Meet the new Aluminum… Busbars

Fabien Dijols – Business Development and
Engineering Manager, Amphenol Auxel

John Mills – Business Development Manager –
Power Products, Amphenol GIS

Presentation Overview

Optimized **L**ocal **S**urface **T**reatment (OLST)

A new high-tech, low-cost application of the legacy Cold Spray process

Agenda

- Aluminum for busbars
- Basics of the Cold Spray technology
- OLST deposition process
- Applications
- Manufacturing process
- More Applications

Aluminum for Busbars

Equivalent weight & section for same electric conductivity

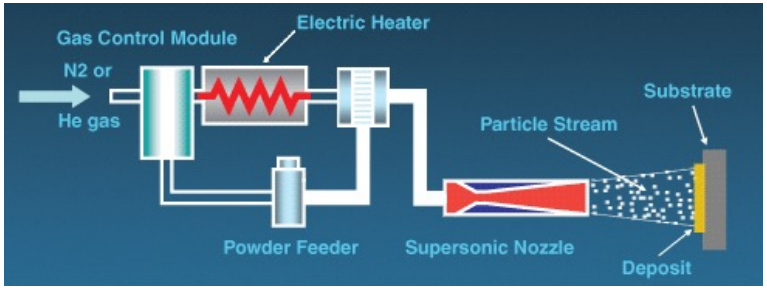
- Aluminum is the 3rd most abundant material on earth (8.23% of the earth crust), copper is the 26th (0.006%)

	Copper CuETP	Aluminum 1050A – Al99,5	Aluminum 6060 – AW-AlMgSi	Aluminum 5754 – AW-AlMg3
Density	8,9	2.7	2.7	2.68
Electric conductivity (%IACS) *International Annealed Copper Standard*	100 %	60%	54%	32,5%
Equivalent section for same electric conductivity		+68% 	+85% 	+207% 
Equivalent weight for same electric conductivity		-49% 	-43% 	-7% 
Main uses in Power Electronics	Flat & bent conductors	Flat & bent conductors	Extruded conductors & profiles	Flat conductors with specific mechanical performances

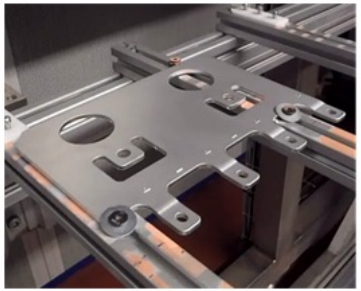
IACS = international annealed copper standard (= reference to copper conductor conductivity)

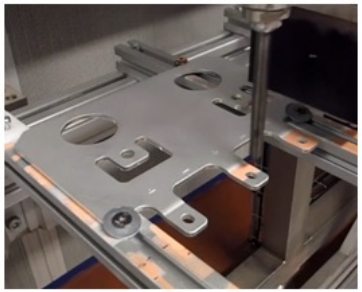
Basics of Cold Spray Technology

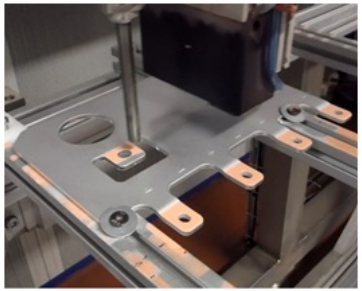
- Gas dynamic cold spraying is a coating deposition method
  - Why “Cold” Spray? = The copper particles are heated, but not above their melting point
  - Technology developed +20 years ago
  - High speed projection of micro-particles: particles bond with the part and creates a cohesive coating
  - No oxidation caused by the cold-spray process.
- Projection: Copper, Nickel, Aluminium, Silver, Steel, other alloys...
- A process mainly limited to niche markets and Lab applications



Source: ResearchGate, Study on Cold Spray Technology, Xi'an Dianzi Keji Daxue Xuebao/Journal of Xidian University



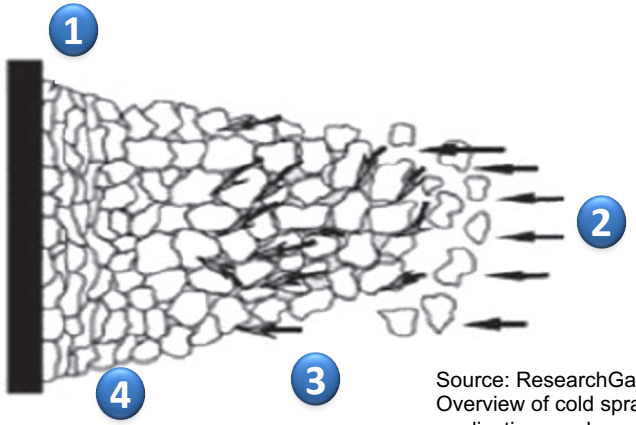




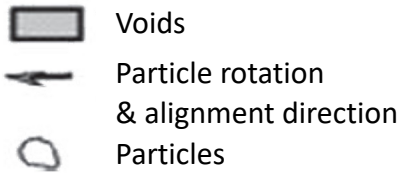
Basics of the Cold Spray technology

Different steps of the depositional process:

1. – Substrate cratering and first layer build-up particles
2. – Particle deformation and realignment
3. – Metallurgical bond formation and void reduction
4. – Bulk formation (cracking, work hardening of particles, removal of previously bonded particles) excess kinetic energy required for this stage



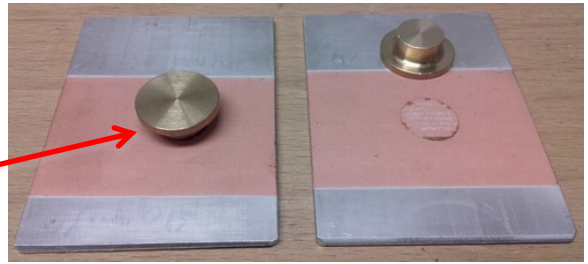
Source: ResearchGate, Overview of cold spray coatings applications and comparisons: a critical review



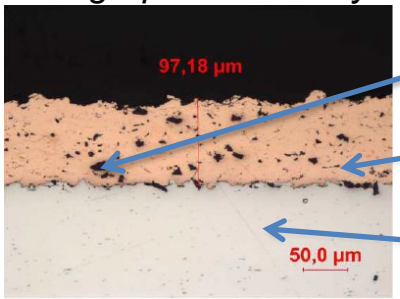
OLST: Optimized Local Surface Treatment

- Machine environment designed for flat processing
  - High speed 3 axes robot
  - Flexibility, large range of deposition possibilities
  - Capability to mix powder produces up-to 2L per 5 minutes.
- Deposit on non-planar surfaces possible by using a 6-axis robot
- Reduce technology costs
  - Powder formulation developed in house: particle size and shape, additives…
  - No neutral/noble gases (nitrogen, helium)
- Qualification plan focused on busbar applications
  - Mechanical: pull-out resistance (>1000N/cm²), porosity level (<5%), flatness / thickness homogeneity (±10 micron), roughness, resistance to humidity / salt fog (600 hrs per EN ISO 9227), mechanical stress
  - Electric: contact resistance (≤ raw copper, roughness), heat rise, short-circuit (3 phases/1600A – Icw: 84.5 kA RMS / 1s – Ipk: 182 kÂ) Icw = permissible current without damage
- 3 patent applications (2018)

Cohesion test samples / pull-out resistance : (>1000N/cm²)



Metallographic cut analysis



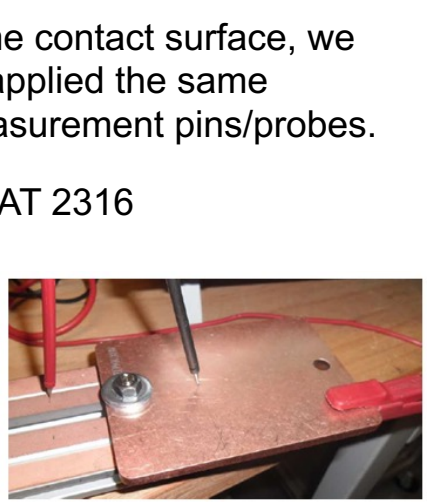
Alumina particle

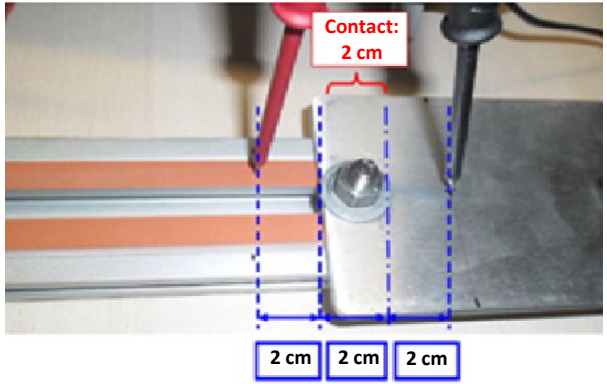
Copper

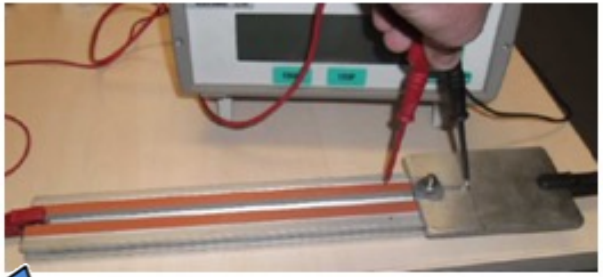
Aluminum

OLST: **O**ptimized **L**ocal **S**urface **T**reatment

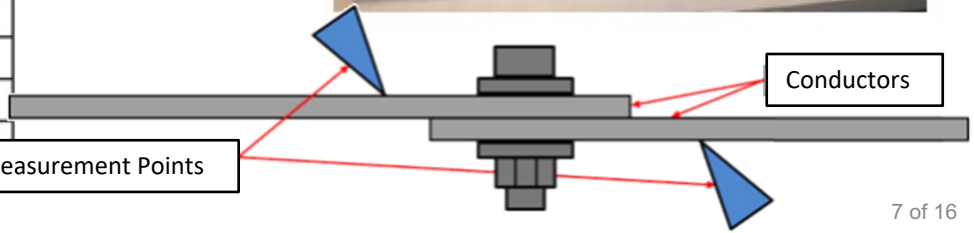
- In all cases, we have considered the same contact surface, we have used the same nuts/fixing system, applied the same tightening torque and used the same measurement pins/probes.
- Equipment: micro-ohmmeter RESISTOMAT 2316
- Screws: M8
- Tightening torque: 20Nm







	Conductivity (μΩ)			
	Test 1	Test 2	Test 3	Average value
Cu / Cu	5,5	5,2	4,7	5,1
Al / Al	13,6	13,6	15,3	14,2
Al / Cu	9,6	9,3	9,1	9,3
Al / OLST	11	11	11	11
Cu / OLST	5,5	5	4,4	5



“Rough” is better

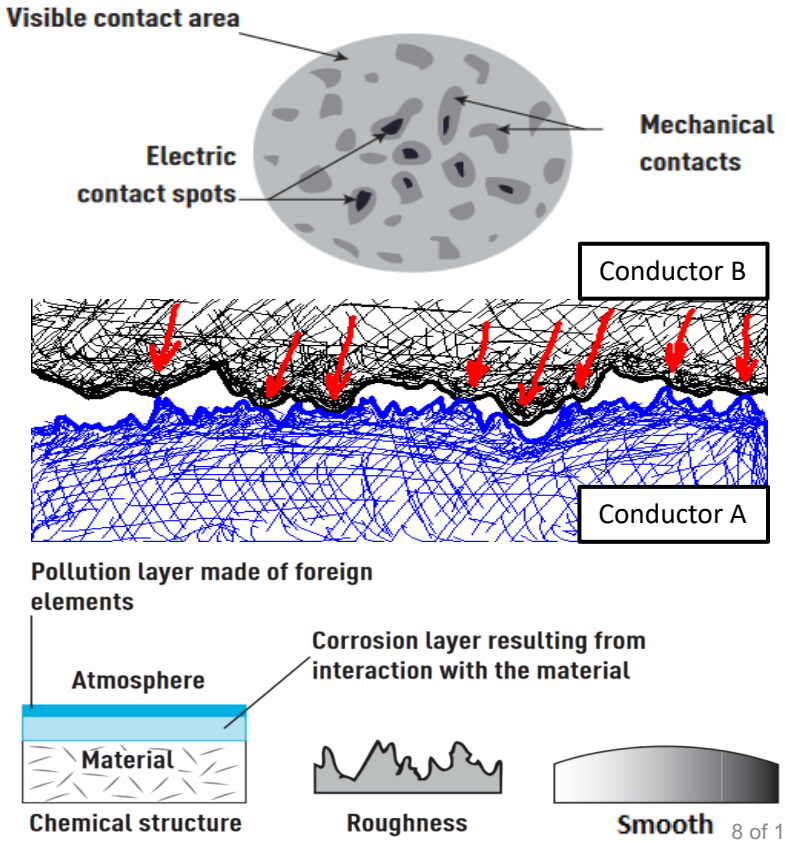
3 parameters determine the status of a contact surface:

1. Chemical structure; foreign elements of the surrounding atmosphere (pollutants) react with the material and form a superficial layer called the corrosion layer.

2. The roughness of the surface depends on the manufacturing technology used and is often to some degree random. More peaks (rougher) result in lower overall resistance by passing thru the pollution layer.

3. The geometrical form of the contact which determines the visible contact area between two surfaces.

Some customers ask for laser treatment in order to increase the contact surface asperities.

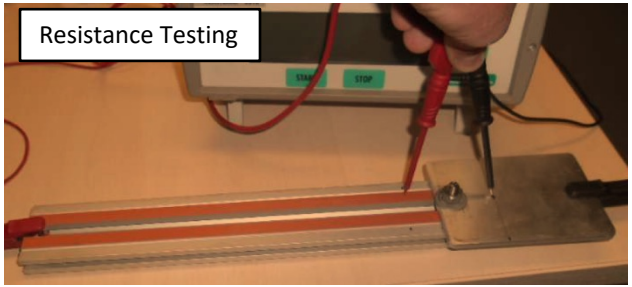


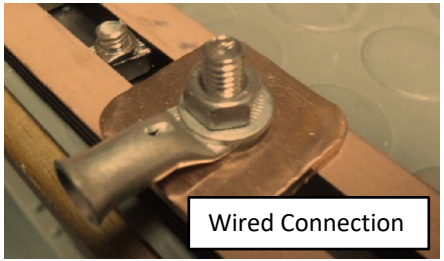
Aluminum vs OLST

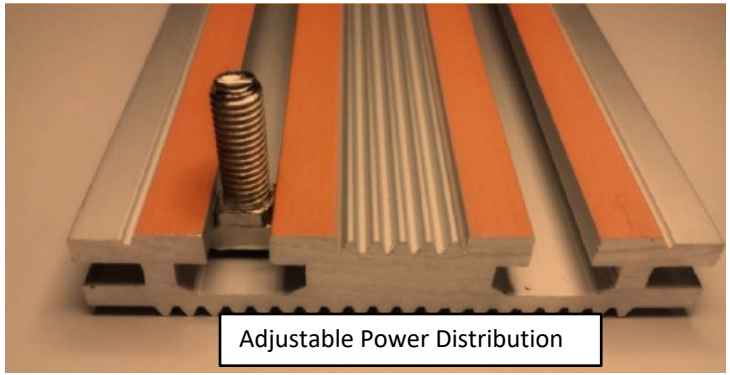
- Oxidation/pollution layer
  - Aluminum oxide = insulation
  - *Pollution layer is fully removed during OLST process.*
- Soldering
  - Difficult to solder to aluminum.
  - *OLST = same properties as copper (easy soldering)*
- Galvanic corrosion
  - Aluminum will be attacked when in contact with a more noble material.
  - *OLST = capability to connect Copper conductors to Aluminum (w/o galvanic corrosion)*

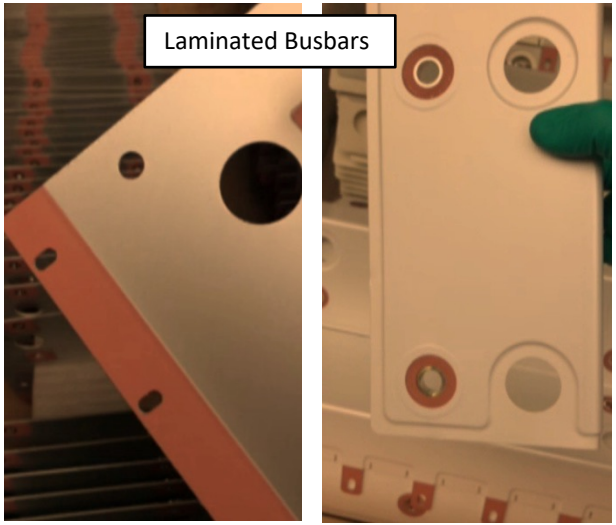
- Surface treatment
  - Limited number of suppliers (especially for large dimensions conductors).
  - Tin coating: underlay is mandatory, tin whiskers are problematic.
  - Nickel coating: cost, trouble for some specific bendings.
  - Use of raw aluminum interconnect: heat rise
  - *OLST = eliminates all these restrictions.*
- Mechanical assembly systems differ from copper
  - Copper to Aluminum connection requires time consuming area prep prior to securing - (cleaning, grease, brush, etc.)
  - *OLST = does not require surface prep prior to securing the connection.*

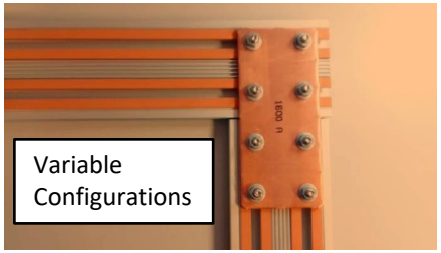
Some Applications

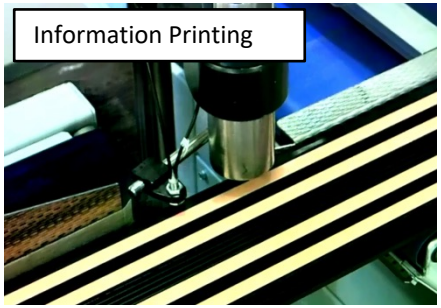






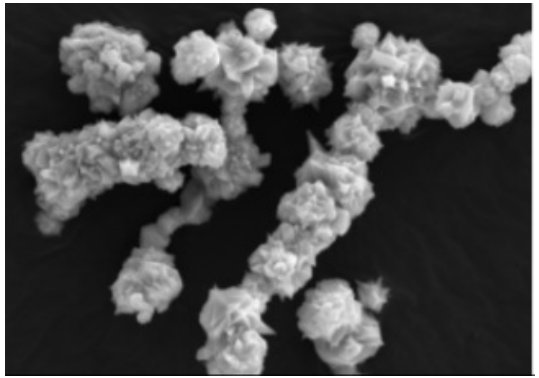






OLST Nickel

- Nickel = standard coating for aluminum conductors
- Advantages (vs. OLST copper):
  - Stronger and more durable than copper (corrosion)
  - Aesthetic (no finger stain)
- Advantages (vs. standard Nickel chemical coating):
  - Selective coating / less costly (large size)
- Nickel deposit on copper conductor (vs. chemical coating process)
  - Not economically feasible (selective or not)
- Qualification in progress



High purity nickel powder T255™ with a fine, three-dimensional filamentary ("chain-like") – size 2-6 microns (microscopic view)

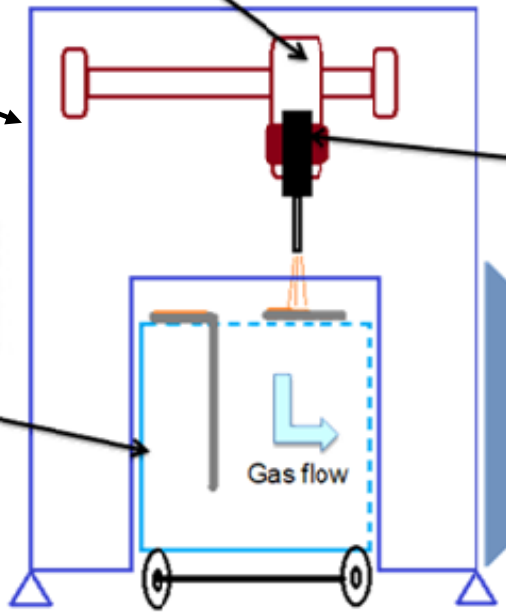
Machine Environment

Rigid enclosure with controlled air-tightness

Trolley

Work area = (2m(l) x 1m(w) x 30cm(h)

Cartesian 3 fast axes robot



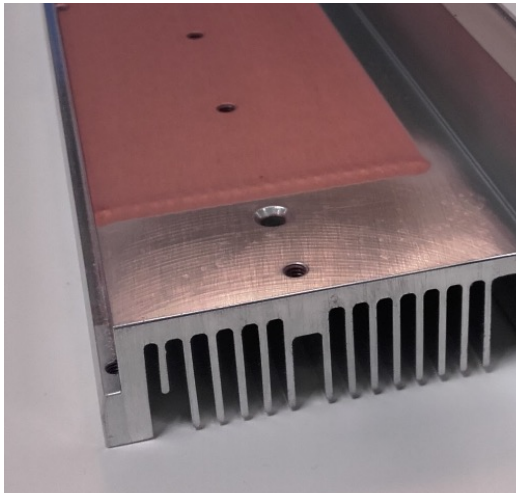
Gun / Nozzle

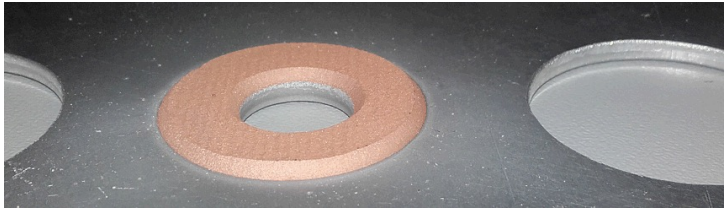
Wet Vac w/Filtering

Central Unit & Feeders

A Few More Applications

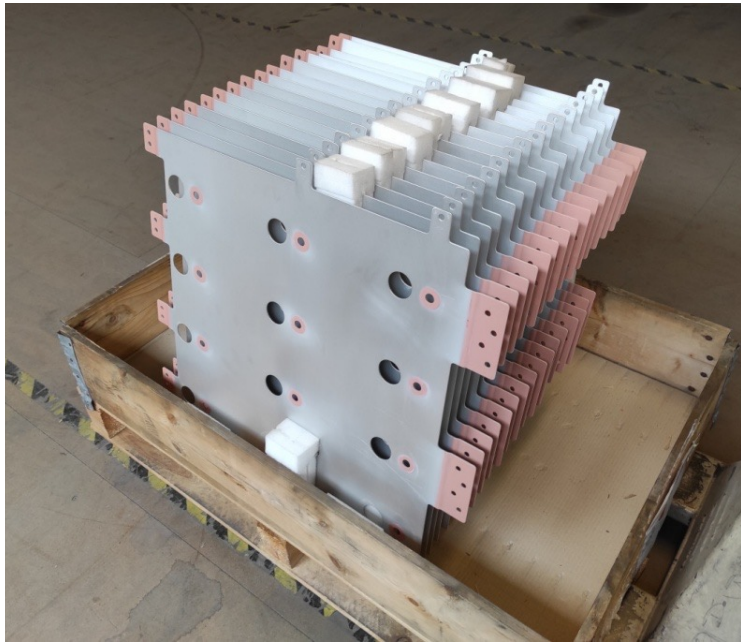
- Mechanical interfacing
  - A thick copper coating (2mm+) on an aluminum heatsink gives better heat transfer and stress relief due to CTE mismatch, when mounted to a module, than simple thermal grease.
  - It is possible to overcoat AL with OLST in order to solder a semiconductor device (thin layer, 50 µm).
  - An alternative to embossments.
- Eliminates loose hardware
  - Decrease hot spot temperature (with the OLST process you can increase the conductor's cross-section only where the hot-spots are located). This eliminates loose hardware from the current process, and hence, also reduces cost and improves reliability.
  - Connection height-leveling (replacing busbar spacers).





Summary of the OLST technology

- Coating materials:
  - Copper
  - Nickel (qualification in process)
- Base materials:
  - Aluminium
- Main advantages of this technology:
  - Attractive cost
  - Enables use of Lightweight Aluminum
  - Large range of conductor dimensions
  - No galvanic corrosion (connection between raw aluminum and copper busbars/conductors)
  - Contact resistance = copper



Contact Information:

Fabien Dijols – fabien.dijols@auxel.com

Mobile : **+33 (0)6 23 16 53 05**

John Mills – john.mills@amphenol-gis.com

Mobile : **+1 (860)560-6612**

https://www.amphenol-gis.com/power-solutions