Preparation of Ta/Zry-4 Alloy Coated W target plates by HIP Diffusion Welding

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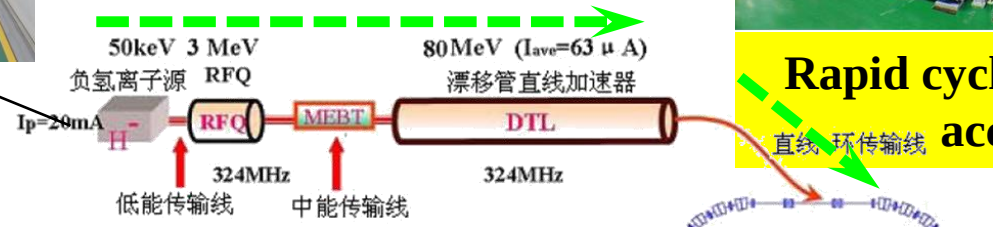
Outline

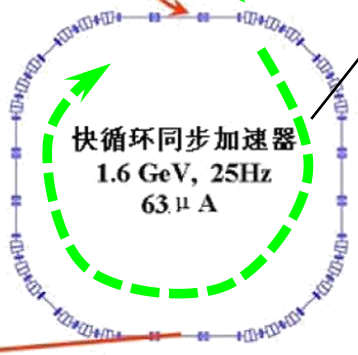
- Introduction
- Preparation and Optimization of HIP process for Ta cladded W target
- Development of Zry-4 alloy cladded W plate
- Summary

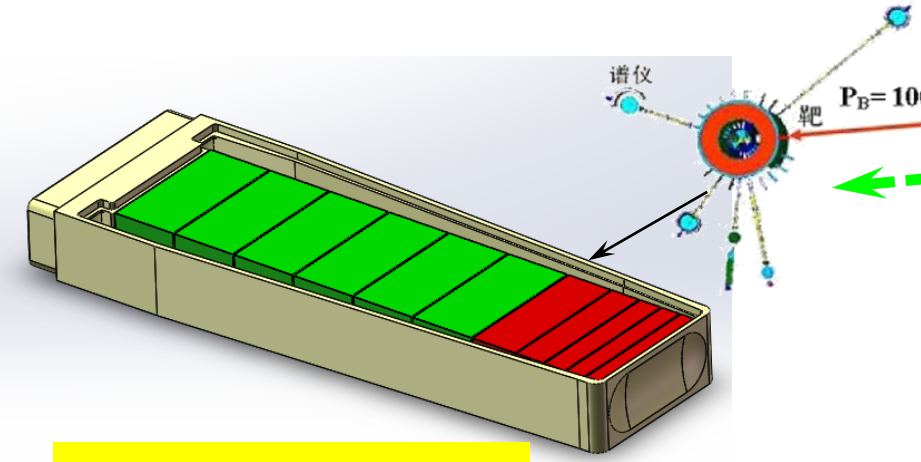
1、Introduction

linear accelerator

Rapid cycling synchrotron accelerator



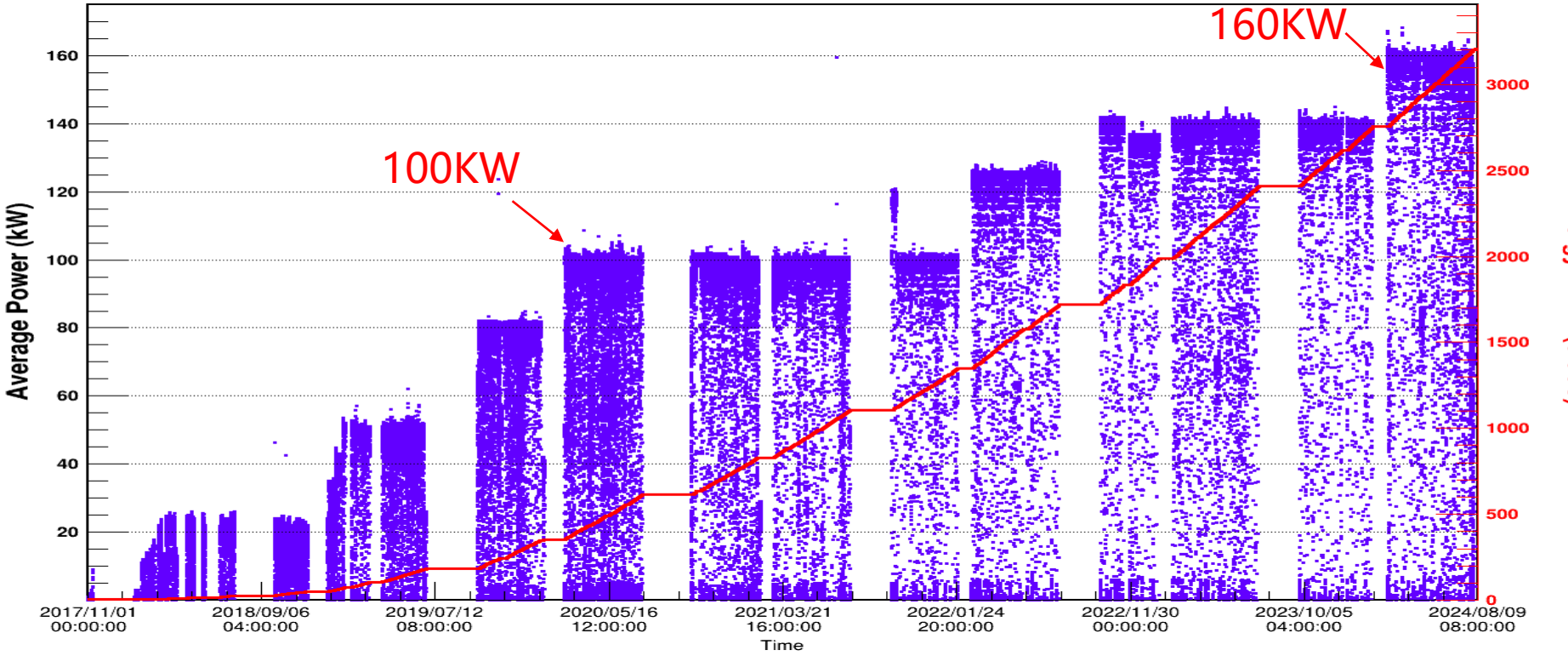




Solid Target

Target material：**W cladding Ta**

1、Introduction



As the operating power of CSNS continues to increase, the power will increase to 500kW in sever years, the service conditions of target materials become more severe, requiring continuous optimization and improvement of target performance.

2、Preparation and optimization of Ta cladded W plate

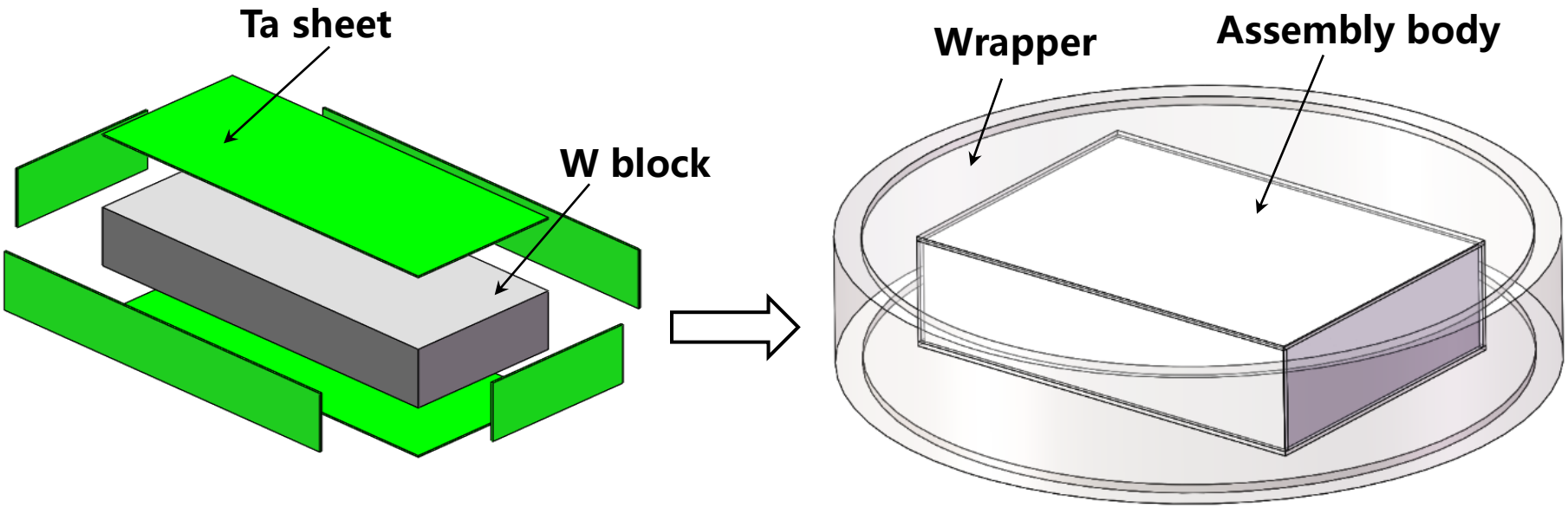
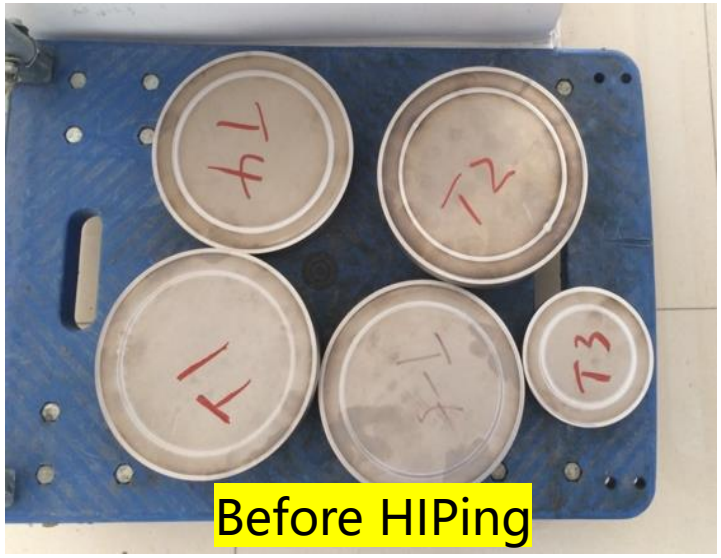


Diagram of target block preparation process

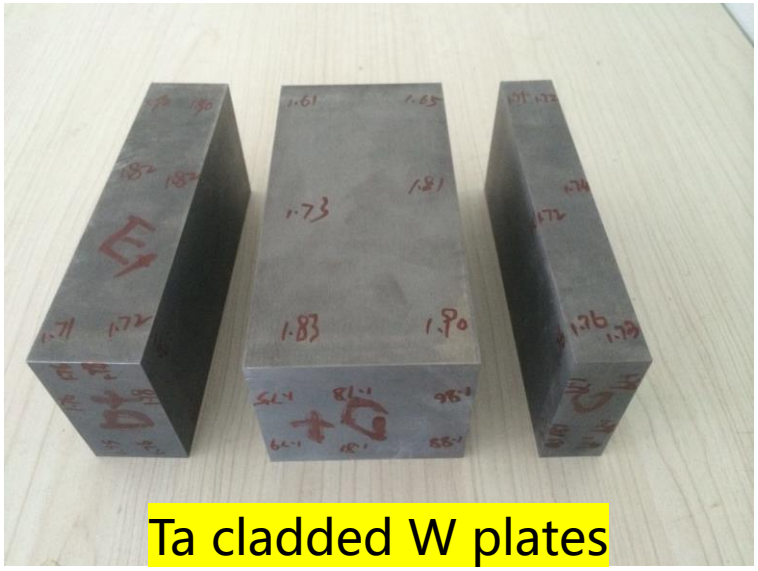
- Using a wrapper to fixed the Ta sheets around the W block;
- Removing the wrapper after HIPing can obtain the Ta cladded W block;

2、Preparation and optimization of Ta cladded W plate


Assemble



Before HIPing


Ta cladded W plates


After HIPing

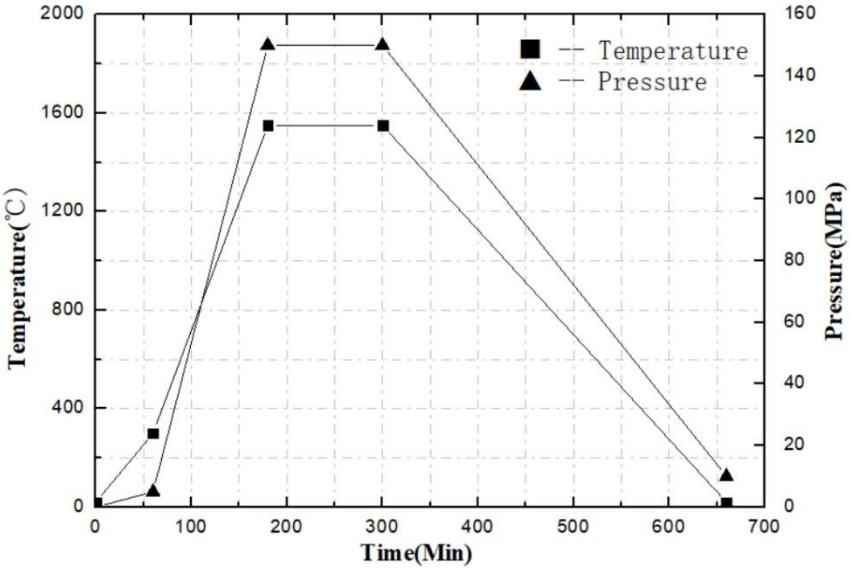
2、Preparation and optimization of Ta cladded W plate

HIP parameters:

T-Temperature

P-Pressure

t-Holding time



HIP parameters of Ta cladded W

Temperature of diffusion welding of dissimilar metals

$$T \approx 0.4T_m \sim 0.8T_m$$

T_m is the melting point of low melting point metals

W -- 3420℃

Ta-- 2996℃

T≈1200 ℃ -2400℃

2、Preparation and optimization of Ta cladded W plate

Optimization of HIPing parameters

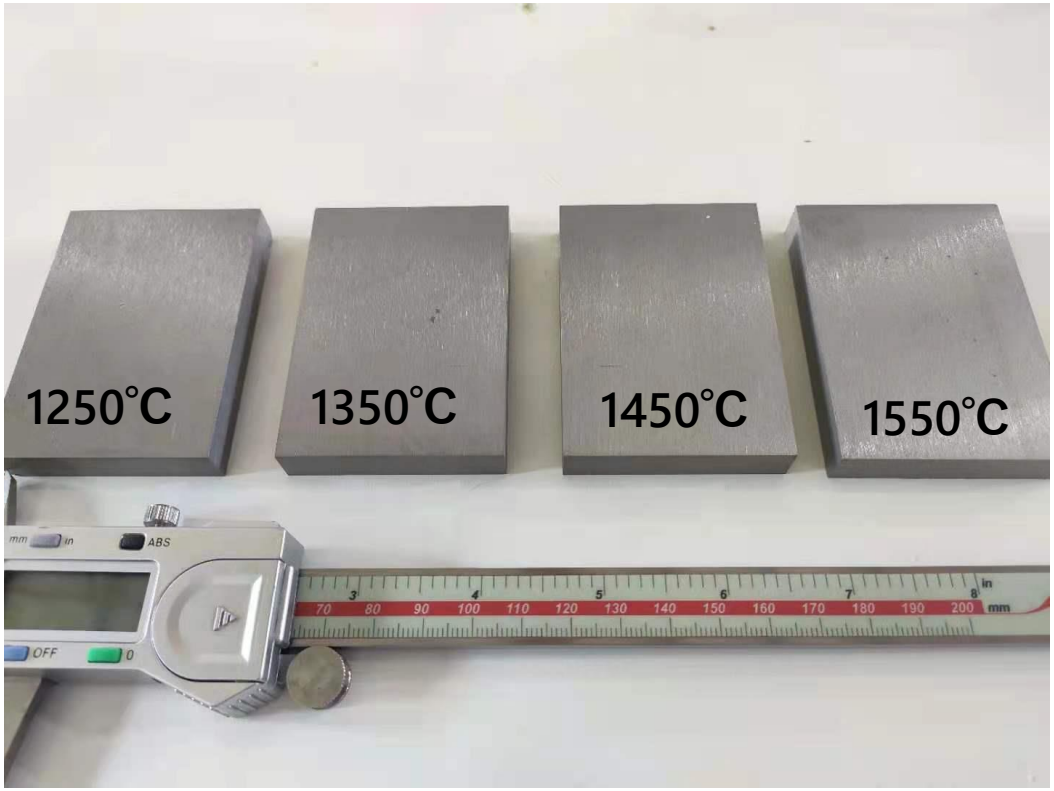
4 different HIP temperatures

Frist

- ✓ 1250℃, 130MPa, 2h
- ✓ 1350℃, 130MPa, 2h
- ✓ 1450℃, 130MPa, 2h
- ✓ 1550℃, 130MPa, 2h

Second

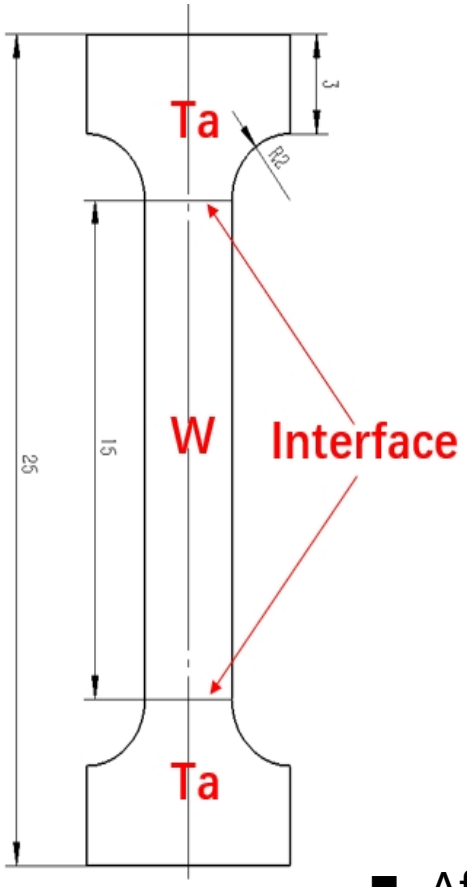
- ✓ 1450℃, 130MPa, 30min
- ✓ 1450℃, 130MPa, 60min
- ✓ 1450℃, 130MPa, 90min
- ✓ 1450℃, 130MPa, 120min
- ✓ 1450℃, 130MPa, 150min



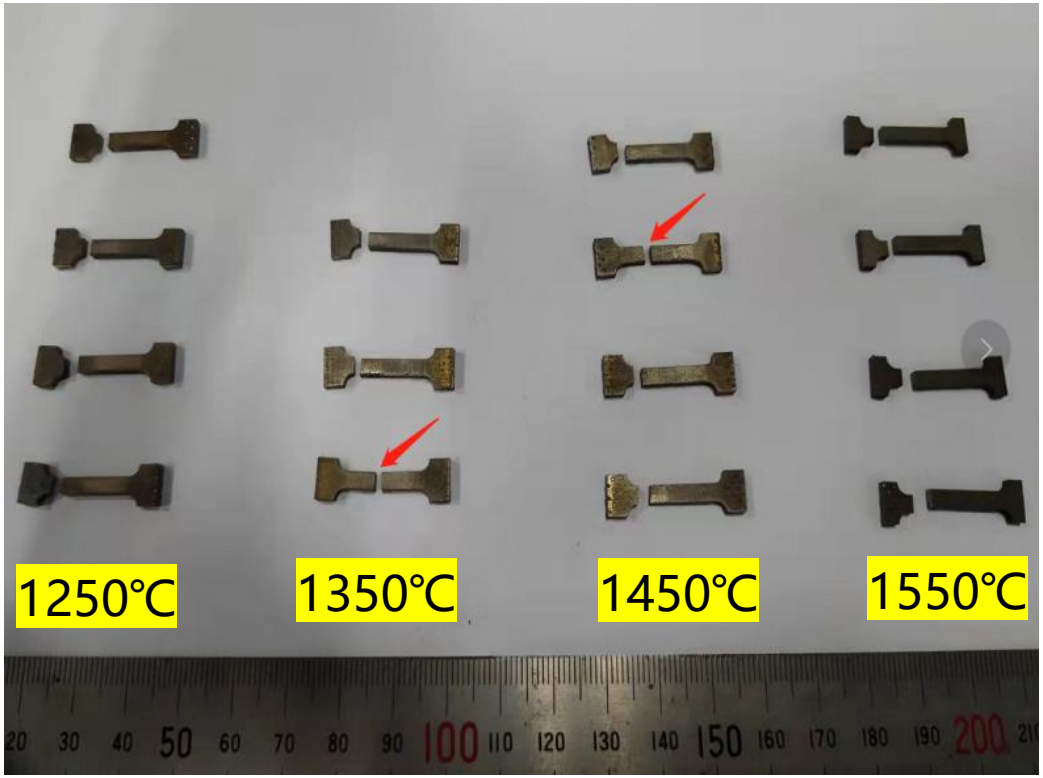
Ta cladded W Samples

2、Preparation and optimization of Ta cladded W plate

Tensile strength test of Ta-W



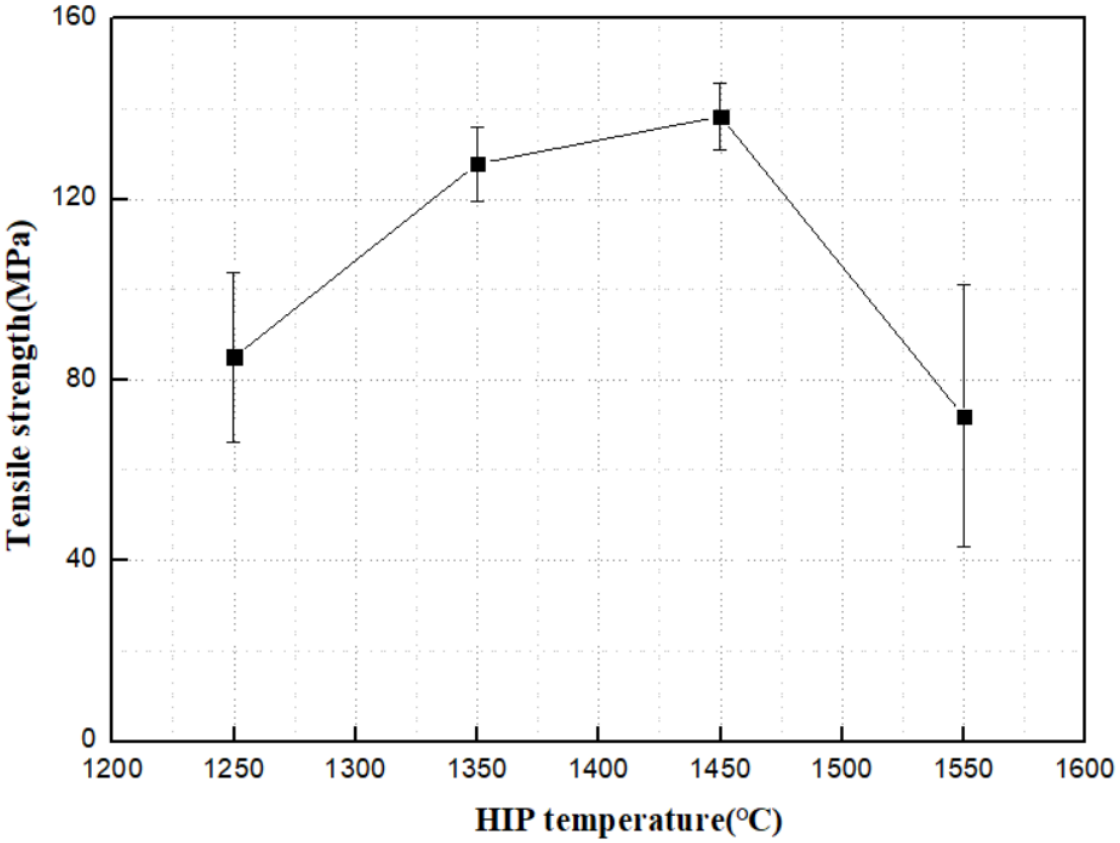
Sample size



Samples after tensile test

- After the tensile test of the samples, majority of the fracture positions are located near the interface, some samples (1350 ℃ and 1450 ℃) have fracture in W;

2、Preparation and optimization of Ta cladded W plate



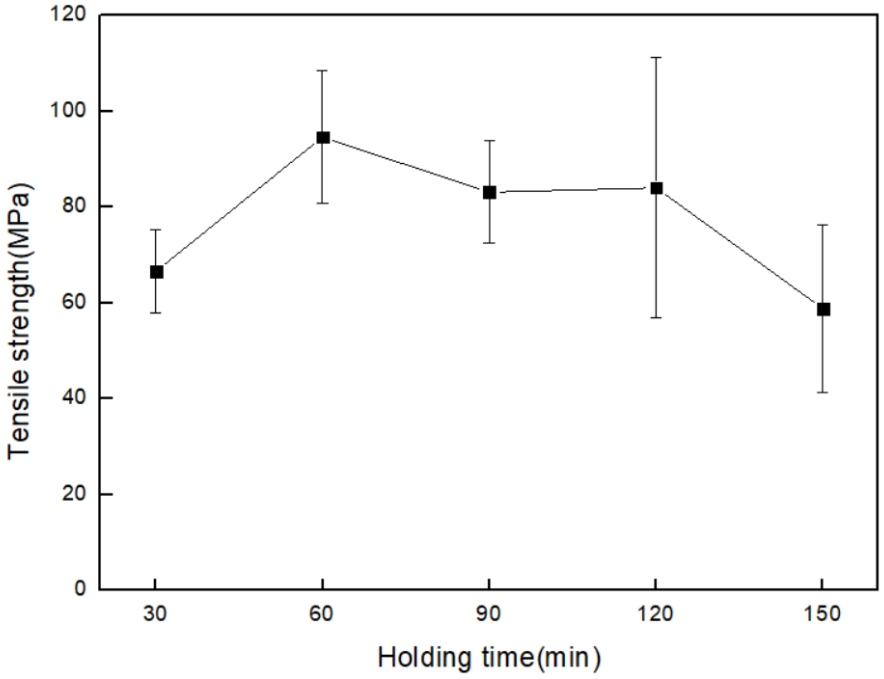
Tensile strength of samples at different HIP temperatures

- The tensile results show that as the HIP temperature increases, the bonding strength of the W-Ta interface first increases, then decreases, reaching a maximum of 139.1 MPa at 1450 ℃;

2、Preparation and optimization of Ta cladded W plate

5 different Holding time

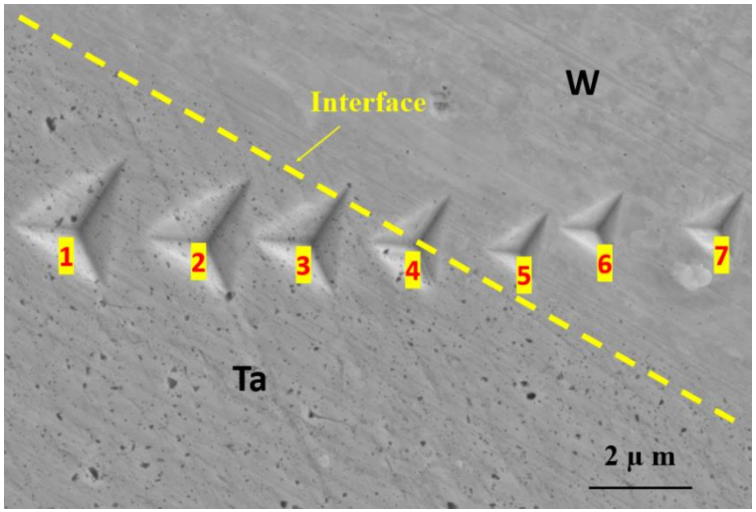
- ✓ 1450℃, 130MPa，holding time 30min
- ✓ 1450℃, 130MPa，holding time 60min
- ✓ 1450℃, 130MPa，holding time 90min
- ✓ 1450℃, 130MPa，holding time 120min
- ✓ 1450℃, 130MPa，holding time 150min



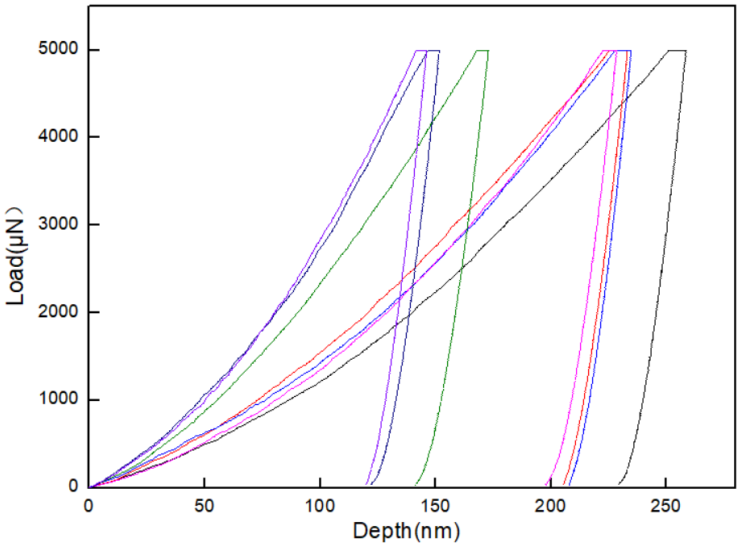
- With the holding time increased, the bonding strength of the W-Ta interface of the sample shows a trend of first increases and then decreases.
- The final choice of diffusion welding parameters is 1450C, 130MPa, and 60 minutes.

2、Preparation and optimization of Ta cladded W plate

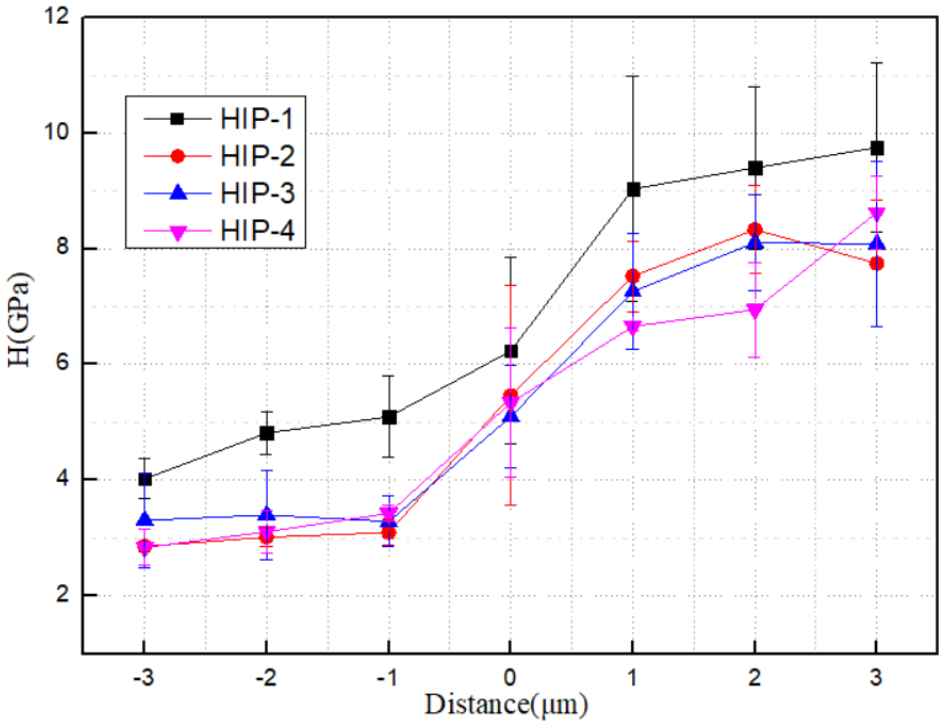
(3) Nanoindentation Hardness Measurement of Ta-W interface



SEM photos after nanoindentation hardness test



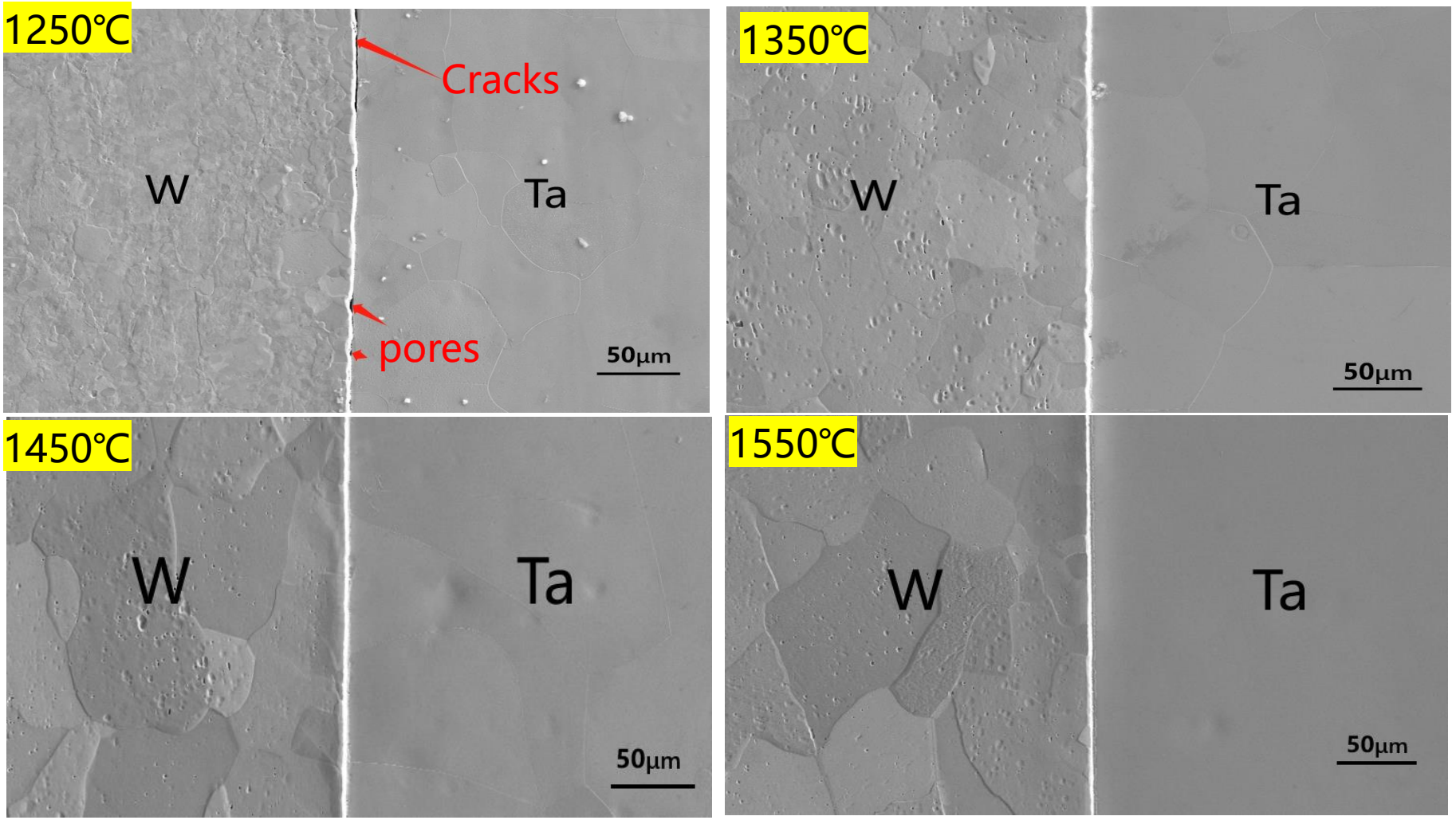
Nano indentation hardness testing curve



Nano indentation hardness results of 4 HIP temperature samples

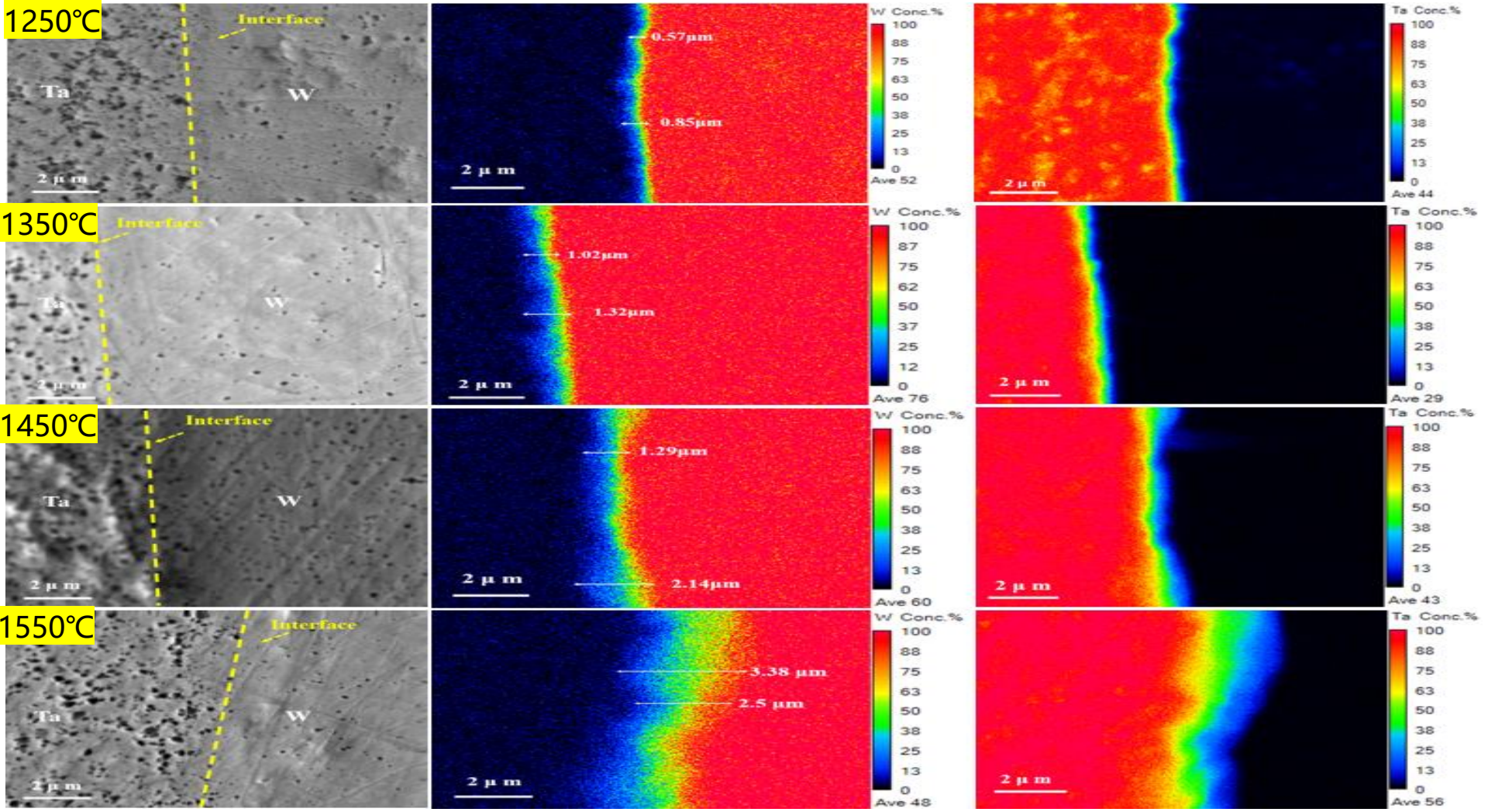
- Ta has a lower hardness, while W has a higher hardness, and the hardness at the interface is between Ta and W.

2、Preparation and optimization of Ta cladded W plate



- At 1250 ℃, some defects were found at the W-Ta interface, including pores ,gaps and cracks;
- When the HIP temperature increases to 1350 ℃ and above, no obvious defects are found at the W-Ta interface ;
- As the HIP temperature increases, the grains size increase both in W and Ta ;

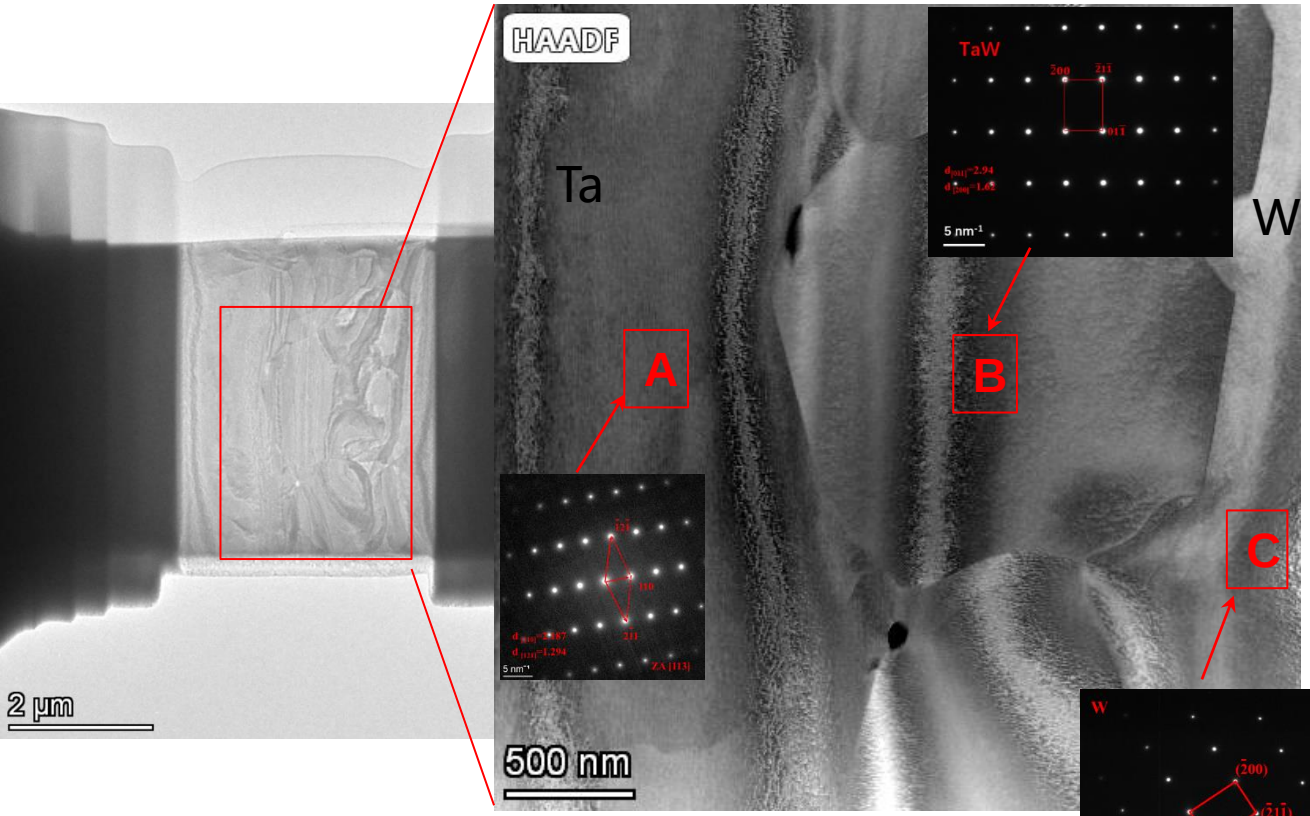
2、Preparation and optimization of Ta cladded W plate

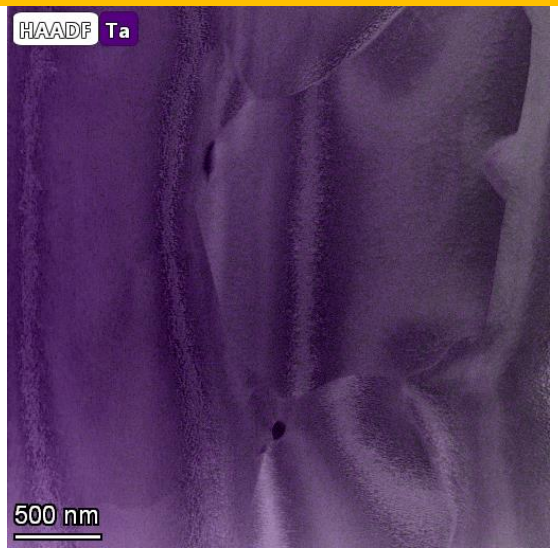


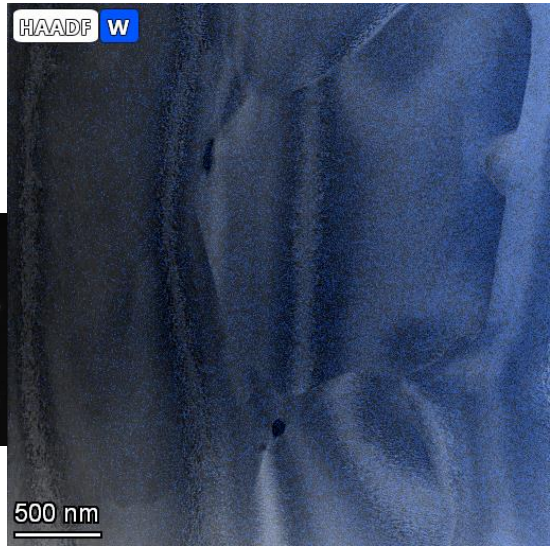
- The EPMA analysis results at the interface show that a diffusion layer is formed at the interface;
- As the HIP temperature increases, the thickness of the diffusion layer increases from 0.74 μ m to 2.94 μ m when the HIP temperature increases from 1250 ℃ to 1550 ℃.

2、Preparation and optimization of Ta cladded W plate

TEM/EDS of the W-Ta interface



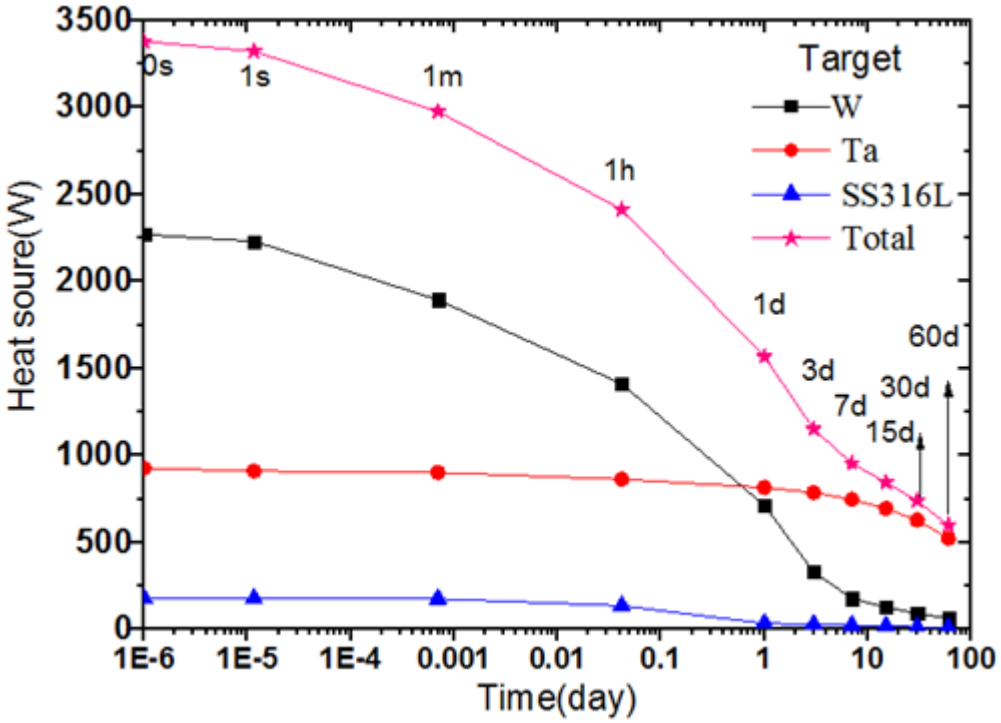




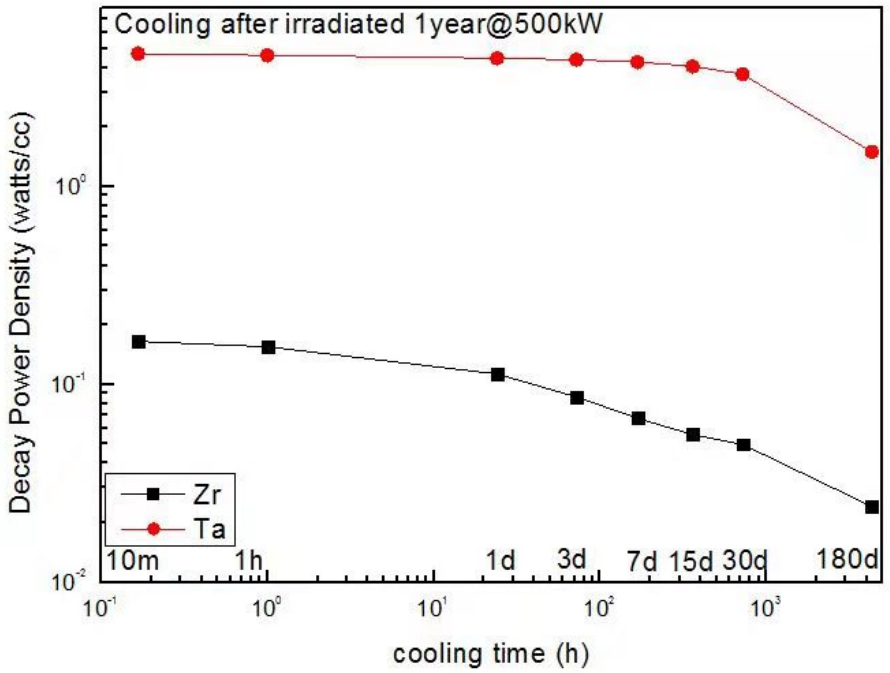
- W and Ta atoms diffusing to each other.
- The selected area electron diffraction results show that the interface diffusion layer is a TaW solid solution.

Microstructure and strength of the Ta cladded W targets prepared by electron beam welding followed by hot isostatic pressure，
International Journal of Refractory Metals and Hard Materials 116 (2023) 106341

3、Development of Zry-4 alloy cladded W plate



After hear curve when the beam power 500kW operation 3000 hours



Comparison of after hear between Ta and Zr (500kW operation 3000 hours)

- ✓ If the after heat of the target is too high, Higher requirements for post heating removal of the target under abnormal beam stopping conditions.
- ✓ The decay heat power density of Zr is only 1/10 of Ta

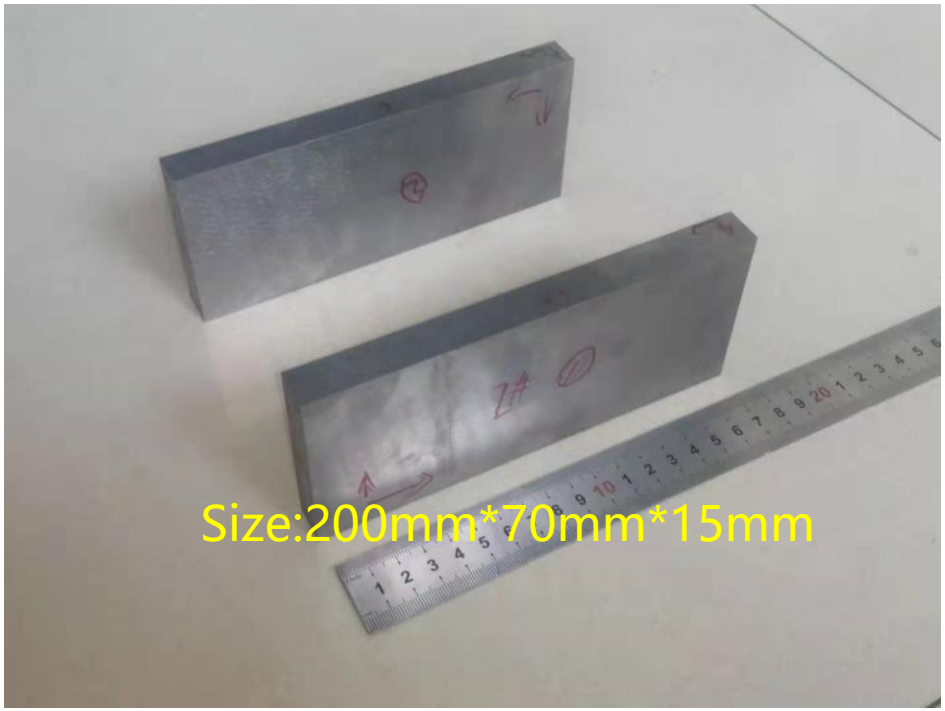
3、Development of Zry-4 alloy cladded W plate

The manufacturing process of Zry-4 alloy coating is similar to that of Ta cladded W.

Zry-4 alloy

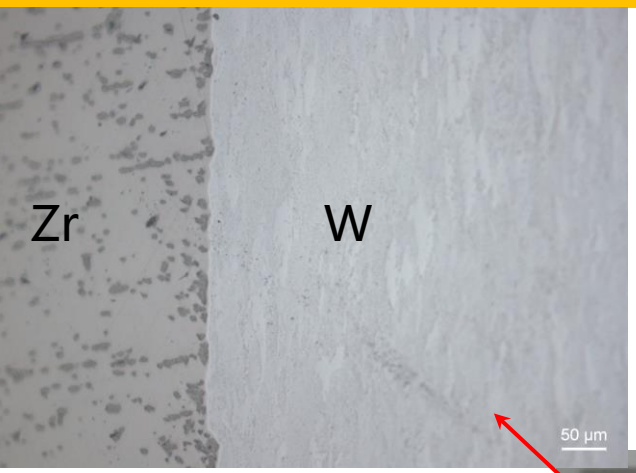
element	Sn	Fe	Cr	Al	0	Fe+Cr	Zr
Content(wt%)	1.3	0.21	0.11	0.003	0.13	0.32	

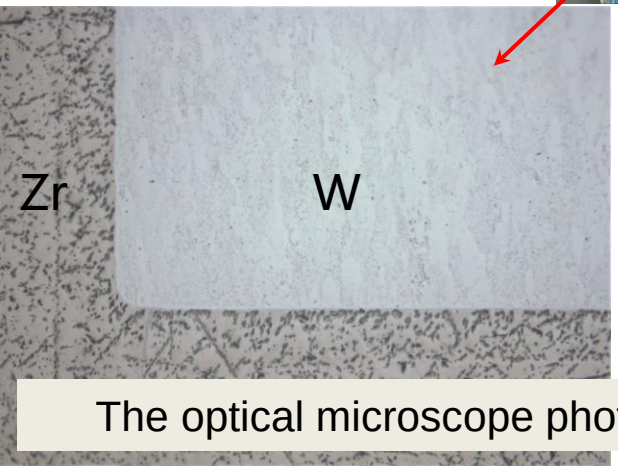
After HIPing

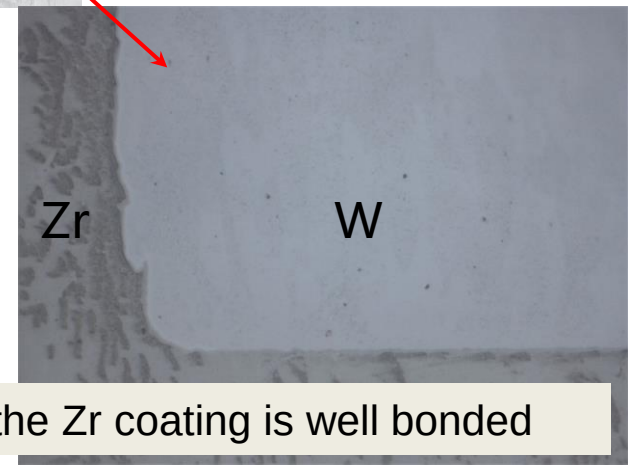


Zry cladded W plates

3、Development of Zry-4 alloy cladded W plate

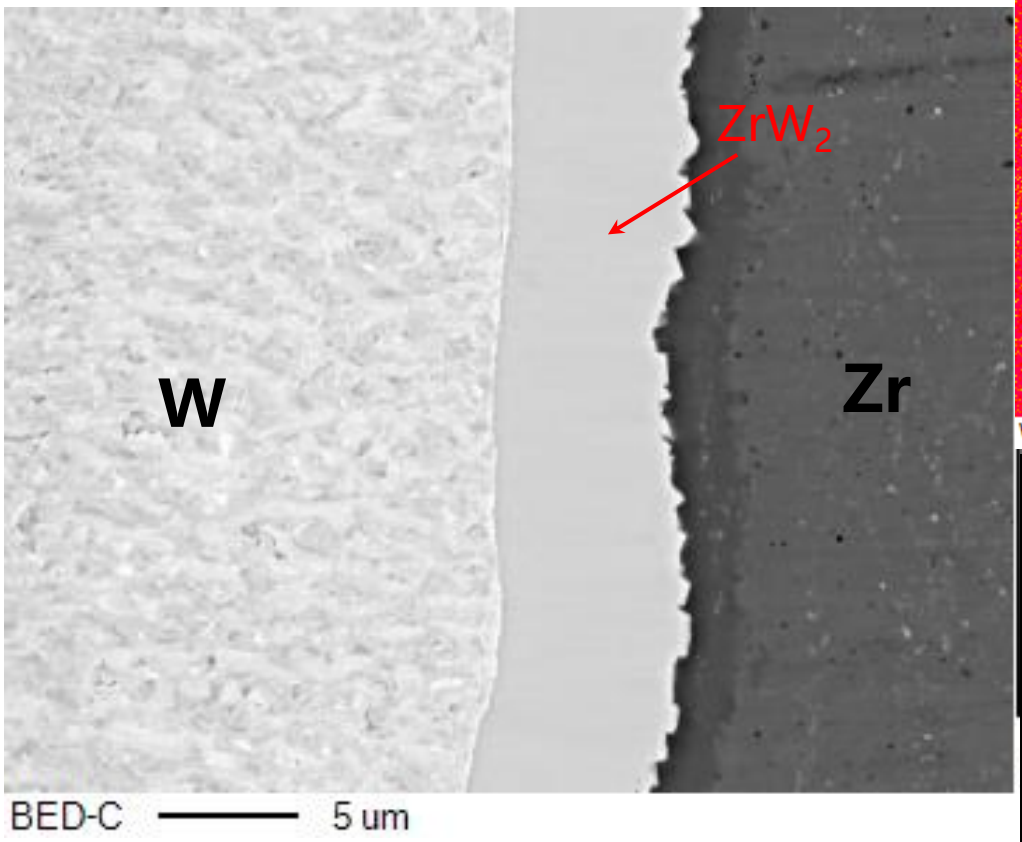


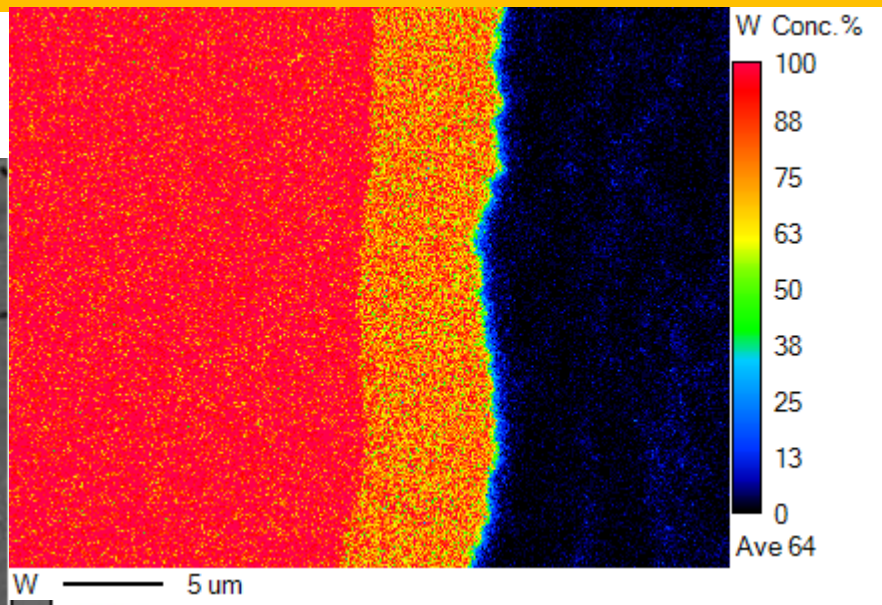


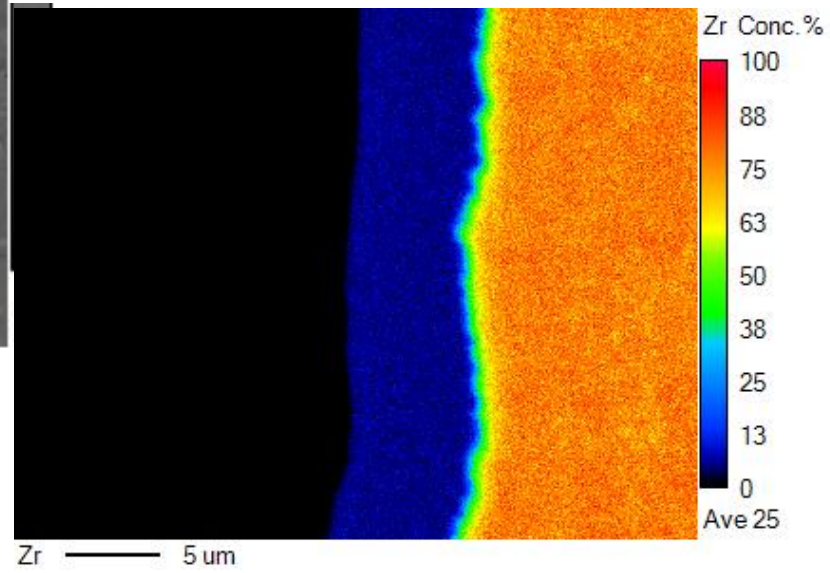


The optical microscope photos of the Zr-W interface show that the Zr coating is well bonded

3、Development of Zry-4 alloy cladded W plate

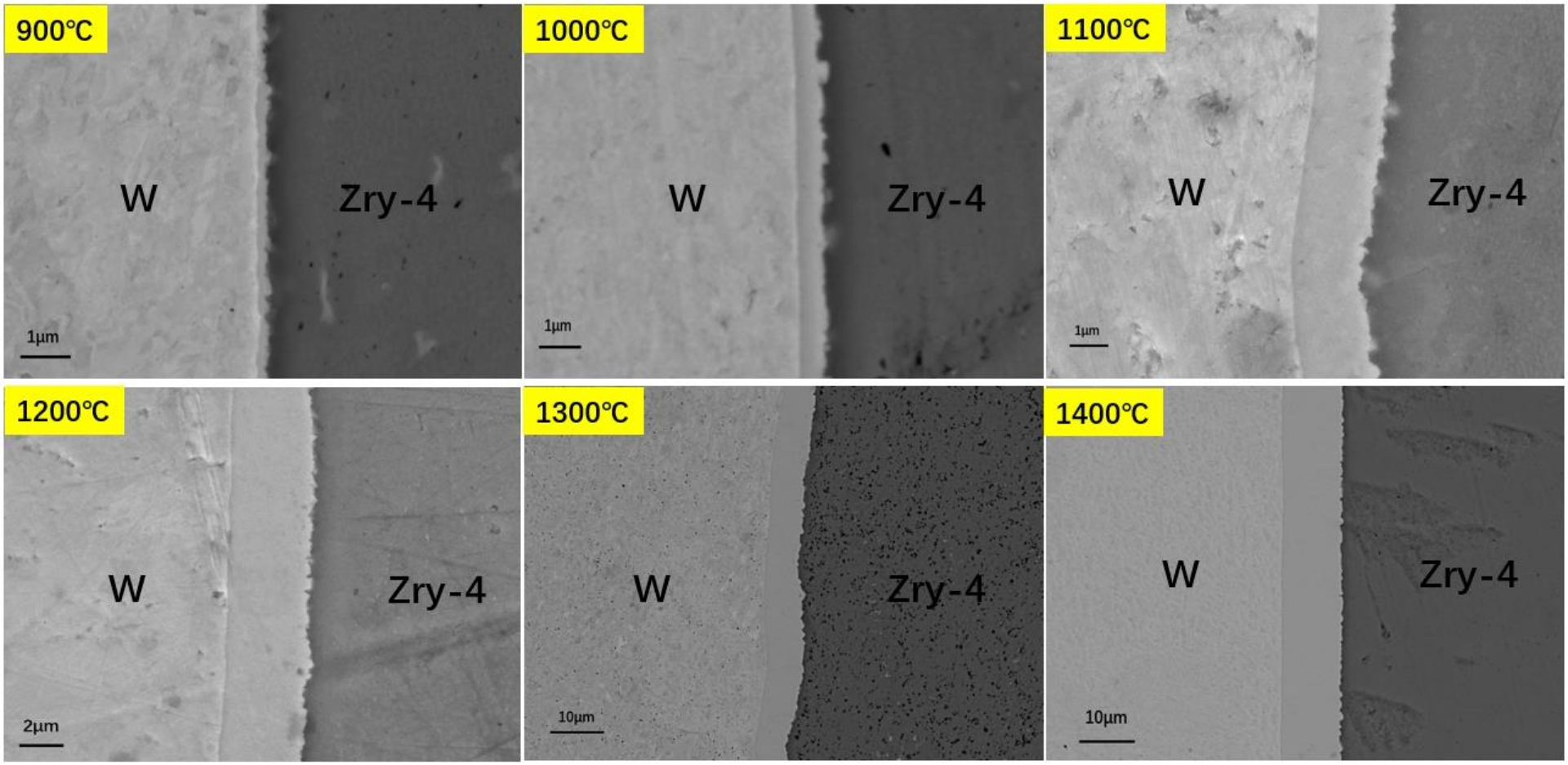






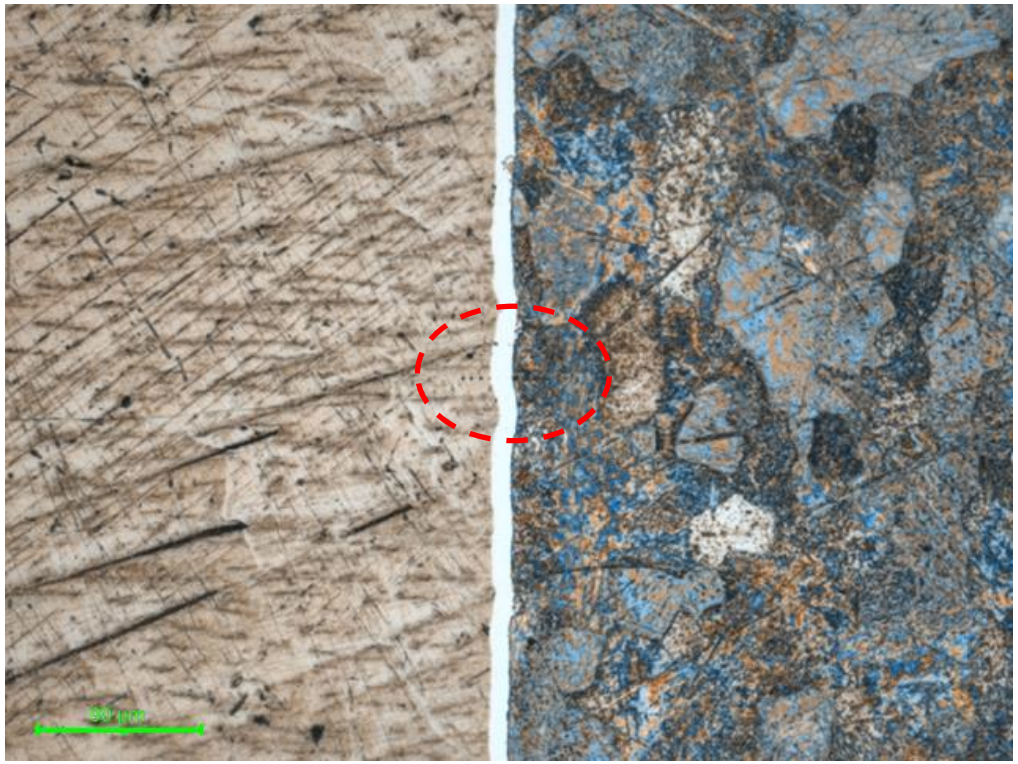
ZrW_2 alloy is formed at the interface after diffusion welding.

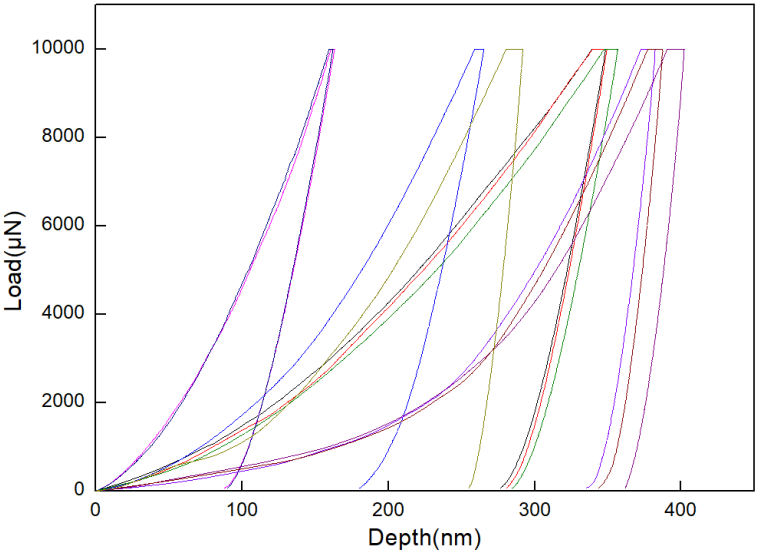
3、Development of Zry-4 alloy cladded W plate

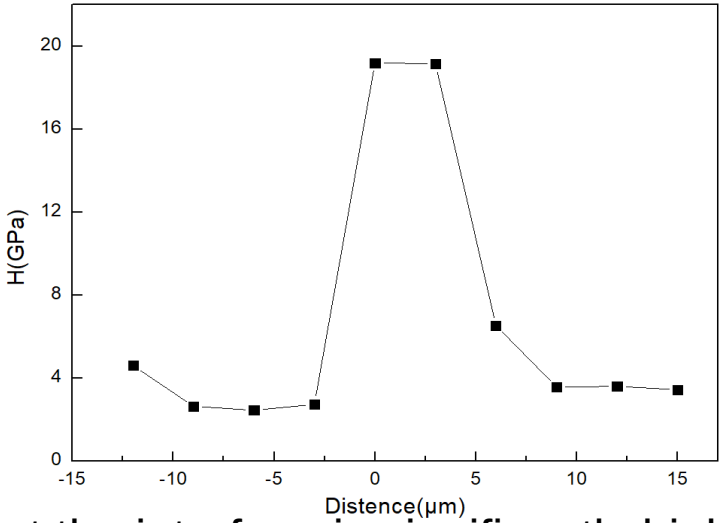


As the HIP temperature increases, the thickness of the intermediate transition layer also increases

3、Development of Zry-4 alloy cladded W plate



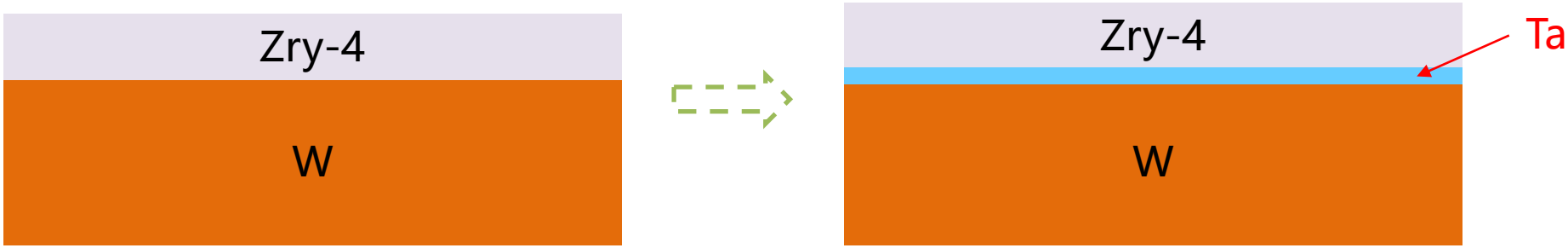


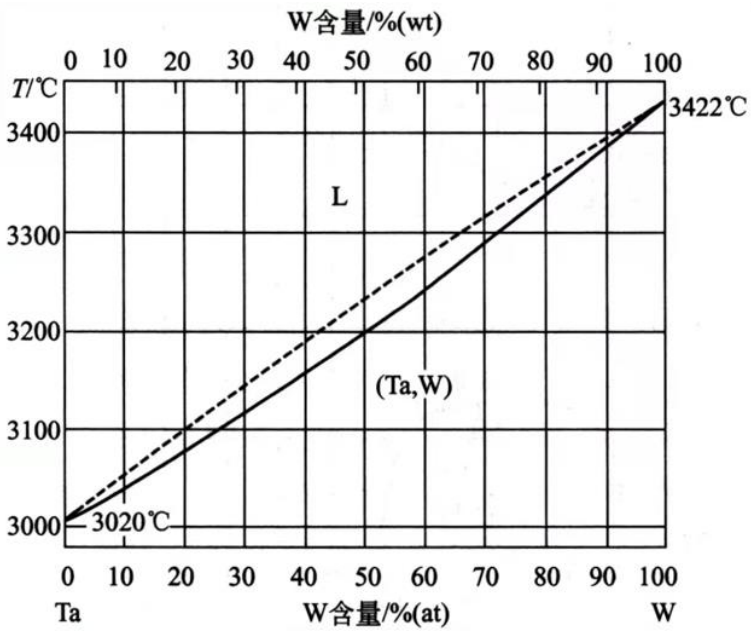


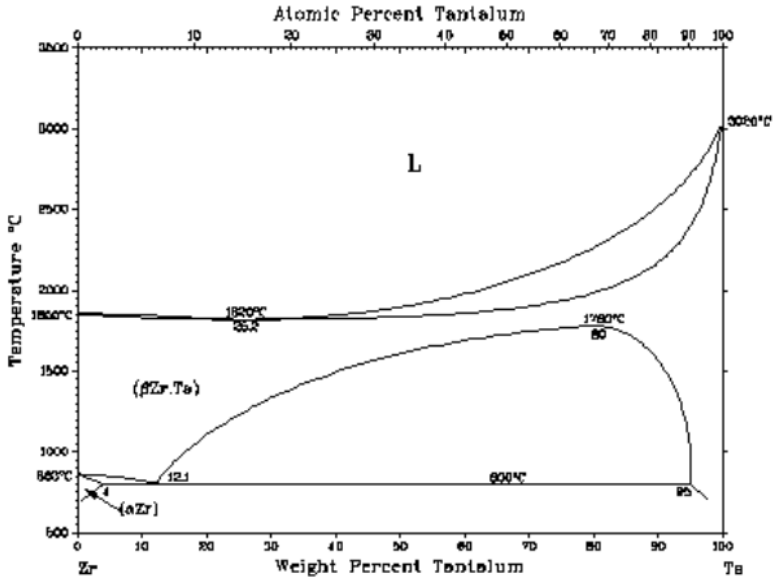
The nanoindentation hardness of the ZrW_2 layer at the interface is significantly higher than that of the W and Ta, ZrW_2 should be a brittle phase.

3、Development of Zry-4 alloy cladded W plate

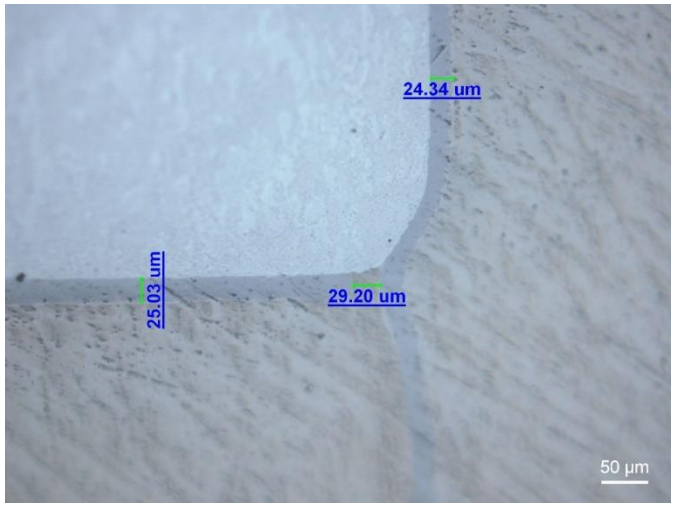
Adding a third metal layer can avoid the formation of brittle phases ZrW_2 and improve welding performance

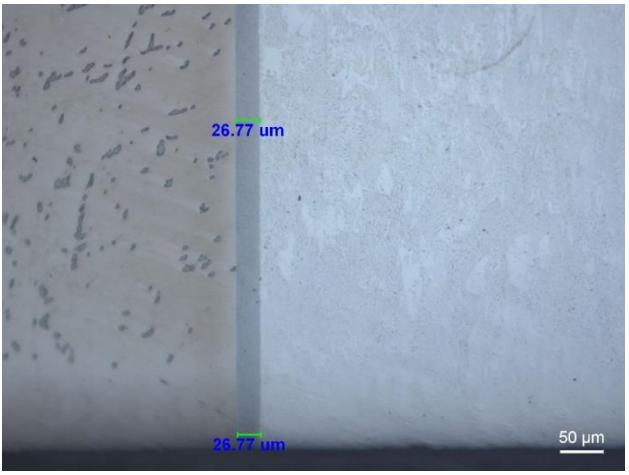


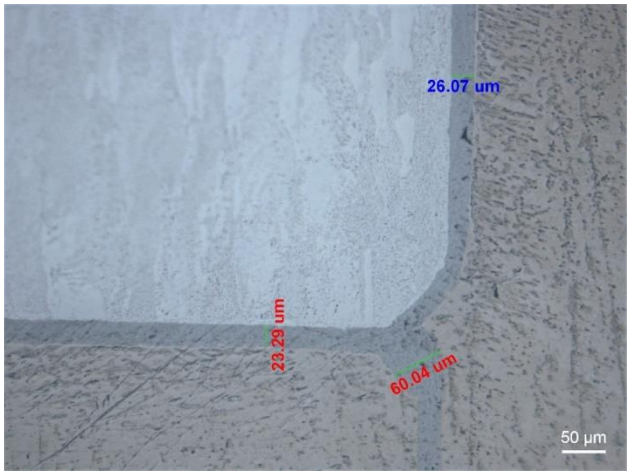


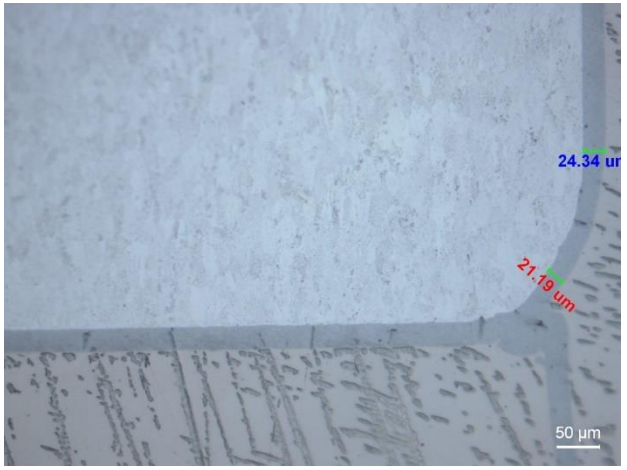


3、Development of Zry-4 alloy cladded W plate



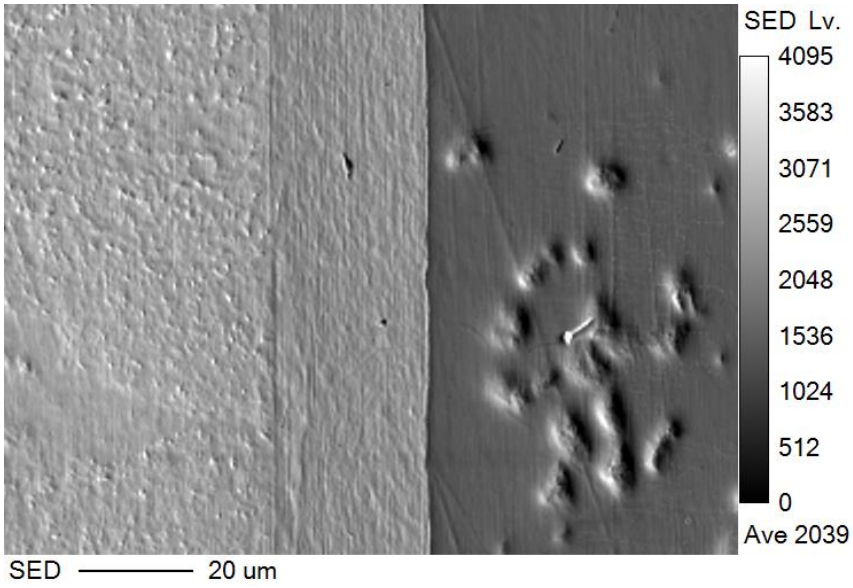


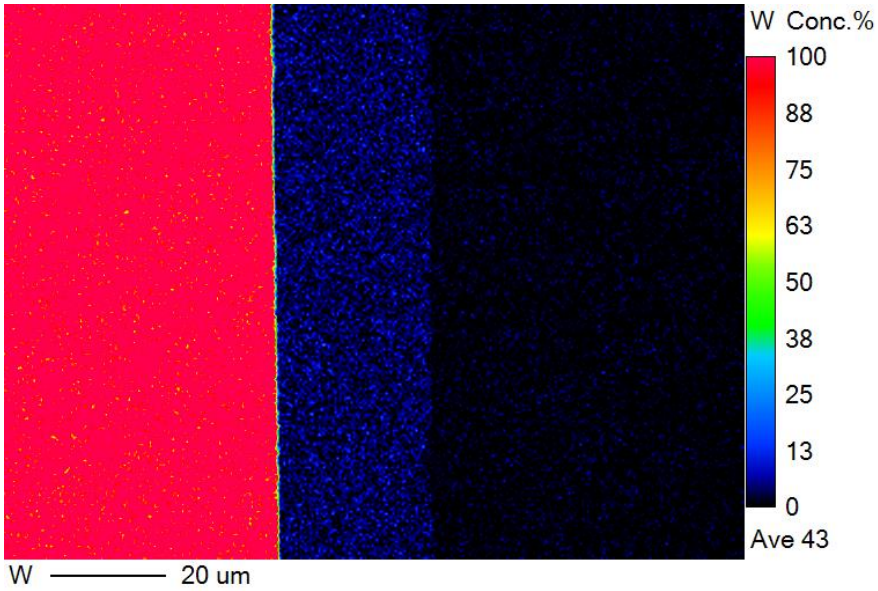


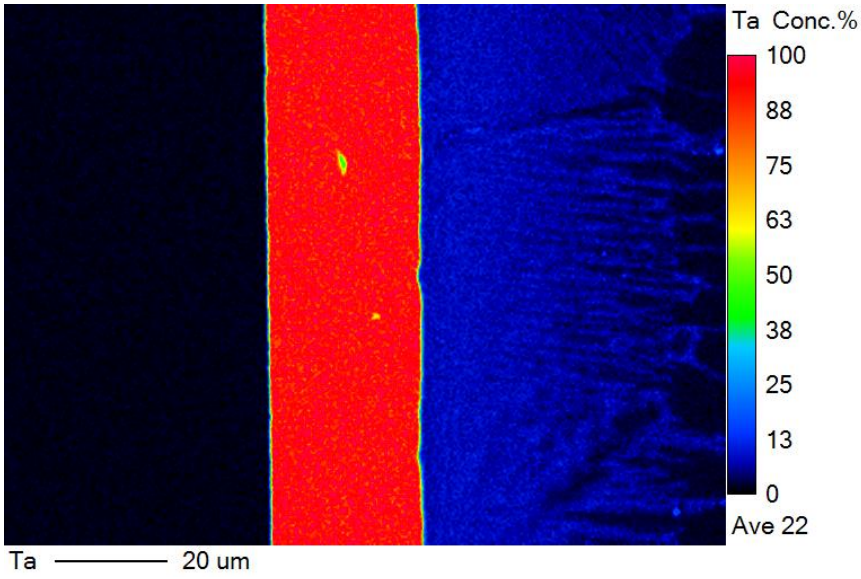


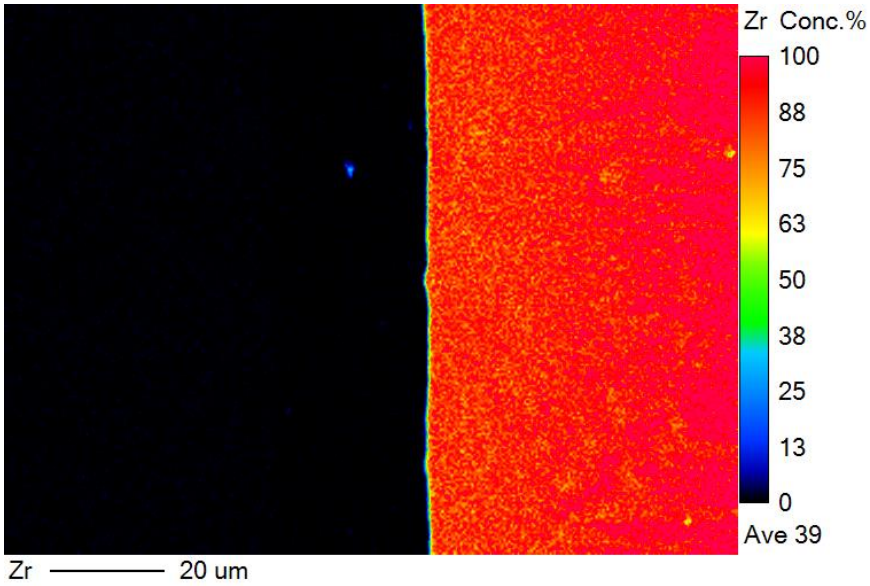
The optical photo results show that the W-Ta-Zr interface has good bonding, no obvious defects were found

3、Development of Zry-4 alloy cladded W plate





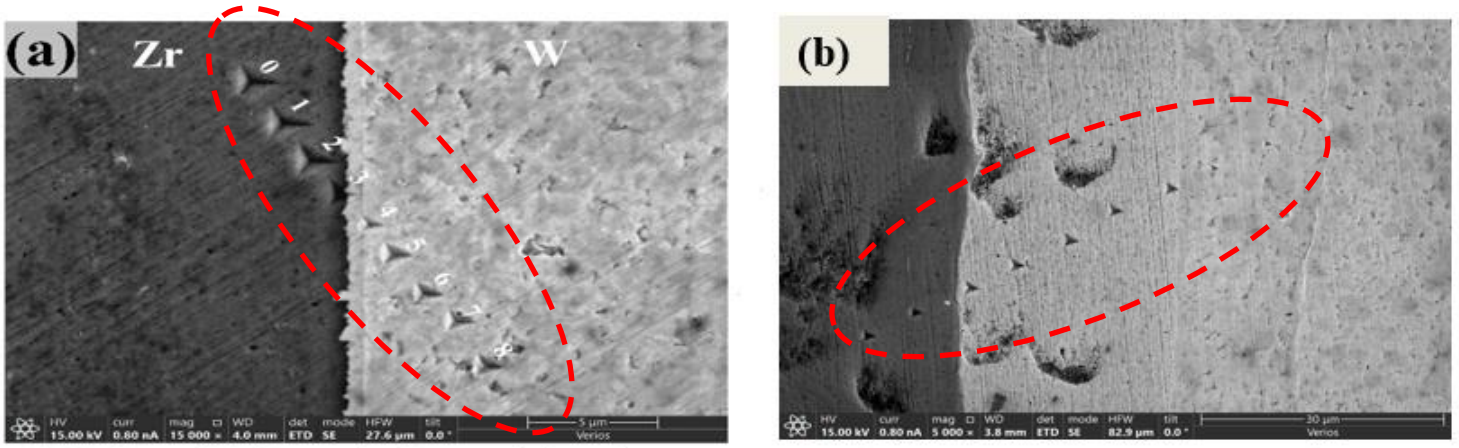




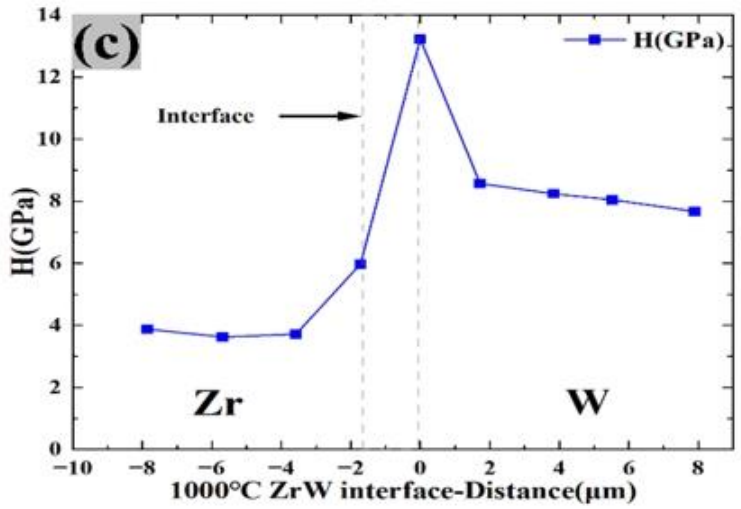
EPMA results of W-Ta-Zr

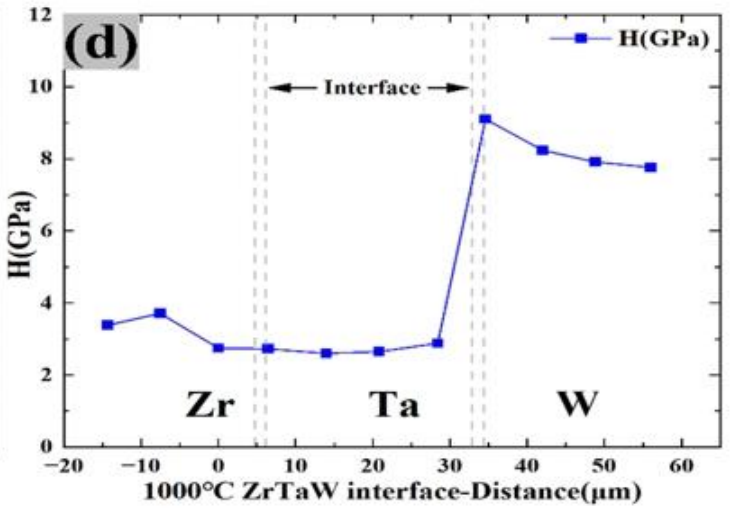
3、Development of Zry-4 alloy cladded W plate

The addition of Ta in the intermediate layer effectively reduces the hardness gradient at the interface



SEM photo of Zr-W sample after nanoindentation test





Microstructure and Mechanical Properties of Zr-W and Zr-Ta-W interface Fabricated by Hot Isostatic Pressing Diffusion welding. To be submitte

4、Summary

1. Ta cladded W were prepared by HIP diffusion welding.
2. The HIP welding process has been optimized, 1450 ℃, 130MPa，60min was a suitable parameter.
3. WTa solid phase was formed when W and Ta diffusion welding, as the HIP temperature increases, the thickness of the diffusion layer increases；
4. CSNS is developing Zr alloy cladded W target plate.
5. Direct welding of Zry-4 alloy and W will result in the formation of brittle phase ZrW_2 at the interface, adding a third metal layer Ta to the interface can effectively prevent the formation of brittle phases.

Thanks for your attentions