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He-Cooled Divertor for Demo: Technological Study on Joining Tungsten Components with Titanium Interlayer

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Introduction

- The He-cooled divertor concept HEMJ for DEMO (Fig. 1) has been investigated at KIT with aim to reach 10 MW/m².
- HEMJ design uses: impinging He jets @ 10 MPa, 600°C,
- hexa. W tile (SW 18) brazed to WL10 thimble (Ø15x1mm),
- modular system: 1-finger, 9-finger modules, div. cassette,
- ODS Eurofer structure (connection via transition pieces).

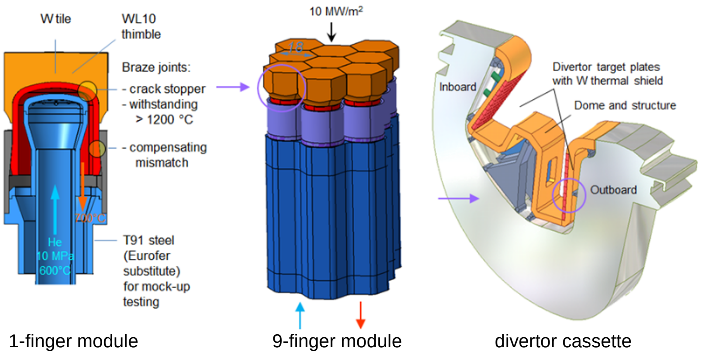

Fig. 1: He-cooled modular divertor with jet cooling (HEMJ).

Requirements for the W–W joint:

- Crack stopper function (sufficient toughness of interlayer)
- Resisting high operating joint temperature > 1200 °C
- Using low-activation interlayer material, having:
- high melting point, high thermal conductivity, high toughness,
- and good bonding capability with W (no intermetalic phase)

→ This leads to the use of Titanium (Tm = 1668°C) as interlayer.

Method A): W–W brazing with Ti interlayer (Fig. 2)

- Using induction furnace,
- a stack of samples: W cylinder (Ø12x12), Ti sheet (Ø10x1, 99.999% grade), ¼ of a W disc (Ø20x1),
- aceton sample cleaning,
- pyrometer T measurement (range 500–2000 °C, accy ± 50 °C).

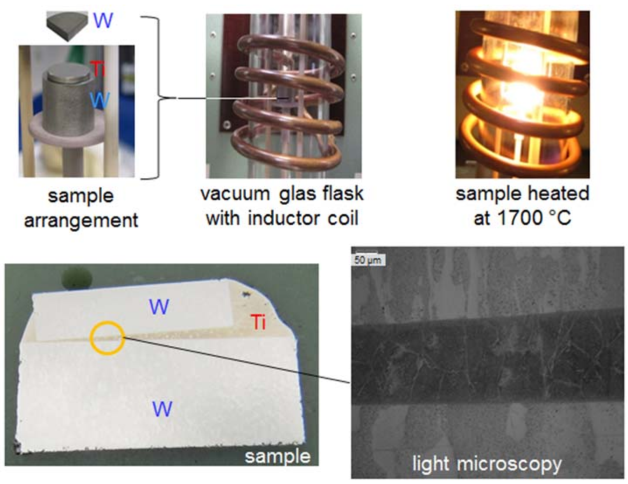

Fig. 2: W–W brazing test w. Ti interlayer in induction furnace.

- W-W brazing procedure:
- sample glass flask flushed with argon and evacuated @ 1 mbar,
- brazing temp. ~1820 °C @ W surface (heating rate ~2 K/s),
- hold time ~2.5 min (total 12 min).
- Results: no cracks and delamination of flat W–Ti interfaces, but
- undesired W grain growth and W diffusion phase in Ti observed.

Method B): W–W diffusion bonding with Ti interlayer (Fig. 3)

- Using vacuum furnace (a) with unaxial pressing device,
- WL10 thimble and tile-like W cyl. sample (99.97 wt% purity) with true to original interface geometry (b),
- Ti sheet (Ø10x1, 99.999% grade, 3 pieces) (b),
- aceton sample cleaning.
- Diffusion bonding (DB) procedure:
- bonding temp. ~900 °C,
- constant displacement rate of 1 µm/s,
- max. surface pressure ~150 MPa,
- hold time ~1 h,
- vacuum ~$5 \cdot 10^{-5}$ mbar.
- Results: perfect bonding of W–Ti at interfaces (c) (d),
- no W grain growth and negligibly small W inter-diffusion layer in Ti observed (d) (e),
- no excessive hardness along the joint interfaces (f).

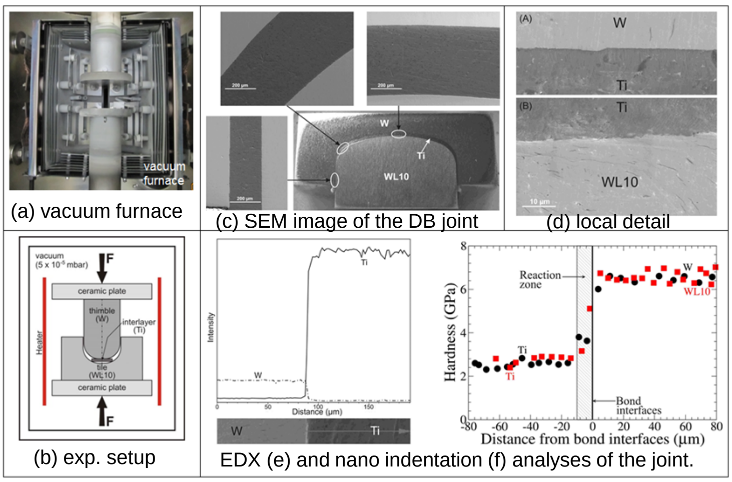

Fig. 3: Diffusion bonding of W-W connection with Ti interlayer.

Conclusion and outlook

- Both investigated brazing and diffusion bonding methods for joining tungsten parts with Ti interlayer have shown error-free and satisfactory results.
- Nevertheless, the latter proofs to be the better method because of the non-occurence of grain coarsening and the occurrence of negligibly small inter-diffusion layer.
- Future R&D needs: Characterization of the joint and investigation of its behavior under neutron irradiation.