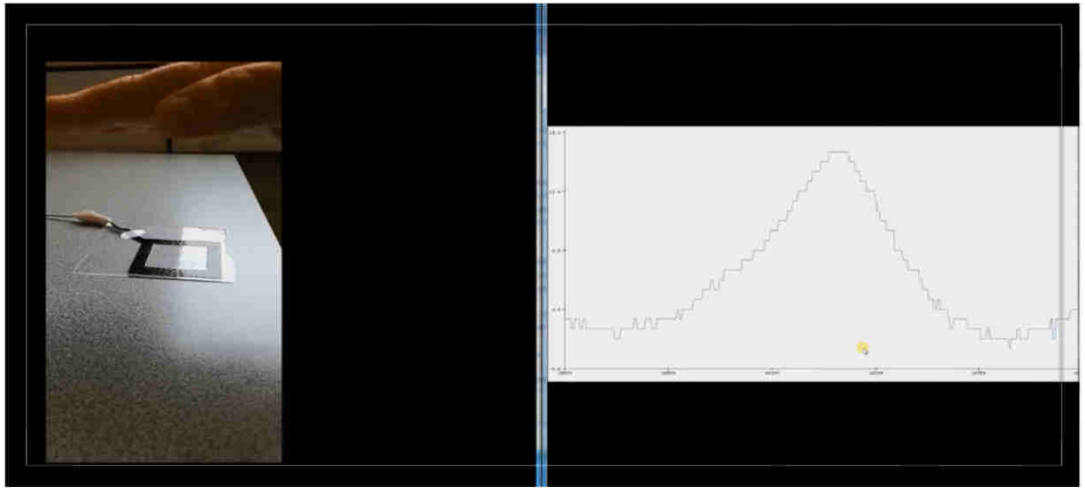


Fraunhofer IPA

SMART SURFACES
SMART TEXTILES AND TIRES







Conclusions

- The Automotive Industry will change dramatically (soon)
- Nano Materials are commonly used in Cars
- A significant increase in synthetic electronic is expected
- Connectivity is a key feature for future cars
- Smart Surface are and important part of a successful digitalization strategy
- The future will need more, interdisciplinary and creative engineers. Talent management will be crucial for successes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APPLIED SMART MATERIAL FOR AUTOMOTIVE
„FUNCTIONAL MATERIALS : DISRUPTIVE TECHNOLOGIES FOR CONNECTED CARS“
Stuttgart 8th November 2017