Investigation of Vacuum Properties of CuCrZr Alloy Used as High-Heat-Load Absorber

Taiwan Photon Source (TPS), a third-generation accelerator with electron energy 3 GeV, has achieved its design goal, 500 mA, in NSRRC. In the TPS ultrahigh-vacuum (UHV) system, high-heat-load (HHL) components of varied types have been customized to meet the various power-load and density-flux requirements of the beam-line users, and to take account of the thermomechanical limits of the materials. Absorbers, a type of HHL component, are designed to be installed between straight chambers and to protect the downstream-chamber wall from synchrotron radiation, thereby avoiding overheating of the chamber. The most important considerations for the HHL absorber are thus thermal conduction and thermal outgassing. GlidCop® and oxygen-free copper are materials typically used for HHL components, but a vacuum leakage is commonly observed at a brazed interface between a stainless-steel flange and the material of the HHL components, for various reasons such as brazing failure and cracks at the brazing interface after heat treatments (**Fig. 1**). One solution of this issue is thus to integrate the formation of HHL with ConFlat® CuCrZr flanges, as shown in **Figs. 2(a) and 2(b)**. In this work, Chin Shueh *et al*. proposed to use the CuCrZr alloy (ASTM C18150) for the HHL absorber body and ConFlat® flanges. This material is chosen because of its specific advantages, which include satisfactory thermal conductivity, great mechanical strength, high softening temperature, and acceptable weldability. We applied a throughput method to measure the rate of thermal outgassing and a helium leak detector to verify the vacuum seal between the CuCrZr alloy and stainless-steel flanges.

Fig. 1: Failed components (contaminated).

The samples examined in this work were CuCrZr alloys (ASTM C18150). Before measuring the rate of outgassing, each sample was cleaned with Citranox.[1] The rate of outgassing was measured with the throughput method[1], which has the advantage of measuring that rate in real time. All measurements of that rate were performed during baking at 160 °C. To verify the vacuum seal, we also sequentially mounted and unmounted the CuCrZr flanges connected to the stainless-steel flanges ten times, followed by baking at 250 °C, to ensure that the CuCrZr flanges were robust and suitable for UHV applications.

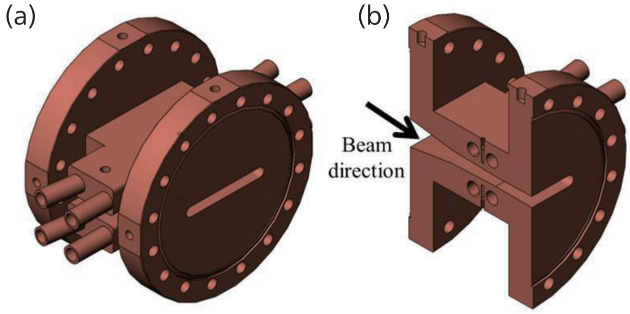

Fig. 2: Design (a) and section view (b) of a CuCrZr high-heat-load absorber. [Reproduced from Ref. 1]

The pressure in an UHV system is determined mainly by the rate at which gases are desorbed from the inner wall of the chamber or from other components in the UHV system; the rate of outgassing is the most important factor in an UHV system. In a normal case, an outgassing rate less than 1 x 10^{-9} Pa m/s is suitable for use in a UHV system. In this work, the rates of outgassing at 10 and 72 h (q_{10} and q_{72}) are given in Table 1 and compared with the team's previous work. The rate of outgassing of Al and stainless steel is about a tenth that of CuCrZr, but these rates become roughly the same (10^{-10} Pa m/s) after pumping for 72 h and baking at 160 °C. The slightly large initial rate of outgassing might result from gas stored near the surface, making it easily desorbed on baking and producing the large rate q_{10}.

Figure 3 shows the rate of helium leakage as a function of fastening torque (7, 9, 11, 15 and 20 N m) and baking at 250 °C for mounting and unmounting a CuCrZr flange connected to a stainless-steel flange

Table 1: Rate of outgassing of CuCrZr, Al and stainless steel after 10 and 72 h [Reproduced from Ref. 1]

	Rate of outgassing [Pa m/s]	
	10 h	72 h
CuCrZr	1.2×10^{-6}	5.8×10^{-10}
Al	3.3×10^{-7}	1.6×10^{-10}
Stainless steel	1.8×10^{-7}	1.5×10^{-10}

ten times with stainless-steel M8 bolts. The CuCrZr and stainless-steel flanges were the DN 100 ConFlat® type, which has the same size as an absorber flange. The results reveal that a fastening torque ≥ 11 N m is required to achieve an effective vacuum seal even after baking at 250 °C (*i.e.*, a leakage rate less than 9.6×10^{-11} Pa m^3/s and no helium leakage signal after injecting helium between the CuCrZr and stainless-steel flanges).

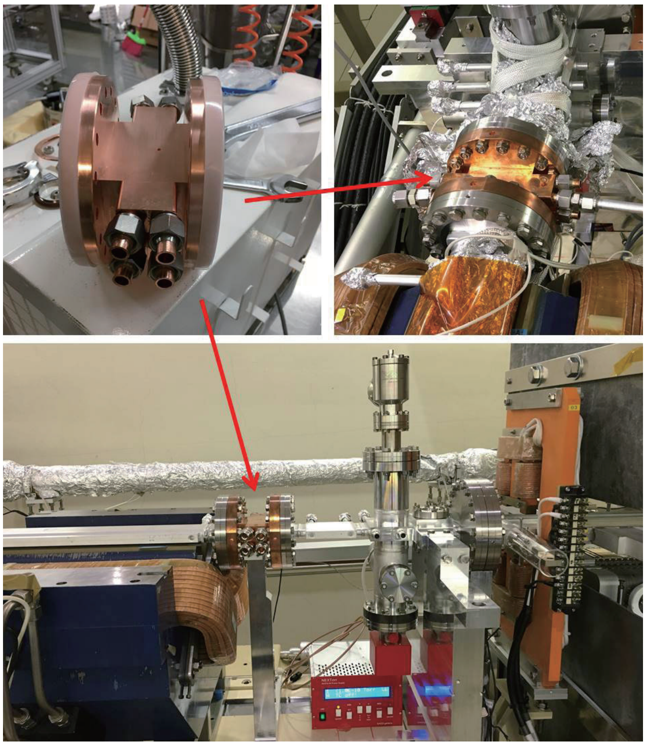

Fig. 3: Leakage rate vs. fastening torque with 7, 9, 11,15 and 20 N m and no baking and with fastening torque 11 N m and baking at 250 °C. [Reproduced from Ref. 1]

Despite the satisfactory thermal characteristics of CuCrZr flanges and no visual damage to the knife edge even after ten sealing tests (**Fig. 4**), one disadvantage is that CuCrZr is less hard than stainless steel, which means that the knife edge of the CuCrZr flange must be carefully connected with the stainless-steel flange with an oxygen-free-copper gasket.

Shueh studied the usability of integrating a CuCrZr high-heat-load absorber with a CuCrZr flange in TPS. The rate of outgassing from the CuCrZr was mea-

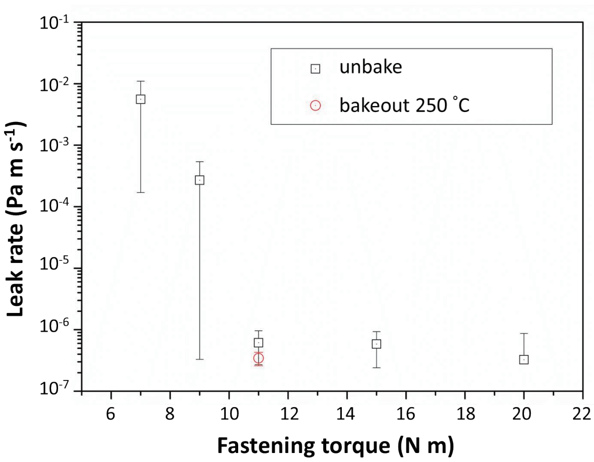

Fig. 4: Optical microscopic inspection of the knife edge of a CuCrZr flange. [Reproduced from Ref. 1]

sured; the robustness of the vacuum seal provided with CuCrZr flanges connected to stainless-steel flanges was tested under thermal cycling undertaken in baking cycles. The results reveal that the rate of outgassing, although initially large, decreased to a level comparable to that of aluminium and stainless steel after 72 h of baking at 160 °C. In addition, the baking thermal cycling does not degrade the vacuum seal between CuCrZr and stainless-steel flanges, providing that the flanges are tightened with torque at least 11 N m. This work hence opens a new possibility for high-heat-load components in UHV systems, which should be of interest to those in synchrotron facilities. This work completes the development of a prototype of CuCrZr-made HHL absorbers with ConFlat® flanges through computer-numeric-control (CNC) machining, which were installed in the TPS storage ring for testing in July, 2016 (**Fig. 5**). (Reported by Chin Shueh and I-Ching Sheng)

Fig. 5: Photographs of installation of a CuCrZr HHL absorber in section 21 of the storage ring.

| Reference |

1. C. Shueh, C.-K. Chan, C.-C. Chang and I.-C. Sheng, Nucl. Instrum. Meth. A **841**, 1 (2017).