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THE DEVELOPMENT OF CUCRZR HIGH HEAT LOAD ABSORBER IN TPS

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Abstract

Taiwan Photon Source (TPS) project in National Synchrotron Radiation Research Centre (NSRRC) has reached 500mA design goal. Several upgrades and design enhancements are also under development. CuCrZr copper alloy has been selected to examine its UHV compatibility, machinability and high heat load sustainability as one of the upgrade activities. Most importantly, the absorber is made entirely by CuCrZr (including two end flanges) and installed in the mid-section of double minimum of tandem EPU48 undulators to shadow beam miss-steered synchrotron radiation from upstream EPU. Both the result and fabrication time (without brazing) are promising.

INTRODUCTIONS

As to synchrotron accelerator machine, synchrotron radiation is always associated with high density power, and 99% of them are to be shadowed before it reaches beam line users. Due to its high conductivity and ultra-high vacuum (UHV) compatibility, Oxygen free high conductivity (OFHC) copper and GlidCop® are two of the commonly used materials to shadow the unneeded synchrotron power. OFHC is used to absorber lower power density synchrotron radiation whereas GlidCop® can be much higher due to its excellent mechanical material properties.

However GlidCop® is solely fabricated by the company named North American Höganäs, it is much more expensive and it is not readily available when it comes to specific sizes.

In 2013, we have considered other copper material which can replace OFHC and GlidCop®. The reason being is to marry with stainless steel, both them require brazing process, which either is time consuming or has high failure rate. We searched for couple of candidates and found out CuCrZr alloy is the right material to use due to

- It has high yield and tensile strength.
- It is much cheaper than GlidCop® and is available even in our local supply vendors.
- It can be welded with stainless steel.
- It is UHV compatibility.

As shown in Table 1, CuCrZr alloy has comparable mechanical properties with GlidCop®, with a little bit lower thermal conductivity (16% lower than that of OFHC) but its high yield and tensile strength, this alloy is worthwhile to give a try. Other accelerators have used it for undulator chamber [1].

Table 1: Material Properties

Property	OFHC	GlidCop®*	CuCrZr[2]
Conductivity (W/cm°K)	3.83	3.65	3.23
Thermal expansion (m/°K×10^{-6})	16.6	17	18.6
Poisson ratio	0.31	0.35	0.18
Yield strength (Gpa)	0.049-0.078	0.33	0.27-0.44
Tensile strength (Gpa)	0.215-0.254	0.42	0.37-0.47

**GlidCop-15*

In the following sections, we will present how we carry out vacuum and weld tests of CuCrZr copper alloy.

VACUUM TEST

Templates are provided for recommended software and authors are advised to use them. Please consult the individual conference help pages if questions arise.

An outgassing rate test is performed in our vacuum laboratory. The layout is shown in Figure 1.

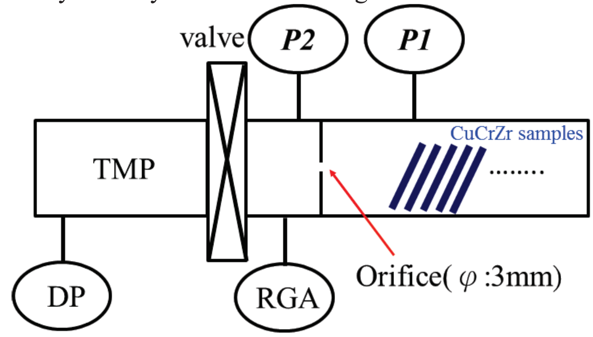

Figure 1: CuCrZr sample outgassing test layout.

The CuCrZr alloy plates has total surface of 4000 cm^2 piled up in the vacuum chamber. They are ultrasonic cleaning in Citranox®, rinsing with de-ionized water for 10 minutes, and dry with 99.9999% nitrogen. Comparing with other materials such as Al and Stainless steel, we list their outgassing rate in Table 2:

The result of outgassing rate comparing with CuCrZr, Aluminum and Stainless steel is illustrated in Figure 2:

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Table 2: Outgassing rate of CuCrZr, Aluminum and Stainless Steel.

Material	Outgassing rate (Pa m s^{-1})	
	Q_{10}	Q^*_{72}
CuCrZr	1.6×10^{-6}	5.8×10^{-6}
Aluminium	3.3×10^{-6}	1.6×10^{-6}
Stainless Steel	1.8×10^{-6}	1.5×10^{-6}

*Baked out then pumped down.

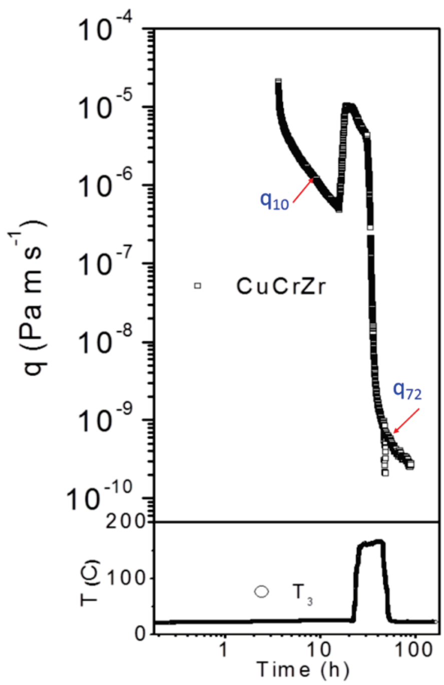

Figure 2: Outgassing rate curve for CuCrZr.

A series of baking out test is also performed in the laboratory. We applied 11N-m torque while bolting CuCrZr-made flange with stainless steel flange. We then baked, pumping down, replace new copper gasket, bolted again. Total of 10 cycles of this process is repeated to the same CuCrZr flange. Each time we recorded its leaked rate. Figure 3 illustrates that even after 10 bake-out cycles, CuCrZr flange still has good leak rate. No visual damages on the knife edges are observed.

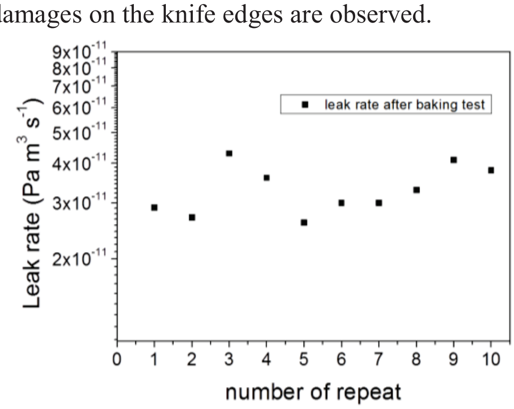

Figure 3: Leak rate of CuCrZr after numbers of flange bolting.

WELDING TEST

Since CuCrZr can be welded with Stainless steel by e-beam weld, it indicates these two dissimilar materials can be jointed together by welding. Even E-beam is able to provide precise, smaller HAZ and deep penetration but it is not readily available among local vendors. Samples of Stainless steel and CuCrZr plates are also prepared and TIG welded together. Due to different thermal conductivities and thermal expansion, extra attention is required during welding. Figure 4 shows post weld result of Stainless steel plate and CuCrZr sample plate.

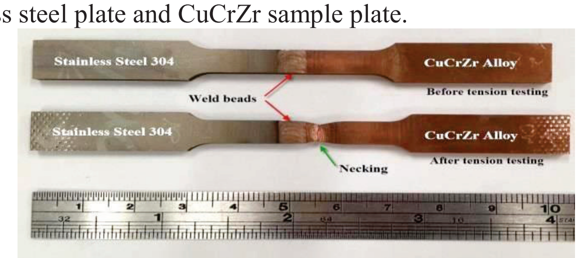

Figure 4: Welded CuCrZr/Stainless steel sample after tensile test.

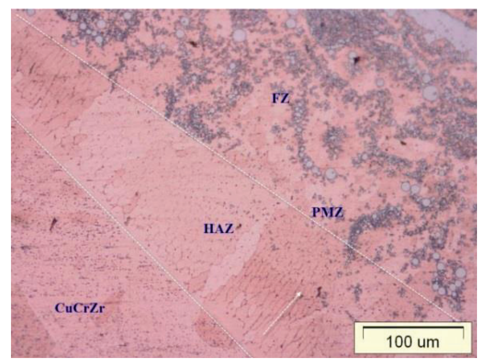

Figure 5: Microscope view of CuCrZr/Stainless steel HAZ area.

The microscope photo in Figure 5 reveals clear Heat affective zone (HAZ) between CuCrZr alloy grain boundary and stainless steel fusion zone (FZ). Stainless steel particles are surrounded by CuCrZr copper matrix. It is believed that stainless steel particles behave as slipping obstacles along the copper grain boundaries to enhance material strength. That's why in Figure 4 the necking appears on the CuCrZr side instead of on the weld bead, this indicates that welded interface is indeed has higher tensile strength that that in CuCrZr itself, as is shown in Figure 6.

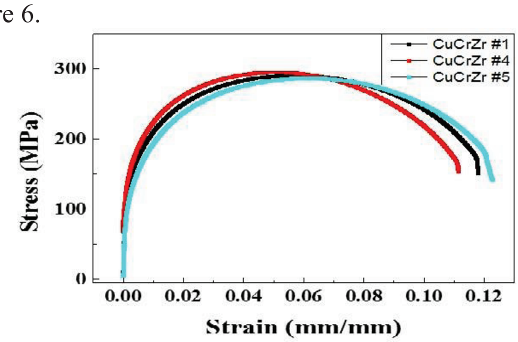

Figure 6: Tensile test result of welded CuCrZr/Stainless steel sample plate.

Facility Design and Updates

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CUCRZR ABSORBERS

In this 2016 July-August shutdown, TPS had experienced several upgrade and maintenance. One of them is to replace middle section of double minimum EPU48. The original chamber height in this section is 8mm, which leads to high radiation dose and high temperature rise on the 8mm height bellow. We upgraded this section by a 20mm height Aluminium chamber. A tapper down absorber (inside aperture is tapered from 20mm back to 8mm downstream EPU48 chamber) is required to absorb synchrotron radiation from its upstream EPU48 during beam miss-steering. A CuCrZr absorber is made and installed for this function, both the flanges, absorber body are fabricated in one piece without any welding or brazing. This largely reduces the cost as well as eliminates the brazing time.

Figure 7 shows the CuCrZr absorber installed in the mid-section of double minimum EPU48 chambers.

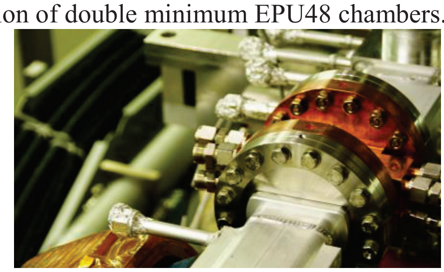

Figure 7: CuCrZr absorber in mid-section of double-minimum EPU48s.

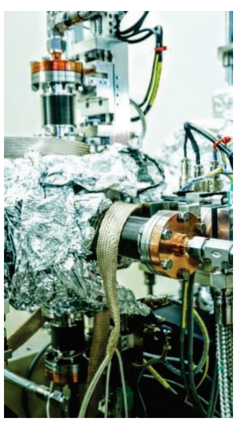

Figure 8: CuCrZr slits in TPS front end 24.

Front end 24 (for TPS phase II beamline) has been installed, as shown in Figure 8, we also designed a four ways slit to confine bending magnet fan for the beam line user. Each slit is made of one piece of CuCrZr alloy, which includes cooling tube, flange and counter flow cooling body.

These two cooling assemblies are first two CuCrZr high heat load components currently installed in TPS storage ring in this year (August, 2016).

NEG COATING

NEG coating on CuCrZr material has also been studied in TPS. The Ti-Zr-V getter films were grown on the CuCrZr alloys. Prior to getter films deposition, the CuCrZr samples were cleaned by the standard cleaning process same as for the TPS vacuum chambers. In our experiments, direct current sputtering method was used. The base pressure of the sputtering chamber was 1.5×10^{-4} Pa. The thickness of the films is in the range of 0.5-1 μm. After a getter film coating was completed, the samples were subjected to a series of analyses and measurement. The surface morphology and the X-ray diffraction pattern of the film were shown in Figure 9 (a), and (b), respectively. The NEG films have a rough surface and circular pores. In addition, the signals marked in Figure 9 (b) come from the Ti-Zr-V getter films and the original substrate. The peak associated with the Ti-Zr-V film occurs at approximately $2\theta=34^{\circ}$. The average grain size of Ti-Zr-V films was calculated to be 1.5 nm. It indicates that the Ti-Zr-V films have nanocrystalline structures.

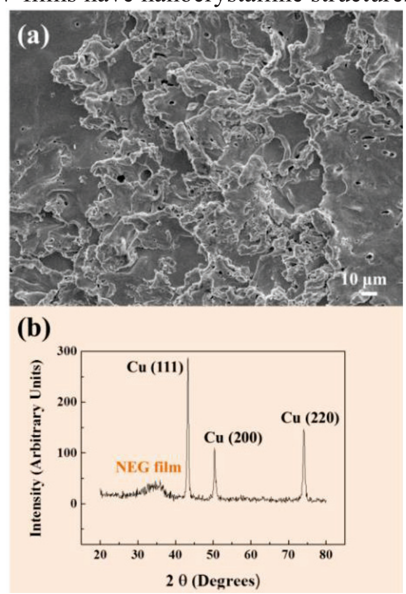

Figure 9: (a) The surface morphology (b) X-ray diffraction pattern of Ti-Zr-V getter films on the CuCrZr alloys.

DISCUSSION AND CONCLUSIONS

CuCrZr alloy has been test and adopted as our new candidate for high heat load components in TPS. Its UHV compatibility has been proved by our outgassing rate test. By carefully controlled welding parameters we are able to TIG weld the alloy with stainless steel. Tensile test has also been carried out to ensure its weldability; primary research on NEG coating on CuCrZr alloy is also studied.

Two high heat load components, TPS double-minimum EPU48 mid-section transition absorber and front end 24 water cooled slits are made in one full CuCrZr piece of material and have been installed in 2016 summer shutdown maintenance. They will be used as first touchstone to verify using this alloy as our next generation high heat load components.

REFERENCES

[1] *Vacuum Science and Technology for Accelerator Vacuum Systems*, CLASSEE, Ithaca, NY, Jan. 2015, pp. 34.

[2] www.conductivity-app.org/download-alloy-pdf/19.