

## Objective:

To develop a manufacturing process for seamless Ta tube with a uniform fine-grain microstructure, with near circumferentially uniform texture, and good co-deformability in a Cu matrix.

## Problem:

Economically viable Ta tube is generally produced by seam welding a rolled Ta sheet. Differences in properties along the circumference of the tube cause non-uniform co-deformation of the Ta layer in a composite conductor.

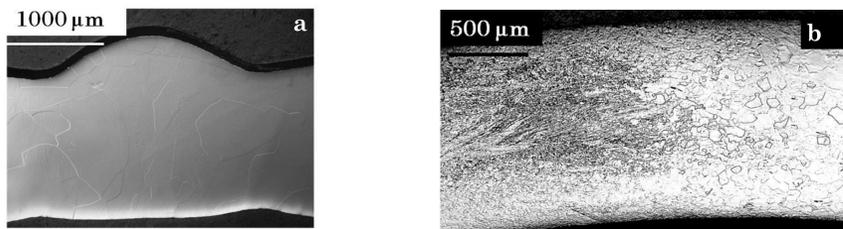


Figure 1. Microstructure variation in Ta tube due to fabrication methodology: a) Electron Beam Weld bead with solidification structures of the order of 300-500 μm, and b) variation in the base material, incomplete recrystallization, possibly due to non-uniform strain (cold work) in material.

## Microstructure and deformation characteristics:

- Finer grain sizes in Ta sheet lead to better deformability in a composite conductor. Ta layers of thickness down to 2 μm, have been achieved in a Cu matrix without any intermediate fracture of the wire.
- Achieving uniform microstructures in Ta is a challenge; viable bulk processing strategy is severe plastic deformation (SPD) by Equal Channel Angular Extrusion (ECAE).

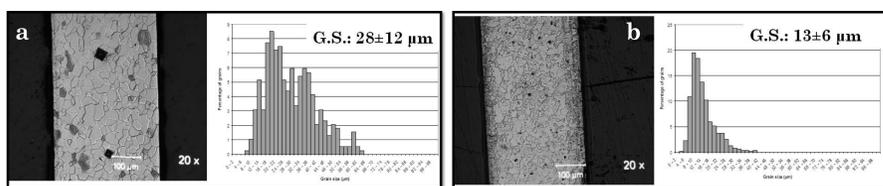


Figure 2. Comparison between Ta sheet microstructures. Processing prior to rolling affects the final sheet microstructure in terms of grain size and distribution. Micrographs represent Ta sheets processed by: a) conventional processing, b) SPD by ECAE.

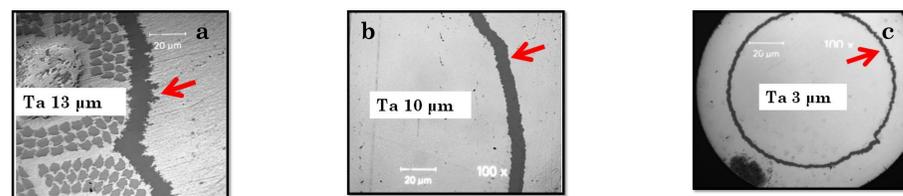


Figure 3. Comparison between Ta sheet deformation in a Cu matrix. Commercial conductor using conventional Ta sheet shows higher interface roughness at the same Ta layer thickness compared to SPD processed fine grain Ta, (b) which can be further drawn as shown in (c).

## Motivation: Tube ECAE (tECAE) and weld "healing"

- SPD can be applied directly to seam welded tubes leading to weld "healing".
- Convergence in properties in the weld and parent metal region is expected.

### Example of weld healing in a Nb tube

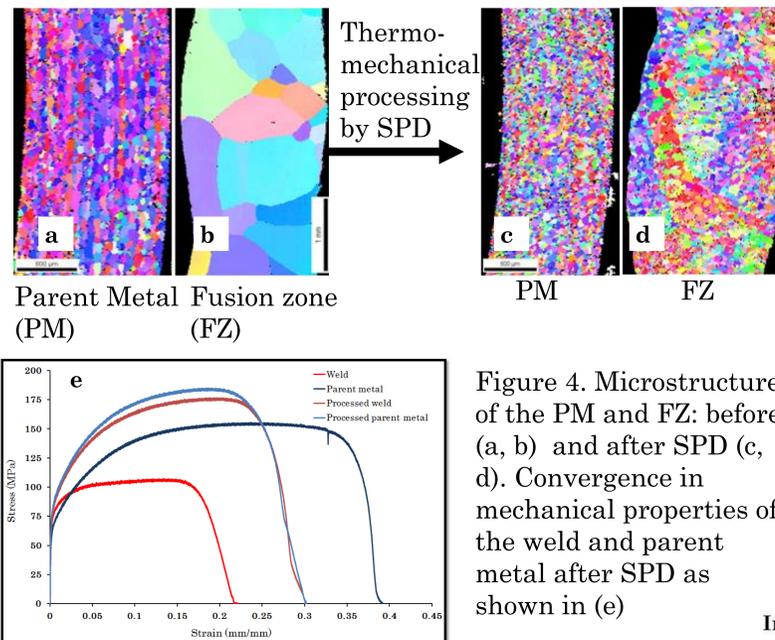


Figure 4. Microstructure of the PM and FZ: before (a, b) and after SPD (c, d). Convergence in mechanical properties of the weld and parent metal after SPD as shown in (e)

## tECAE: Cu-Ta-Cu composite

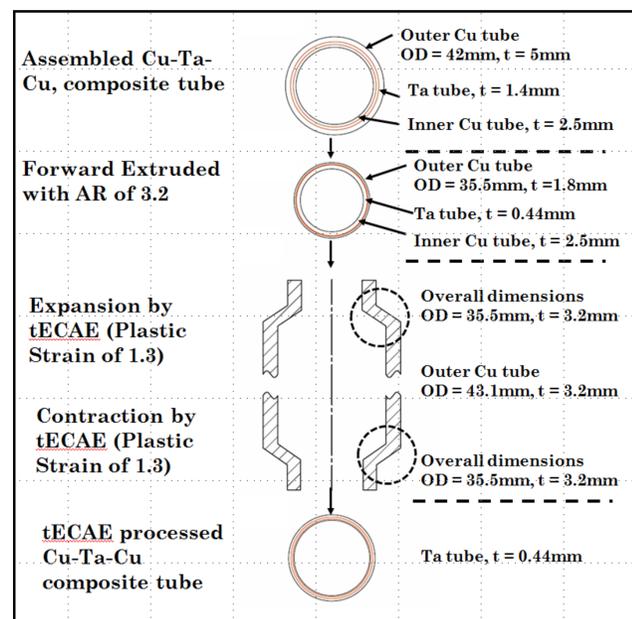


Figure 5. Schematic of the tube ECAE process as applied to a seam welded Ta tube in a Cu composite. For a die angle of 135°; the total strain that a tube undergoes in an expansion-contraction (E/C) cycle is 1.9. The dimensions of the tube remains unchanged during the process.

## Results:

1. Microstructure and hardness after tECAE and recrystallization of a seam welded Ta tube.

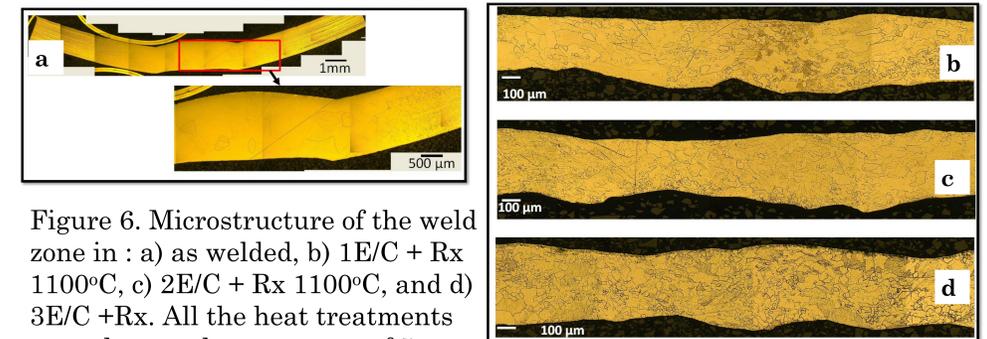


Figure 6. Microstructure of the weld zone in : a) as welded, b) 1E/C + Rx 1100°C, c) 2E/C + Rx 1100°C, and d) 3E/C + Rx. All the heat treatments were done under a vacuum of  $5 \times 10^{-5}$  torr or higher.

2. Recrystallized Ta tubes with circumferentially uniform microstructure.

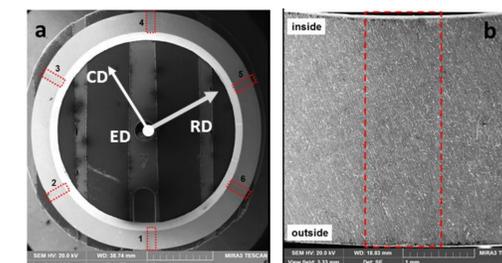


Figure 7. Sample orientation along the circumference of the tube. ED= Extrusion Direction, RD = Rolling Direction, CD = Circumferential Direction. Through thickness scans 60° apart across the circumference.

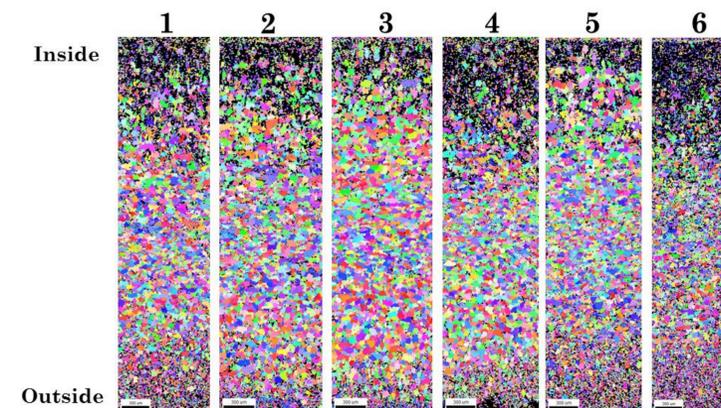


Figure 8. OIM maps of circumferential scans indicate that random orientations along the through thickness irrespective of the location of the sample.

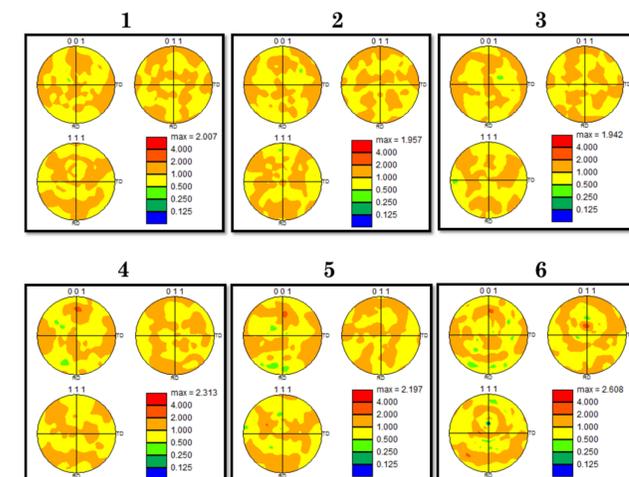


Figure 9. Pole figures (PF) along the extrusion direction corresponding to circumferential scans. The texture strengths are relatively weak irrespective of the location of the sample.

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