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Stainless Steel to Titanium Bimetallic Transitions

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Overview

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- Test samples
  - Tensile test
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Introduction

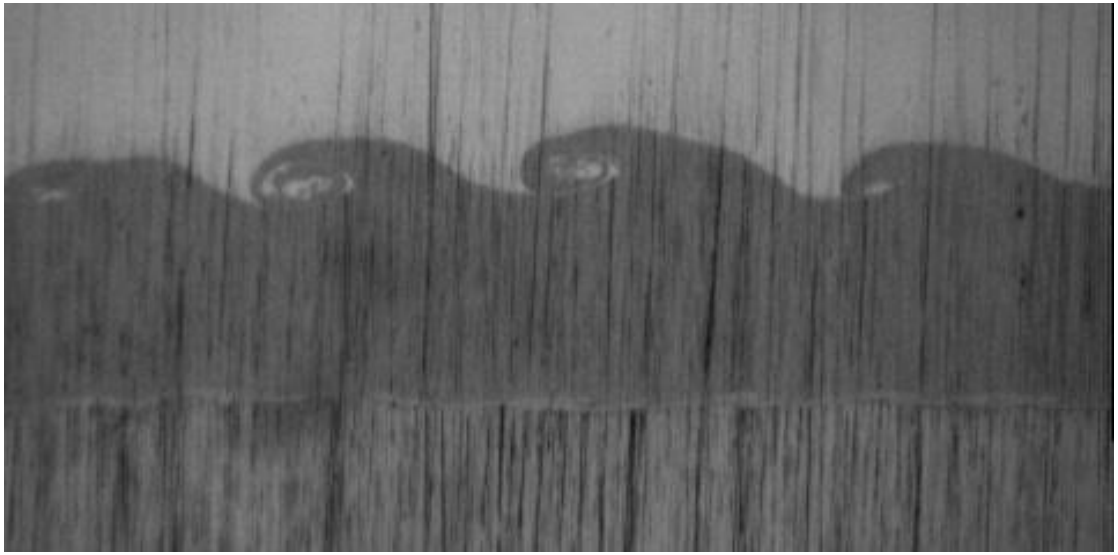
- Used to connect titanium vessels to stainless steel piping
  - Connection holds superfluid helium during operation
- Early development and use in Spallation Neutron Source at Jefferson Lab
  - Added tantalum layer between metals
  - Increased length of metal on either side of the joint
  - Heatsink near joint during welding
  - Weld procedures to limit heating
- LCLS-II vessel includes three transitions
  - One large transition
  - Two small transitions

Base Materials

- 1 inch stainless steel plate
- 0.010 inch tantalum
- 1 inch titanium plate

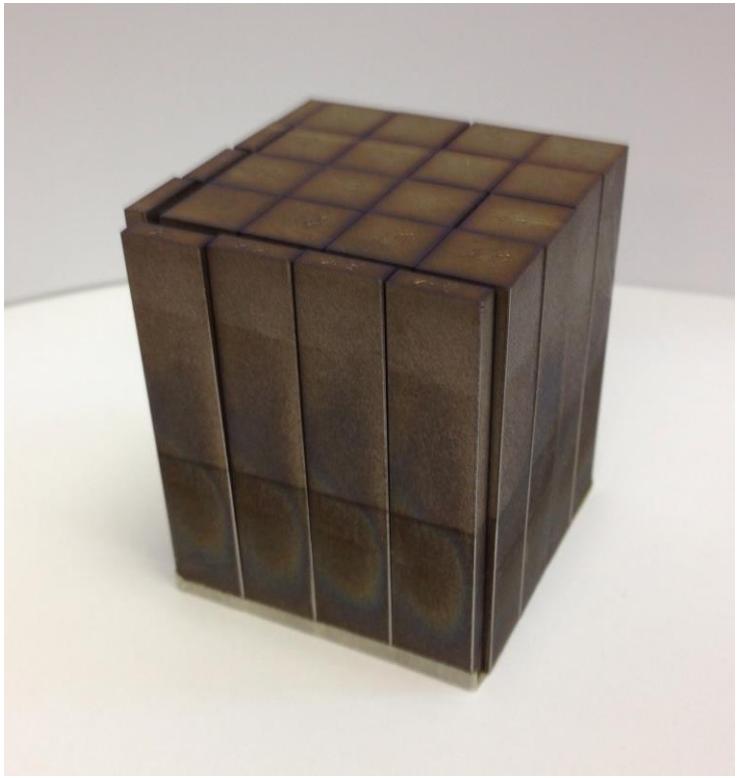
- Explosion welded together by High Energy Metals, Inc.

Ultimate strength of base materials	
Room Temperature (around 295 K)	
SS316L	560 MPa
Ti gr.2	345 MPa
Tantalum	276 MPa
Cryogenic Temperature	
SS316L (4K annealed)	860 MPa
SS316L (4K 20% cold worked)	1734 MPa
Ti gr.2 (2 K)	1117 MPa
Tantalum (70 K)	1034 MPa



Sample Testing

- Block of material cut into 24 samples
- Samples sent to St. Louis Testing Laboratories, Inc.
  - Tensile test at 295 K and 4 K
    - Tensile samples were machined round by the testing lab
  - Charpy test at 295 K and 4 K
    - Charpy samples were notched by the testing lab
- One sample was polished to view joint



Tensile Test

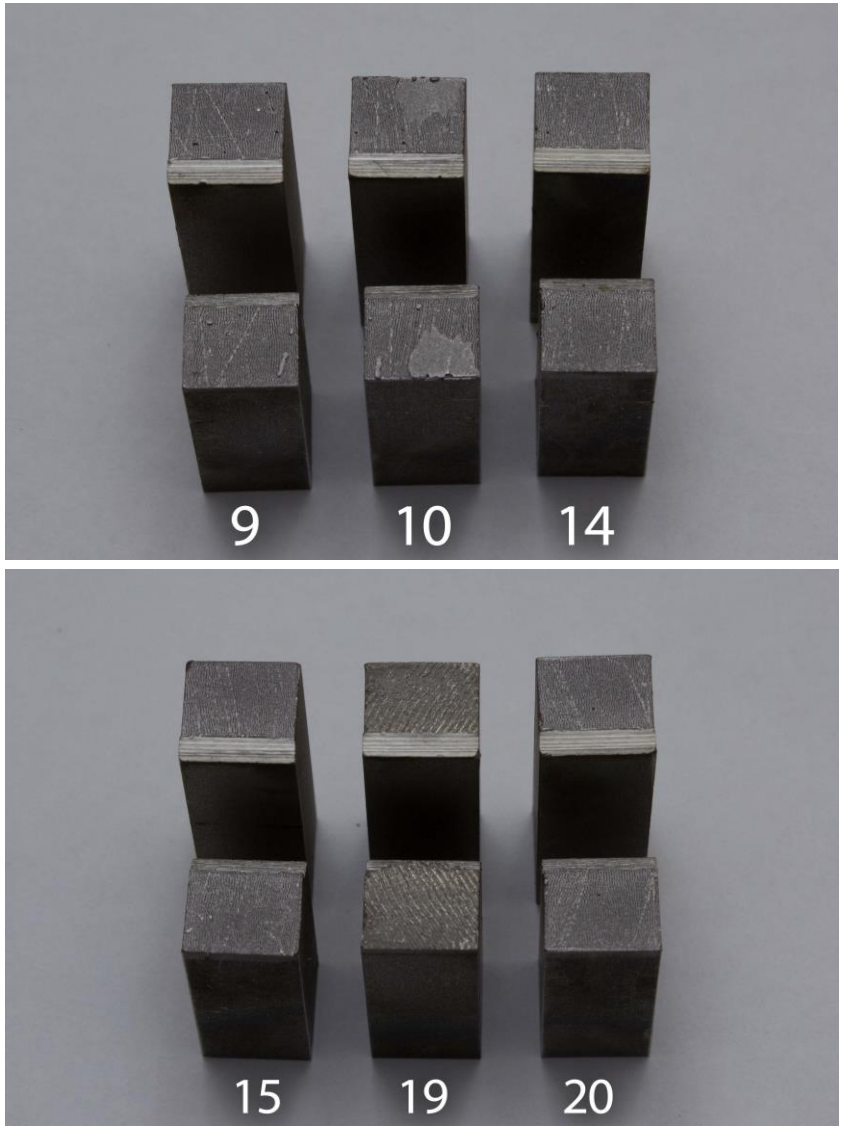
- Room temperature tests shown on top with break in the titanium
- 4 K tests shown on bottom with the break near the joint

Tensile Test - Bond Ultimate Strength	
Test temperature - 295 K	
Sample #4	789 MPa
Sample #5	788 MPa
Sample #7	774 MPa
Test temperature - 4 K	
Sample #12	1138 MPa
Sample #13	1259 MPa
Sample #18	1328 MPa

Charpy Impact Test

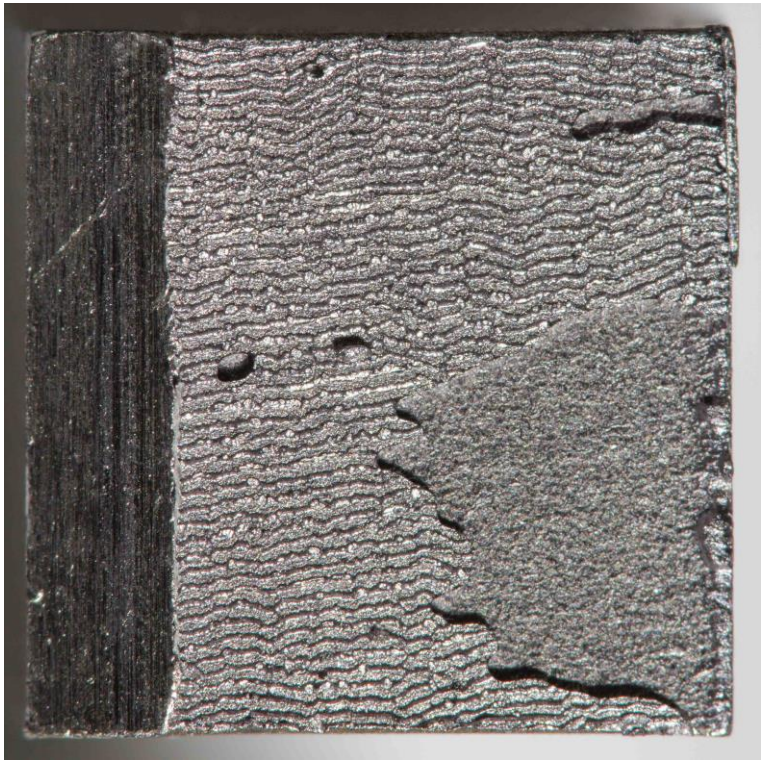
- Room temperature tests shown on top
- 4 K tests shown on bottom
- Break near joint for all samples (notched near joint)

Charpy Test	
Test temperature - 295 K	
Sample #9	9.5 ft-lbs (12.9 J)
Sample #10	6.0 ft-lbs (8.1 J)
Sample #14	7.5 ft-lbs (10.2 J)
Test temperature - 4 K	
Sample #15	2.0 ft-lbs (2.7 J)
Sample #19	2.0 ft-lbs (2.7 J)
Sample #20	1.5 ft-lbs (2.0 J)



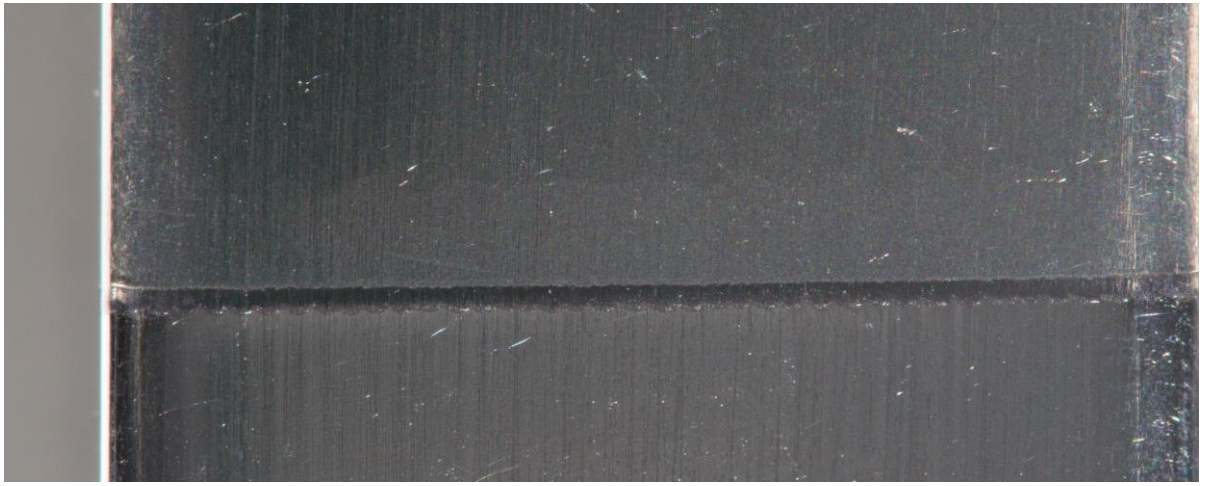
Charpy Impact Test

- Close up of Charpy impact test break
- One of the 4 K Charpy and tensile breaks occurred in the titanium near the joint



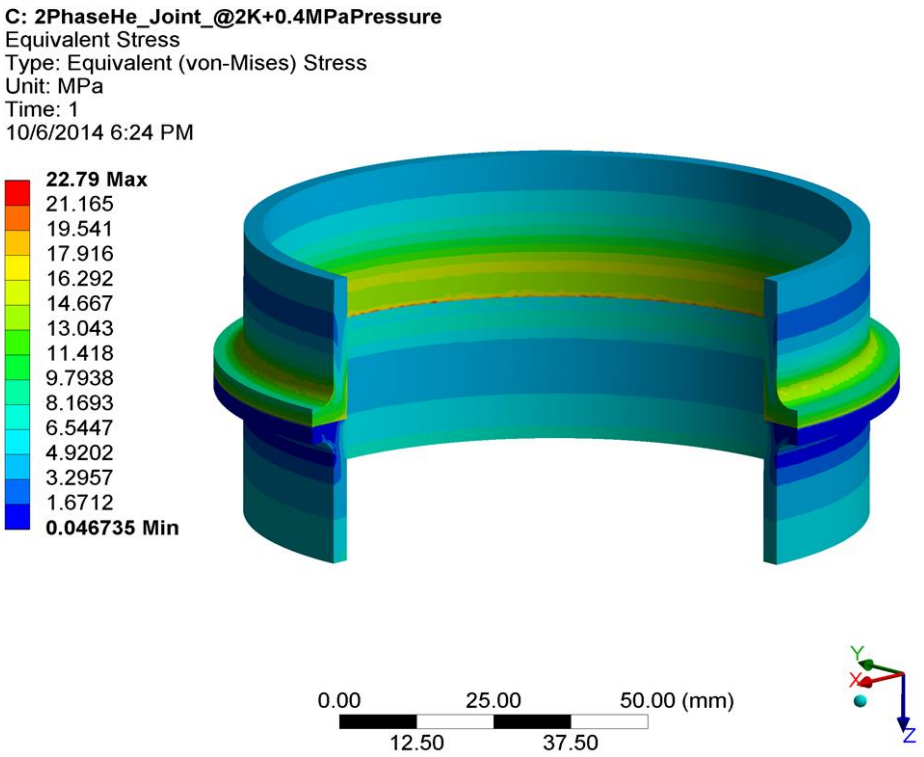
Polished Sample

- A sample was polished on two perpendicular sides
- Polished samples show the waves in the explosion bonded joint
- The boundary in the titanium can also be seen in the samples



Transition Tube Geometry and Analysis

- The geometry for the large transition is shown
- The transition is flared out at the joint to increase the surface area of the explosion weld joint
- The stress in the transition is due to differential thermal contraction and internal pressure



Transition Tube Tests

- The transition was welded into a test tube
- Tests performed
  - Radiograph joint
  - TIG weld cap and extension tube
  - Radiograph joint
  - Cold shock to 77K - 12 times
  - Leak check
  - Radiograph joint

Conclusion

- A bimetallic transition joint from titanium to stainless steel has been analyzed and tested
- The transition has been used in LCLS-II dressed cavity tests at Fermilab and Jefferson Lab
- The transition is part of the LCLS-II cryomodule design

- Future work
  - Tensile and Charpy test base material before and after explosion welding
  - Additional study on boundary in titanium near the joint