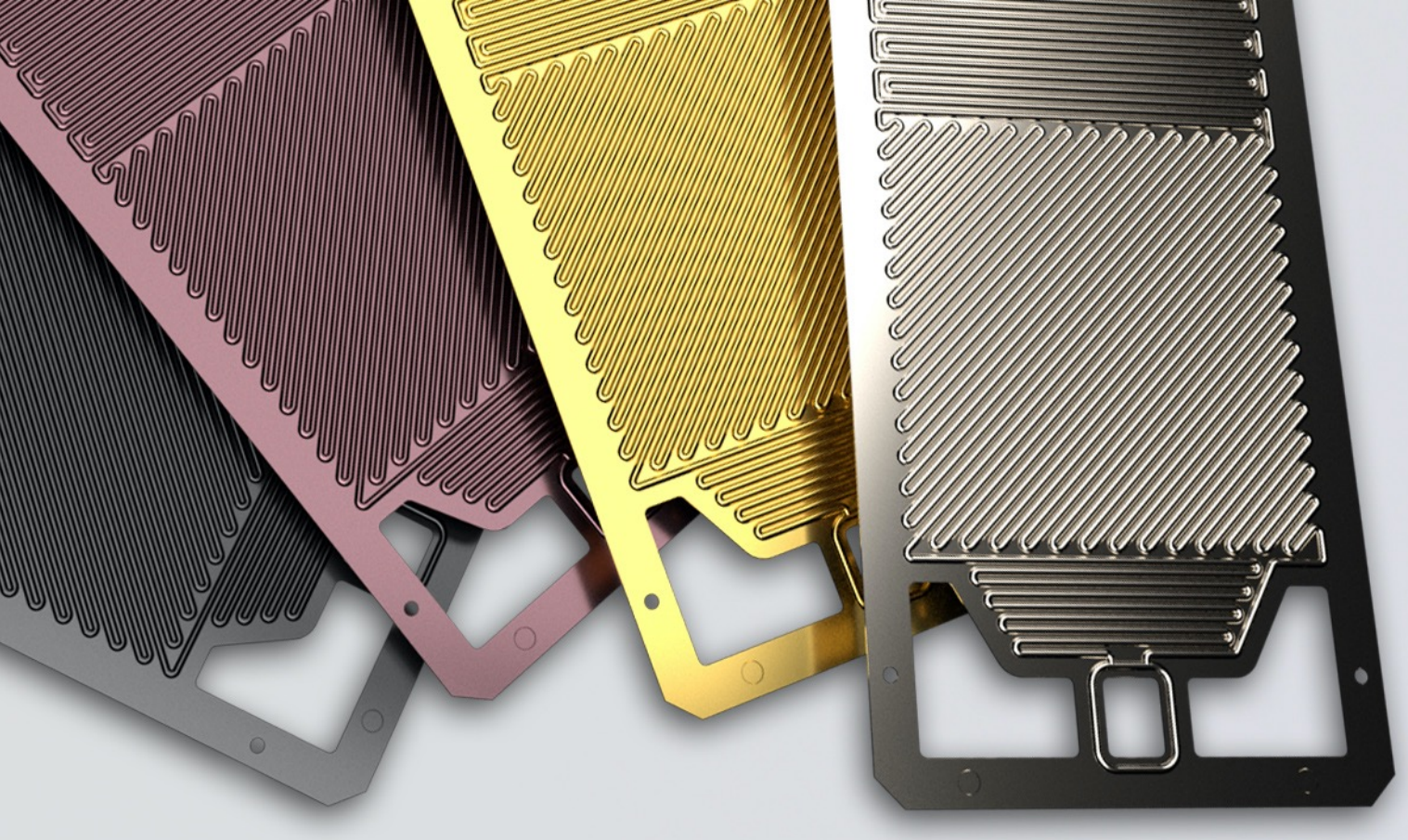


PVD Coatings for Fuel Cells and Electrolyzers

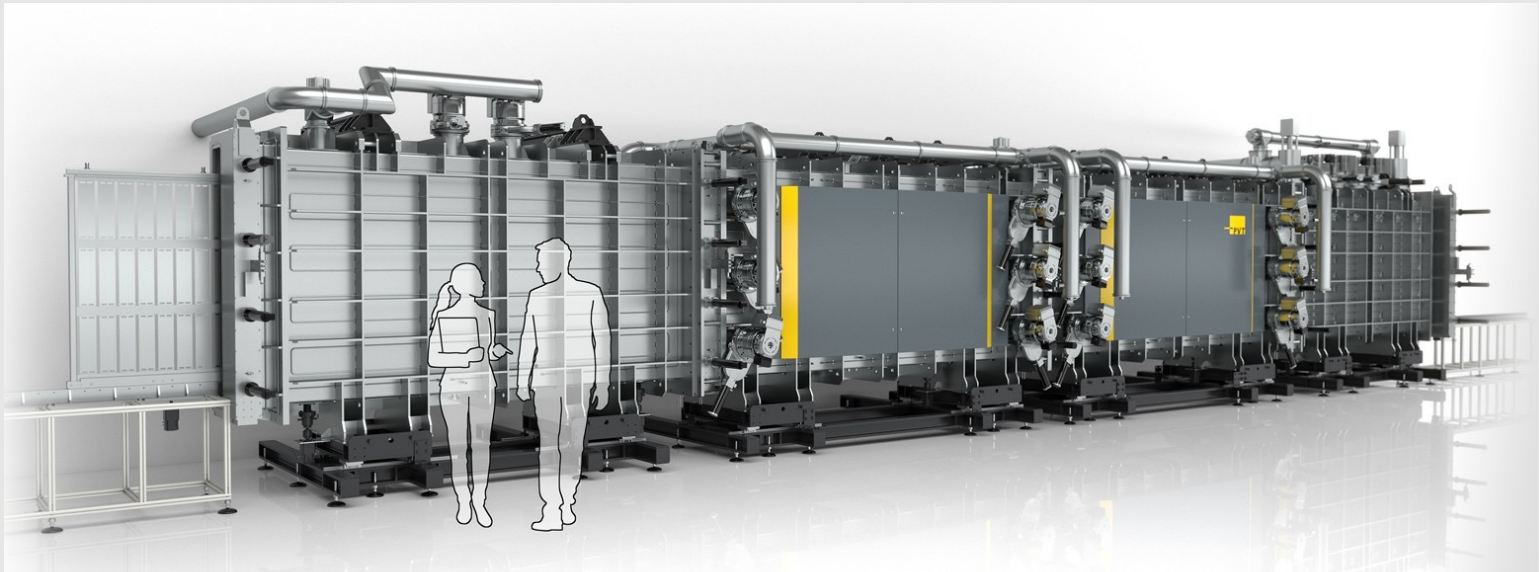
by PVT Plasma und Vakuum Technik

PVT | People with Vision and Technology

- Headquarter in Bensheim, Germany
- 35 years experience in wear resistance and tribological coatings by PVD (Arc evaporation, Magnetron sputtering, HiPIMS) and PECVD
- R&D of coating processes
- Turn-key solutions and manufacturer of vacuum coating systems
- Job coating services

PVT | Coating systems for BiPs

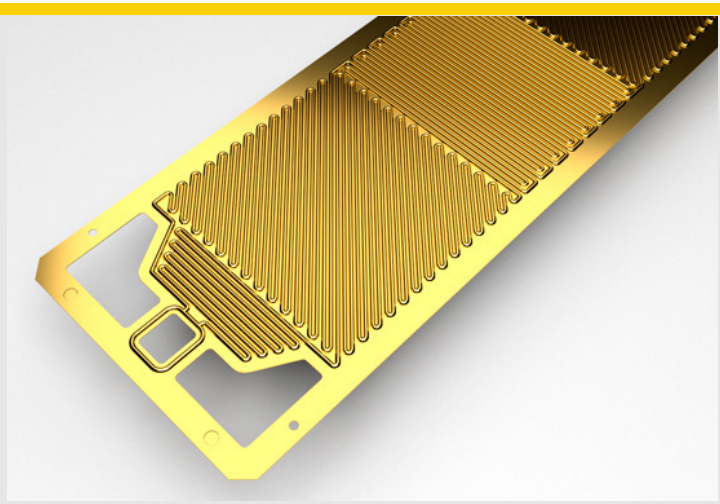
- In-Line coating systems
- Coating of BiPs for fuel cells or eletrolyzers
- Throughput up to 5.000.000 bipolar plates (500 mm x 150 mm) per year, cost per plate < 1 €
- Maximum dimensions up to 3.5 x 1.5 m

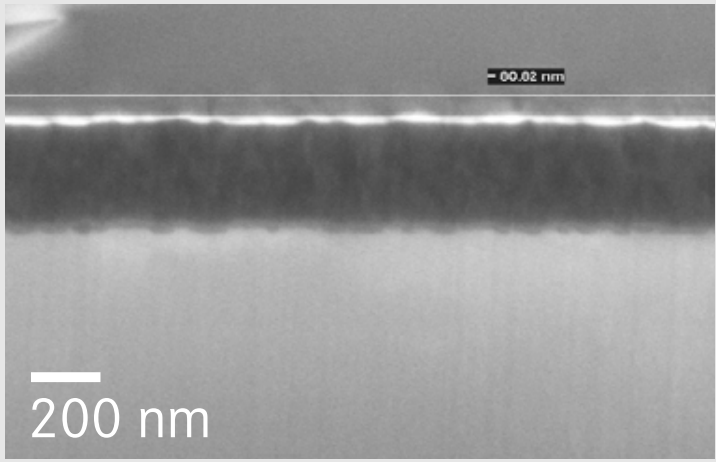


PVT | Nano-Oxide based coatings for BiPs

Low resistance Nano-Ox multilayer for BiPS

- 4-fold multilayer coating with cathodic corrosion protection
- Protection against hydrogen permeation; no embrittlement
- Coating optimized according to the rules of electrochemical and chemical reaction basis
- Significant security above the DOE rules in order to meet also irregular stack conditions
- tested under real conditions and extreme laboratory conditions with cold start, starvation and idle conditions





Nano-Ox based partner:
evm repenning

Energy Value Management Repenning

PVT | Nano-Oxide based coatings for BiPs

Contact resistance evolution under harsh oxygen conditions in comparison to different materials

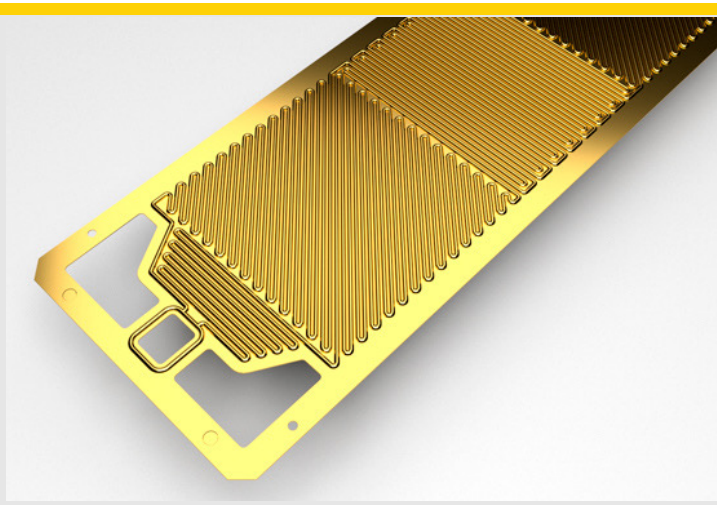
fuel cell operation: start-stop cycling, 0,5A/cm²; 70°C;
O2/H2 test, testing time: 1650h
conditions contact resistance: BiP between 2 Toray GDL;
200N/cm² contact pressure, test surface 10 cm²

	BOT [mΩ·cm²]	EOT [mΩ·cm²]
graphite coated cathode	0,8	11
graphite coated anode	2,2	7
gold cathode	0,8	2
gold anode	1,9	6
nano-Ox cathode	**0,8**	**1,2**
nano-Ox anode	**0,8**	**1,1**

Contact resistance evolution of 4 different BiPs of a 30 kW stack

2000h test under extreme conditions with cold start, starvation and idle conditions

	BOT [mΩ·cm²]	EOT [mΩ·cm²]
1st plate	7	6
2nd plate	4,2	4,7
3rd plate	3,8	4,1
4th plate	5,9	5,2

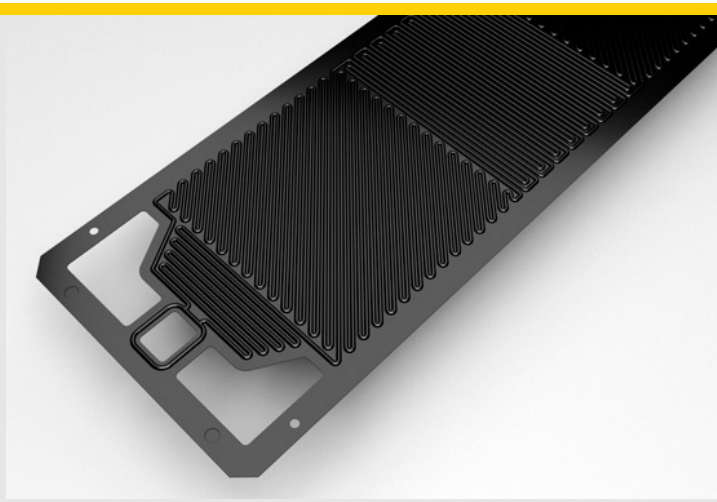


Nano-Ox based partner:
evm repenning

Energy Value Management Repenning

PVT | DLC based coatings for BiPs

- Coatings improve electrical conductivity and corrosion resistance
- Optimized carbon coatings to enhance durability under automotive operating conditions (0.6V) and withstand high voltage peaks that might occur during transitories (1.4 V)



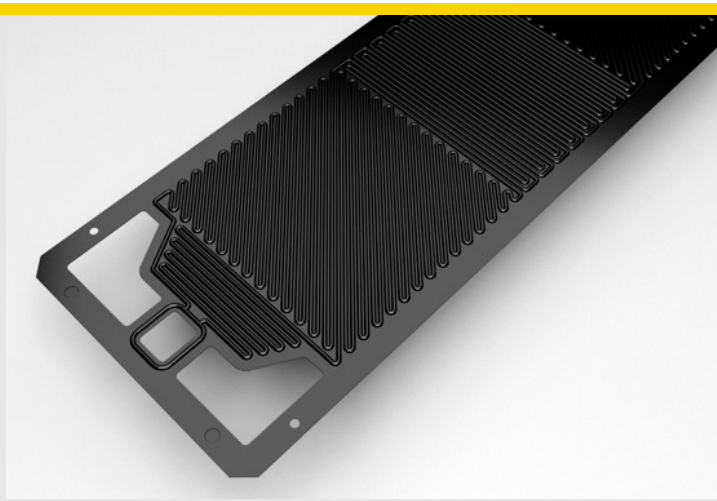
Condition tests	ICR Uncoated (mΩ·cm²)	ICR DLC (mΩ·cm²)
0.0 V	32	1.3
0.6 V	50.2	1.7
1.4 V*	>100	2.1
1.8 V*	>100	2.4

**Transitory conditions during 10 min*

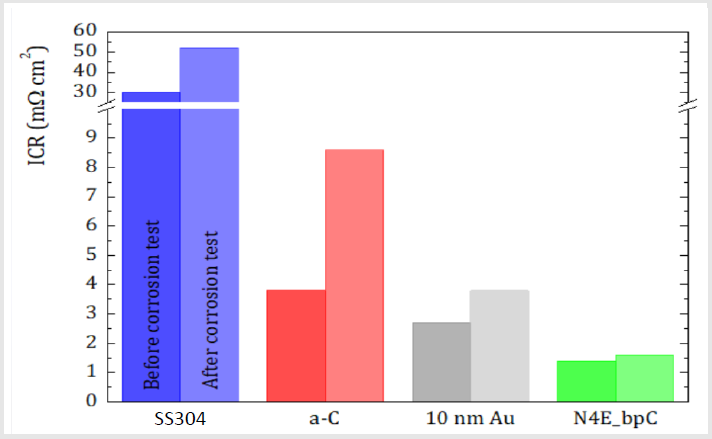
DLC partner:
N4E, Madrid

PVT | DLC based coatings for BiPs

- HiPiMS plasma surface pretreatment for improved adhesion and coating/substrate interface contact. HiPIMS coatings improve smoothness and reduce surface defects
- Me-doped nanostructured DLC coatings to enhance properties under different PEMFC and PEMWE working conditions



	DoE technical targets	DLC
ICR	<10 mΩ·cm2	1.7 mΩ·cm2
Corrosion	< 1 μA/cm²	0.35 μA/cm²



DLC partner:
N4E, Madrid