High-Precision Stamping of Titanium for Fiber Optics

Rand Dannenberg, Ann Huang

Presented to:
The Titanium Society
Paris, France
April 2016
Deepest thanks to Titanium Society for inviting nanoPrecision to Paris

Merci Jennifer King, et Jennifer Simpson, et Nate Fairfield de Uniti!
Talk Outline – Questions to Answer

- Why are we in Paris Today?
  
  - Spur interest in use of Titanium in fiber optical communication components.

- What is nanoPrecision Products making with Titanium Grade 2?

- Why do we use Titanium Grade 2 for our products?

- Answer Industrial Applications Committee questions.

We will play a 2 minute corporate movie showing our pilot line
Why are we in Paris today?
Rand Dannenberg, Ann Huang – please find us

- Our stamping production will consume 1600 metric tons of Titanium Grade 2 per year.

- Seeking to hire, contract, consult, or collaborate with experts in the following technical areas:
  - Anti-galling coatings for stamping tools forming Titanium.
  - Liquid lubrication chemistry for Titanium forming.
  - Liquid lubrication application for reel-to-reel Titanium processes.
  - Galling resistant Titanium alloys & related metallurgy.
  - Fracture prevention in thermal oxide coatings grown on Titanium.
  - Precision blanking of Titanium.
  - Laser welding of Titanium.
  - Hot forming of Titanium.

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About Us – Precision material forming

- nanoPrecision Products, Inc. (nPP) is the innovator and world leader in the field of complex material forming with nanometer accuracies and tolerances – 70 people

- Our high-tech products are created through the innovative use of:
  
  materials science
  computational mechanics
  physical optics
  precision engineering
  manufacturing technologies

![Diagram of metal optical rivet (stamped) with 250 μm mirror]
“Stamping Bubble” – Fiber Optics

Our products couple optical fiber

- Telecom.
- Datacom.
- Datacenters “Wild West”
- Supercomputers.
- Anywhere / everywhere a fiber optic connection is needed.
- Billion Dollar Industry
Precision results from...

- Proprietary method for compensation of tool shape for workpiece elastic springback, frictional heating, and tool elastic deformation - tools are not the same shape as the parts.

- Three dimensional part and tool metrology with CMM and interferometry.

- FEA simulation of the forming processes, fine tool shape corrections to prevent stress concentrators that would plastically deform the tools.

- Proprietary press sensorization, monitoring, maintenance
Ferrolder® Product Line
Titanium Grade 2

**SC Ferrolder®**

- Packaged halves for key account cable assemblers
- Cable assemblies - samples and custom applications
- Exceeds Telcordia requirements and objectives
- Pilot Manufacturing Line: 2 Million/Month - in qualification at this time

The competition – Zirconia ferrule

Titanium Grade 2 Ferrolder ®

Zirconia Alignment Sleeve

“Split Sleeve”

Ferrules must survive 500+ matings in the sleeve
The established competition -
Zirconia ferrules vs. Ferrolder®

1 billion of these single fiber ceramic ferrules are sold per annum and growing.
Lire le film!
Ferrolder® (Ferrule + Holder)

**Competitive Advantages**

- Cost – ceramic ferrules are ground.
- Eliminates epoxy – single largest cause of connector failure.
- Better Optical Performance
  - OD & concentricity
  - Fiber-as-tool
- No need for fiber clocking.
- Fiber endface can be laser polished.
- Dual electrical/optical connection.

Titanium Grade 2

125 micron diameter optical fiber – metal has plastically deformed around it

Invisible contact seam is just above dotted line
Fiber held in place by residual elastic forces

SC Style Ferrolder®

Fully Backward Compatible
Why Titanium Grade 2?

- **Matches the coefficient of thermal expansion (CTE) of Zirconia at 10 ppm/° C:**
  - backwards compatible with ceramic technology
  - ensures good mating over Telcordia temperature range -40 to 70° C
- Formable at room temperature – does not break forming tools, 400 MPa yield stress and low work hardening.
- Laser weldable.
- Superior chemical inertness and corrosion resistance.
- Fibers can be laser polished – much less expensive process than mechanical polishing.
- Protective 1 micron thick thermal oxidation can be grown on the product in air to pass the insertion cycling in the split sleeve 500+ times, as durable as the ceramic and cheap.
- Low elastic modulus of 100 GPa helps as follows:
  - allows for form error on the outer body as it complies to the dimensions of the sleeve – better optical mating.
  - anchors the fiber by residual elastic stresses without causing damage to the fiber or optical loss.
Laser polishing of optical fiber

- Titanium Ferrolder® permits the endface of the fiber to be polished by a laser process that reflows the glass fiber and conditions the surface – cheap and fast.

- The ceramic ferrule and the epoxy are not able to conduct away the heat and are destroyed – restricted to the old expensive mechanical polishing.
Thermal Tests – Optical Loss

<table>
<thead>
<tr>
<th>Objective</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Aging</td>
<td>85°C, 168hr</td>
</tr>
<tr>
<td>Thermal Cycling</td>
<td>-40°C to 75°C, 21 cycles, 168hr</td>
</tr>
<tr>
<td>Humidity Aging</td>
<td>75°C, 95%RH, 168hr</td>
</tr>
<tr>
<td>Humidity Cycling</td>
<td>-10°C to 65°C, 14 cycles, 168hr</td>
</tr>
<tr>
<td>Post-condensation thermal cycling</td>
<td>-40°C to 75°C, 21 cycles, 168hr</td>
</tr>
</tbody>
</table>

Ch2-3: Ferrolder® Sample 2 to Ferrolder® Sample 3
Ch4-5: Ferrolder® Sample 4 to Ferrolder® Sample 5
Ch6-7: Ferrolder® Sample 6 to Ferrolder® Sample 7
Ch8: Ferrolder® Sample 8 to Ceramic connector
Ch9: Ferrolder® Sample 9 to Ceramic connector
Ch10: Ferrolder® Sample 10 to Ceramic connector

nanoPrecision products

4/19/2016
High Temperature Cycling Test – Optical Loss

From -55C to 165C

Time (Hr)

Temperature (°C)

Change in Transmission (dB)

Ch 1-1310nm

Ch 2-1310nm

CIT Requirement per MIL-PRF-64266

4/19/2016
PERRY JOHNSON REGISTRARS, INC.

Certificate of Registration

Perry Johnson Registrars, Inc., has audited the Quality Management System of:

nanoPrecision Products, Inc.
411 Coral Circle, El Segundo, CA 90245 United States
(This is a complex scheme. See Appendix for site specific details.)

(Acéntico called the Organization) hereby declares that Organization is in conformance with

ISO 9001:2008

This Registration is in response to the following scope:

Design, Manufacture and Sale of Complex Parts with Nano Scale Accuracies and Tolerances for the Telecommunications, Data Communications, Consumer Electronics, Aerospace, Medical Devices and Super Computer Market

This Registration is granted subject to the system rules governing the Registration referred to above, and the Organization hereby agrees with the Assessment Body to observe and comply with the said rules.

[Signature]

[Name, Title]

[Note: The use of the USAS registration symbol is in respect to the activities covered by the Accreditation Certificate Number 4385. The validity of this certificate is dependent upon ongoing surveillance.]

[Identification Details]

[Effective Date: August 11, 2015]

[Revision Date: August 20, 2015]

[Certificate No.: C2013-6226-B2]

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ISO & AS9100C Certified
Questions asked by Ind. Apps. committee

- You have listed 4 attributes of titanium that are beneficial for the application, does the fact that the density of titanium is 30% lower than zirconia ceramics have a favorable impact as well?

- The lower Ti mass density may have an advantage in mil-aero, transportation, and future biomedical applications.

<table>
<thead>
<tr>
<th>No.</th>
<th>Manufacturer</th>
<th>Mass, g</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>nanoPrecision</td>
<td>0.3575</td>
<td>All Titanium</td>
</tr>
<tr>
<td>2</td>
<td>Company #1</td>
<td>0.5906</td>
<td>Metal holder</td>
</tr>
<tr>
<td>3</td>
<td>Company #2</td>
<td>0.3400</td>
<td>Plastic holder</td>
</tr>
<tr>
<td>4</td>
<td>Company #3</td>
<td>0.6581</td>
<td>Metal holder</td>
</tr>
<tr>
<td>5</td>
<td>Company #4</td>
<td>0.5554</td>
<td>Metal holder</td>
</tr>
</tbody>
</table>

- Will this stamping process be applicable to other products/applications with different size/shape requirements?

- “Yes” to shape, “Depends” on size. Focus is in the realm of 1 – 10 millimeter overall dimensions, with geometric tolerances over the body of 300 nanometers, and features of 50 microns.

- **Not for automotive body or airframe components**
Titanium is known to rapidly produce tool-wear on dies. How have you overcome this in order to maintain nano-scale tolerances when performing such a high volume of stampings?

Titanium wears tools by galling and adhesive transfer of Ti to the tools that makes them grow inward, and generates particles.

Adhesive transfer is strongly affected by the coefficient of friction, which from 0.1 to 0.8 changes the Ti transfer rate over several orders.

- Stamping tools are produced by a process that achieves $R_a \approx 4$ nm so the friction is inherently low.
- Fastidious in-line maintenance procedures prevent particle accumulation while running.
- Carefully developed blanking tools produce negligible burring, reducing particles in 3-D forming.
- Carefully selected in-line cleaning with detergents and sonication
- Highly sensorized presses with dense load-stroke data to detect load increases and stop, using “big data” analysis techniques and automation.
- Identified and tested galling resistant tool materials, anti-galling wear coatings, wet lubrication for tools (ionic liquids with halogens), all of which we have begun to implement in the processes.
- Learned about the relationships between c/a ratio, cross slip, stacking fault energy and galling of Ti with alloying and want to explore this more deeply.

**Improving a black art, which brings us back to...**
Why are we in Paris today, again?

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Please contact Rand Dannenberg or Ann Huang – we are both at this show

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Non-Titanium Products

Time Permitting
Football Ferrule® Product Line
316 L Stainless Steel

- FootballFerrule® Connector
  - Packaged halves for key account cable assemblers
  - Cable assemblies: samples and custom applications
  - Very strong, positive market reaction

Mated 12-Fiber FootballFerrules® in alignment sleeve

12 - fiber FootballFerrule® in SC connector

4 – Fiber FootballFerrule®
FootballFerrule® and Connector
316 L Stainless Steel

- Stamped ferrule halves (1.5 x 3.5 mm²) clamp fiber ribbon
- Alignment sleeve (transparent purple)
- Ferrule (green & red)
- Slide ferrule into sleeve
- Multiple fibers in ribbon cable

Comparison of FootballFerrule® and MT Ferrule

- Slide ferrule into sleeve
- Multiple fibers in ribbon cable

Connector configurations:
- SC
- FC
- ST
Low Profile Connector Product Line
316 L Stainless Steel and Aluminum

- Low Profile Connectors (LPC): multiple counts family, 4, 8, 12 ...
  - Based on micro-mirror technologies
  - Can combine with FootballFerrule® connector to form jumper cables
  - Available for single and multi mode photonic interconnects
  - Samples provided to major transceiver manufacturers

Micro-mirror connectors

Replace MT ferrule with smaller FootballFerrule®

Epoxy