The progress on R&D of CSNS target station materials

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SNS
CHINESE ACADEMY OF SCIENCES

Outline

◆   Target material: Tantalum cladding W

◆   Moderator: Connecting piece

◆   Chopper: B_4C coating on aluminum alloy

◆   Summary

Target material :W

Advantage:

➢ High atomic order for a high production rate of spallation neutrons(74/184)

➢ High density for high luminosity(19.3g/cm3)

➢ Good thermal conductivity ($163.3Wm^{-1}K^{-1}$)

➢ Radiation stability for high lifetime

➢Low neutron absorption for high neutron intensity

➢Low after-heat and induced radioactivity

Disadvantage:

➢ Poor corrosion resistance against water due to formation of brittle W-hydroxide under high temperature and irradiations

➢ Intense susceptibility to irradiation embrittlement

Cladding material (Prof. Jia Xuejun)

➤**Ta is promising because its highest density among the candidate materials – highest neutron yield and also its corrosion resistant**

W side

Ta side
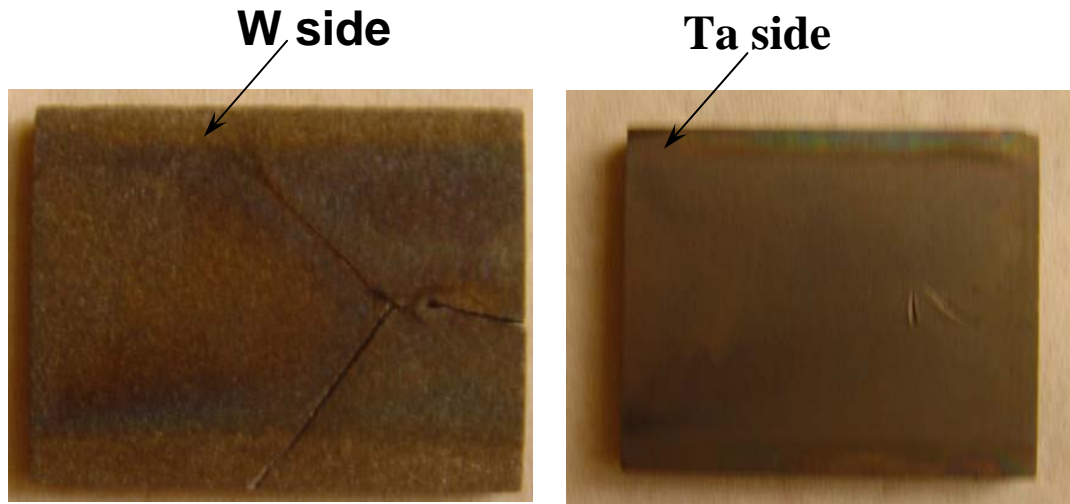
Condition

flowing water with a dissolved oxygen content of 400 ppb

flow rate：3 m/s

Test temperature ：300 ℃

Test time：1000 hours

corrosion test

Conclusion: tungsten wrapped with a thin layer of tantalum target is a good choice

HIP Methods for manufacturing of a tantalum-clad tungsten target
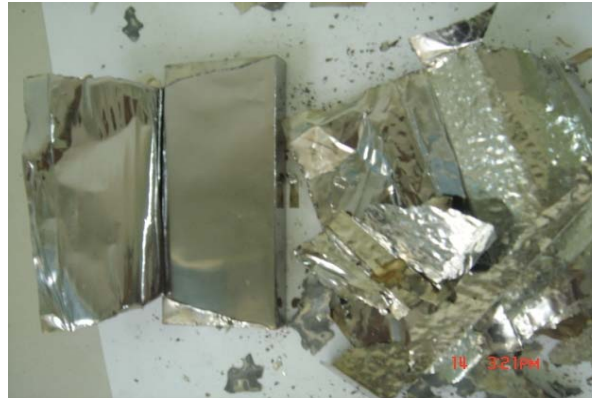
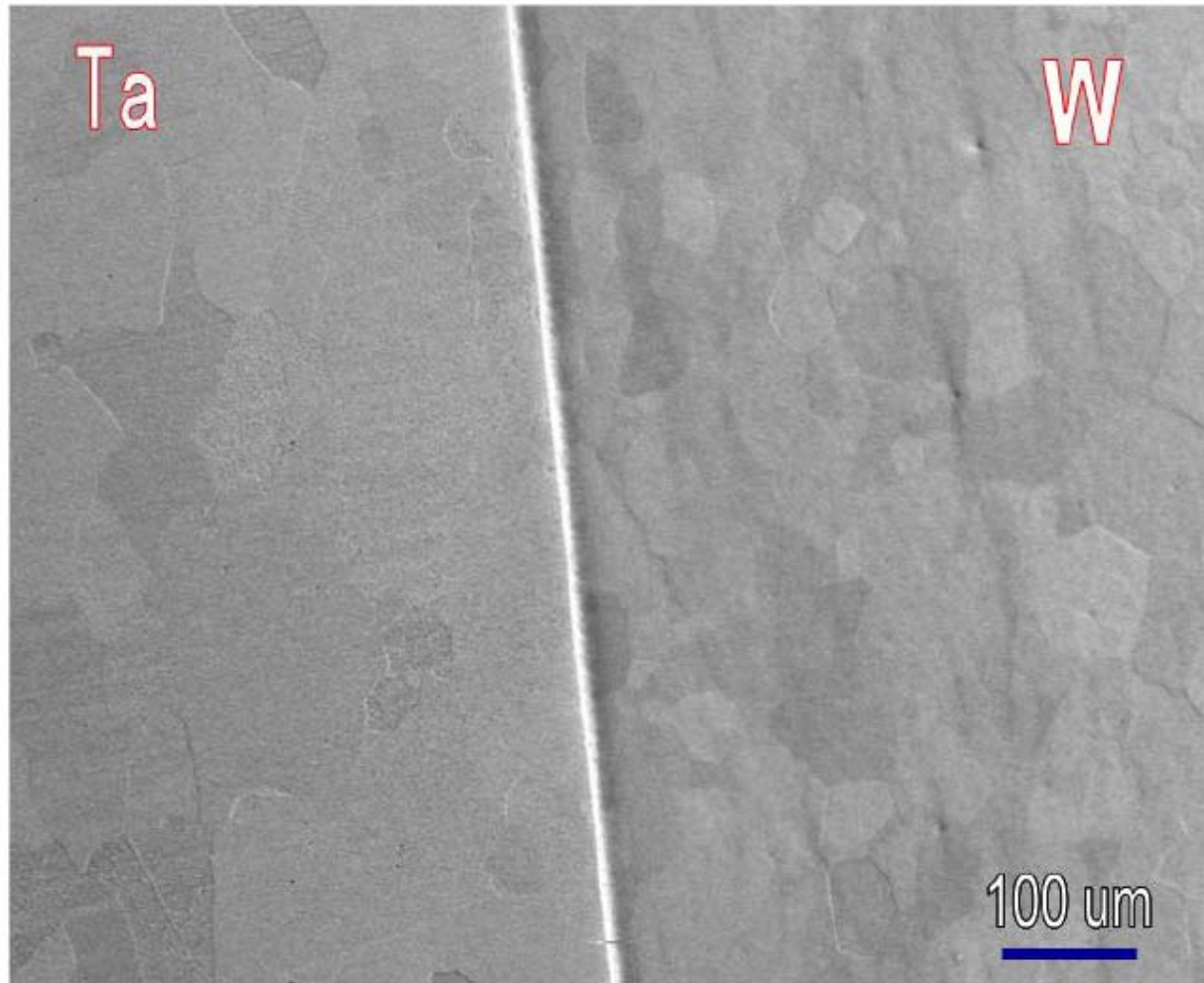HIP conditions:

Temperature：1793K

Pressure：200MPa

Cover gas: Ar, 5N；

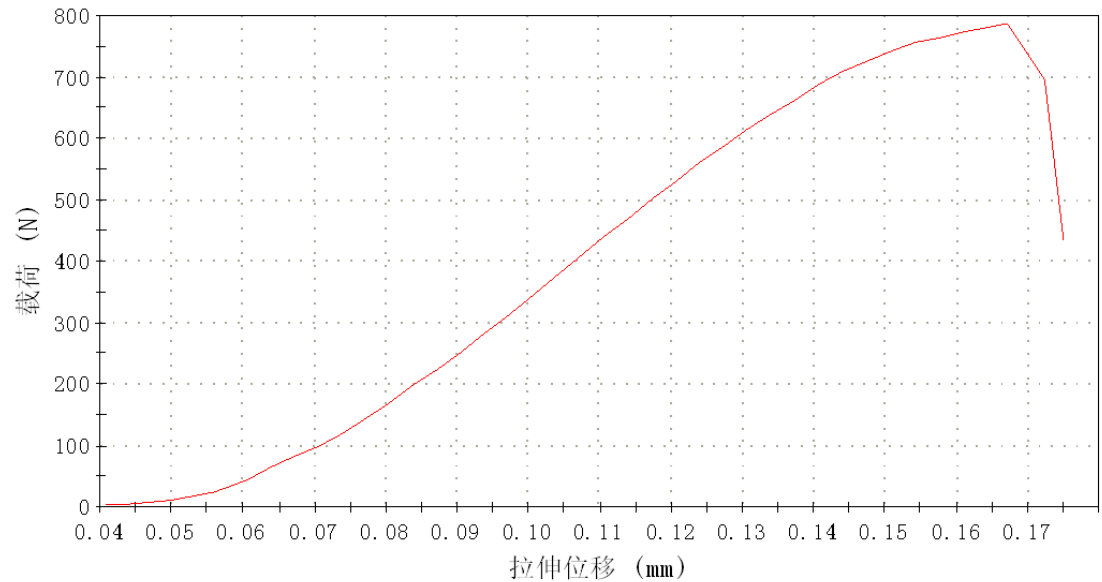Duration: 3 hours

tungsten clad tantalum target block after HIP

From the international cooperation, we developed our HIP conditions and successfully trial-produced the tungsten tantalum target modules

Microstructure analysis

SEM photo shows that tantalum and tungsten connected well
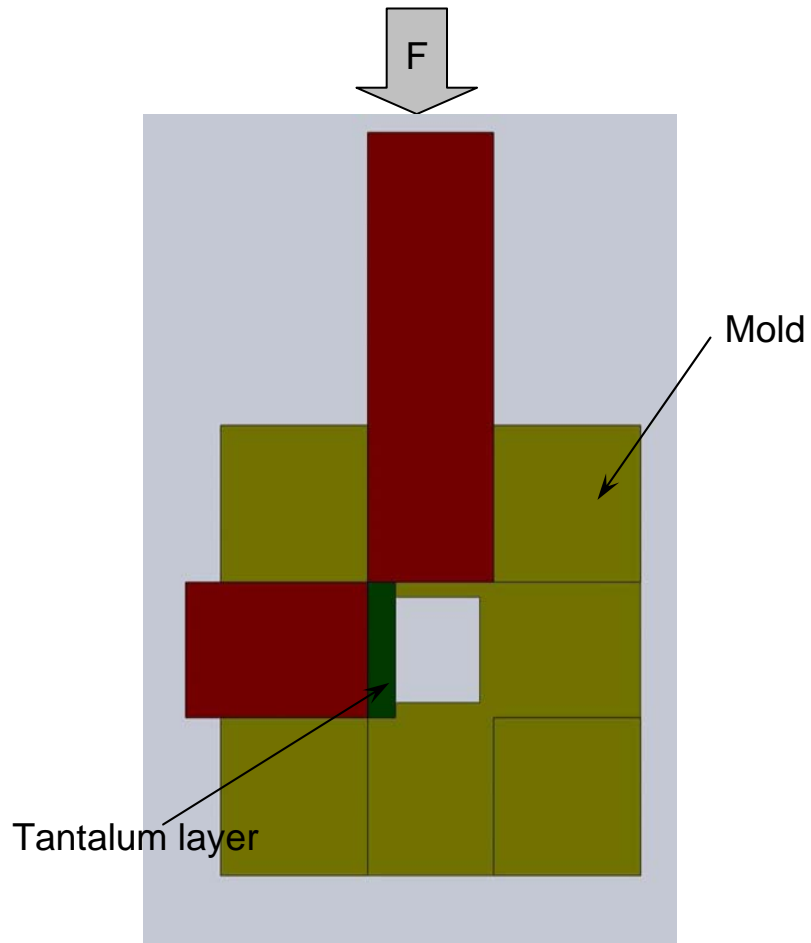
Mechanics Performance Testing (Tensile experiments)
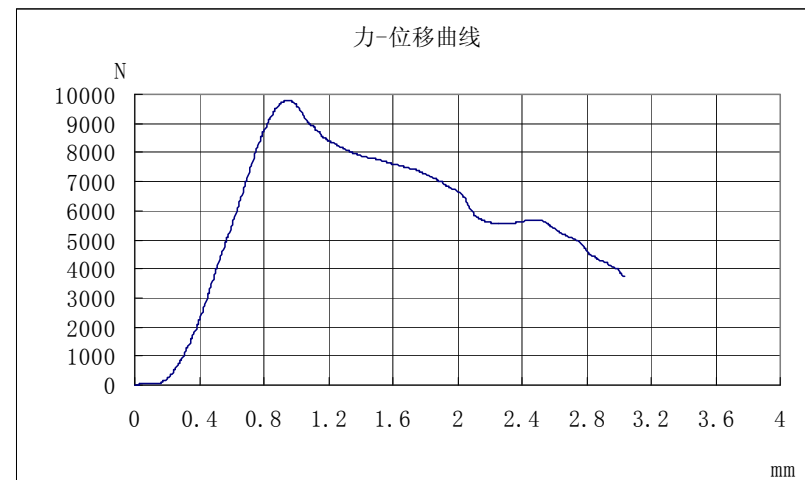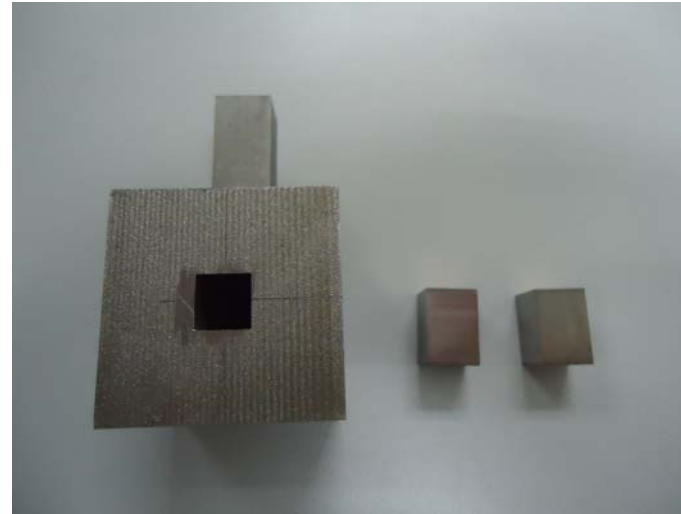

P>F/S=31.5MPa

  This tensile experiment used for measuring thin coating bonding, and it is a half quantitative measurement.
  The fracture located in glue, so, the bonding intensity of the tantalum layer is larger than 31.5MPa

Glue

Tantalum(0.5mm)

Tungsten

F

F

Mechanics Performance Testing (Shear experiments)

F

Mold

Tantalum layer

Experiment model

力-位移曲线

P=F/S=121.5MPa

Ultrasonic Testing

Color Plot - 2010-8-1.SDT (1 of 2)

File View Palette Options Process Analysis Edit Data Window

mm

(66.890 mm, 110.724 mm) = 0.398 Volts   112 %

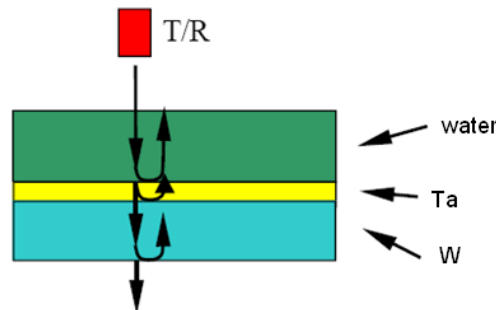Deep color area

Target area

C-Scan area

experiment result

Beijing Institute of Aeronautical Materials
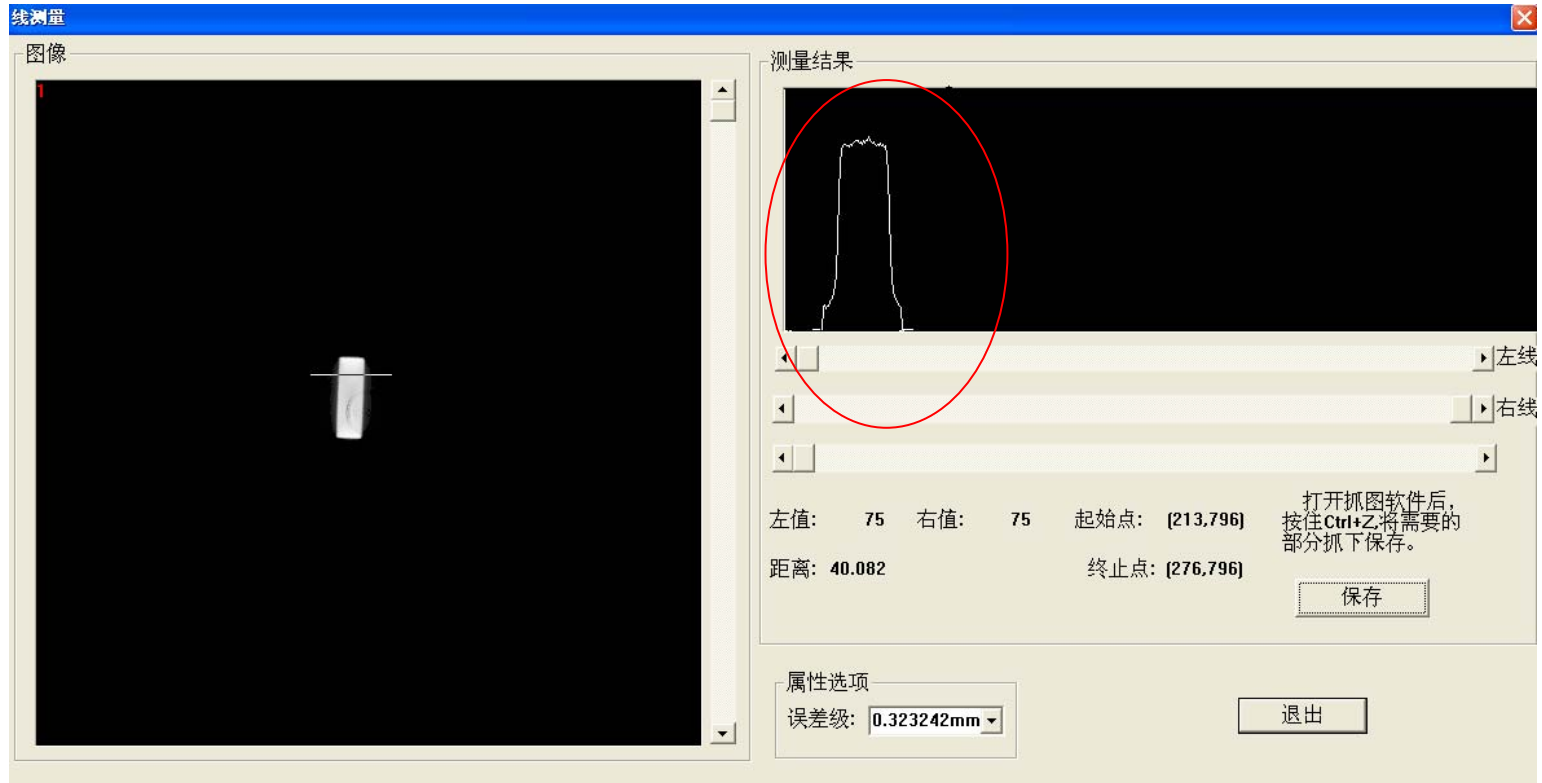
Frequency: 10MHz

T/R

water

Ta

W
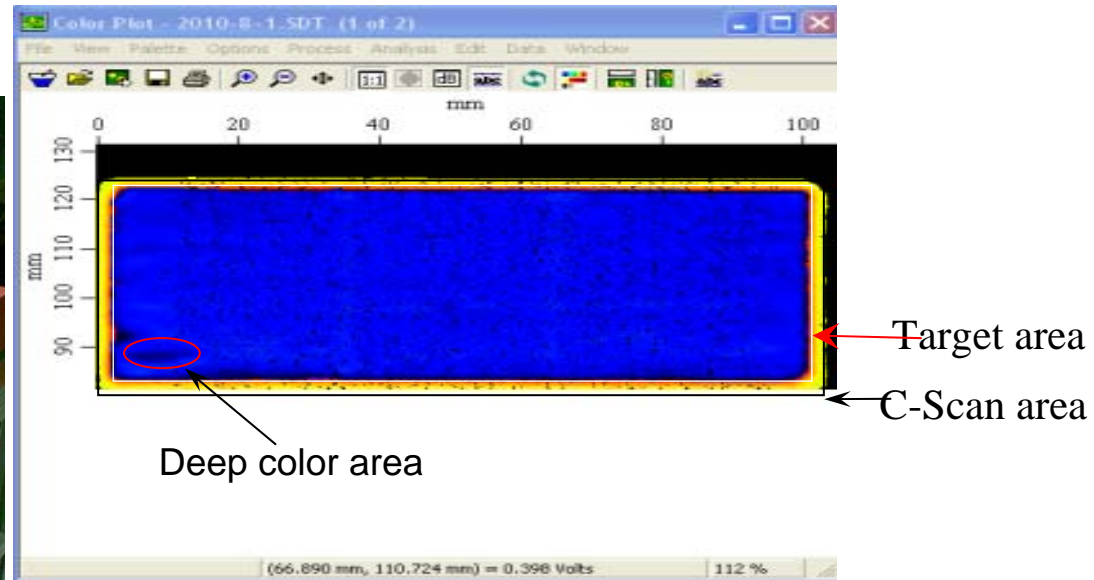
$$R = \frac{Z_2 - Z_1}{Z_2 + Z_1}$$

R: reflection coefficient
Z_1, Z_2 :acoustic impedance

The acoustic impedance of air is far less than metal, When the interface have holes or gaps, $Z_2/Z_1 \approx 0$, R=1, it means total reflection, under this circumstances, the color is absolute different from others area.
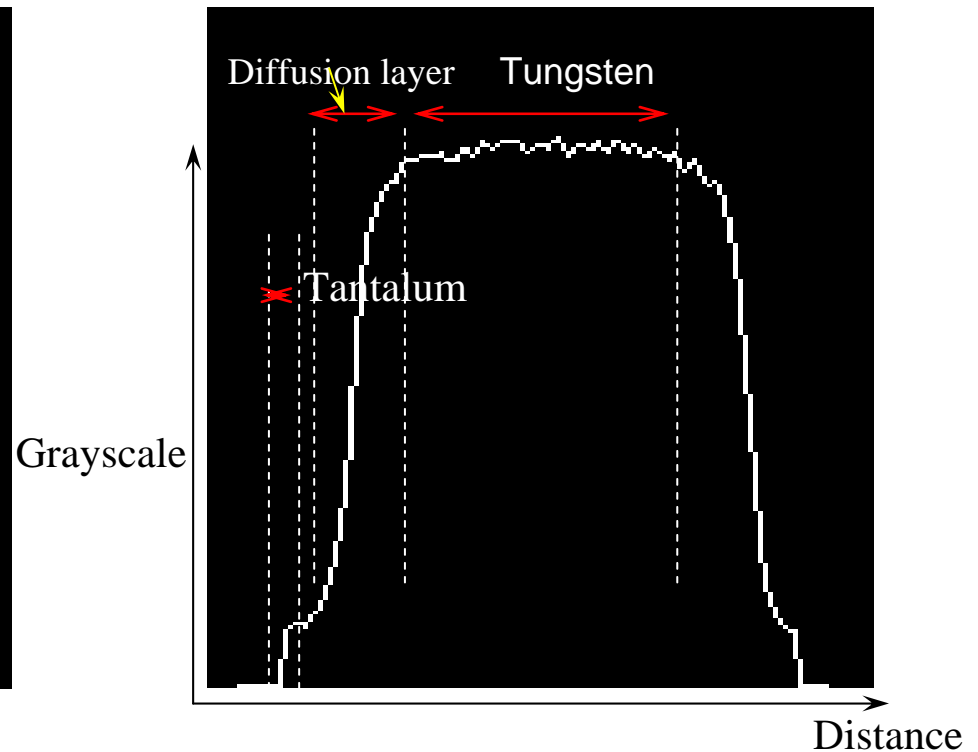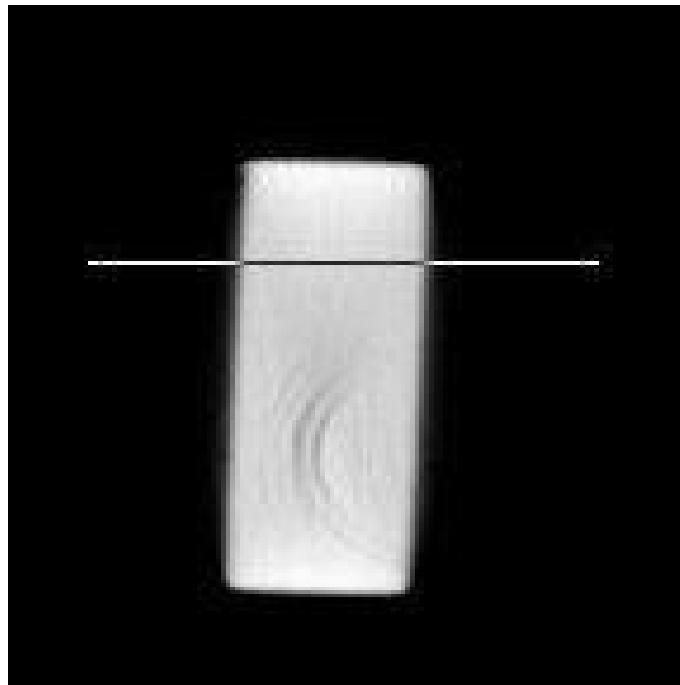
Industrial CT Cross-section Image

Institute of high energy physics, Chinese Academy of Sciences

Energy: 8Mev

Industrial CT Cross-section Image

Grayscale

Diffusion layer   Tungsten

Tantalum

Distance

The horizontal axis is distance, the vertical axis is gray. Grayscale value indirect shows density, In this white line, from the change of gray, We may distinguish tantalum, diffusion layer and tungsten.

◆ Target material: Tantalum cladding

◆ Moderator: Connecting piece

◆ Chopper: B_4C coating on aluminum alloy

◆ Summary

Connecting piece(Invar and 6061 aluminum alloy)

Liquid hydrogen line

Connecting piece

Liquid hydrogen Moderator

Invar
Invar
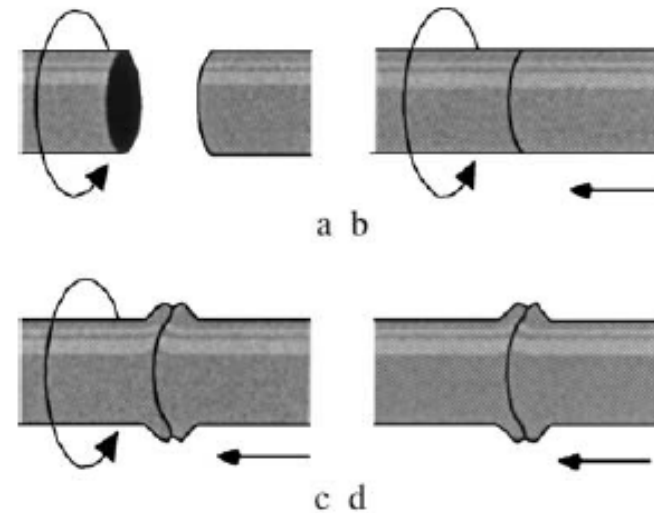Al6061-T6
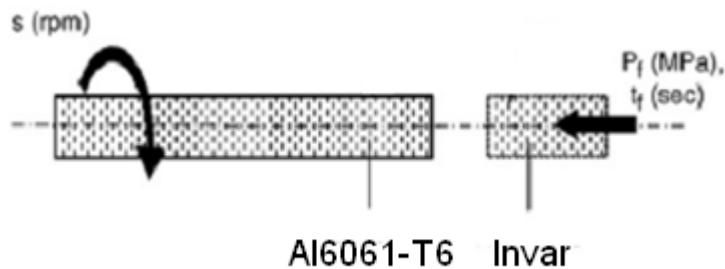Al6061-T6
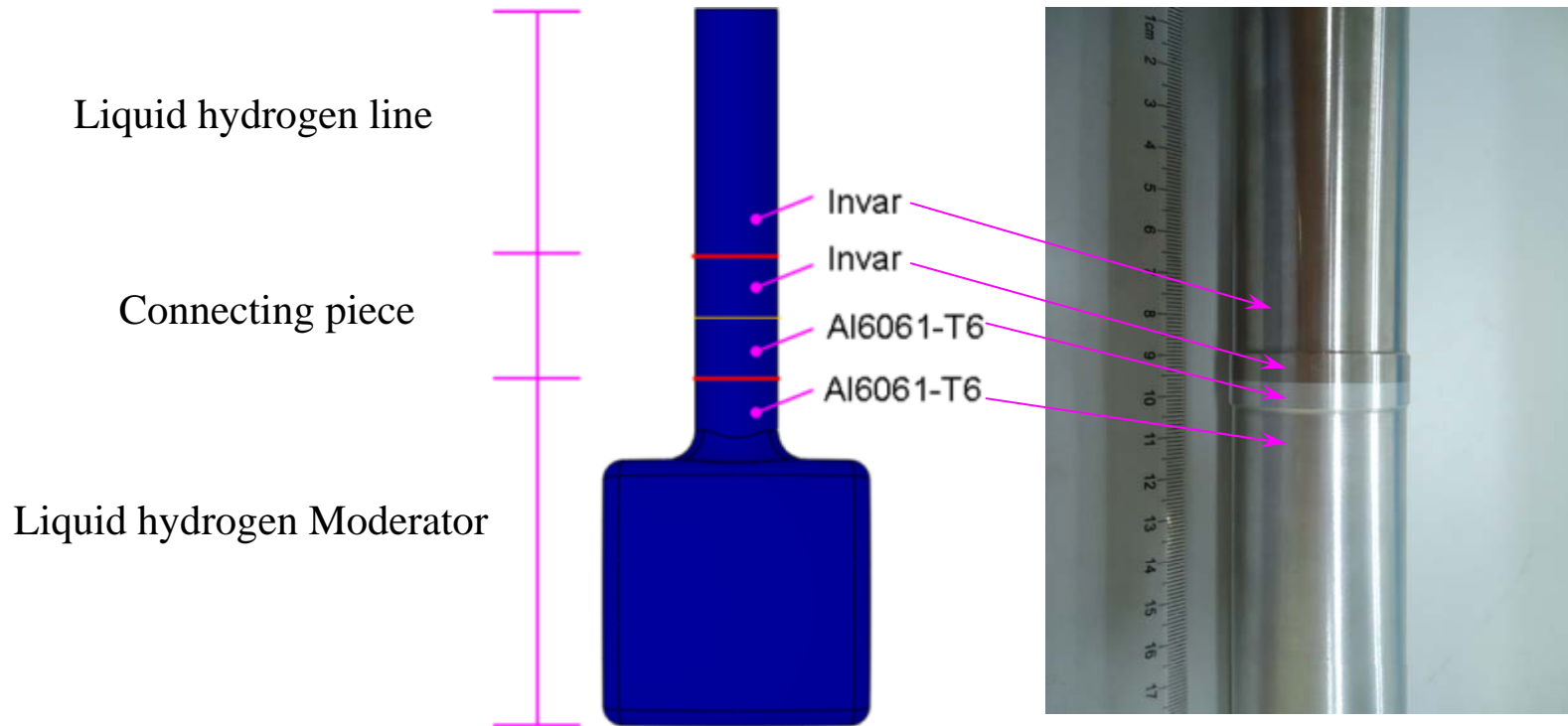
Inertia Friction Welding

Fig. 1. Schematic representation of the IFW process.

Stage 1. One of the two workpieces is fixed while the other is given a rotational velocity. A flywheel connected to the rotating workpiece gives an initial inertial energy (Fig. 1(a)).

Stage 2. (initial contact). The two workpieces are held in contact leading to an initial interfacial frictional heating. This removes surface irregularities, and it is a function of the process conditions, material and loading (Fig. 1(b)).

Inertia Friction Welding(Invar and 6061 aluminum alloy)
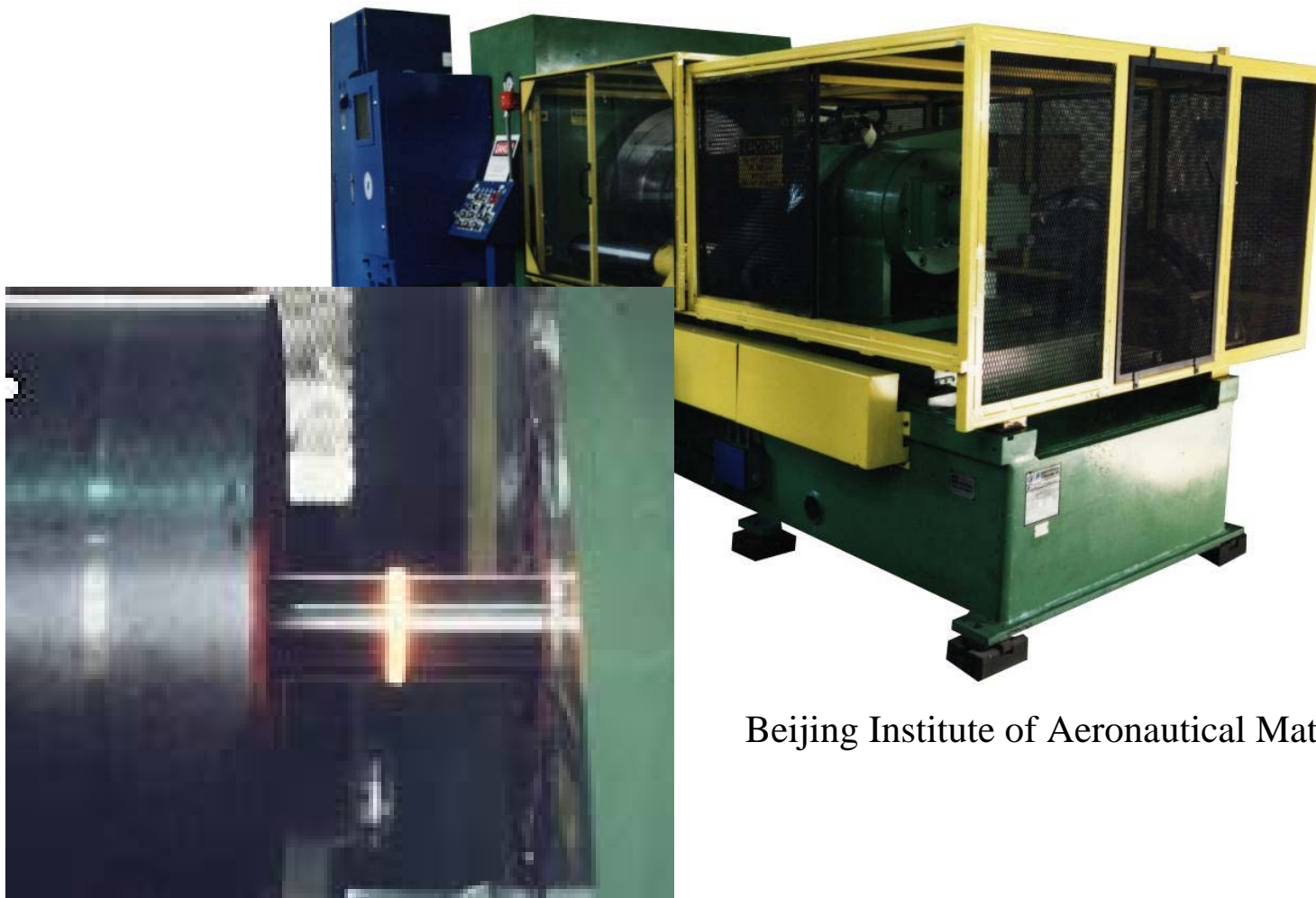
Beijing Institute of Aeronautical Materials
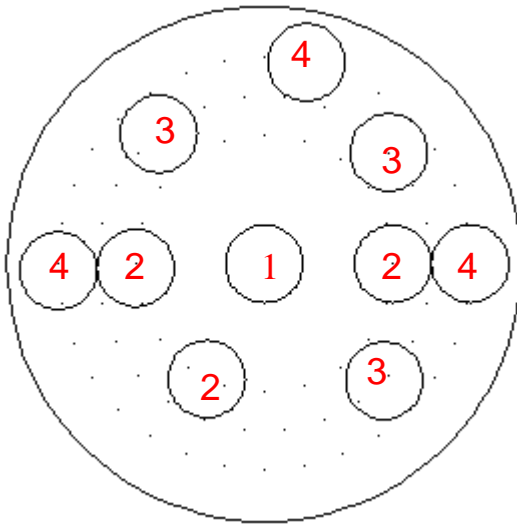
Inertia Friction Welding(Invar and 6061 aluminum alloy)

Tapering
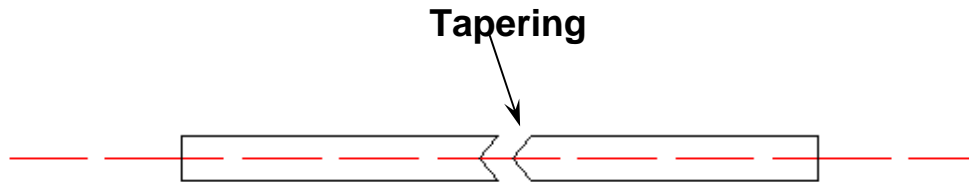
Conditions:
 Rotation speed:900RPM
 Friction pressure: 700PSI

 In order to increase friction area,
we use the cone replaced the plane

Mechanics Performance Test

Sample 1

Other samples

The distribution of samples positions

| Sample	Distance（mm）	**Tensile strength (MPa)**
1	0	0
2	10	235
3	13	237
4	16	230

➢**The sample located in the center of rod was broken because the friction of center is relatively small;**

➢**The tensile strength of other samples are more than 230 MPa, which achieve 80% of 6061 aluminum alloy's.**

Microstructure analysis
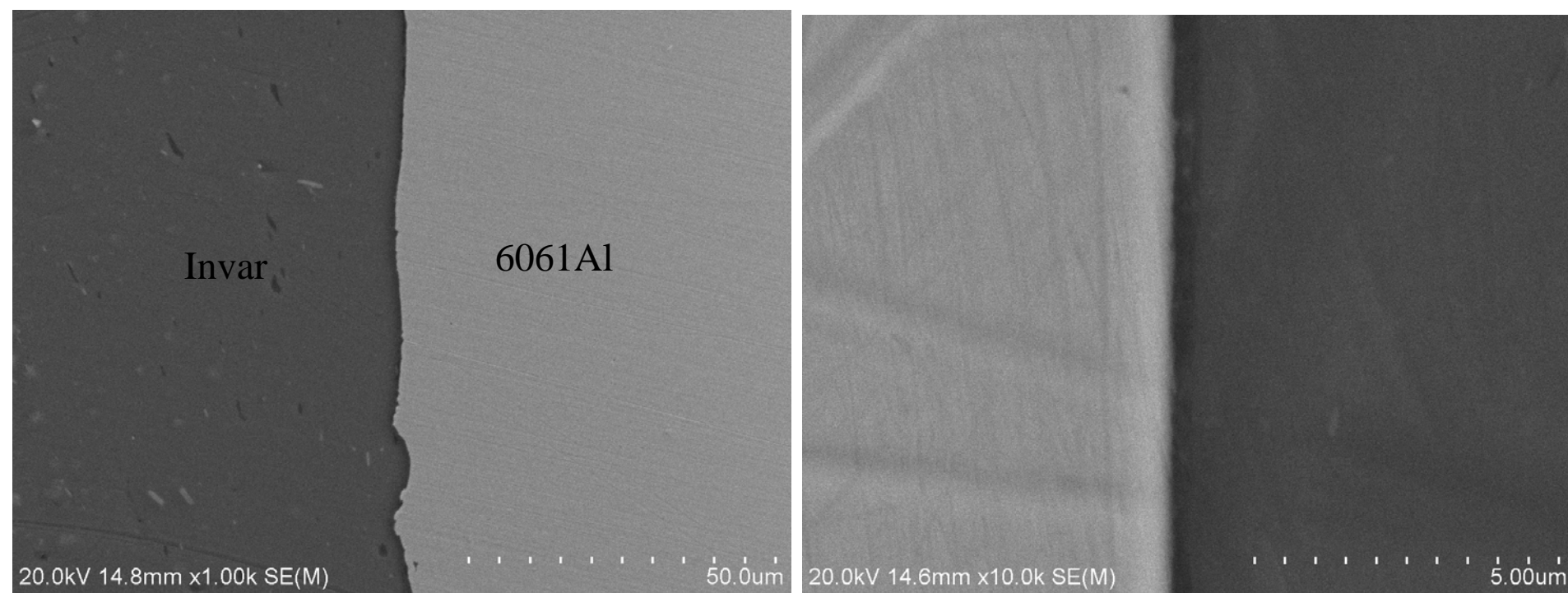
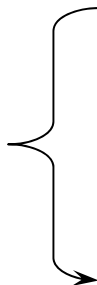SEM photos show that invar and aluminum alloy connected well.

Hardness test
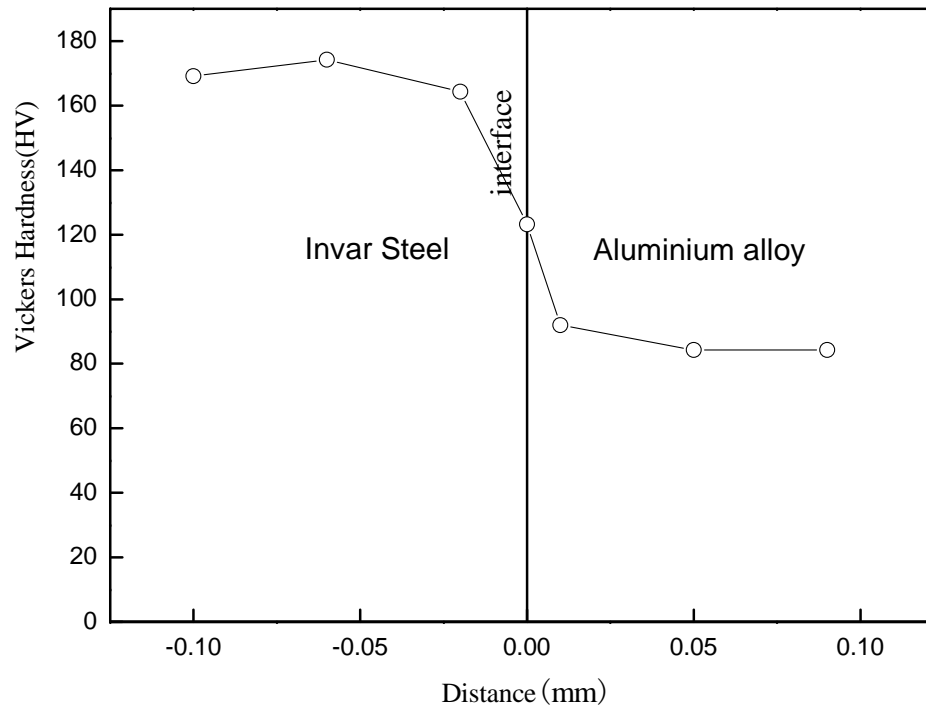
➤The curve shows the hardness change from invar steel to aluminium alloy

➤The hardness value of interface is about 120HV, which is between invar and 6061 aluminium alloy's

◆ Target material: Tantalum cladding

◆ Moderator: Connecting piece

◆ Chopper: B_4C coating on aluminum alloy

◆ Summary

Boron carbide coating on aluminum alloy is used for chopper to absorbing neutrons. There are three ways to form boron carbide coating on aluminum alloy:

Bonding with epoxy resin mixed with boron carbide

Plasma spraying boron carbide coating

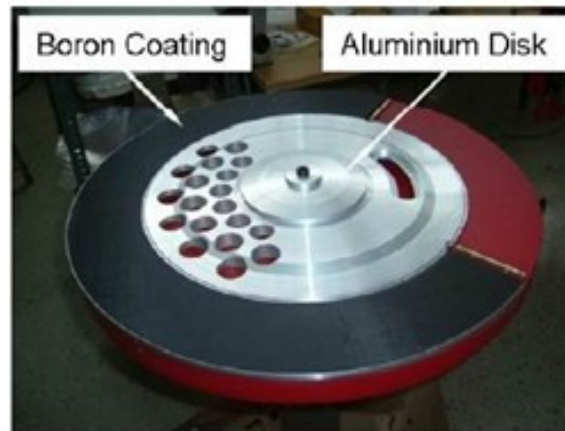Preparation of aluminum and boron carbide composite materials

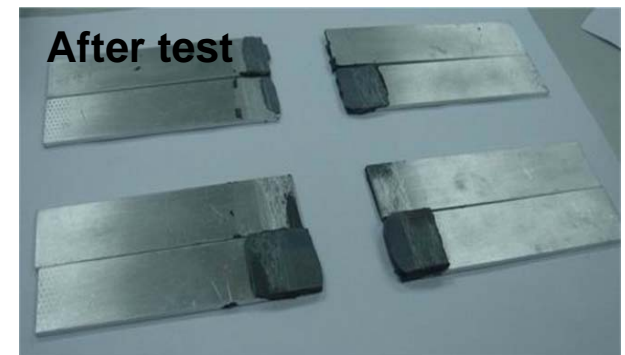Bonding with epoxy resin mixed with boron carbide or ^{10}B

SNS
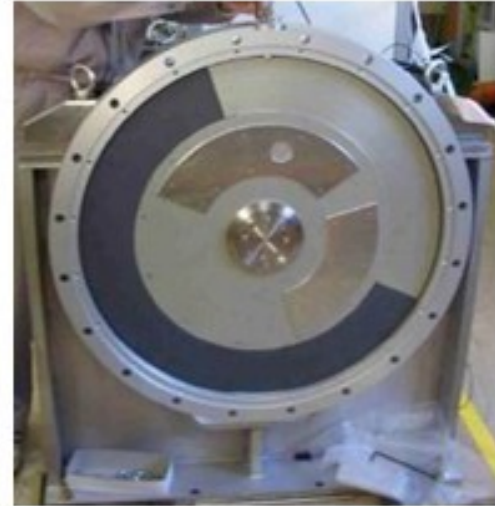
J-PARC
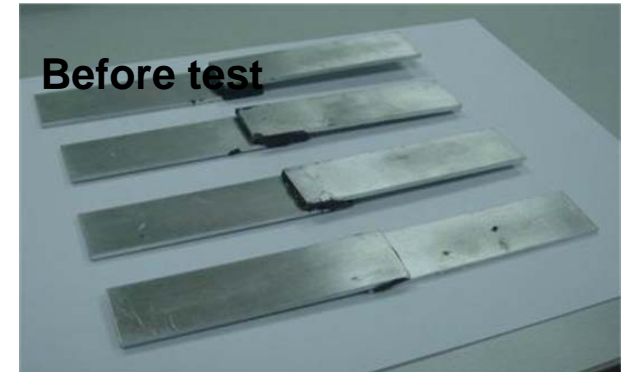
Julich

Small shear test of epoxy resin mixed with boron carbide on aluminum alloy

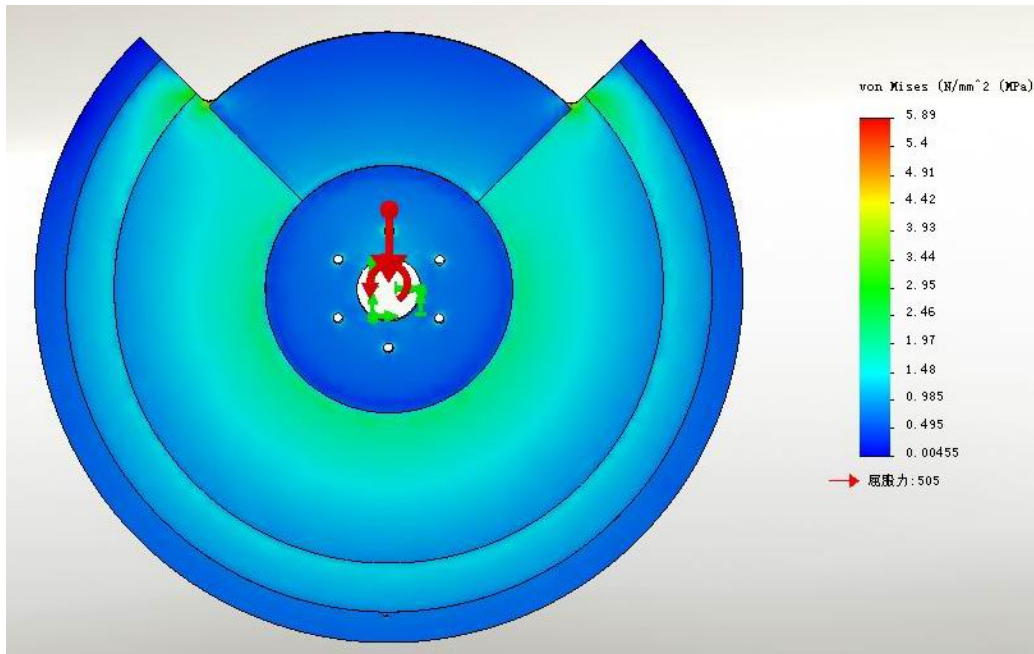Material: epoxy resin mixed with boron carbide
7A09 aluminum alloy

Condition: different thickness

No.	Thickness	Shear strength
1	0.7mm	11.39MPa
2	1.25mm	8.34MPa
3	1.55mm	6.84MPa
4	3.6mm	5.26MPa

Before test

After test

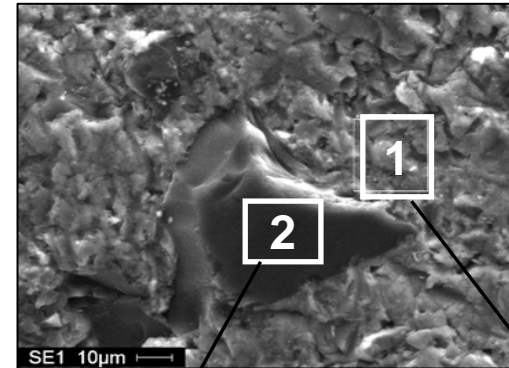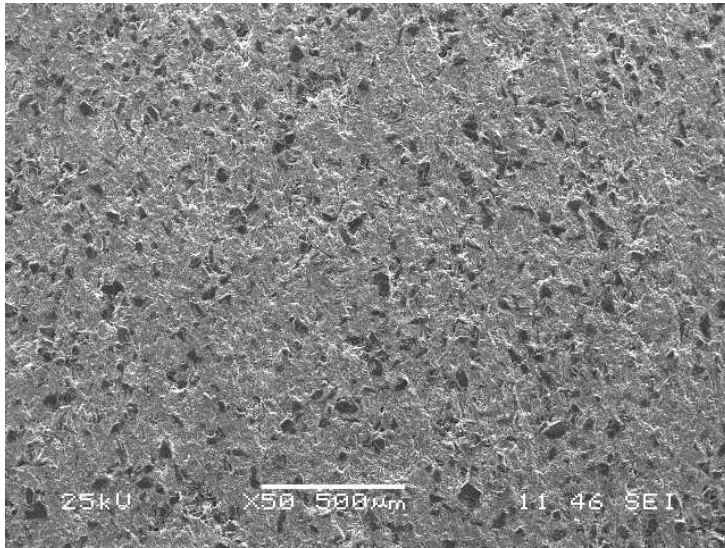COSMOS finite element analysis of stress distribution in chopper
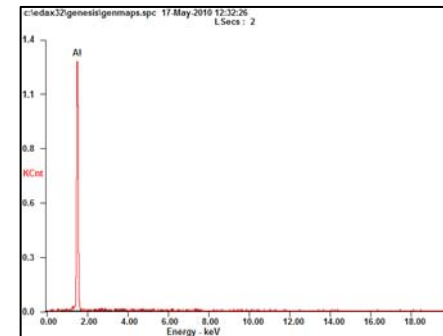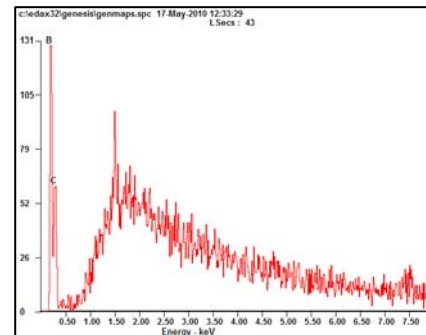

Material: 7A09 aluminum alloy

Frequency :25Hz

Maximum stress at the coating is obout 3 MPa, lower than the intensity of experiment samples .

Preparation of aluminum and boron carbide composite materials

SEM photo of aluminum and boron carbide composite materials

Element	Wt%	At%
BK	67.50	69.77
CK	32.50	30.23
Matrix	Correction	ZAF

Element	Wt%	At%
AlK	100.00	100.00
Matrix	Correction	ZAF

✓ B$_4$C uniform distributed in aluminum

✓ By mechanical testing, the flexural strength of composite materials is above 190MPa

Summary:

- CSNS target materials in progress

- Much work to be carried out further

- CSNS target station materials research need a lot of help from other Spallation Neutron source

Acknowledgement

CSNS target station team

IHEP: Mr. Que Jiemin

Beijing Institute of Aeronautical Materials: Dr. Liang Jing

Central South University : Dr. Jiang Kui

Thanks for your attentions