Unique solid-state deposition process which utilizes high velocity particles impinging upon a substrate to build up material

- Feed stock typically ranges from 1 to 50 µm
- Particle ductility is crucial
- Gas temperature range from R.T. to 800°C
- No melting of particles
- Negligible oxidation
- No decomposition or phase changes of deposited particles or substrate
<table>
<thead>
<tr>
<th>Operating Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Pressure</td>
<td>250 – 550 psi</td>
</tr>
<tr>
<td>Gas Temperature</td>
<td>300 - 1000 Degree C</td>
</tr>
<tr>
<td>Gas Flow</td>
<td>50 - 200 SCFM</td>
</tr>
<tr>
<td>Powder Flow</td>
<td>10 – 50 gram/minute</td>
</tr>
<tr>
<td>Particle Exit Velocity</td>
<td>700 - 2000 meter/second</td>
</tr>
</tbody>
</table>
ARL Center for Cold Spray

• World Class Research and Development Facility Recognized Internationally

• ARL Center for Cold Spray est. 2000 (8 dedicated employees, 14 CS systems)

The direct link is: www.arl.army.mil/www/default.htm The link from the homepage is: Doing Business with ARL | Center for Cold Spray

• Working with over 125 companies, as well as DOD, DOE, Foreign Countries

• Aerospace, automotive, petrochemical, medical & electronics applications

• Cold Spray Additive Manufacturing *Hot Isostatic Press (HIP)

• Integrated Diode Laser with Cold Spray (1KW Continuous)

• DPV 2000 Dual Slit Laser Particle Measuring System

• Developed the first Cold Spray Process Specification (MIL-STD-3021, titled “Materials Deposition, Cold Spray”)
Applications development not limited to a particular CS system

- Ktech Stationary Systems 1st Commercial Unit in the USA
- CGT 4000’s- Multiple
- Plasma Giken- Japanese Higher Pressure to 1000°C
- Inovati Kinetic Metallization System
- ARL High Pressure (500psi) Portable Cold Spray Systems
- Centerline Portable Cold Spray Systems
- Dymet Portable Cold Spray System
- CGT Portable Cold Spray System (300psi)
- Liquid Particle Acceleration (SBIR Phase II)

Thermal Spray Capabilities

- Thermal Arc Spray, Plasma Spray, HVOF, HVAF, D-Gun
- PTA anticipated FY13
Fielded SH-60 Seahawk with Cold Spray Mg Repair
Operating Since August, 2009-Australian Navy
ARL/JSF/DSTO Collaboration

Fielded B-1 Bomber with Cold Spray Ti Repair
Operating Since September 2009- Tinker AFB
ARL/Tinker AFB/HF Webster Collaboration

Three Fielded Blackhawk Medvac Units with Cold Spray Al Repair
Operating Since August, 2009
ARL/AMCOM/Ft. Hood Collaboration

Two Expeditionary Fighting Vehicles with Cold Spray Mg Repair
Fielded and Operating Since September, 2008

- Power Transfer Module - PTM
  - 10 Magnesium Castings
- Transmission
  - 13 Magnesium Castings
Difference in Particle Size & Morphology

Accushape CP-Titanium
(Mean Particle Size = 39 um, SD = 27.2)

AP&C CP-Titanium
(Mean Particle Size = 12 um, SD= 5.0)
Typical Nozzle Performance

39um powder

V_e, m/s  866  
T_e, °C  280
<table>
<thead>
<tr>
<th>Powder</th>
<th>Substrate</th>
<th>Adhesion (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acushape CP-Ti</td>
<td>6061 Aluminum</td>
<td>11233</td>
</tr>
<tr>
<td>Acushape CP-Ti</td>
<td>Ti6Al4V</td>
<td>11626</td>
</tr>
<tr>
<td>AP&amp;C CP-Ti</td>
<td>6061 Aluminum</td>
<td>9785</td>
</tr>
<tr>
<td>AP&amp;C CP-Ti</td>
<td>Ti6Al4V</td>
<td>7166</td>
</tr>
</tbody>
</table>
Dr. Fukanuma, Plasma Giken  http://coldsprayteam.org/
Helium Microstructure
Ti-6Al-4V
Helium Tensile Properties
Ti-6Al-4V
Nitrogen Microstructure
Ti-6Al-4V
Nitrogen Microstructure
He vs. N₂ Microstructure
Ti-6Al-4V

Helium
Modulus 14.1 msi
Strength 60 ksi

Nitrogen
Modulus ~2 msi
Strength ~10-20 ksi
Problem: Chaffing of hydraulic tubing is a common problem

Cause: Vibration or other abrasive action

Effect: Significant cost in maintenance man-hours and operational readiness rates
Replacement is expensive

Solution: Cold Spray Repair
A technological solution that reduces the frequency of hydraulic tubing chafing would have broad applicability across the DOD and would result in

- Reduced maintenance man-hours
- Reduced costs
- Improved mission capable rates.

Supersonic Cold Spray is a technology which can be used to apply a metal coating on titanium tubing providing a wear surface in areas of known chafing problems. This preventative measure could be performed during programmed depot maintenance or during the high velocity maintenance process to prevent or reduce occurrences of hydraulic tubing chafing in the field.
Cold Spraying CP-Ti on Hydraulic Tubing

Application of Cold Spray to .375” Haynes AMS 4944 (Ti3Al2.5V) Hydraulic Tubing
Cold Spraying CP-Ti on Hydraulic Tubing
Summary

• Cold Spray can be used to deposit fairly dense CP-Titanium and Ti-6Al-4V coatings
  – It is difficult to achieve a good quality Ti-6-4 with N2 using currently available high pressure systems
  – Helium can be used to deposit a reasonable quality Ti-6Al-4V coating
• It is feasible to use Cold Spray as an Additive Manufacturing technology for Titanium alloys
  – Need a decrease in porosity and an increase in ductility (particle to particle bonding)
  – Next step is try a angular Ti-6Al-4V Powder
• Already have identified numerous applications such as the B-1B where these coatings can possibly be implemented