COLD SPRAY ACTION TEAM 2020

- Commercial and Defense Transition & Applications Development
- The Past, Present, and Future of Government & Industry Programs
- Advancements in Materials, Processes, Controls, Inspection & Hardware

Cold Spray Roadmaps, Additive Manufacturing, Structural Repair, Chrome Replacement, Machine Learning, Applications & Transition, Bond Inspection

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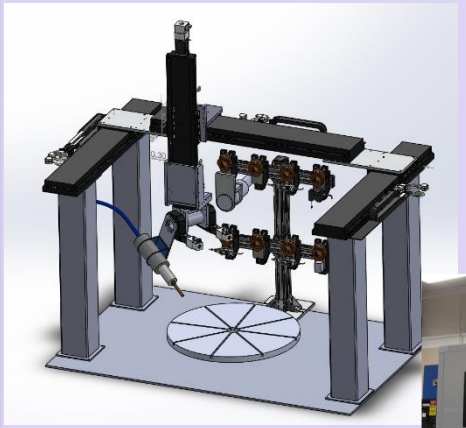
Non-structural Repair 1990's → **Structural Repair** → **Near-net Parts Present**

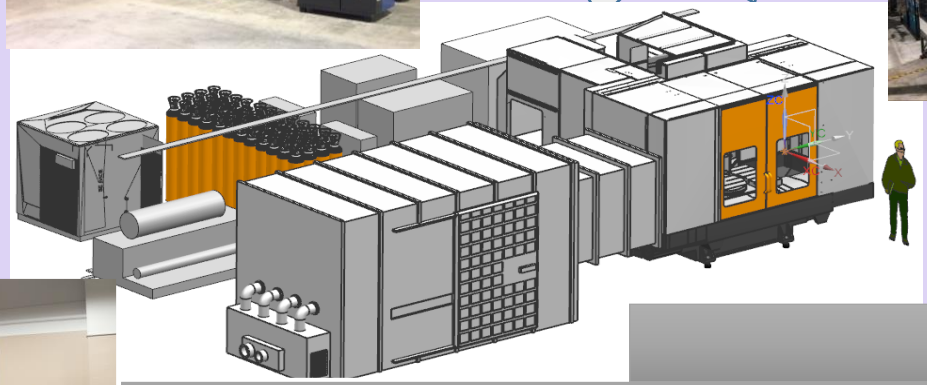
Phase I

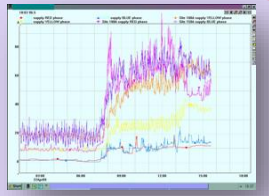
Enabled Cold Spray Production Capability for High Volume



Phase II

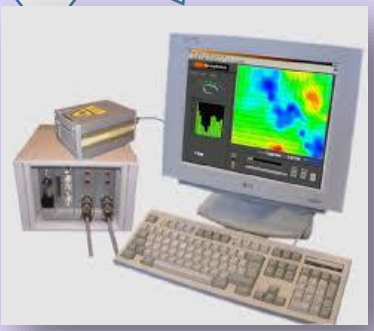
Increased Operating Envelope & Established Helium Recovery to Reduce Costs





Phase III

Incorporate Advanced Automation & System Controls



Intelligent Automation & Controls

In-flight Particle Temperature, Velocity, and Particle Size Measurement

Advanced Motion and Path Planning Capability and Automated System Process Controls

Ensure Predictable, Repeatable and Reliable Material Properties/integrity of AM and Structural Applications

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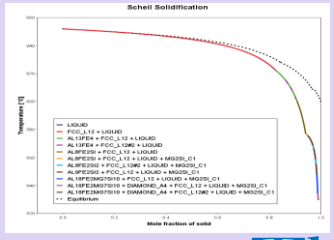
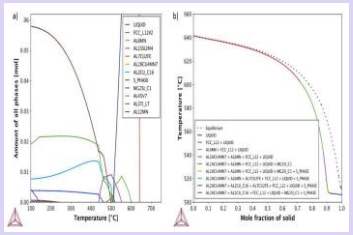
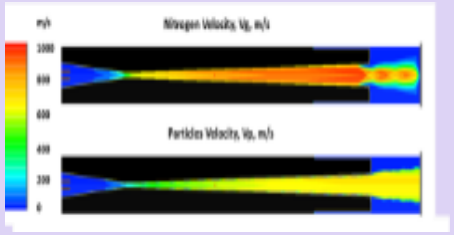
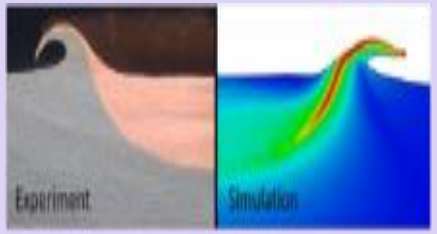
ARL Holistic Approach to CS Development

Solidification *Thermodynamic* *Particle Acceleration* *Particle Impact*



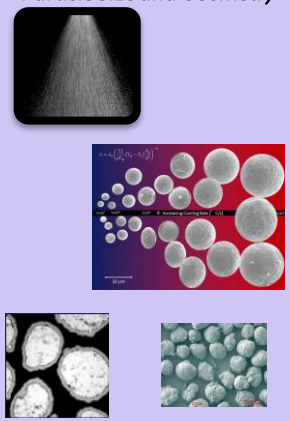






Theoretical Models & Empirical Studies

- *Chemistry*
- *Manufacturing process*
- *Particle Size and Geometry*

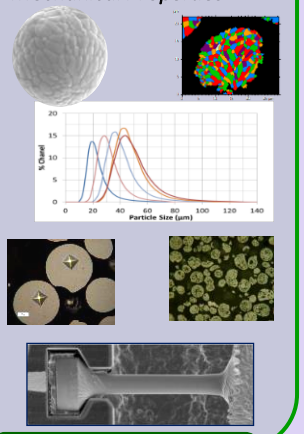


Powder / Material Selection

- *Degassing*
- *Heat Treating*
- *Blending*
- *Milling*

Powder Processing

- *Microstructure*
- *Particle Size*
- *Morphology*
- *Mechanical Properties*

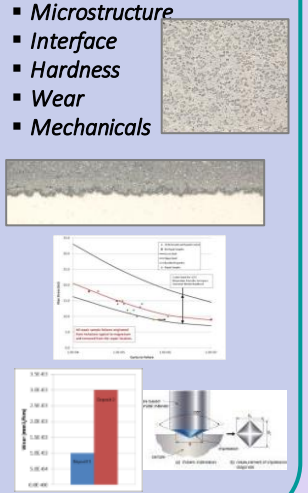


Powder / Material Characterization

- *Pressure*
- *Temperature*
- *Nozzle Geometry*
- *Substrate Preparation*
- *Motion Control*

Cold Spray Process

- *Porosity*
- *Microstructure*
- *Interface*
- *Hardness*
- *Wear*
- *Mechanicals*



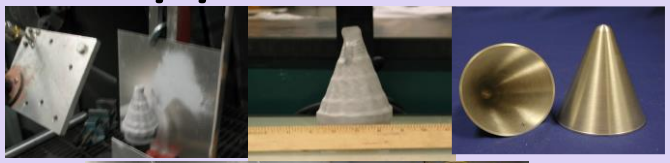
Post-Processing Characterization

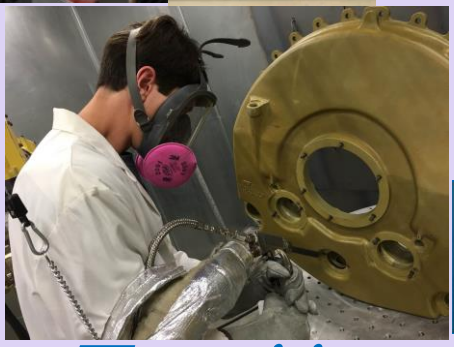
Transition

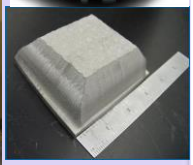
- *Repair*
- *AM Parts*
- *Advanced Automation*
- *Sensors & Controls*
- *Machine Learning*
- *NDT*
- *Hardware & Software*

Production & Portability

Applications







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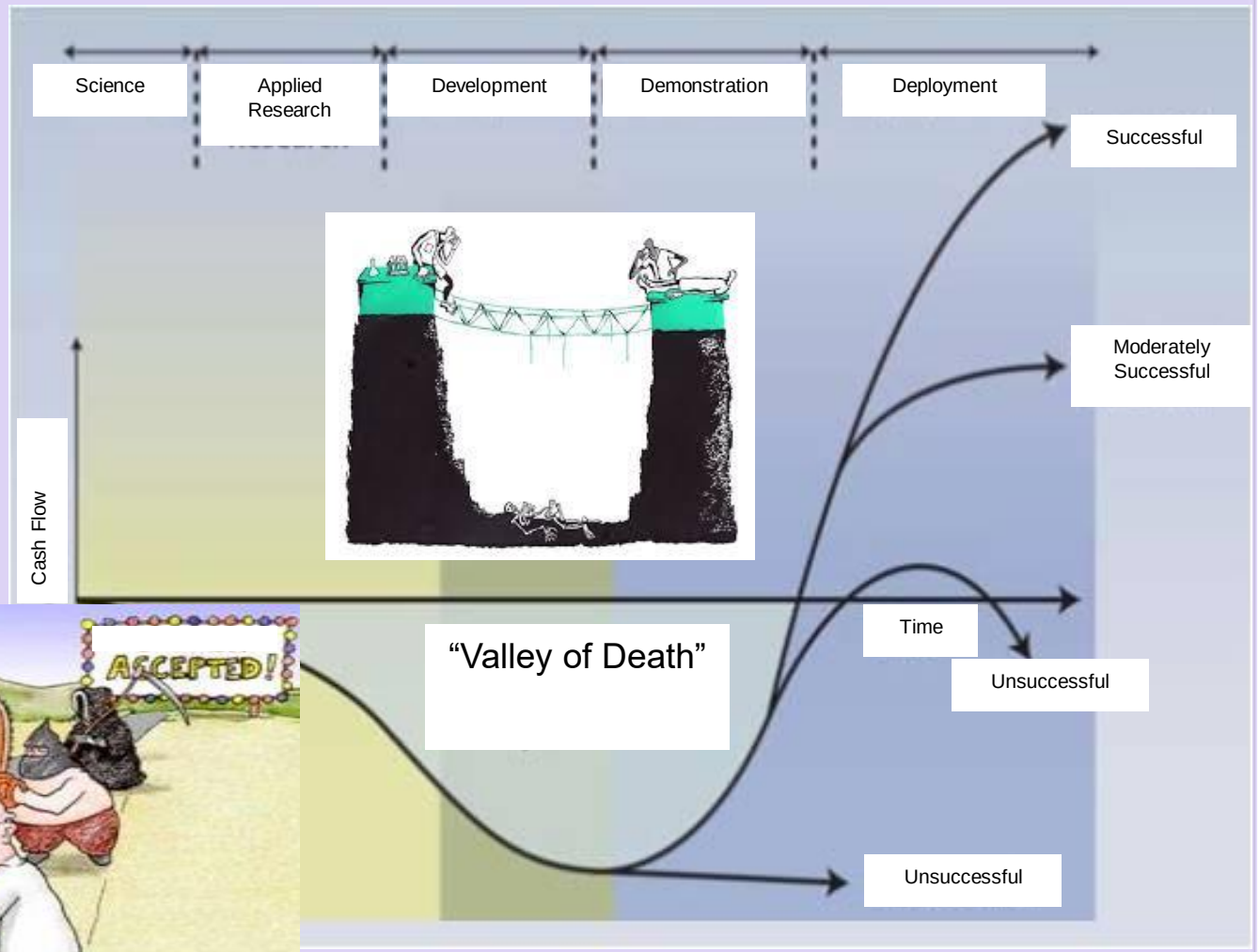
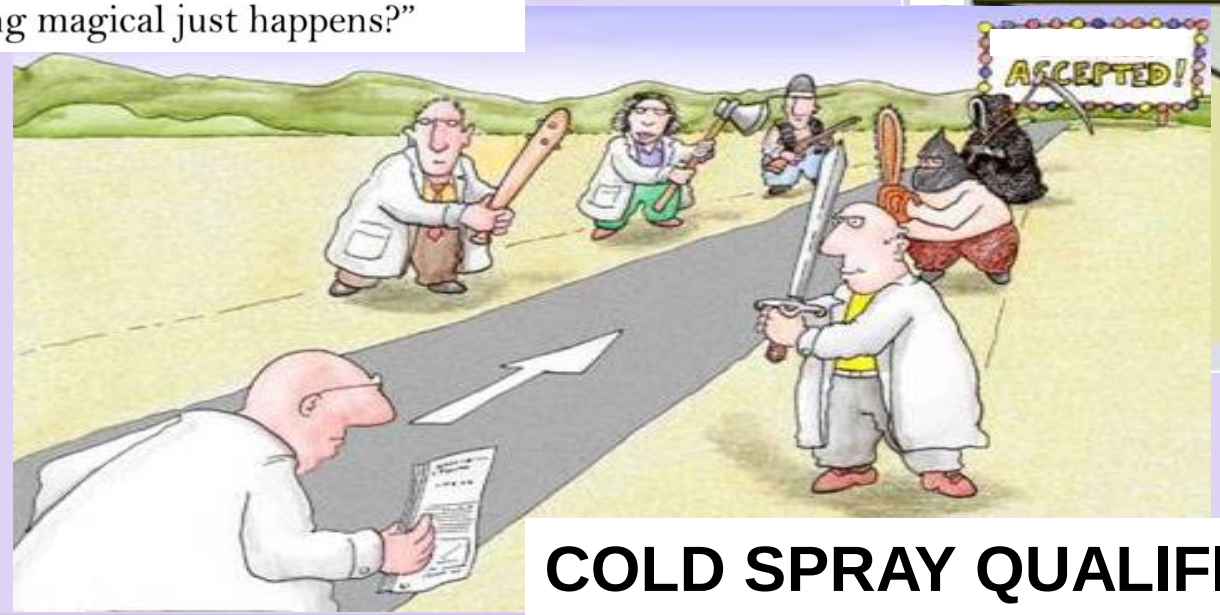
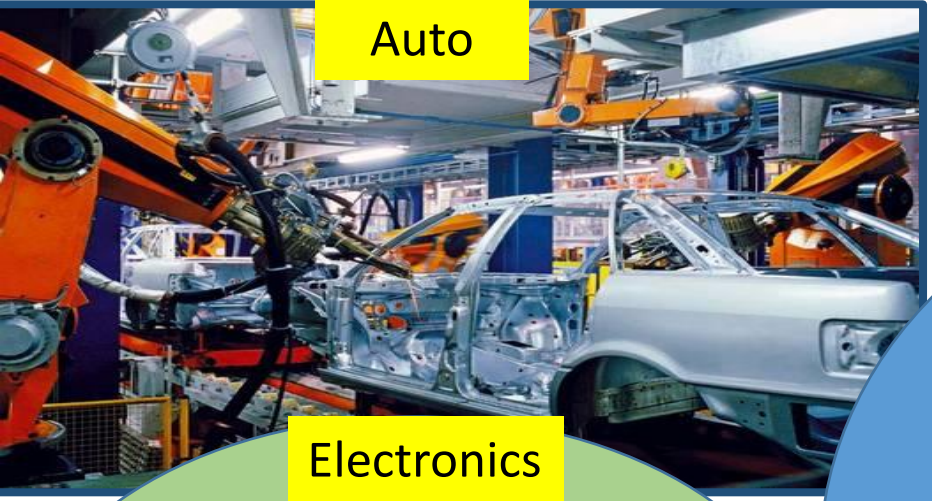




COLD SPRAY QUALIFICATION PROCESS

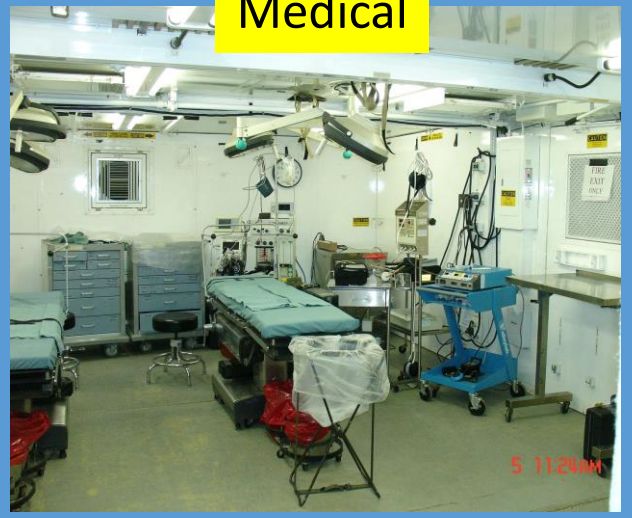
Global Industries

Auto

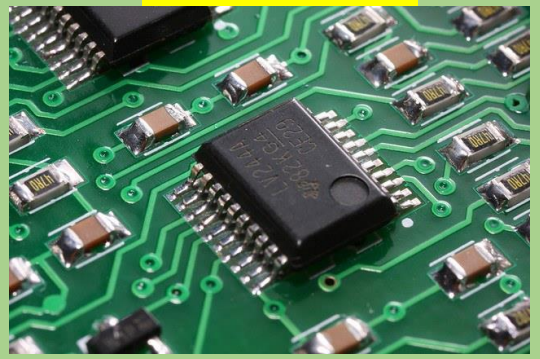


Aerospace

Medical



Electronics



Nuclear

Gas & Oil

Ship

Subs

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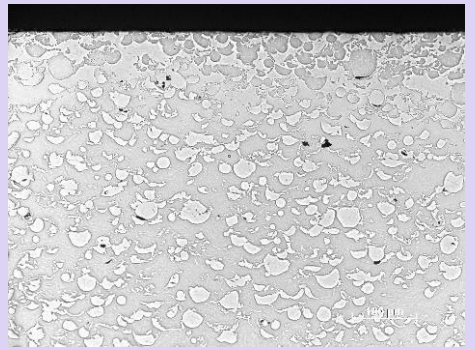
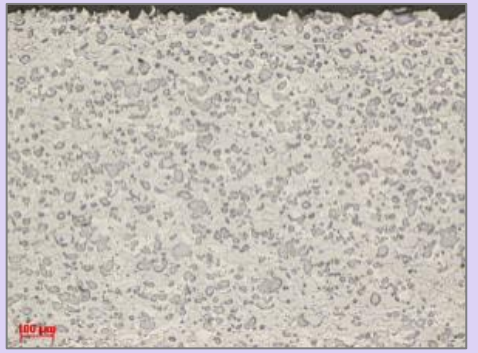
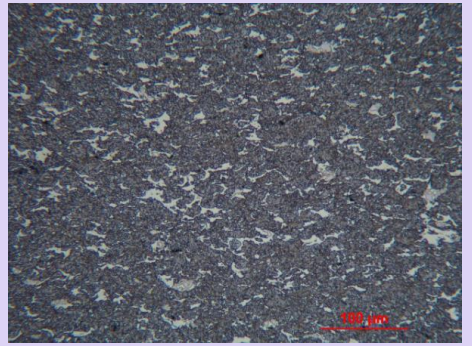
Current State of Development with WIP Coatings

- **WIP-C1 and WIP-C2**
  - These deposits are being rolled out into several applications and have by far the most robust set of data and spray conditions of all WIP materials
  - Vendors have been set up to produce this material commercially for easier procurement
  - Deposits have been demonstrated with both helium and nitrogen with good quality
  - Deposits can be machined by milling, turning, or grinding
- **WIP-F1**
  - This material is very similar to WIP-C1 and C2 but is completely iron based for applications where EH&S concerns about nickel based deposits may be present
  - More work needs to be done to characterize the properties, especially wear performance, of this material
  - Scale-up of this material to production quantities will follow the process for WIP-C1 and C2
- **WIP-W1**
  - This material has the greatest potential for direct chrome replacement in most applications
  - The data generated has shown excellent wear
  - Deposits must be ground, but can be ground with SiC or diamond
  - All powders have been produced using production robust processes







All coatings can be applied in line of site applications as well as in features as small as 1.8 - 2 inches

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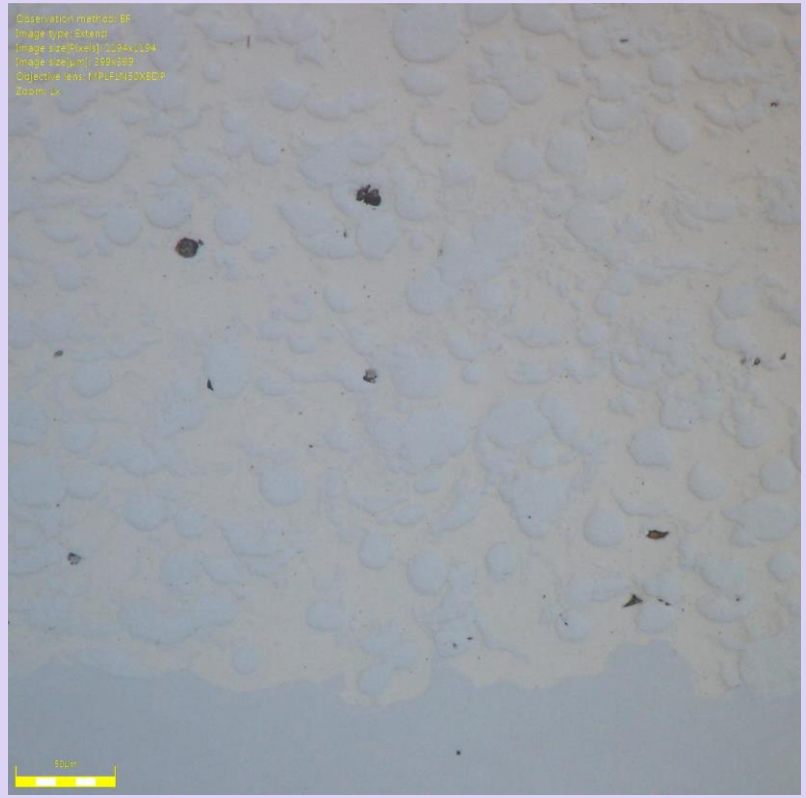
WIP-C1 Technical data

- Sprayable with N_2 or He
  - 1.5%-3% porosity with N_2
  - <1% porosity with He
- Suitable for many substrates
  - HRC 30-55 steels
  - Stainless
  - Monel
  - Copper-Nickel
- Similar or better wear performance than Cr plating
- Suitable for high impact conditions

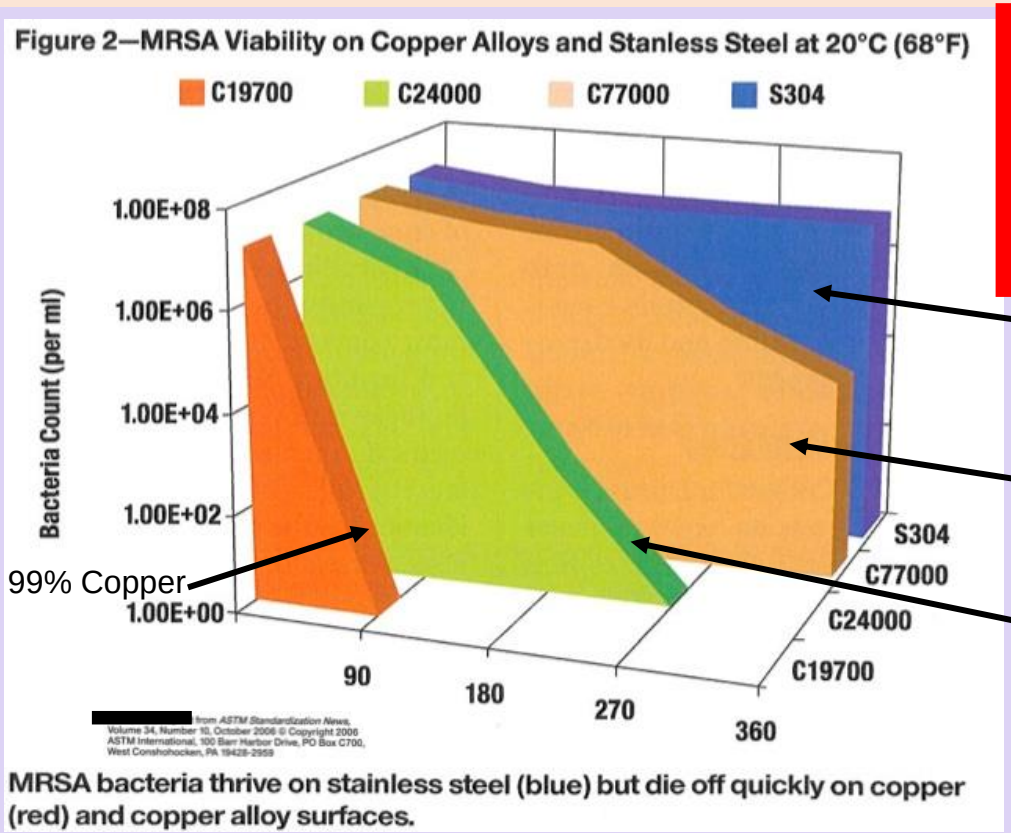
- https://www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Surface-Engineering-and-Structural-Materials/Composites-Alloys-and-Ceramics/WP-2607/(language)/eng-US
- Final Report Posted 2/2020
- Cold Spray Coatings for Chromium and Nickle Plating Replacement (WP-2607)

Substrate	Lug Shear Strength (ksi)
17-4PH	~20
High Hardness Steel	~20-25
4340	> 50 (He), ~28 (N2)
4330V	~38



Measured Porosity: <0.5%

Identification of Areas for the Use of Copper or Copper-Based Coatings in the Army Standard Family of ISO Shelters to Prevent the Growth of Micro-Organisms in a Hospital & Surgical Setting Through Laboratory and On-Site Testing/Evaluation



MRSA bacteria thrive on stainless steel (blue) but die off quickly on copper (red) and copper alloy surfaces.

Cold Spray Copper Coating has demonstrated up to a >99.999% ($\log_{10}$ >5.8), of Staphylococcus aureus-Methicillin resisant (MRSA) (ATCC 33592) following 2 hour exposure period at room temperature (23.0°C)

https://www.af.mil/News/Radio/videoid/134780/dvpTag/copper/

ARL Inside: Cold Spray Center of Excellence, **Army Research Laboratory,** May 12, 2010

- Laboratory tests conducted under the Environmental Protection Agency (EPA) Good Laboratory Practices (GLP) protocols have provided evidence that copper surfaces kill microbes in a matter of hours.
- To date, no other material has been qualified to make this public health claim under the EPA guidelines.

MEMORIAL SLOAN-KETTERING CANCER CENTER

US ARMY NATICK SOLDIER RD&E CENTER

Fort DETRICK A Community of Excellence

MUSC MEDICAL UNIVERSITY OF SOUTH CAROLINA

ATI Advancing Technology through Collaboration

United States Department of Veterans Affairs

CDA COPPER.org A service of the Copper Development Association for the copper and brass industries in the USA

Infection Slows Brady's Rehab

More complications can't be ruled out

By Shira Springer , Globe Staff / November 11, 2008

When news surfaced almost four weeks ago that Brady had developed a postoperative infection, the sports medicine community shuddered. The patella tendon graft surgery performed Oct. 6 was required to replace his torn ACL.

Doctors fear nothing more than the development of infections and blood clots.

If not caught quickly and treated properly, such complications can threaten a patient's life. In Brady's case, the infection was caught early and treated aggressively with wash-out procedures and IV antibiotics.

Patriots 17, Chiefs 10

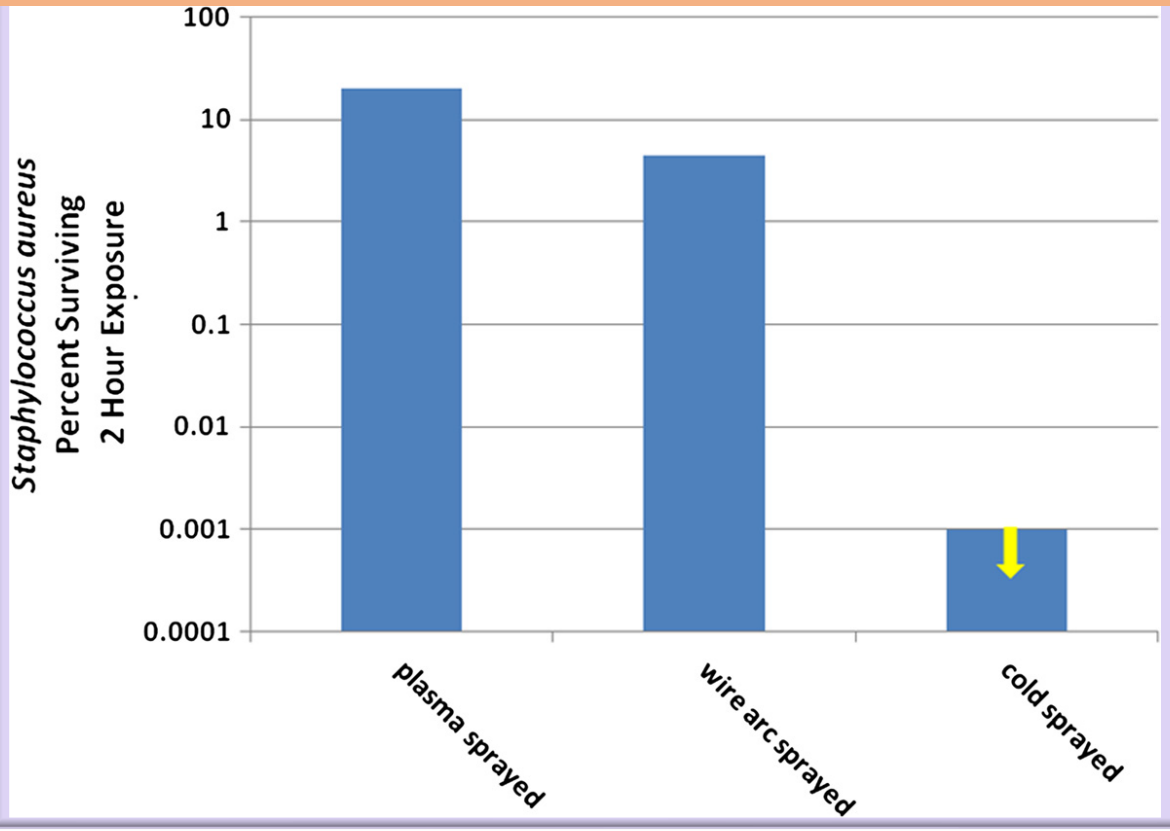
by **RichieG5-1** November 11, 2009

I had knee surgery 19 years ago. The surgery went fine. The staph infection I got nearly killed me. When I left the hospital (thankfully with my leg), I was told I would never walk without again without assistance. 3 years of physical therapy, and I can walk, jog a little, and run with pain. I'm not expecting to see Brady until 2010.

- This study revealed significant microbiologic differences between coatings produced by different spray techniques and demonstrates the importance of the copper.

- Cold spray shows superior anti-microbial effectiveness caused by the high impact velocity which results in high dislocation density and high ionic diffusivity.

The reduction of inoculated S. aureus was normalized by the results of the control exposure to a stainless steel surface. Results are in terms of the percent of surviving S. aureus after two hours.



Diffusivity in metals varies as the square of hardness and is very sensitive to impact hardening by cold spray deposition.

The diffusion of copper ions can therefore be significantly increased through the hardness increase produced by the cold spray process, which serves to enhance the flow of Cu2+ ions needed for microbial destruction.

ITSC 2021 Preview: Virtual Session

"Coatings for Anti-Virus, Bacteria and Fungus Applications"

Thursday, June 18, 2020 - 10:00 - 11:30 a.m. ET

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Cold Spray Antimicrobial Coatings Research Papers

1. Victor Champagne, Kristin Sundberg and Dennis Helfritch (2019), *Kinetically Deposited Copper Antimicrobial Surfaces.* Coatings, *9*(4), 257; https://doi.org/10.3390/coatings9040257

2. Kristin Sundberg, Matt Gleason, Baillie Haddad, Victor Champagne, Chris Brown, Richard Sisson, and Danielle Cote (2019), International Journal of Nanotechnology in Medicine & Engineering, *The Effect of Nano-Scale Surface Roughness on Copper Cold Spray Inactivation of Influenza A Virus,* ISSN 2474-8811

3. Sundberg K, Champagne V, McNally B, Helfritch D, Sisson R (2015), *Effectiveness of Nanomaterial Copper Cold Spray Surfaces on Inactivation of Influenza A Virus*. J Biotechnology & Biomaterials, 5: 205. doi:10.4172/2155-952X.1000205

4. Champagne and Helfritch (2013), *A Demonstration of the Antimicrobial Effectiveness of Various Copper Surfaces.* Journal of Biological Engineering, 7:8. http://www.jbioleng.org/content/7/1/8

5. https://www.af.mil/News/Radio/videoid/134780/dvpTag/copper/, ARL Inside: Cold Spray Center of Excellence, **Army Research Laboratory,** May 12, 2010 | 3:51, *This edition features a story on ARL and the Natick Soldier Research, Development and Engineering Center which are collaborating to investigate the antimicrobial benefit of using copper and copper alloys for use in medical shelters that will be used in theater to treat injured Soldiers.*