Electric vehicles and new energy – Surface treatment opportunities

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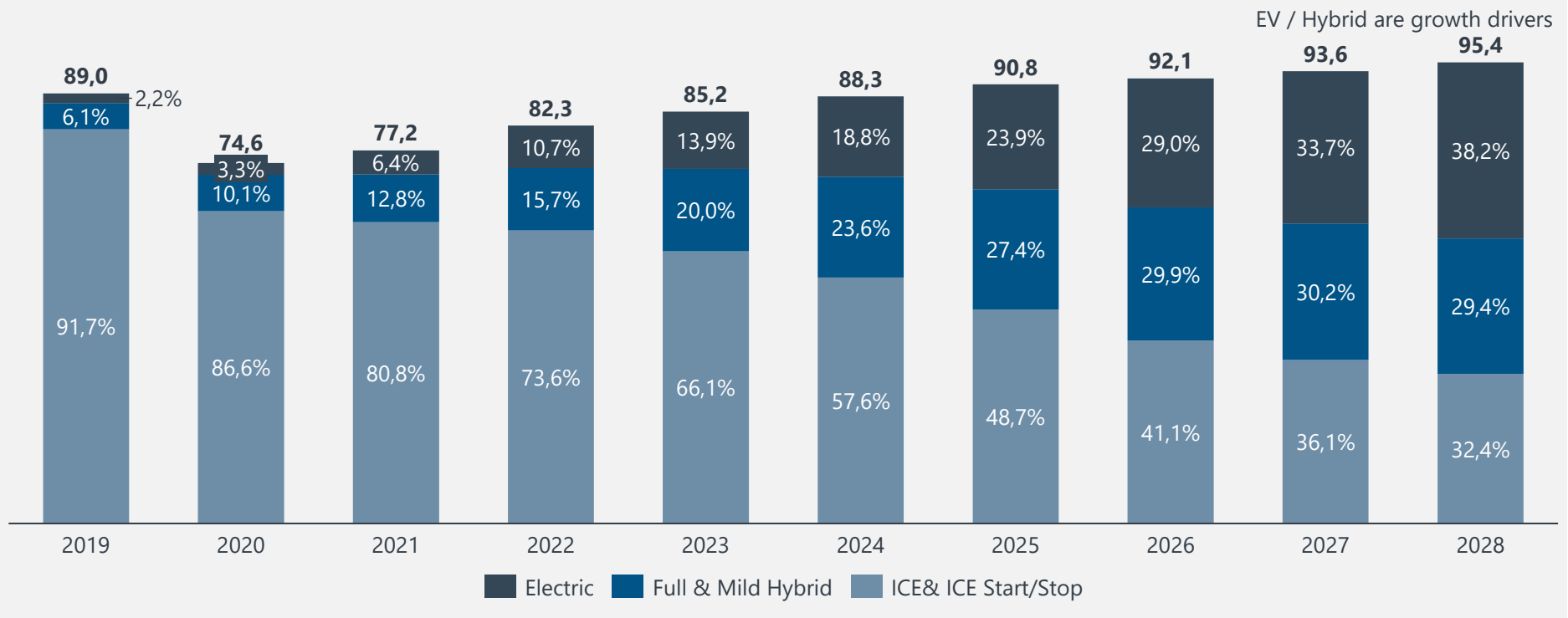
EV and NE

Electrical **V**ehicles
and
New **E**nergy

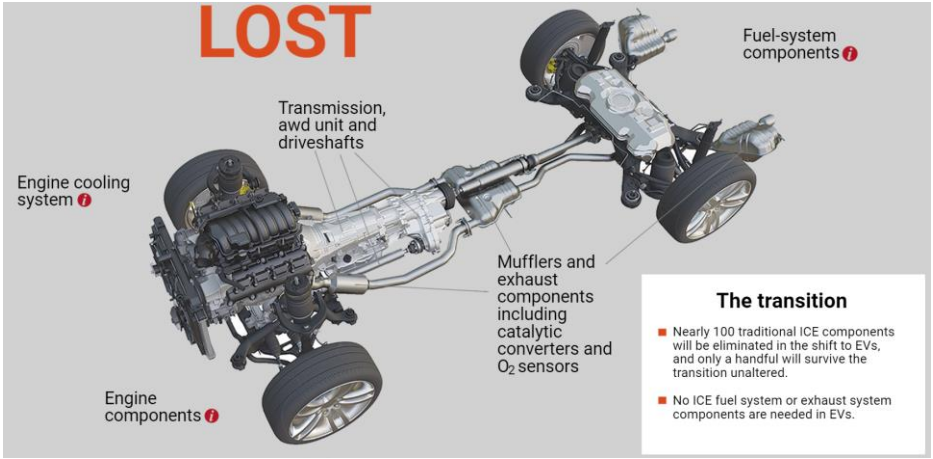
Global automotive market information

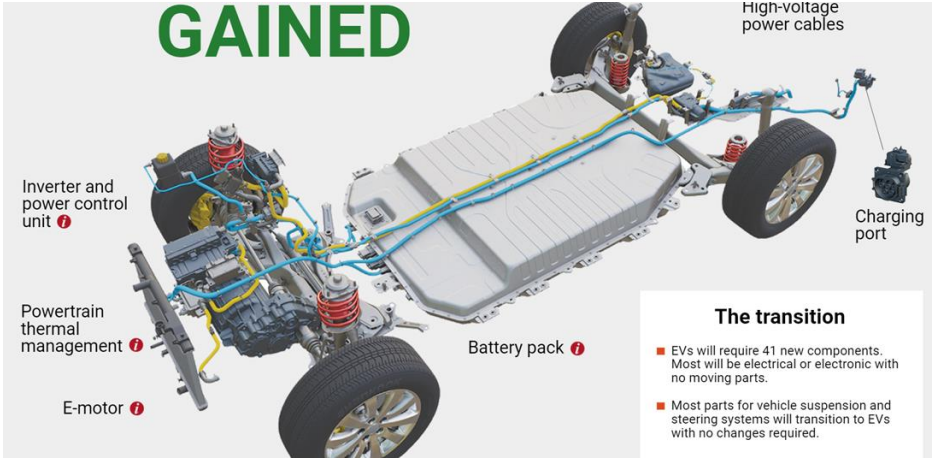
Global automotive production



Source: IHS March 2023

ICE vs. BEV



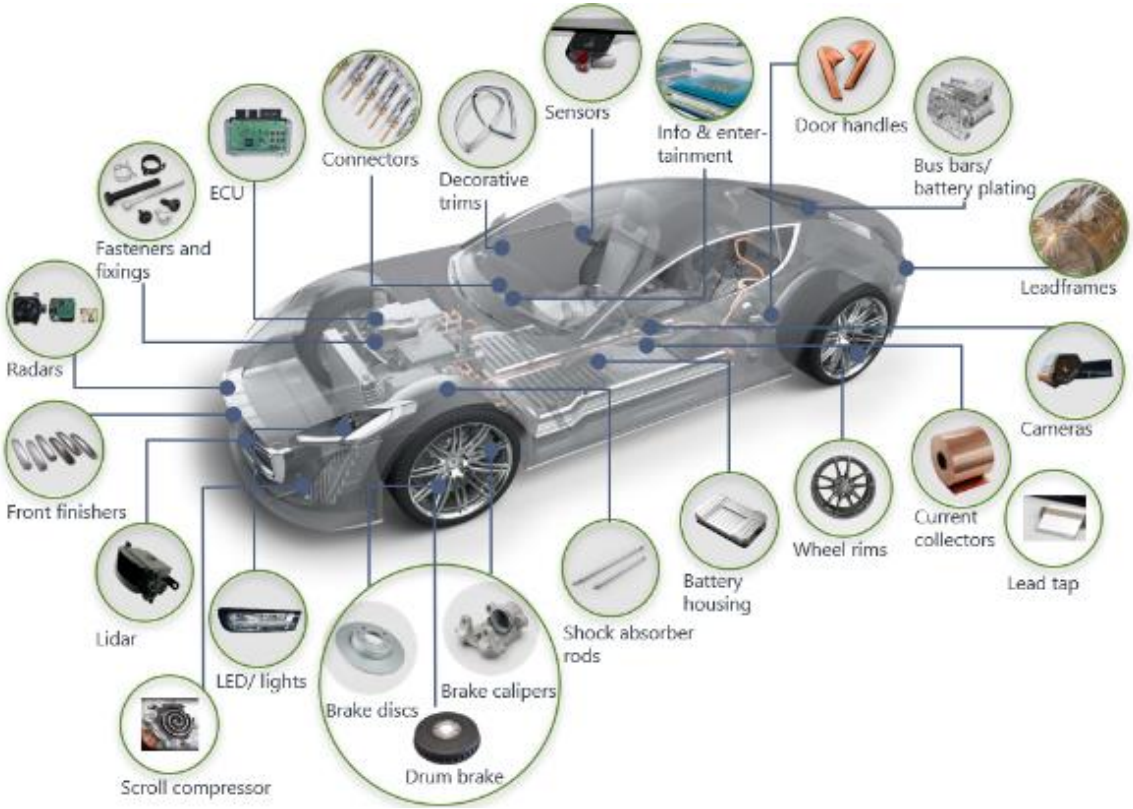


– Engine/parts
– Engine cooling system (front finisher)
– Fuel system
– Exhaust system
– Gear box/transmission

+ Charging
+ Gear box E-drive/recuperation system
+ Battery system
+ Sophisticated thermal management system
+ More electronics

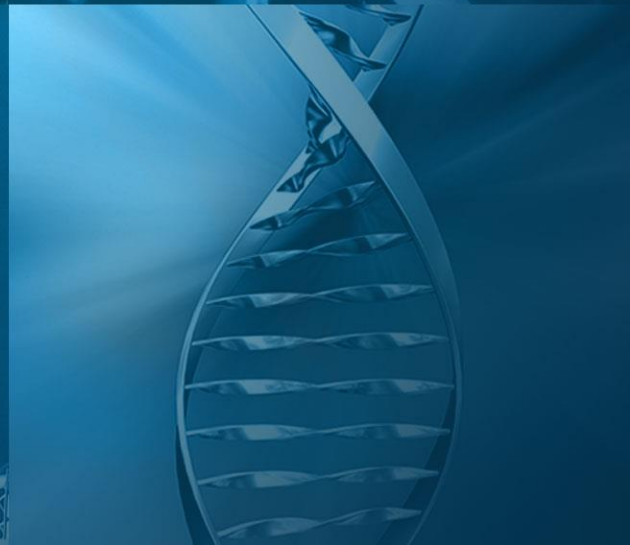
Source: Automotive news, July 2022

Automotive trends
Overview

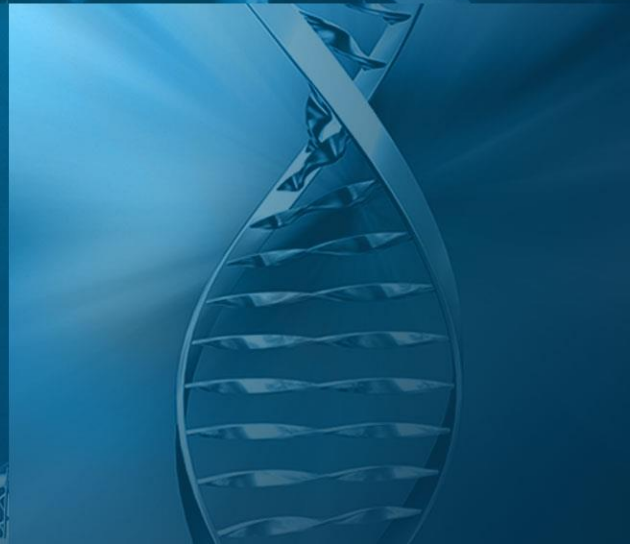


EV and NE

Applications and opportunities



Battery housings



Battery housings

Function:

Outer covers for battery cell modules and packs

Base material:

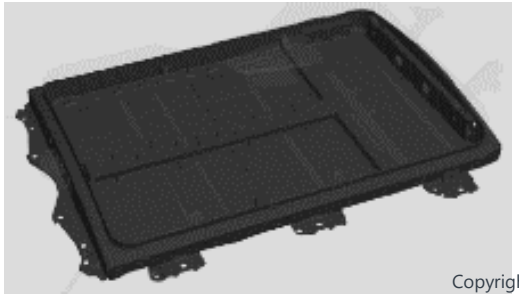
Al, steel, plastic, C-fiber

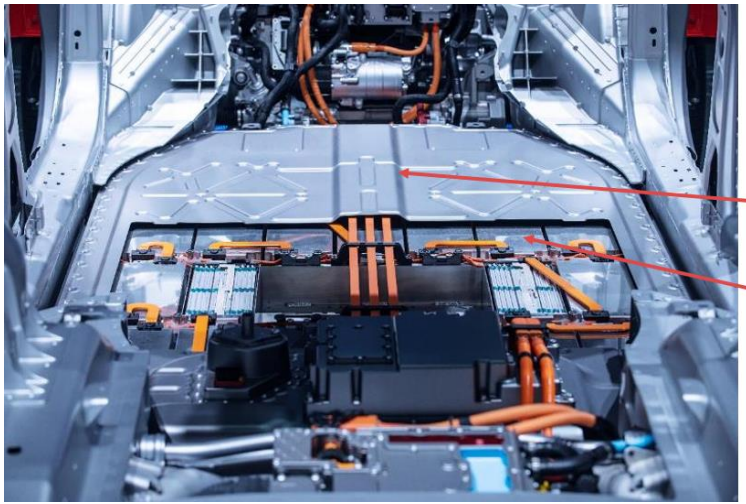
Surface treatment:

- Al: Conversion coating
- Steel: Corrosion protection
- Cleaning, preparation for paint/e-coat

Additional applications:

- Paint removal for reclamation of defective parts
- Paint removal for fixture and rack cleaning

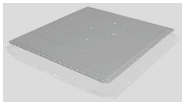


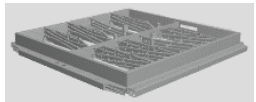


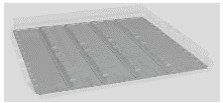
Battery housings
Current EV mass production – Examples

VW ID.3

- AlMg4.5Mn0.4
- AlSi7Mg
- AlMg4.5Mn0.4

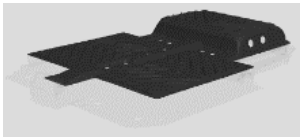


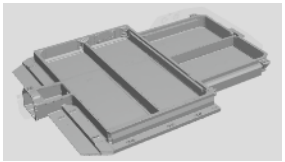




Mercedes EQA 250 AMG

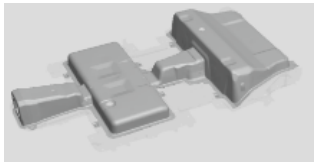
- Steel
- AlMg5Si2Mn

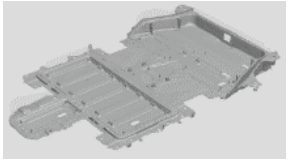




Peugeot 208 e GT

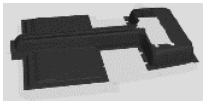
- Steel
- Steel

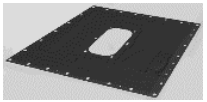


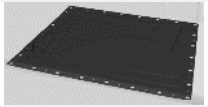


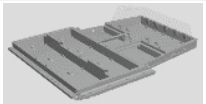
Polestar 2

- Steel; Plastic unknown
- Steel
- Steel
- Nonferrous metal; Steel



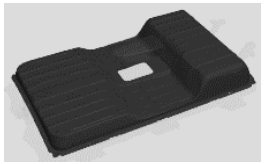


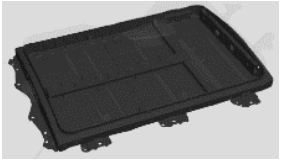




Nissan Leaf Tekna

- Steel
- Steel

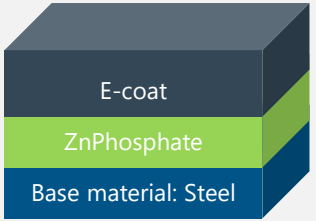




Steel battery housings
Surface treatment technologies

Past trend:

Simple coatings for steel



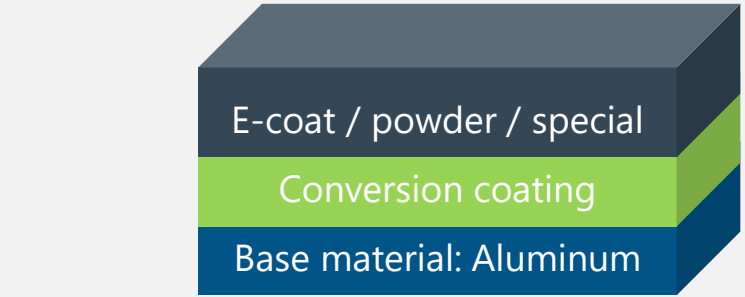
Future trend:

Higher standards, longer vehicle lifetime

- Enhanced corrosion and adhesion characteristics required
- More advanced coating systems are needed

Aluminum battery housings
Surface treatment technologies

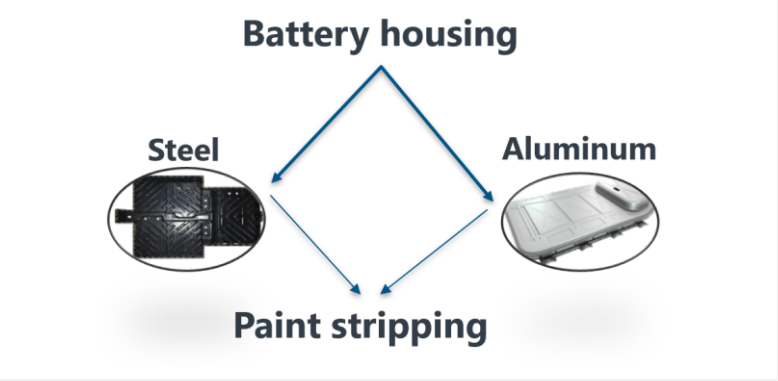
- Trends in the new vehicle design (weight reduction, carbon footprint reduction)
  - Aluminum use
  - Adhesive instead of welds and mechanical fasteners
- Contact/volume/surface resistance is becoming increasingly important in the battery system, specifically for passivated components
- Where is it used: Aluminum closures (doors, hoods, trunks and liftgates), body structure and chassis (underbody, pillars and roof), battery pack
- For enhanced corrosion and adhesion characteristics, a more advanced pretreatment system is needed
- All process steps or a selective selection depending on technical requirements



UniPrep®	Cleaning/degreasing of organic contaminants
	Surface preparation for removal of inorganic contaminants
Interlox®	• Conversion coating • Passivation
	• E-coat/KTL • Coating for fire or dielectric resistance

Additional applications
Paint stripping

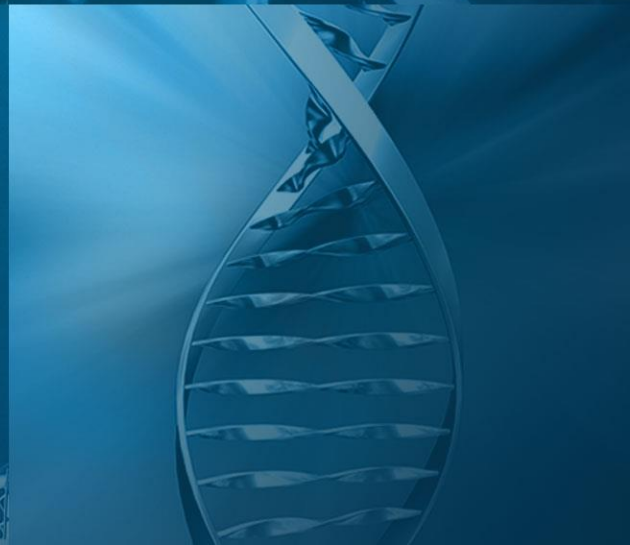
- Two scenarios: part reclamation and rack/fixture cleaning
  - Battery housings are a complex and expensive component; when re-painting is not possible, complete removal of the paint is required
  - Rack cleaning is essential to ensure proper grounding or fixturing of the part
- Incomplete removal of paint from battery housings or racks can increase the risk of producing defective parts
- Conventional processes, such as thermal or mechanical paint removal, are not ideal options in these applications
  - Mechanical methods can damage substrate and leave residues in recessed areas
  - Thermal methods are typically not applicable for aluminum components due to the very high temperatures used (>500 °C) which would severely compromise the structural integrity of the housing



Paint fixture prior to paint removal

Paint fixture after paint removal

Thermal management systems

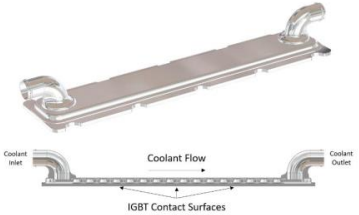


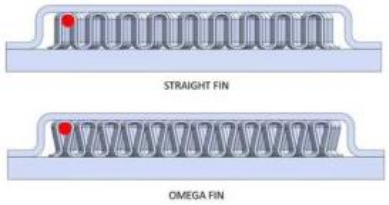
EV – Thermal management systems

IGBT heat sinks, heat spreaders, scroll compressors

Heat sinks and heat spreaders:

- Function: Cooling of electrical devices
- Base material: Cu alloys

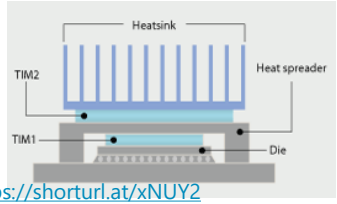




Source: Senior Flexonics

Scroll compressor:

- Function: Heart of EV's climate system, compresses gas from evaporator and relays it to the condenser
- Base material: Al alloys

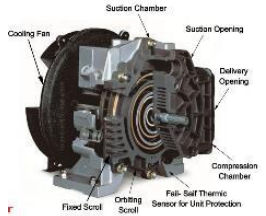


Source: https://shorturl.at/xNUY2

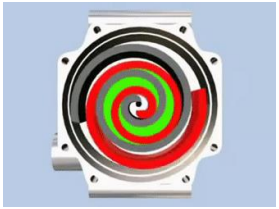
Source: https://shorturl.at/clp08

Surface treatment:

- Pretreatment
- E'less Ni, immersion Sn, anodizing



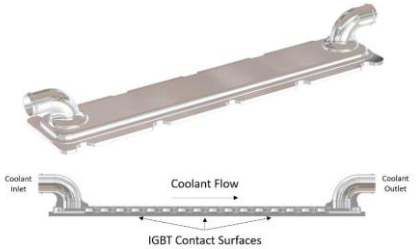
Source: https://railsystem.net/scroll-compressor/



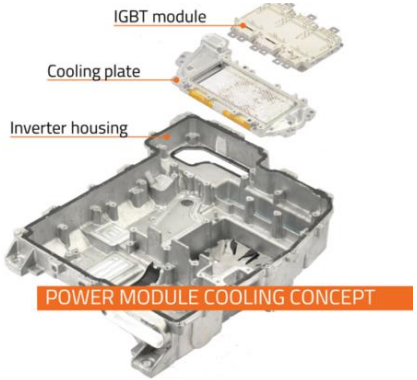
Source: https://gfycat.com/delayedvainannelida

IGBT heat sinks

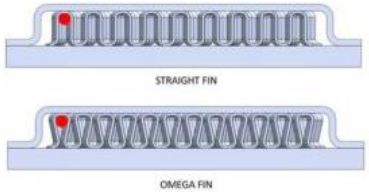
- IGBT inverters transfer power between the motors and batteries and are one of the critical components in an electric vehicle
  - The inverter converts DC to AC when power is required to drive the electric motors and converts in the opposite direction during regenerative braking.
- The main component inside the inverter is the IGBT (**I**nsulated **G**ate **B**ipolar **T**ransistor) which generates a lot of heat.
  - An effective method of cooling the IGBT is through a liquid cooled heat sink



Source: Senior Flexonics



Source: Infenion



The IGBT heat sink is made by brazing together two copper or aluminum plates (cover plate, and fin). Coolant enters through a spigot in the cover plate and then flows across the fin and exits through the spigot on the opposite side. The base plate sits on top of the IGBT to allow for surface contact cooling.

Heat spreaders

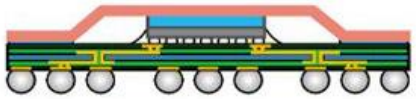
Metal stack

- Mid P Electroless
- Nickel process

- Complete process chemistry

- Nichem® 1120
- Nichem® MP 1188
- ELeVEN® MP 603
- Nichem® HP 1151

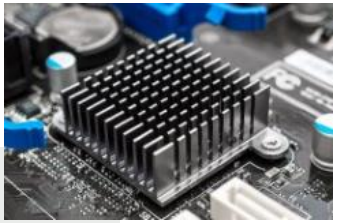
- Uniclean® 154
- Uniclean® 251
- Nichem® Copper Etch
- Nichem® PD
- Nichem® Activator

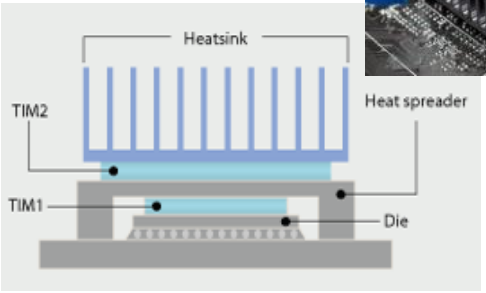


Flip chip BGA with heat spreader

"Heat spreader" is an important component used in IC package for spreading the heat spot to prevent the IC functional failure

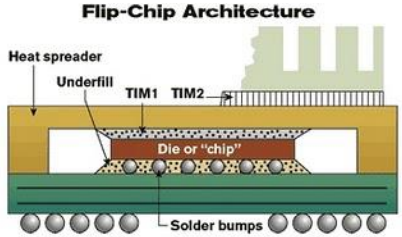
Heat sinks dissipate the heat to the surrounding environment





Heat sinks

- Substrate:
  - Copper
- CPU heat spreader for IC packaging



Advanced cleaning
Sustainable pretreatment process to prepare copper surfaces for plating

NiP is the coating of choice:

- Electroless nickel (3 – 7 µm)
  - Excellent adhesion
  - Good solderability
  - Consistent plating speed
  - Uniform thickness
  - Long bath life
  - Semi-bright and uniform appearance

Sources: https://shorturl.at/xNUY2, https://shorturl.at/clp08, https://shorturl.at/grvzY, https://jaxlifesharing.com/stock2486/

Scroll compressors

Function:

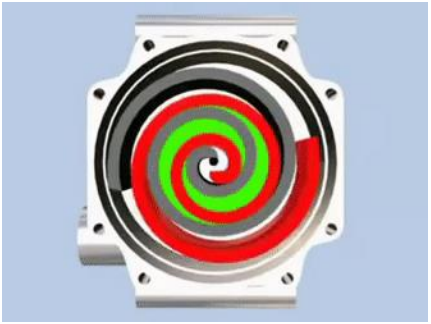
To compress low-pressure and low-temperature gas from the evaporator, converts it into high-pressure gas and relays it to the condenser

Advantages:

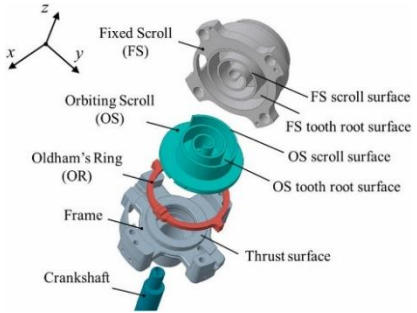
- Reliable (less moving parts)
- Highly efficient
- Quite – Less noise and vibration
- Reduces weight/cost
- Applies to various voltage levels (48 V, 400 V, 800 V)

Uses:

- Automotive superchargers (EV/HEV)
- Refrigeration
- Vacuum pumps



Source: https://gfycat.com/delayedvainannelida



Source:https://www.researchgate.net/figure/Structure-schematic-of-scroll-compressor_fig1_365597813

Scroll compressors – Coating selection

Function of coating:

- Corrosion resistance coating to protect the aluminum substrate surface
- Wear resistance to the aluminum surface during operation
- To ensure tight tolerance between rotating and fix scrolls
- Self lubrication to reduce fretting wear

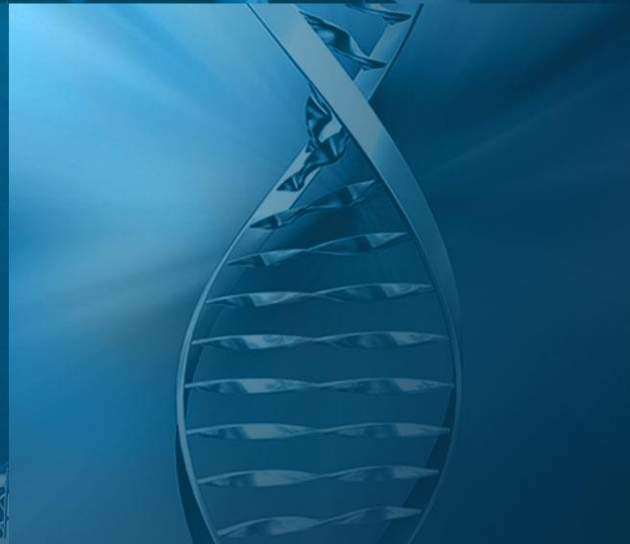
Electroless nickel for rotating scrolls:

- Hard as plated NiP alloy coating – maximum wear resistance
- Uniform deposit thickness over entire surface – no current density distribution effect
- Very high corrosion resistance against aggressive environments
- Low fretting wear

Immersion tin for fixed scrolls:

- Uniform deposit thickness over the whole coating
- Dry lubrication against the opposing surface
- Reduces fretting wear

Fasteners



Fasteners

Function:

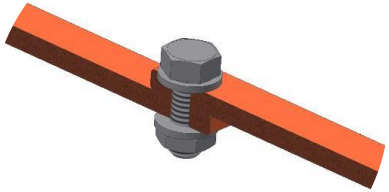
Mechanical connection of various parts and components

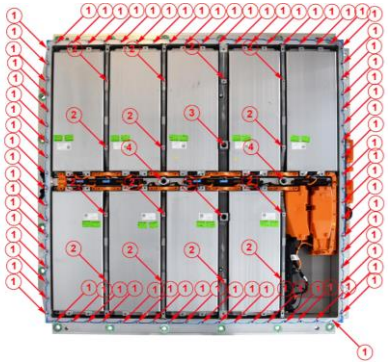
Base material:

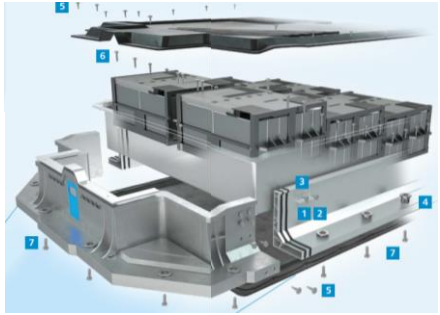
- Steel
- Aluminium

Surface treatment:

- Pretreatment
- Zn, ZnNi, ZnFe, SnZn, ZFC

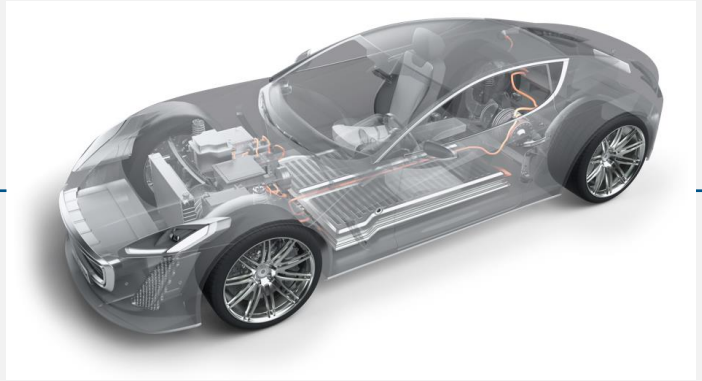






EV Fasteners
Application opportunities

~ 2,500 pcs. fasteners in EVs



Today's fasteners applications

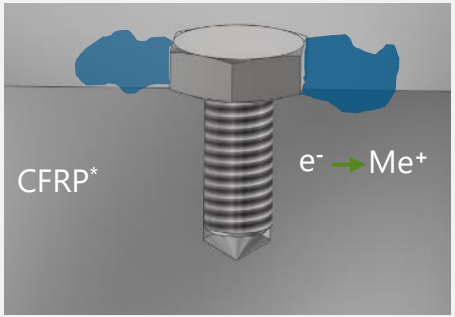
- Zn and ZnNi plated fasteners – Example battery housing applications
- Zinc flake coatings for EVs fastening parts
- CP applications for visible fasteners with specific appearance requirements

Technologies for new applications

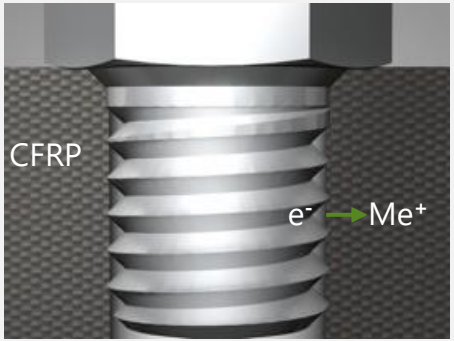
- Conductivity requirements on fasteners
- Extreme technical cleanliness requirements
- Upcoming bi-metallic-corrosion requirements

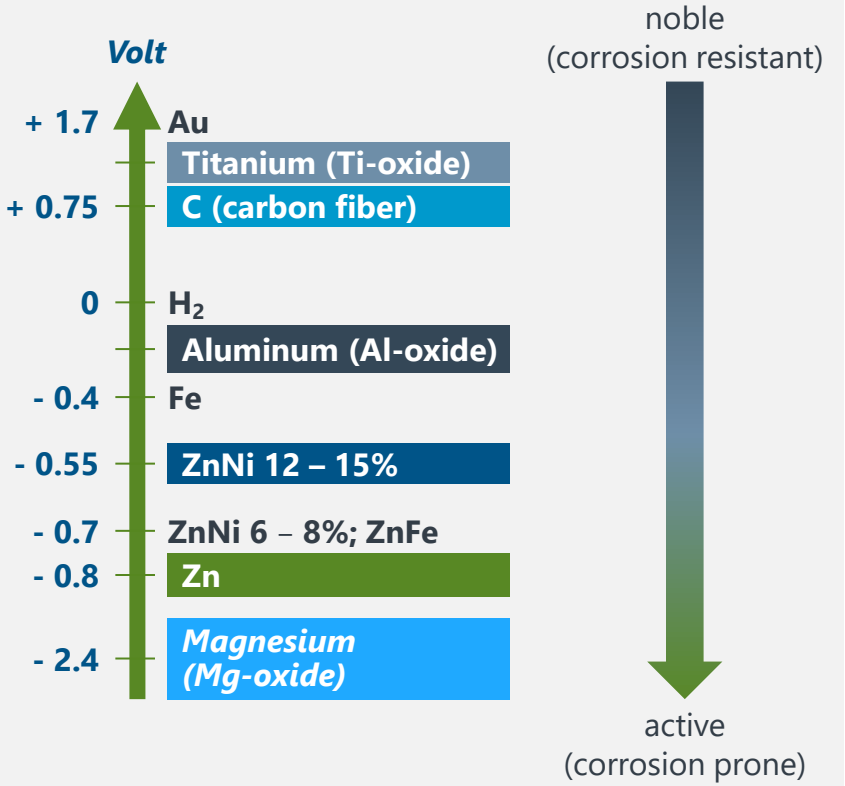
Contact corrosion
Theory

Galvanic contact corrosion is an electrochemical process in which one metal corrodes when it is in electrical contact with another in the presence of an electrolyte



The smaller the potential difference, the lower the corrosion current





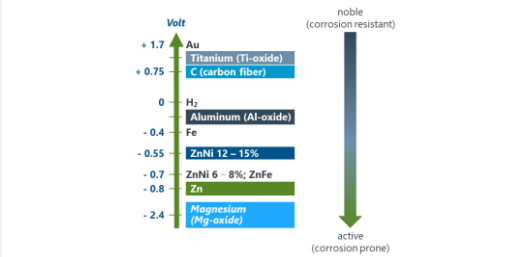
* **c**arbon **f**iber **r**einforced **p**lastic

Contact corrosion
Technical solutions for CFRP

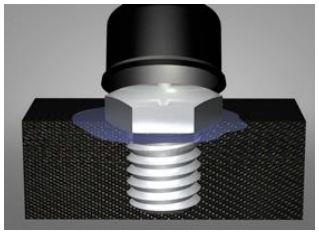
Different measures to avoid contact corrosion:

- Design solutions
- Material of the substrate
- Atotech coatings

Reduction of contact corrosion



Design



Stop electron flow between metallic screw and carbon fibres

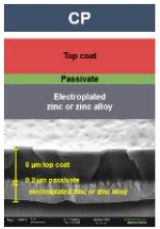
Space requirements

Material

Low potential difference to carbon

Expensive

Coating

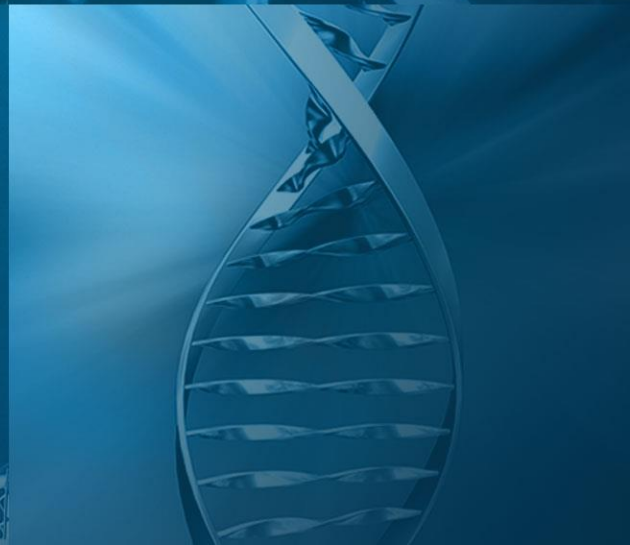


Barrier coating to avoid current flow + potential difference

Under investigation

We offer advanced coating solutions to avoid contact corrosion

Conductive surfaces



EV – Conductive surfaces

Busbars, cables, connectors, lead tabs, battery terminals

Function:

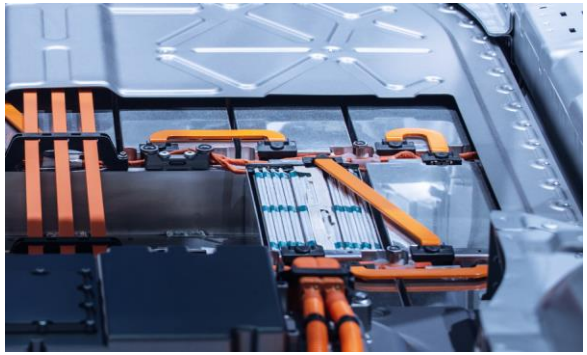
Provide electrical connection between different parts and components

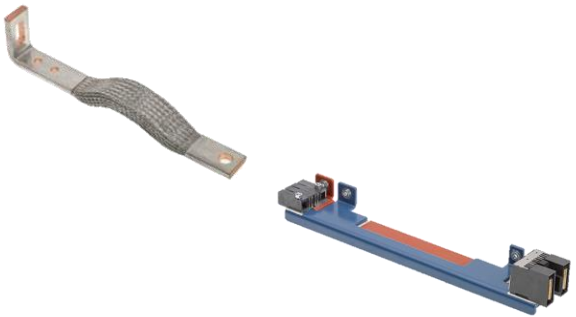
Base material:

- Cu
- Al
- Others

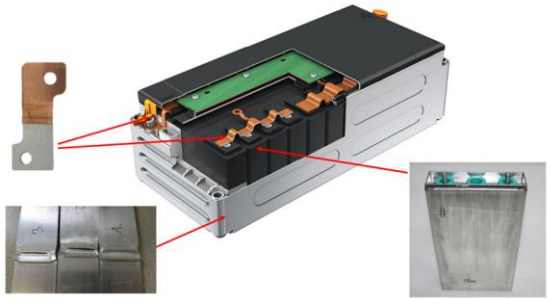
Surface treatment:

- Pretreatment
- FEC, DECO, EN coatings





Source: 987652-0181.pdf (molex.com)



Source: Schnittbild Batterie: Audi-illustrated.com - Bing images

EV – Connectors and busbars

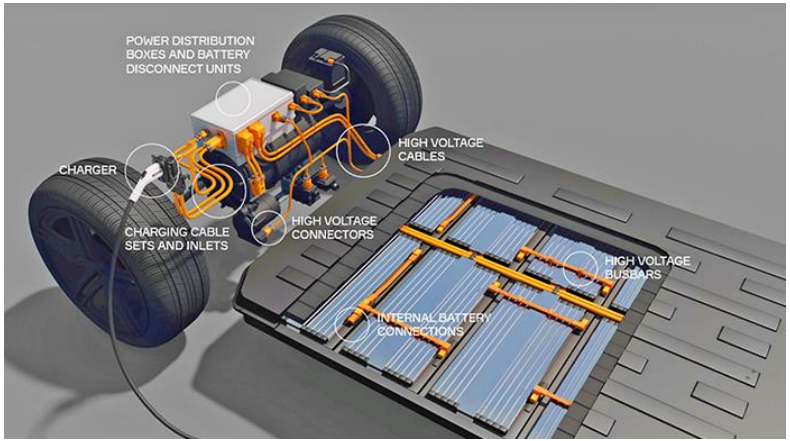
Different base materials and requirements (conductivity, hardness, friction properties, corrosion resistance) → different coatings needed: Ni, Sn, Ag, Au, ...

Various part design → different plating methods: Racks, barrels, reel-to-reel

HV connectors

Battery chargers

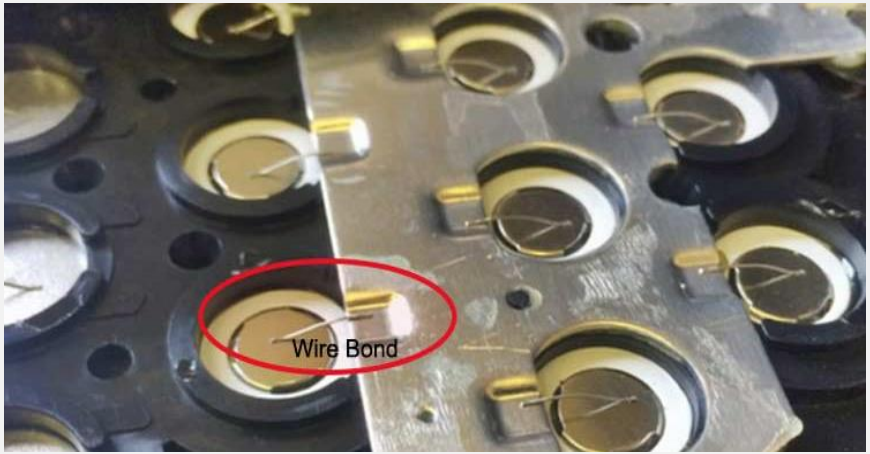
Busbars
cell or module connections



Sources: TE Connectivity, https://iot-automotive.news/aptiv-the-path-to-zero-emissions/, https://www.aptiv.com/en/solutions/vehicle-electrification-systems

EV – Battery terminals

- The number of cells in an EV varies widely based on the cell format. On average, EVs with cylindrical cells have between 5,000 and 9,000 cells
- This is in stark contrast with pouch cells, which only have a few hundred cells, and an even lower number in prismatic cells
- Terminals are made of Cu and plated with either Semi-bright Ni or EN (5 – 8 µm for welding application)



Source https://chargedevs.com/features/a-closer-look-at-wire-bonding/

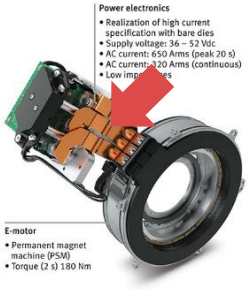
Source: teslamotorsclub.com, https://teslamotorsclub.com/tmc/threads/building-my-own-pseudo-powerwall.154473/

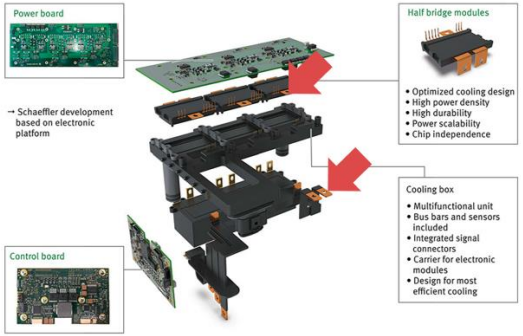
EV – Conductive surfaces

More examples

Source: Nio Battery - Bing images

X-section through a battery charger. Female connector port is a Ag plated Cu alloy for high current density load and multiple connect and disconnect cycles

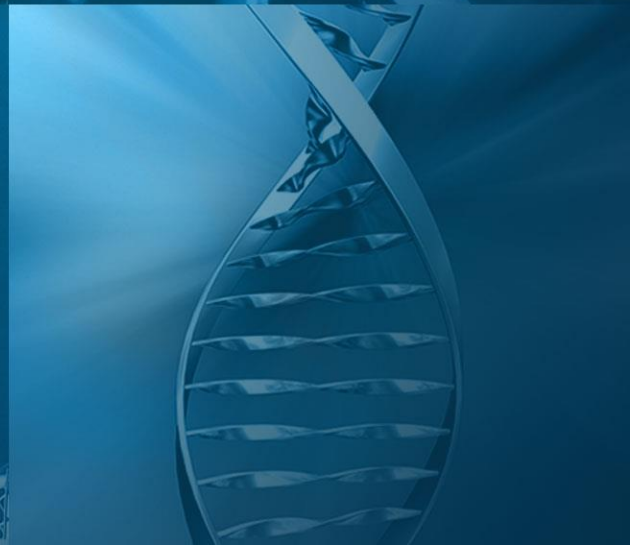




Source Thomas Pfund ; The Schaeffler eDrive Platform, The Schaeffler eDrive platform | Schaeffler Symposium 2018

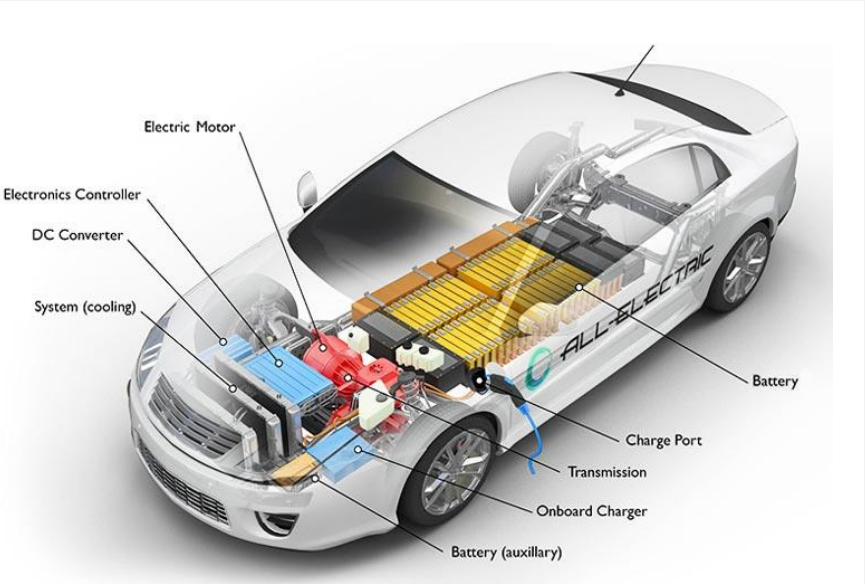
Source: fka - VW ID.3

EMI shielding

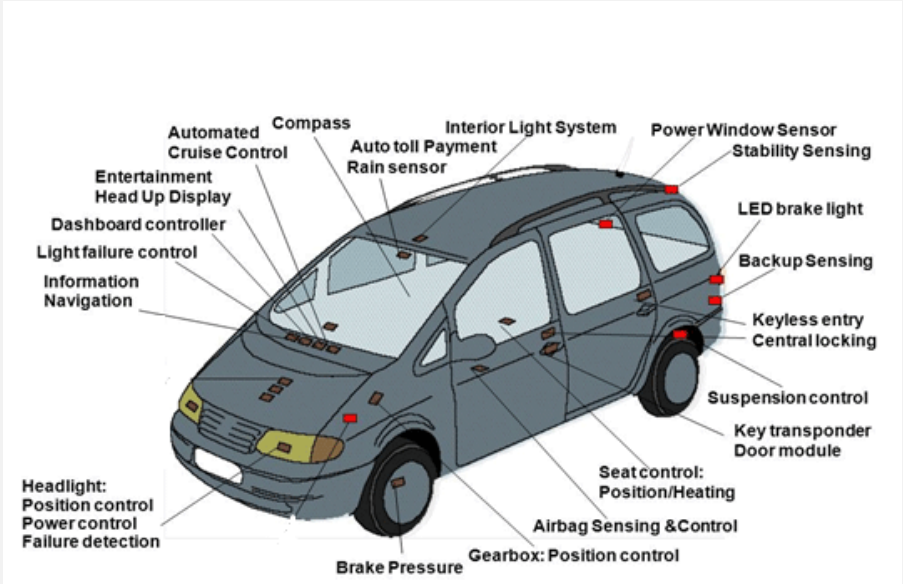


Electromagnetic interference (EMI): Sources and victims

Sources of EMI



Victims of EMI



Source: [circuitdigest]

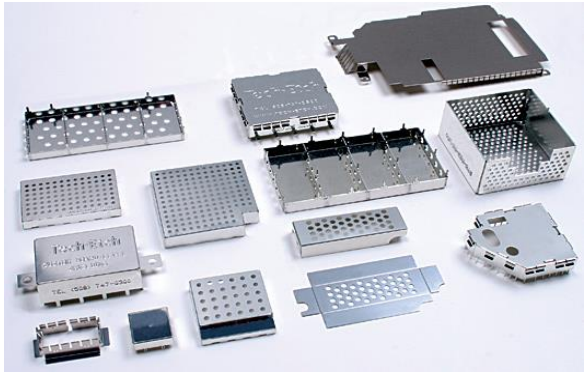
EMI shielding solutions

Known methods:

- Conventional metal cap
- Sputtering
- Spraying a conductive coating
- Electroplating

	Size and weight	Thickness and distri-bution	Side wall coverage	Cost per package	Conduc-tivity	Soft magnetic layer possible?	Sandwich layer
Metal can	Very high	Good	Good, same as on top	Medium	High, almost pure Metal	Yes	Possible
Sputtering	Low	Total thickness limited	Reduced side wall thickness	High	High, almost pure Metal	Yes, but with high tensile stress	Yes, but limited thickness
Spraying	Low	Good	Reduced side wall thickness	Low	Low, metal + organic liquid	No	No
Electro-plating	Low	Good	Good, same as on top	Low	High, pure Metal	Yes	Possible

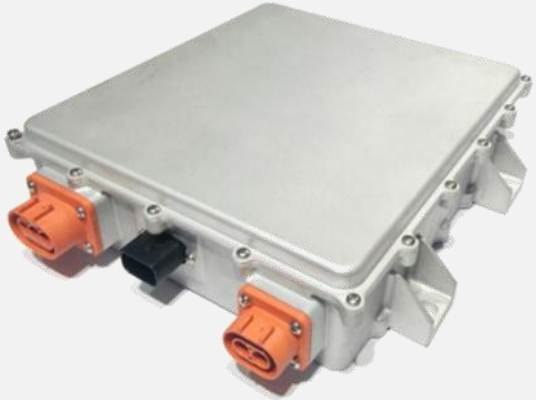
Source: hollandshielding



Source: Tech-etch.com

OEMs are driving weight saving → better travel distance

- Housings of EMI sources comparison



- Steel = 2.7 kg
- Aluminum = 1 kg
- Plastic = 0.4 kg

Example: EV converter 23 dm^2 surface area

- Next step for additional weight saving – Use of engineered plastics
- No shielding as plastic is not conductive
- **Atotech solution: Plating on plastic**

Source: empcasting

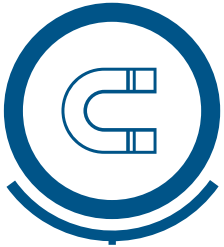
EMI electromagnetic interference

What makes an effective shield?

Low frequency electrical field

High conductive material

\+



Low frequency magnetic field

Thick material – Compared to ‘skin depth’

Electroplating

Adhesion promoter:
Covertron®

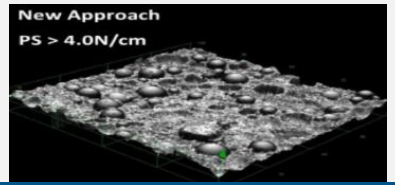
Electrical field
Cupracid®
(Cu)

Magnetic field
Permalloy (NiFe)

“Thick and alternating metal layers” is the sweet spot of electroplating

EMI electromagnetic interference
Milestones

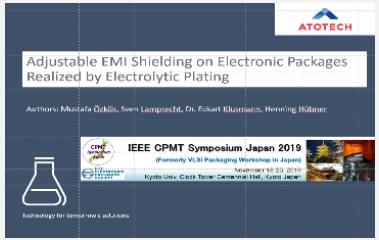
2014

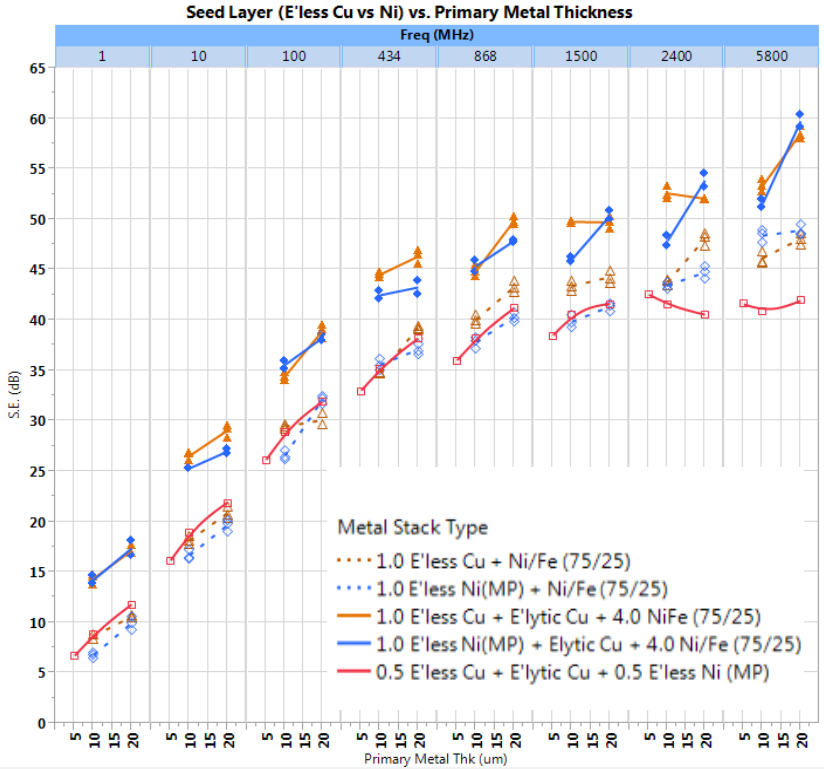


Adhesive enabling technology for directly plating shielding layers on molding resin

2016

2019

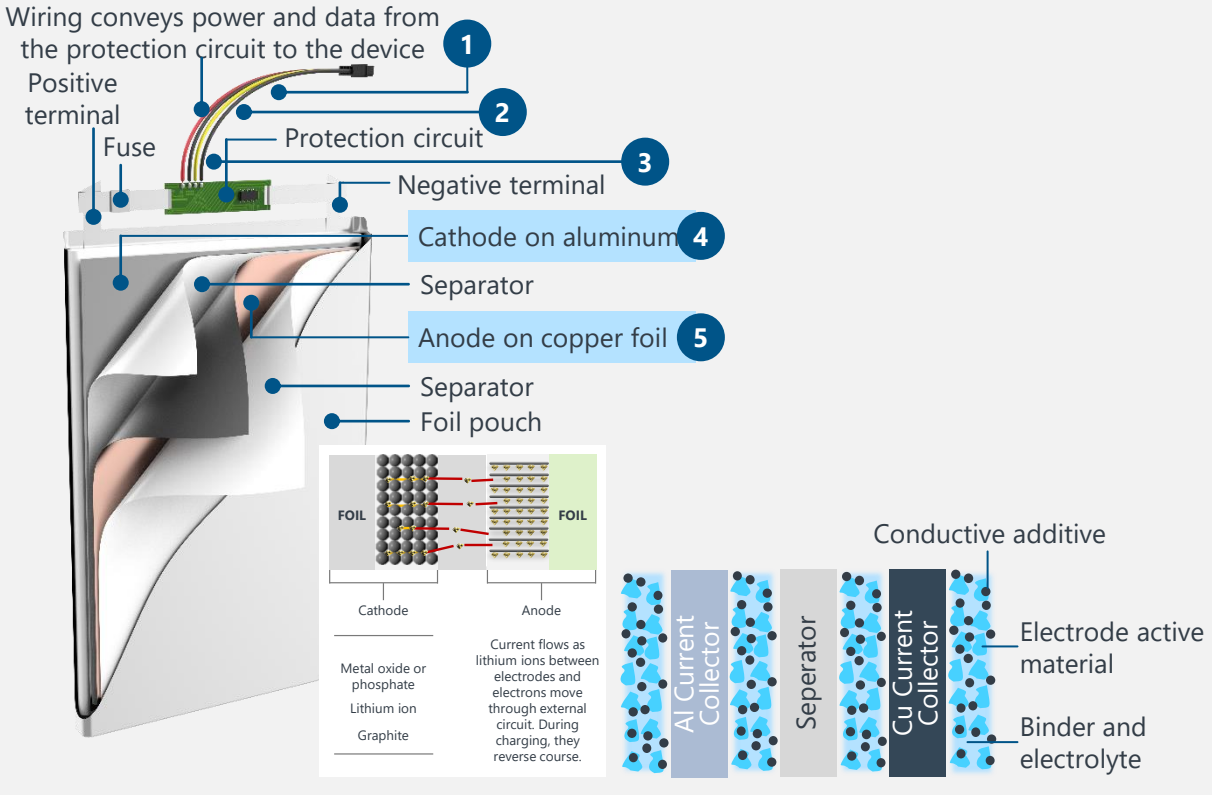




Battery cells

Where you find Atotech solutions in battery cells

Battery cell



1 **Connectors and busbars**	Silver plating, nickel plating, electroless nickel
2 **PCB**	Cu plating, adhesion and final finishes
3 **Anode lead tab**	Corrosion inhibition and Ni plating
4 **Cathode current collector**	Al corrosion and adhesion treatments
5 **Anode current collector**	Cu plating, corrosion and adhesion

Source: https://www.technologyreview.com/2012/06/19/185373/lithium-ion-battery/

EV – Battery foils (current collectors)

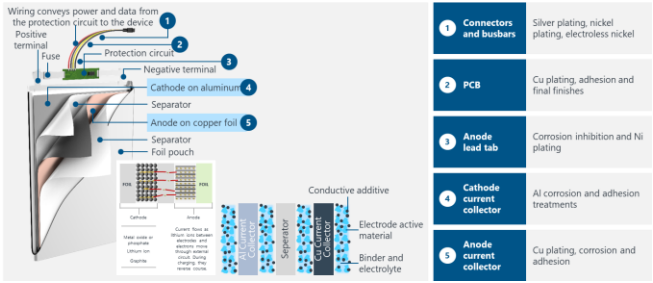
Function:

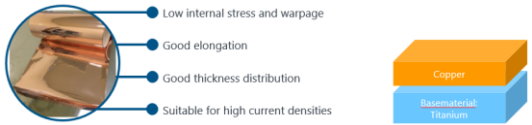
Current collector works as electrical conductor between the electrode and external circuits as well as a support for the coating of the electrode materials

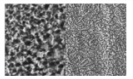
Surface treatment needed:

- Cu, Al corrosion and adhesion treatment
- Ni plating
- Cu plating

- New gen. batteries:
  Ni, Ag, Sn plating

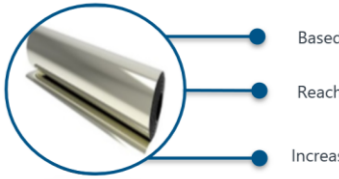




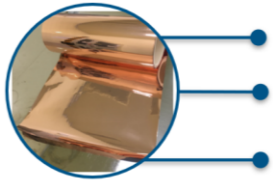
	Adhesion Promotion	Cu Plating	Corrosion Protection
			
Module part	• Current Collectors (AL) • Current Collectors (Cu)	• Current Collectors (Cu) • PET foils	• Current Collectors (Al) • Current Collectors (Cu) • Neg. Lead Tab • Foil pouch
Purpose	• Adhesion Improvement of current collector to active materials/binders • For new active materials with increased expansion	• High perfomance Cu Plating Electrolytes • High speed, low stress and pin hole free	• Cr(VI) free anti-tarnish layer • Improved corrosion protection for hydrofluoric acid (HF) with passivation layer
Process	• Adhesion Promotors	• High Speed Copper • Low stress copper	• Corrosion Inhibitors • Conversion Coatings

Surface treatment technologies

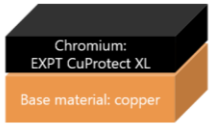
Al and Cu foil treatment



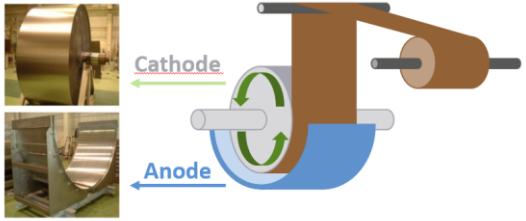
- Based on Zirconium technology
- Reach/RoHS conform
- Increases corrosion resistance on Al



- Effective Cu protection
- Reach/RoHS conform
- Perfect 1:1 substitute for Cr (VI) processes

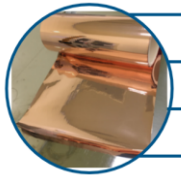


Cu electroplating

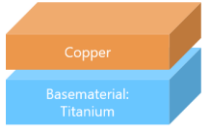


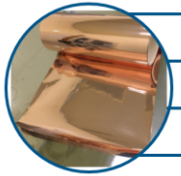
Differences to "standard":

- Higher current densities
  - 50 ASD vs 3 – 5 ASD
- Higher temperature
  - 50°C vs 35°C
- Shorter plating time
  - 60s vs 45 min
  - And more...

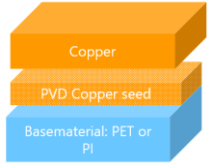


- Low internal stress and warpage
- Good elongation
- Good thickness distribution
- Suitable for high current densities

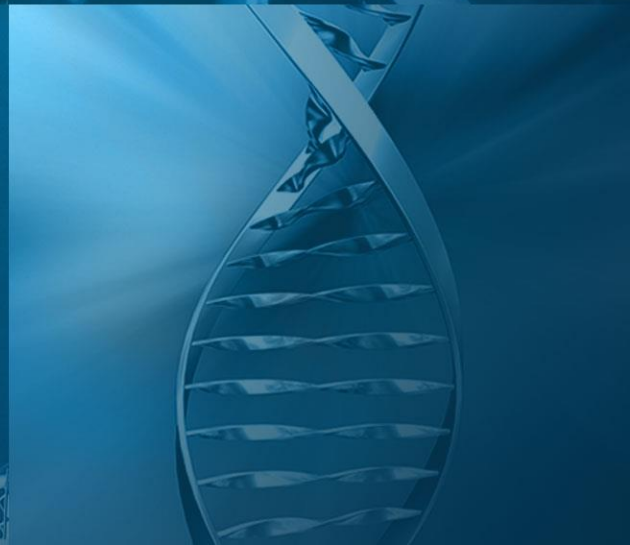




- Low internal stress and warpage
- Good elongation
- Good thickness distribution
- Suitable for low to mid current densities



Other applications



EV – Much more

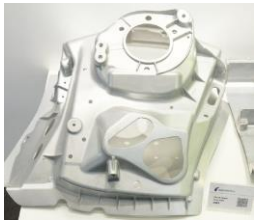
Charging stations, Al applications, braking systems

Charging stations:

Complex units:
Various surface treatment

Al body parts:

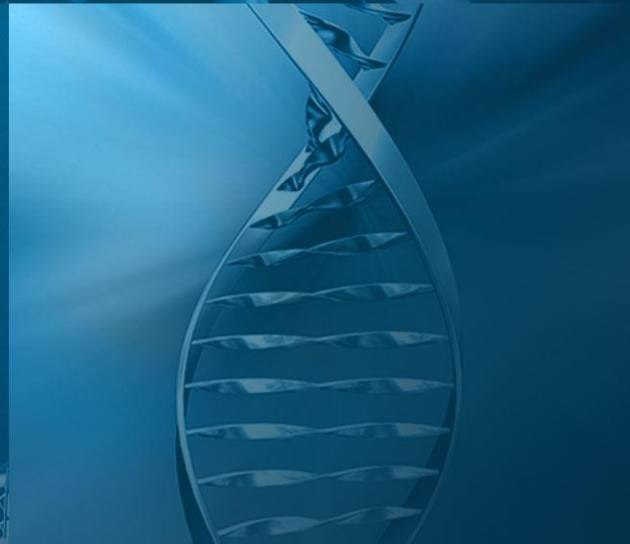
- Al treatment
- Paint pretreatment
- Paint stripping



Braking systems:

- Corrosion protection
- Paint pretreatment
- Paint stripping

New energy – Hydrogen



NE – Hydrogen

Electrolysers, fuel cells, H2 infrastructure

Function:

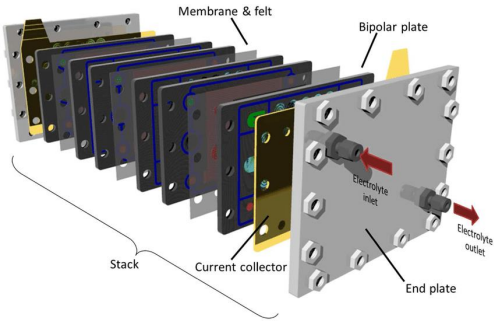
- **Electrolysers** split water molecule into hydrogen and oxygen using electric energy
- **Fuel cells** produce electricity by combining hydrogen and oxygen atoms

Base material:

- Steel
- Ti
- Others

Surface treatment:

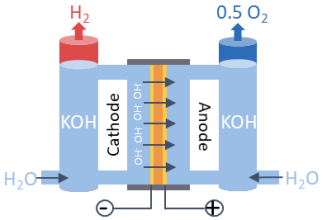
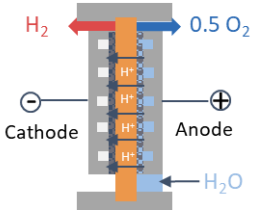
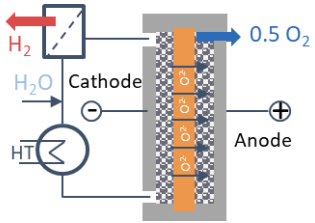
- AEL: EN, eNi coatings
- PEM: Precious metal coatings



Source: https://shorturl.at/otU03

Source: https://shorturl.at/sCEO1

Electrolyser

	AEL	PEM	SOEC
			
Electrolyte and charge carrier	• Liquid electrolyte • Alkaline • KOH/OH-	• Polymer membrane electrolyte • Acidic • H^+	• Solid electrolyte • Ceramic oxide • O^{2-}
Electrode and bipolar-plate	• Raney nickel • Stainless steel / EN or Ni • Cast iron / EN or Ni	• Precious metals (Platinum/Iridium) • New concepts like Pt/Ni alloy	• Ni-Cermet, perovskite
Atotech solution	• ELeVEN® LP 350 (Low P EN) • Nichem® MP 1188 (Mid P EN) • Ni/Fe	• Nichem® HP 1170 (high P EN) • Platinor®	• Atotech is looking for opportunities in this field to develop suitable processes

Atotech metallisation processes to increase efficiency and long term stability

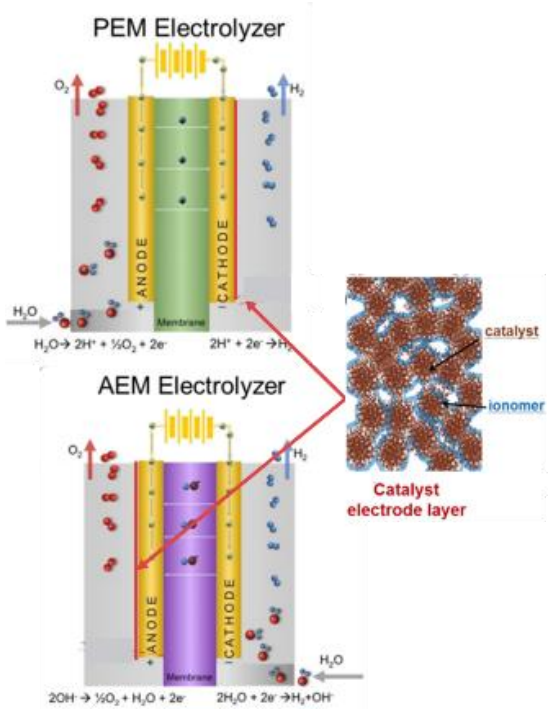
Source: Fraunhofer Institute

Electrolyser

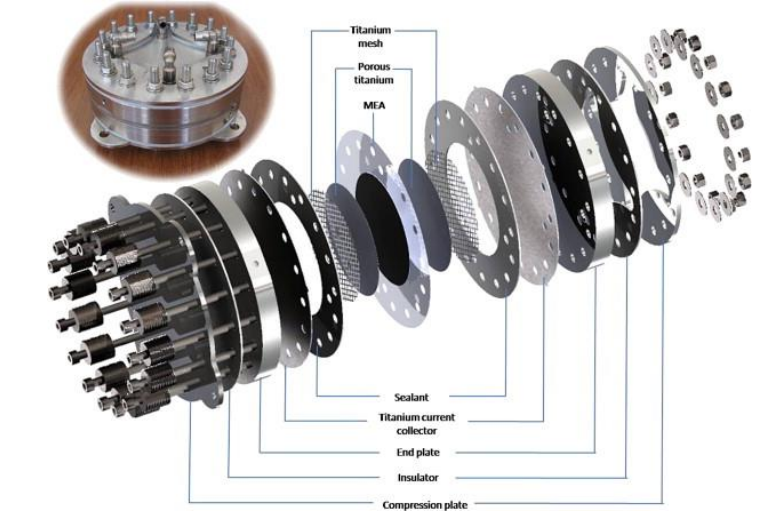
Hydrogen electrolyzer

Source: https://shorturl.at/wAMZ3

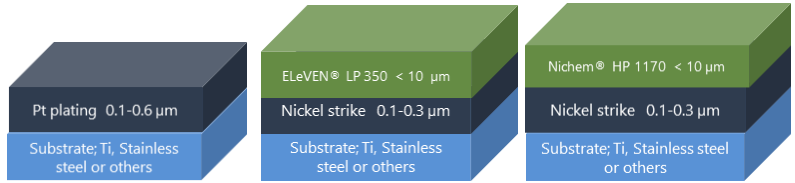
Source: https://shorturl.at/hpNV6



Source: https://shorturl.at/qPUZ1



Source: Academic Library

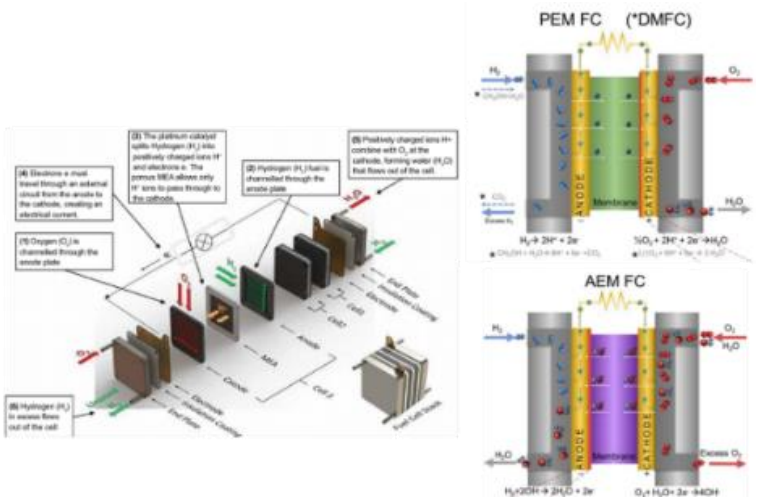


Hydrogen fuel cell

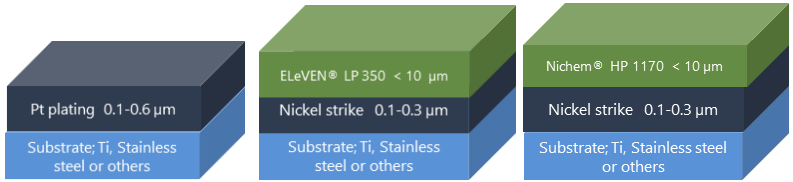
Source: https://shorturl.at/izEO2

Source: ZF and Freudenberg

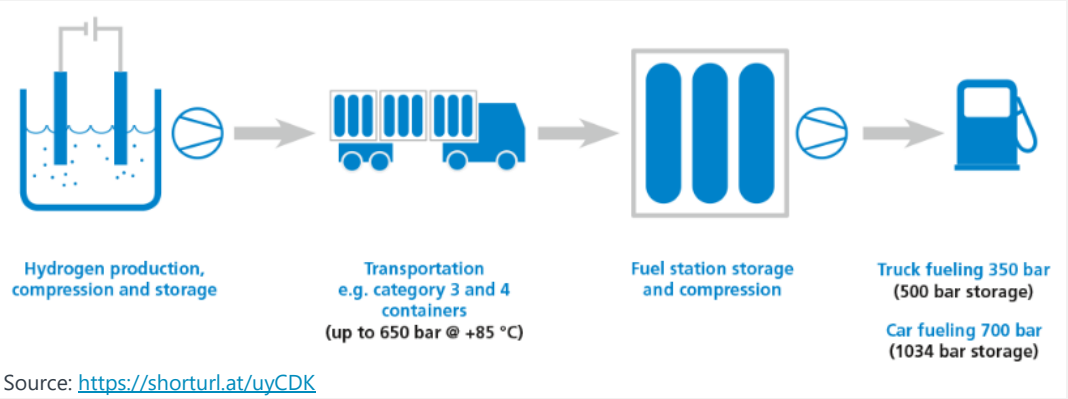
Source: https://shorturl.at/xNO12



Source: https://www.mdpi.com/1099-4300/24/7/1009



Storage and transport



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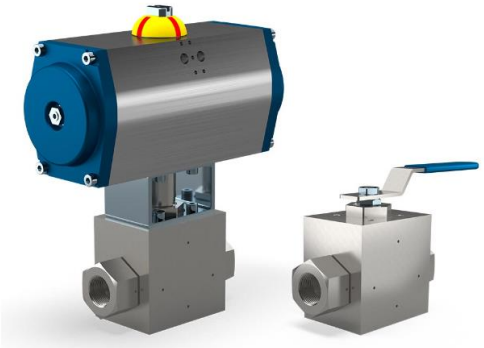
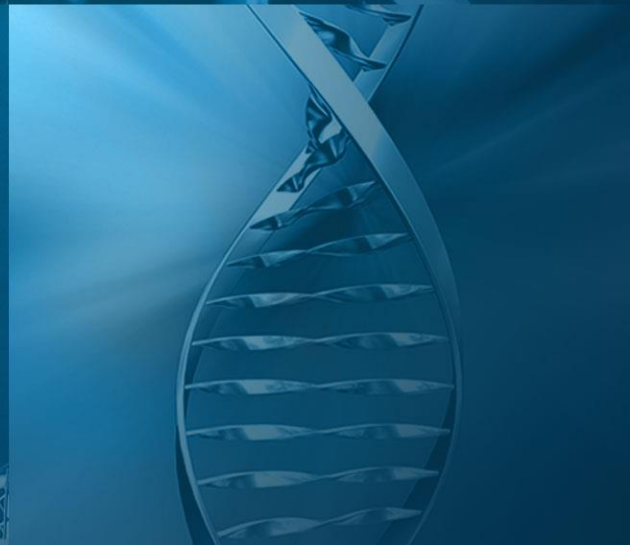


Source: https://shorturl.at/cpuBM

Source: https://shorturl.at/xCJ14

New Energy: Solar cells



NE – Solar cells

Function:

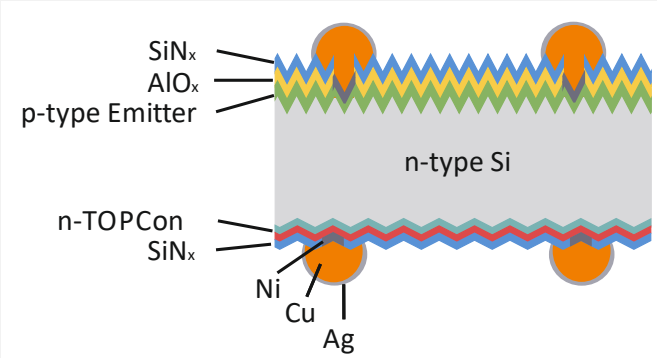
Convert sunlight into electricity

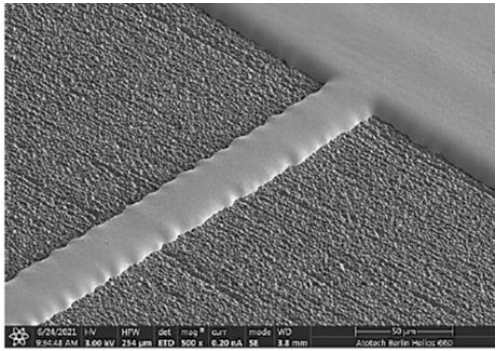
Base material:

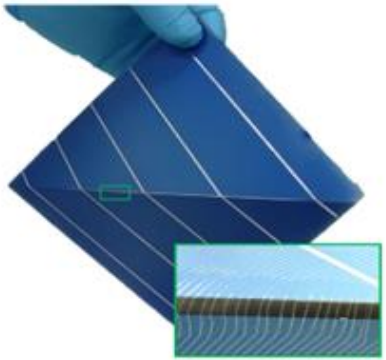
- Si wafer
- Sputtered metal layer

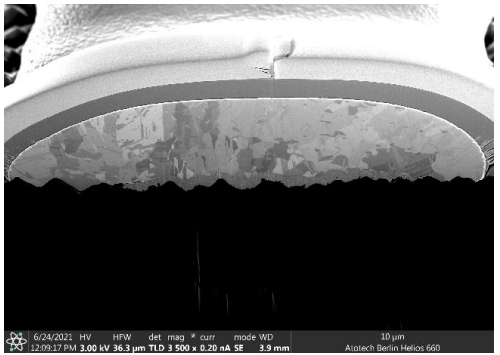
Surface treatment:

- Pretreatment
- Cu, Ni, Sn, Ag plating









Power solutions – Photovoltatics

Need for alternatives to Ag screen print

15 USD/oz → Silver price development Q2 2019 until today → 23 USD/oz

Source: Kitco

+ 53 %

2000 → 2021 → ....

1 % → 12 % → ...

Share of global available silver volume for the solar industry

Source: metals focus

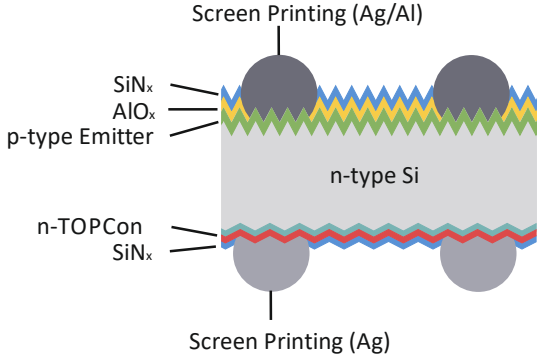
Silver paste consumption

PERC	TOPCon + 50%	HTJ + 200%
Today's technology	Predicted to gain up to 60% market share until 2030	High performance

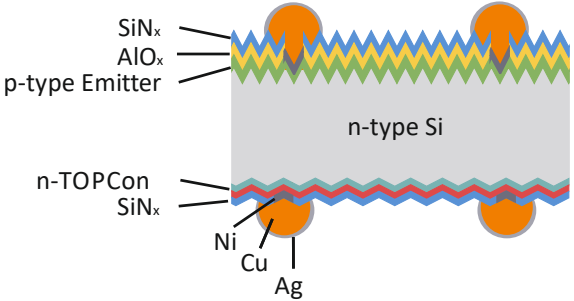
Metallization technologies
PERC, TopCON, IBC, HJT

- PERC – Classical metallization technology based on Ag paste screen printing
- TopCON, IBC, HJT – Advanced technologies, involving plating metallization
- Plating key benefits
  - Higher cell efficiency
  - Better contact and line resistance
  - Narrower finger width
  - Ductile and low stressed metallization
  - Savings/elimination of critical resources - Ag

Classical Ag screen print metallization



Atotech Ni/Cu/Ag plated metallization



Thank you!

Atotech GMF Seminar Poland 2023
September 19 - 21, 2023
Janów Podlaski Castle, Poland