Joining of the armor material tungsten to copper components, which will act as low temperature heat sinks in divertor application, is a challenging process and showed lacks due to their restricted miscibility and alloyability. Electroplating has the feature to generate interlayers in Cu or Pd to react with both alloys W or Cu.

This work was performed to demonstrate that electroplating has the feature to generate diffusion bonded joints of the armor material tungsten to copper components. Testing for the demonstration of future fusion relevant materials and components will be performed applying the electrochemical plating tool and bonding.

The joined joints were qualified by thermomechanical testing for the demonstration of future applicability in fusion development.

**Motivation**

Application of electroplating technology for joining low temperature heat sinks

**Joining of the armor material tungsten to copper components**

- **View of alloy sequence**
  - W armor
  - Cu or CuCrZr
  - Interlayer
  - W part

**Mechanical behavior and characterization of joints**

- **Behavior of joints bonded at 700°C vs bonding time**
  - Bonding time: 1 hour
  - Pressing load: 7 Mpa
  - First reaction at cone ends

**Surface conditioning and electroplating of interlayers**

- **Surface conditioning**
  - Etching by K$_2$[Fe(CN)$_6$]$_3$ + HCl
- **Pd plating on tungsten**
  - Pd deposition from aqueous electrolytes was performed similarly to Cu or Ni plating with a current density of 8 mA/cm² and pH value of 7 to 8.
  - **Characterization of plating layer and joined samples**
  - Pd plating on tungsten
  - Interlayer
  - W part

**Joints processed by electroplating**

- Tools and plating development for adapted joints
  - The development of joining technology by electroplating consists of the two main parts:
    - Electroplating
    - Joining by diffusion bonding
  - Pd was selected as interlayer metal to improve reactions. Electroplating from aqueous electrolytes was performed similarly to Cu or Ni plating with a current density of 8 mA/cm² and pH value of 7 to 8.

**Mechanical characterization of joints**

- **Shear testing of diffusion bonded samples**
  - Sample: Size Diameter 8 mm
  - Temperature range: RT
  - Atmosphere: Air
  - During heating: Preloading of 0.03 kN
  - Displacement rate: 0.01 mm/s

The investigations showed that electroplating is an effective technology in the field of the joining of fusion relevant materials and components. Under industrial view Pd plating on Cu alloy instead on W is recommended. Reactive Pd layers were successfully deposited on W, Cu and CuCrZr by electroplating to obtain improved bonding. Pd reacted with both parts W and Cu / CuCrZr to be joined as expected. Under industrial view Pd plating on Cu alloy instead on W is recommended. Mechanical testing was performed at RT with shear strength of around 100 MPa. Shear strength increased with bonding time. W – CuCrZr joints showed lower strength compared to W – Cu joints. The strength of CuCrZr may initiate microcracks due to expansion mismatch. An additional layer of pure Cu between Pd and CuCrZr may be recommended.

**Conclusions**

- Reactive Pd layers were successfully deposited on W, Cu and CuCrZr by electroplating to obtain improved bonding
- Pd reacted with both parts W and Cu / CuCrZr to be joined as expected
- Under industrial view Pd plating on Cu alloy instead on W is recommended
- Mechanical testing was performed at RT with shear strength of around 100 MPa
- Shear strength increased with bonding time
- W – CuCrZr joints showed lower strength compared to W – Cu joints
- The strength of CuCrZr may initiate microcracks due to expansion mismatch
- An additional layer of pure Cu between Pd and CuCrZr may be recommended

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**Kit – The Research University in the Helmholtz Association**