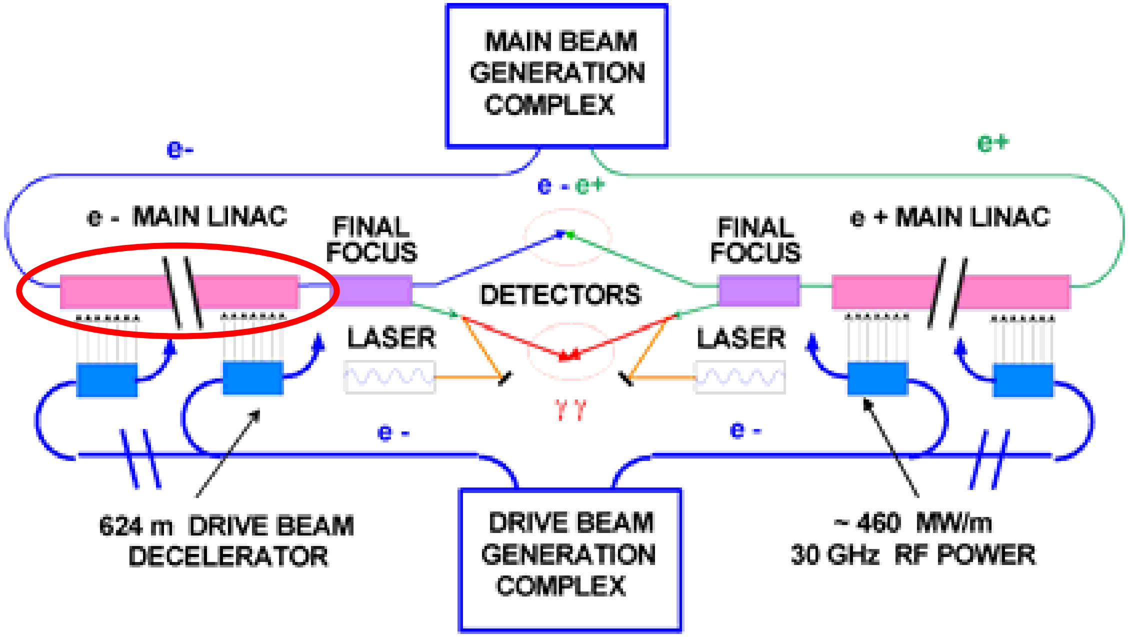
Bimetals for CLIC. Introduction.

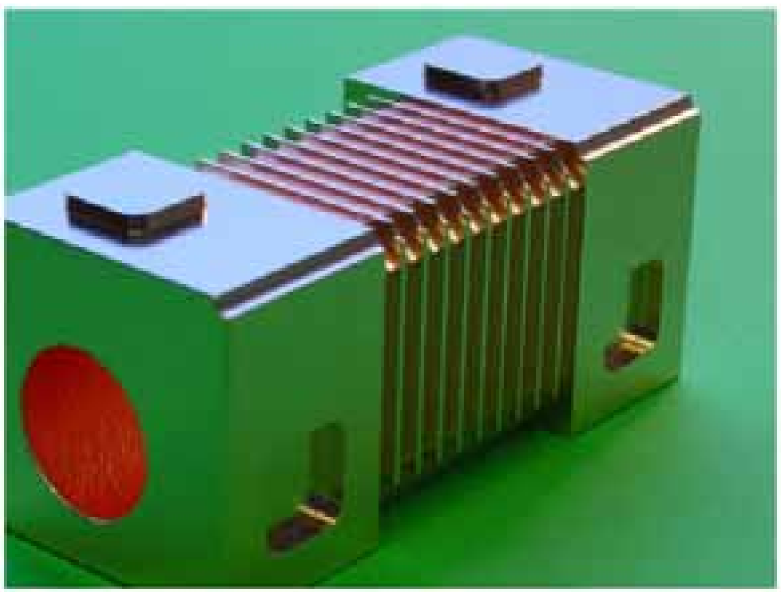
- CLIC (Compact Linear Collider) two beam scheme:



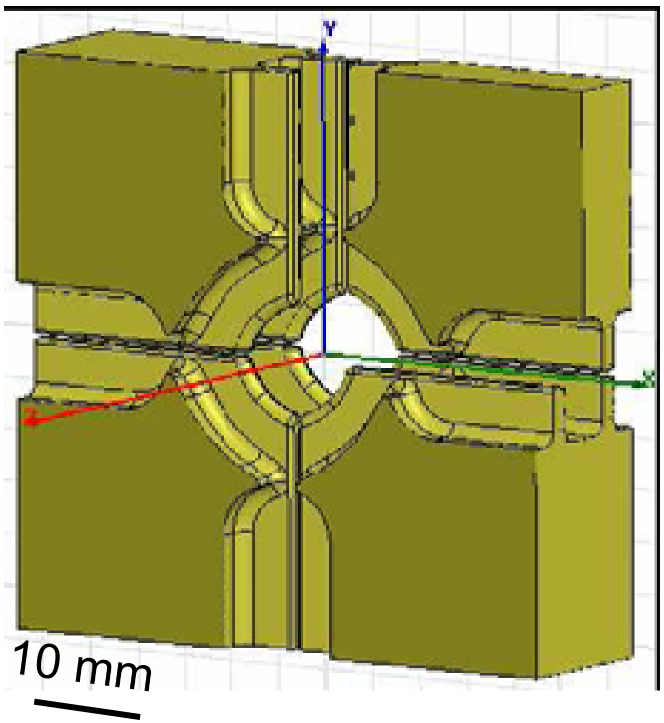
- Acceleration of main e+/e- beam to 1.5+1.5 TeV: use high accelerating field to limit the machine length (15+15 km)
- Demonstration of technical feasibility for 2010.
- Structure technology development (amongst other issues)

Bimetals for CLIC. Introduction.

- Hybrid Dumped accelerating Structures (HDS) concept.



▲ Copper prototype of ¼ of HDS structure containing 10 cell cavities.



▲Detail of HDS cells geometry.

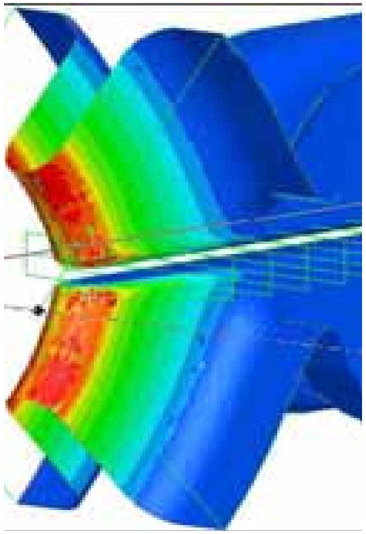
The material problem. High E field regions.

Iris: regions with surface electric field >300 MV/m

⇨ high field and breakdown events

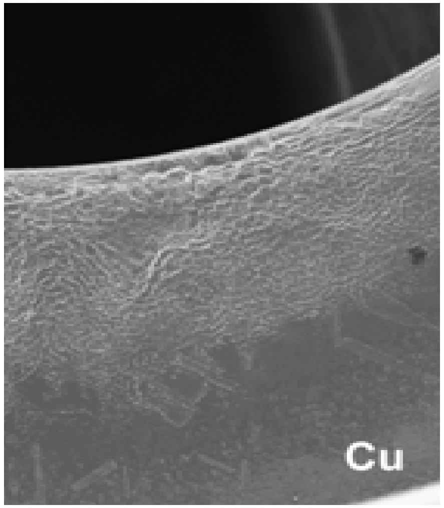
⇨ geometry modification

⇨ use of Mo, or alternative refractory metal.



◄Surface electric field distribution in HDS cell.

▼Accelerating structures in Mo and Cu after RF tests at SLAC.



The material problem. High H field regions.

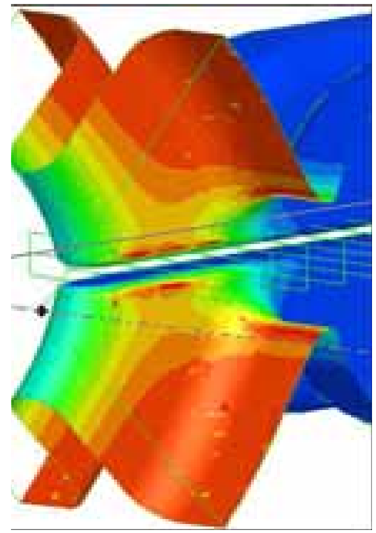
Periphery: regions with pulses of magnetic field inducing surface currents

⇨ $\Delta T = 56$ K, 10^{11} cycles

⇨ pulsating compressive stress 0 to 155 MPa

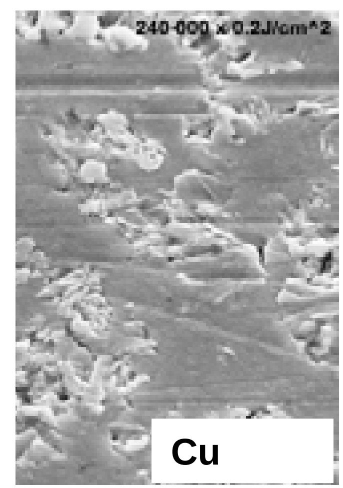
⇨ fatigue surface damage

⇨ use of CuZr, or improved mechanical strength high conductivity alloy.

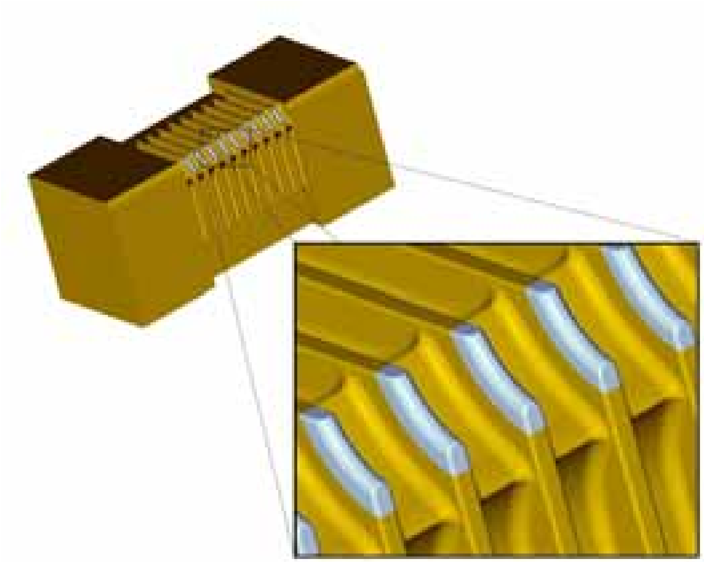


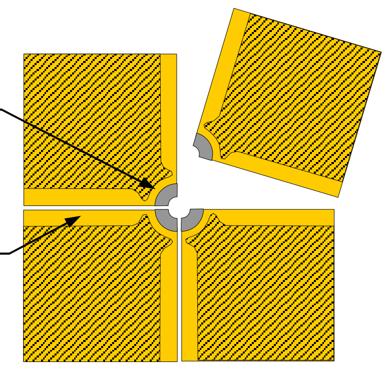
◄Surface magnetic field distribution in HDS cell.

▼Surface of Cu and CuZr specimens after equivalent tests of thermal induced fatigue (laser simulation)



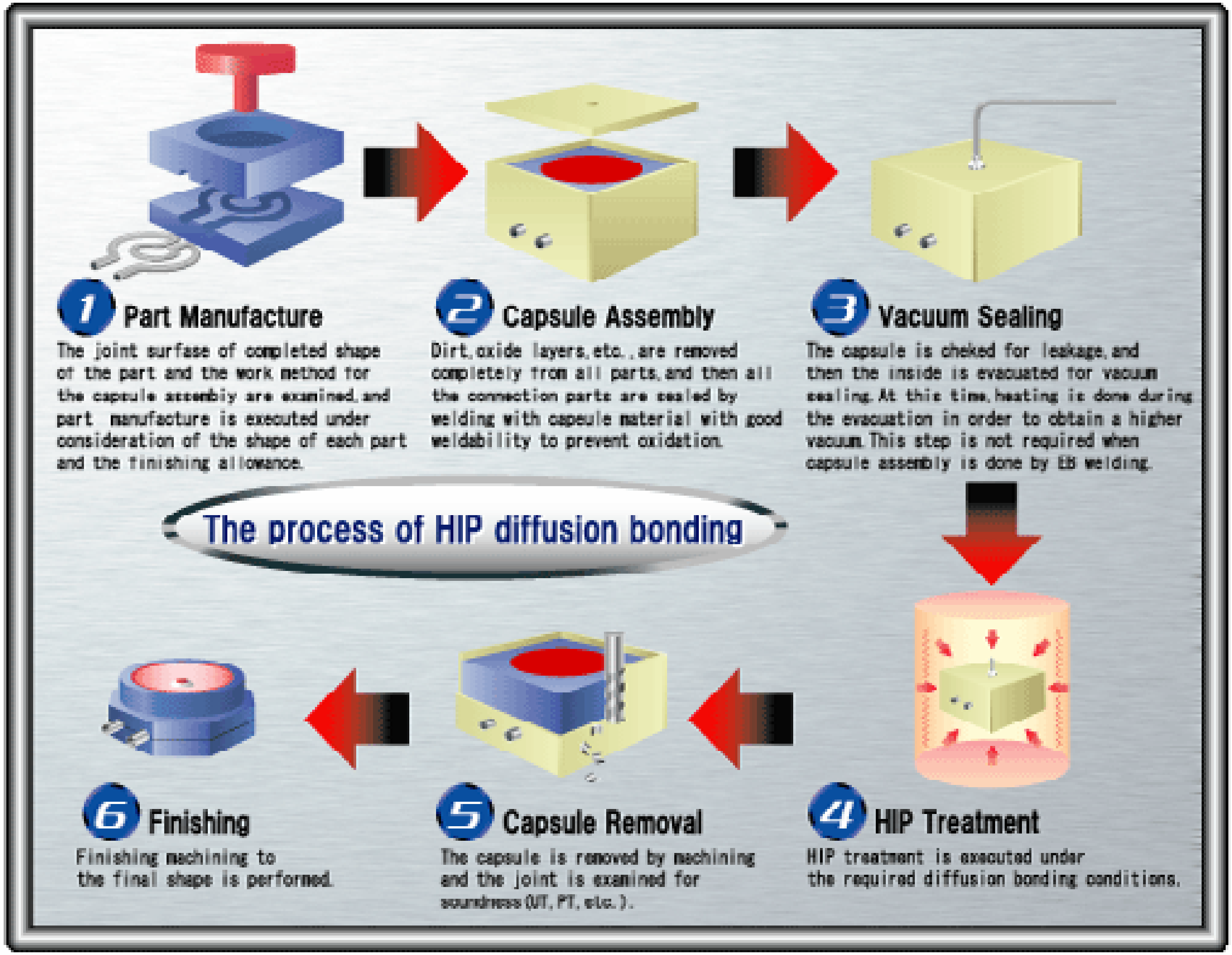
Bimetallic solution for HDS structures





- TS-MME group in charge of producing a prototype of HDS11 for test on CLIC Test Facility III
  - **Bimetallic**: CuZr matrix, Mo insert
  - Four quadrants 30x30x70 mm^3
  - Machined with shape tolerance **± 5 µm on the critical regions**
- Aiming the series fabrication of future structures
  - for ~20 km i.e. ~300000 pieces
  - with shape tolerance ± 1 µm and Ra ≤ 0.05 µm

HIP-diffusion bonding. Technique.



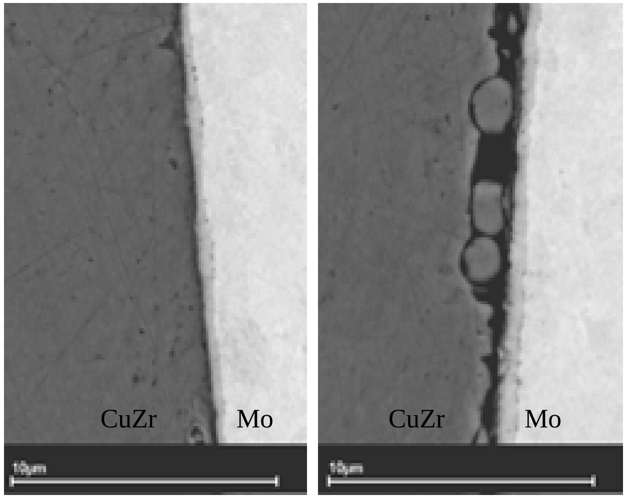
Courtesy of METSO

HIP-DB. Historic of prototypes (METSO)

- Insert 99.97 %Mo, matrix 99.85Cu-0.15Zr
- 1^{st} piece: Ø50 mm x 100 mm, insert Ø5 mm
  - Only characterization
- 2^{nd} piece: Ø87 mm x 300 mm, insert Ø8.6 mm
    - From forged CuZr bar for functional diameter
    - Improved hole drilling (gun drill)
    - Improved cleanliness of interfaces before insertion of Mo bar
    - Shorter stay at HIP (6 h vs. 10 h), but lower cooling speed (0.16 °C/s vs 0.056 °C/s)
  - Portion for characterization and machining test
  - Portion for bi-metallic HDS11 prototype
- Proposals for further development (improved homogeneity, HIP+CIP, HIP+explosion,…)

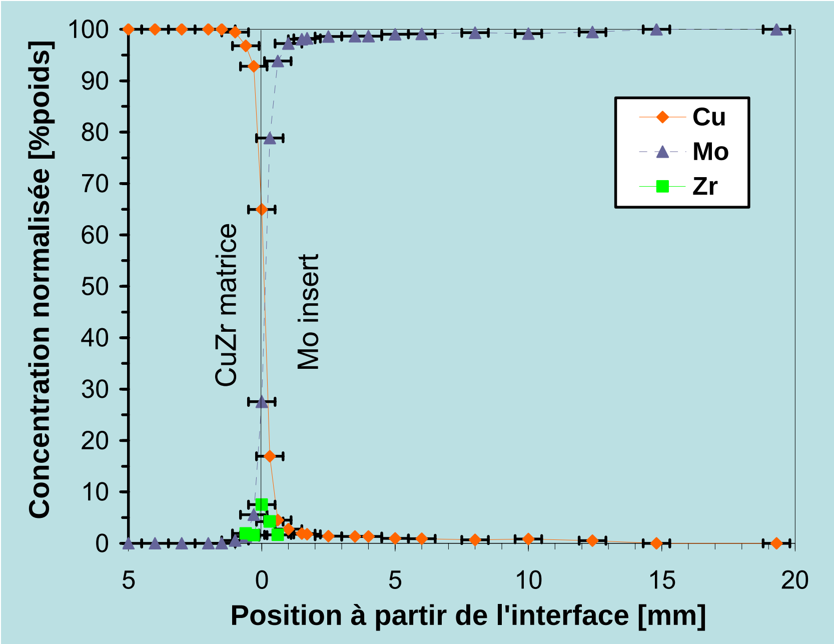
HIP-DB. Characterization (CERN)

- Characterization at CERN
  - Interface
    - Microstructure



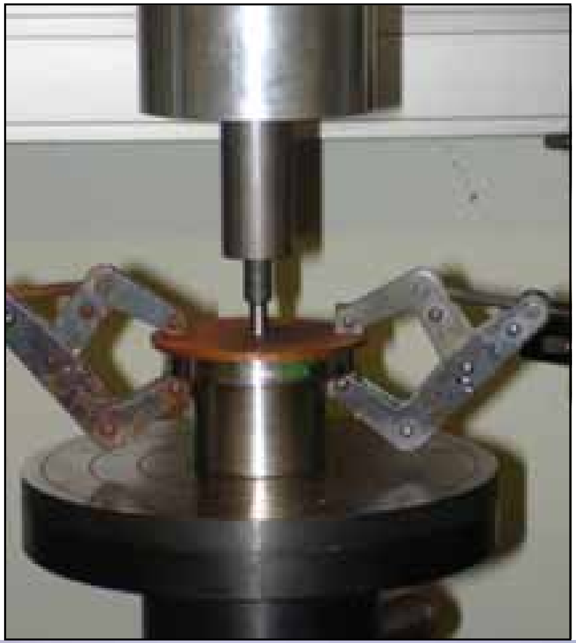
HIP-DB. Characterization (CERN)

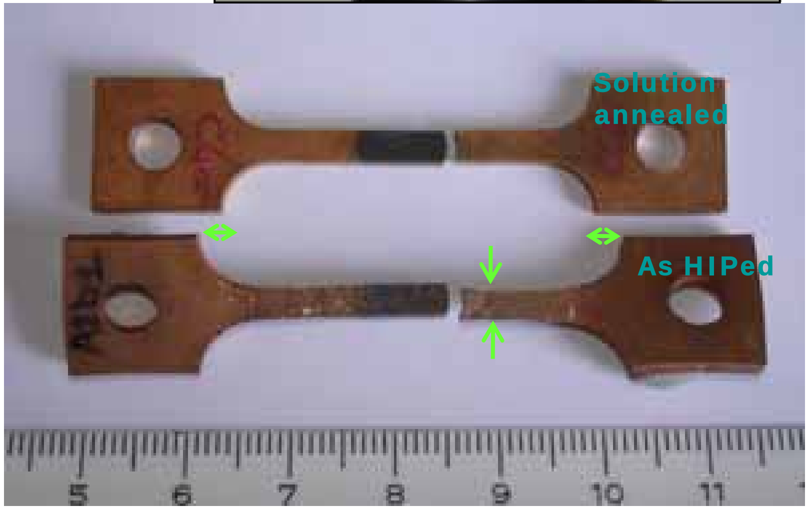
- Characterization at CERN
  - Interface
    - Microstructure
    - Composition profile



HIP-DB. Characterization (CERN)

- Characterization at CERN
  - Interface
    - Microstructure
    - Composition profile
    - Mechanical strength





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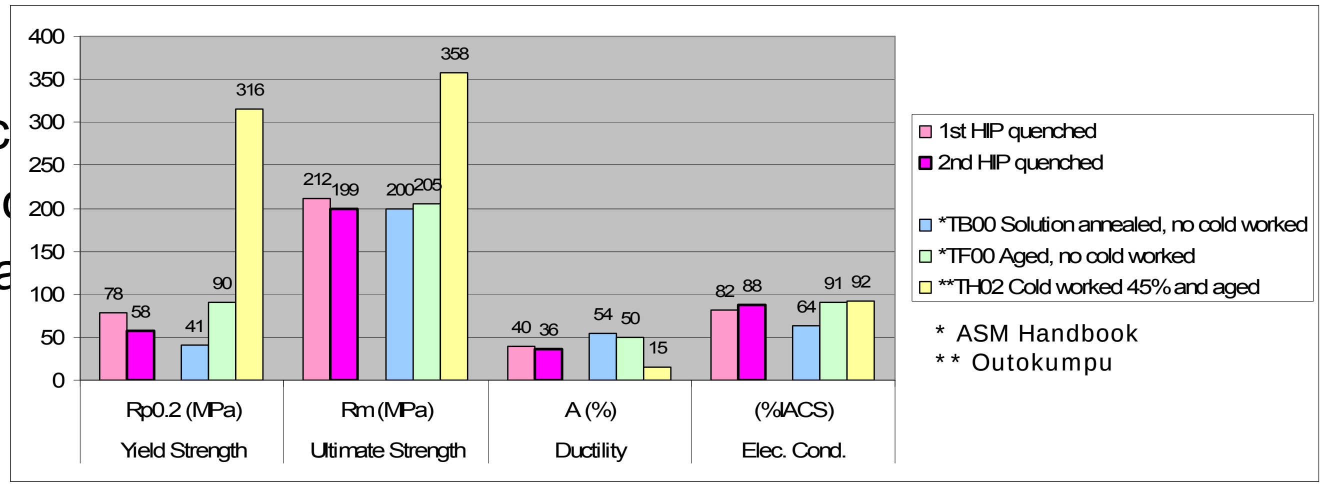


  - Matrices
    - Microstructure
    - Mechanical strength
    - Electrical conductivity
    - Optimization of post-treatments

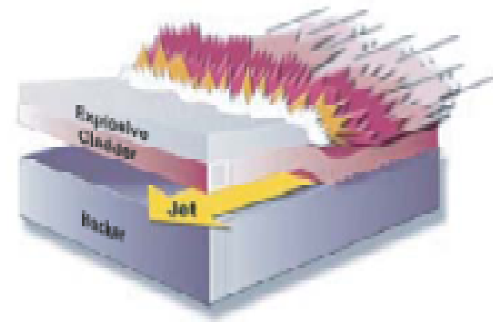
HIP-DB. Characterization (CERN)

- Characterization at CERN
  - Interface
    - Microstructure
    - Composition profile
    - Mechanical strength
  - Matrices
    - Microstructure
    - Mechanical strength
    - Electrical conductivity
    - Optimization of post-treatments
- Outputs
  - Discussion / improvement ideas

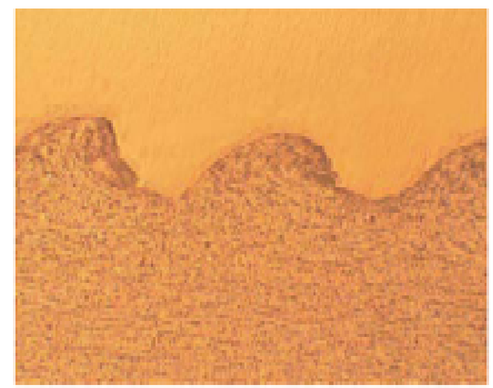
Explosion bonding. Technique

- "Solid state welding process that is used for the metallurgical joining of dissimilar metals. The process uses the forces of controlled detonations to accelerate one metal plate into another creating an atomic bond… is considered a cold-welding process which allows metals to be joined without losing their pre-bonded properties."

1. Metals' surfaces are ground and fixtured parallel.
2. Special formulated explosive powder is placed on the cladder surface.
3. Detonation front travels uniformly across the cladder surface from the initiator.
4. Cladding metal collides with backer at a specific velocity and impact angle.
5. Momentum exchange causes a thin layer of the mating surfaces to be spalled away as a jet.
6. Jet carries spalled metal and oxides from the surfaces ahead of the collision point.
7. Thin layer of "Micro-fusion" 10^{5} inch thick is formed at the characteristic wavy weld line.
8. Force of several million psi forces metals into intimate contact while metallurgical weld solidifies across the complete surface.
9. Speed of the explosive detonation does not allow time for bulk heating of metals.
10. Detaclad® process assures that the backer materials retain specified physical properties and the cladding material retains the specified corrosion resistance properties.



Explosion Welding


Photomicrograph of a typical explosion weld

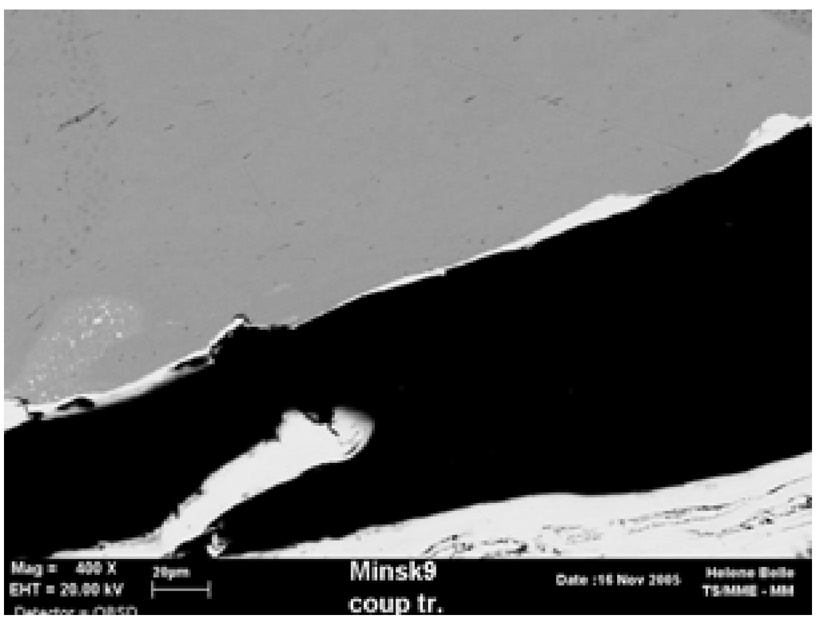
http://www.dynamicmaterials.com

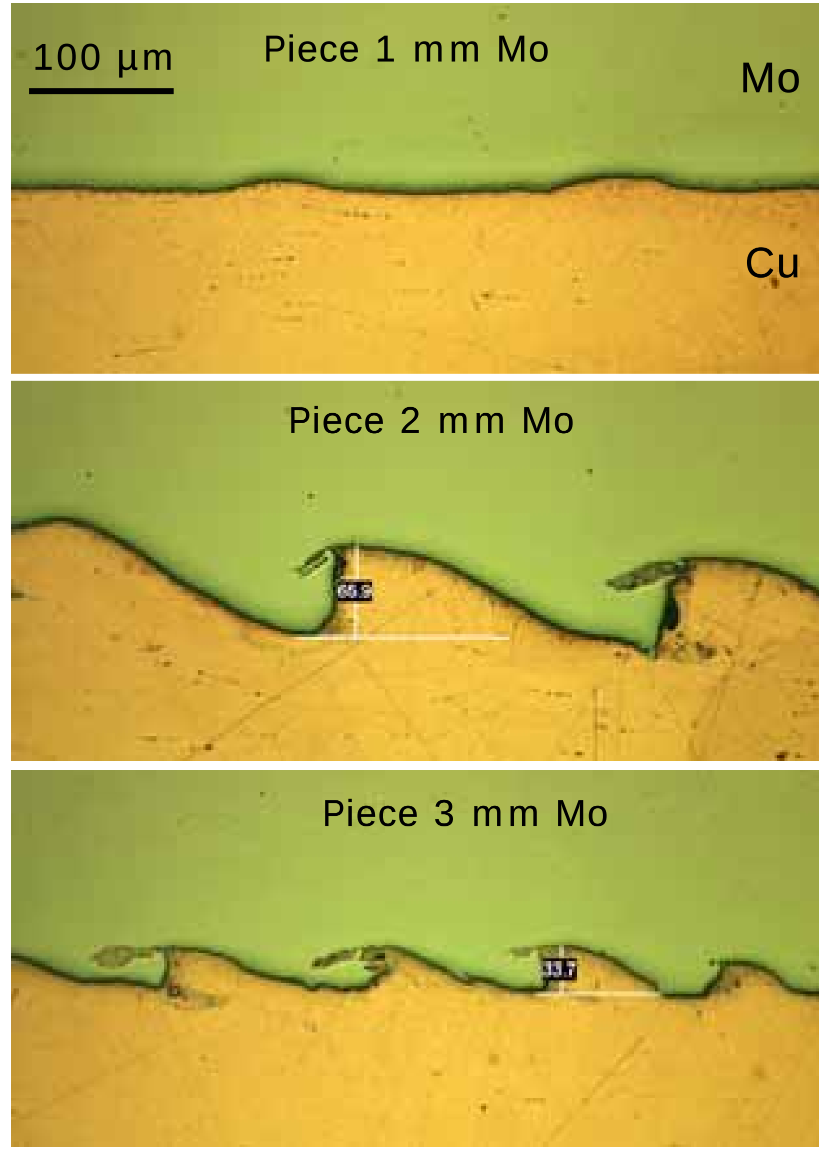
Explosion bonding. Historic of prototypes (Minsk)

- 1st two pieces
  - Mo and Cu procured by Minsk
  - Flat and grooved pieces
  - Characterisation
- 2nd three+1 pieces
  - Mo and CuZr plates procured by CERN
  - Mo thicknesses: 1 mm, 2 mm and 3 mm
  - Only flat pieces
  - Characterisation
- Proposal for 3rd phase
  - Portions for Machining tests (HDS6)
  - Portions for bi-metallic HDS11 prototypes

Explosion bonding. Characterization (CERN)

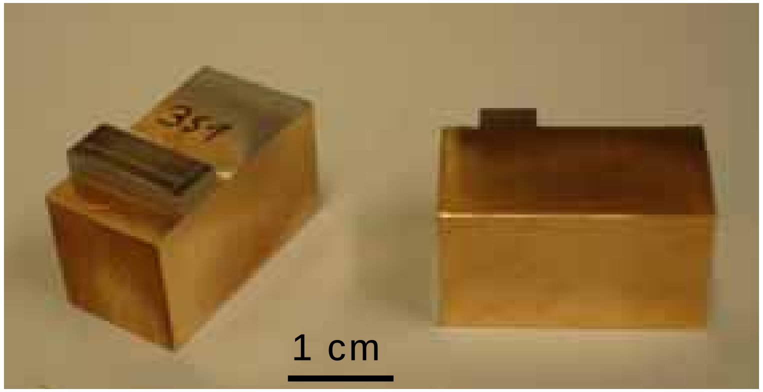
- Characterization at CERN
  - Interface
    - Microstructure

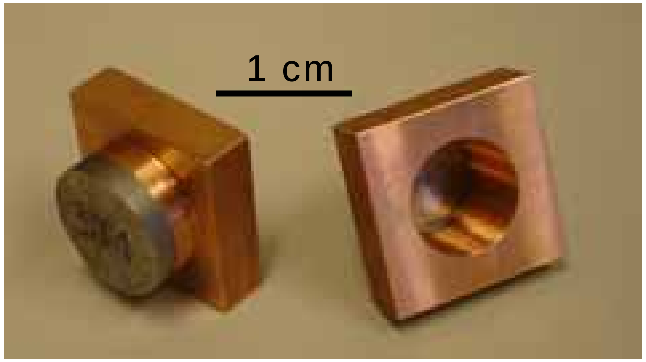


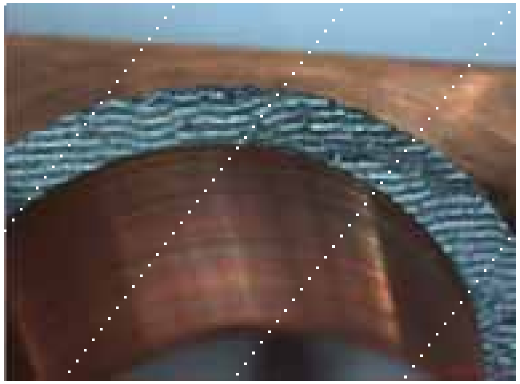


Explosion bonding. Characterization (CERN)

- Characterization at CERN
  - Interface
    - Microstructure
    - Mechanical strength

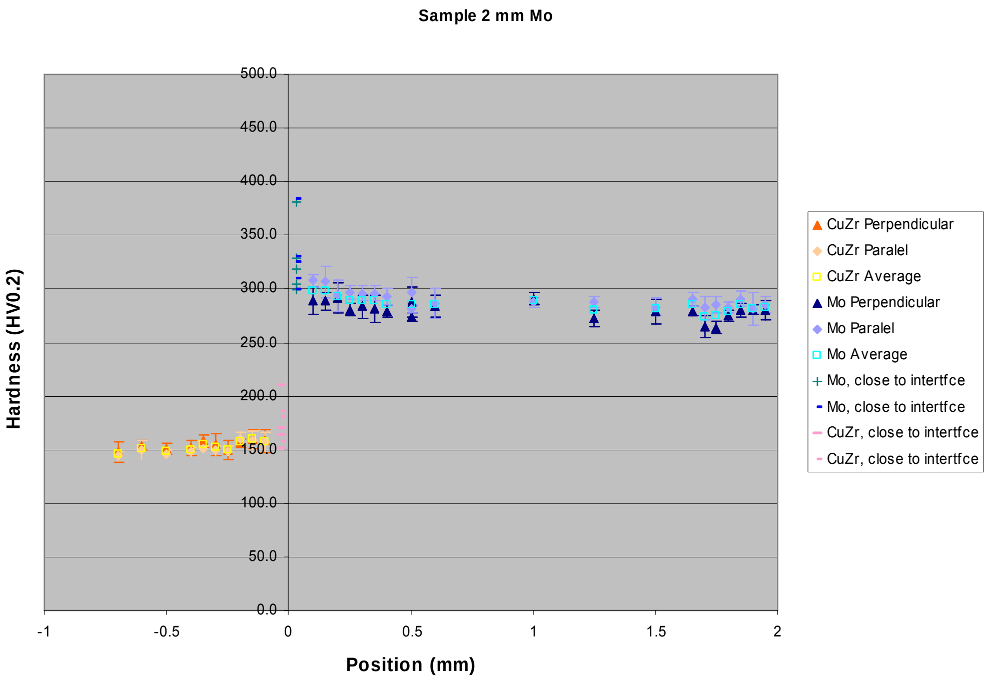






Explosion bonding. Characterization (CERN)

- Characterization at CERN
  - Interface
    - Microstructure
    - Mechanical strength
  - Matrices
    - Microstructure & hardness profile
    - Temper optimized before bonding



Explosion bonding. Characterization (CERN)

- Characterization at CERN
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    - Mechanical strength
  - Matrices
    - Microstructure
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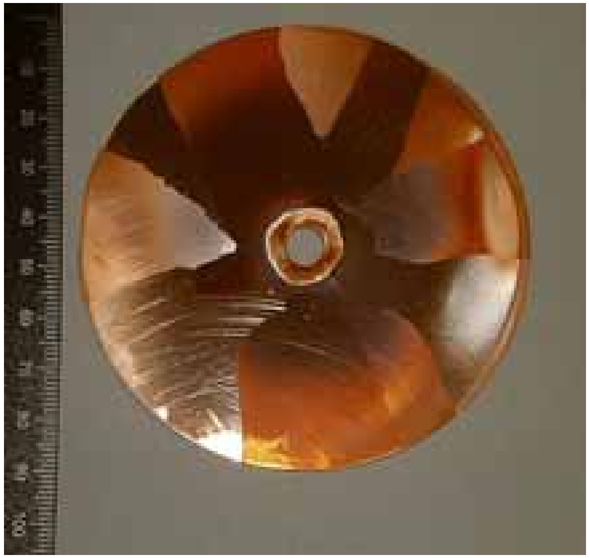
- Outputs
  - Discussion / improvement ideas

Other techniques



▲Coextrusion with intermediate layer (Lutch).

◄Vacuum casting over a solid insert (Starck).