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# GLIDCOP BRAZING IN SIRIUS' HIGH HEAT LOAD FRONT-END COMPONENTS

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## *Abstract*

Sirius is a 4th generation synchrotron light source in project. Some of Sirius' beamlines will have a very high power density, more than 50 kW/mrad², to be dissipated in components that have a limited space condition. Thus, the refrigeration of these components is complex when one has in mind that the coolant flow cannot be too turbulent in order to not induce much vibration in the components.

Oxygen Free Copper (C10200) has been replaced by the Glidcop on high heat load synchrotron applications due to its good thermal conductivity and preservation of mechanical properties after heating cycles. However, this material is not very workable in terms of union with other materials. It leads to the necessity of development of a brazing process for Glidcop and stainless steel union.

Glidcop samples were submitted to a Cu-electroplating process and a silver base alloy (BVAg-8) was used to join the parts in a high vacuum furnace. Electroplating was used to improve the filler metal wettability. The results were very satisfactory, ensuring water and vacuum tightness. A desirable characteristic not yet proved is the virtual leak property. This paper will discourse about this brazing method.


## INTRODUCTION

Currently under construction, Sirius is a 3 GeV, fourth generation synchrotron light source [1]. Sirius is designed to have up to 37 beamlines with ultra-low emittance and high brightness, which will allow high-level research and development on a large range of areas as structural biology, materials science and nanoscience. Development of high-quality technologies is an important point as well (as the Sirius' monochromators and metrology equipment [2]). Figure 1 shows the construction status of the Sirius' project.

Figure 1: Sirius' construction status in August, 2016.

Given its high quality, its components rely on fine requirements on size, safety and cooling capability, having their design on the state of the art. Taking Front-End power absorbers as example: the refrigeration of these components is complex due to their reduced size allied to the high thermal load that is irradiated on them [3]. To solve this problem, engineered materials must be used.

The Glidcop is a good choice due to its good thermal conductivity and preservation of mechanical properties after heating cycles. The difficulty of this project lies on the fact that dissimilar metal components (*i.e.* Glidcop and stainless steel) must be joined and it is needed to isolate both the vacuum and the water chambers. Thus, the joint must be resistant to hold the pressure in the water chamber and must be tight to not allow the transport of small atmosphere molecules to the vacuum chamber. As a trial to manufacture these components, given its specific features, the brazing was chosen as a joining process.

The brazing is a chemical bonding process that consists in heating regions of interest on a set of components in order to reach temperatures at which the filler metal will melt [4]. The liquid filler metal will flow across the gaps by capillary action, covering the mating surfaces and then alloy and create a permanent chemical bond between them. It can join dissimilar metals and porous metal components.

Also, brazing allows the bonding of complex set of components in one operation, saving time and materials that otherwise could be consumed. It is important to emphasize that if the components and the process are properly designed, the brazed joint will be as strong as the base materials and the dimensional stability of the assembly will be maintained. That fact happens because the temperatures reached on a brazing process are much lower in comparison to other processes, as welding.

In addition, if the brazing is done in furnaces the heat is broadly distributed in the whole body volume, reducing the temperature difference between regions. When allied to the smaller heating rates, it results on less stress during the process.

Some other important points are the limitations of the process: stress raisers must be avoided in order to do not result in a fragile brazing joint; and the combination of materials is restricted by the fact that the filler alloy must have its melting temperature below the melting temperature of the base materials.

Brazing is a technique usually applied when there are high demands on strength, fatigue, corrosion and oxidation resistance. Apart from synchrotron technologies, brazing is found on areas such as automotive, aerospace and toll industries.

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## MATERIALS AND METHODS

The materials used on the process were Glidcop Al15 (a copper alloy strengthened with a dispersion of ultrafine particles of aluminium oxide) and stainless steel 304L. They were chosen because they have already been successfully applied on other synchrotron light sources around the world due to great properties as thermal conductivity and mechanical resistance.

The Glidcop is required as a resistant alloy to receive and dissipate the heat load, and the stainless steel is important to give mechanical resistance to the component structure during its whole lifetime.

Considering the whole manufacture chain, the brazing stages are: machining of the Glidcop component; Glidcop coating; machining of the stainless steel components; stainless steel coating; cleaning; assembly; and in-vacuum heating. It is needed two machining steps once the internal diameter dimensions of the stainless steel components will depend on the dimension of the external diameter dimension of the after-coating Glidcop parts. If the coating process is well known, the growth rate will be specified and then it can be done until the component reaches a desired dimension. That fact allows all the machining steps to be done at the beginning of the manufacture chain.

Related to the preparation of the components, the mechanical adjustment was designed to reduce as much as possible the gap between the components, but without resulting on the necessity to apply force while assembling them. In addition, the volume of the filler metal was calculated to be at least the double of the volume of the gap between the components. It was done on the intent to guarantee that all the space on the mating region would be filled.

Later, the coatings used on the base materials were: the nickel strike (which is more aggressive to the surface material in order to allow the deposition and bonding of the first thin nickel layer); the nickel Watt (effectively grows the nickel coating); and copper (which is applied only to the Glidcop parts). There are studies on the literature that shows the applicability of these electroplating coatings [5].

Those coatings were applied to improve the capability of the filler metal to wet the surfaces and to create a barrier to do not let the filler metal to reach the base materials by diffusion. It should be emphasized that the parts were cleaned (including ultrasonic cleaning) just before each new step – being the most critical the one before the assembling and heating stages.

The filler metal chosen was the Cusil (an eutectic copper-silver alloy, trademark from Morgan Advanced Materials) because of its combination of mechanical resistance and melting temperature.

The tests done up to now were on specimen rather than on real components in order to reduce machining time. The Photon Shutter, a power absorber that will be brazed by this technique, is shown on Figure 2. Its brazing points are four: one on each very last point of contact between the Glidcop body and the stainless steel tube (*i.e.* on both tube endings); and two more on the ending diameters of the Glidcop body, where it mates the flanges.

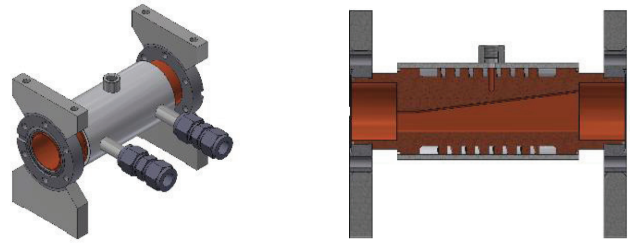

Figure 2: The photon shutter (isometric view on the left and half section view on the right side).

This manufacture chain will build two more components: the Fixed Mask and the High Power Slits (both having the same external dimensions as the Photon Shutter, varying mostly on length). The external dimensions of the specimen are equal to the ones of the real component.

The major simplifications done were on the shape of the longitudinal whole and on the water-chamber helical channels. As the materials are the same, the brazing steps and brazing cycle that will be applied to the manufacture of the real components will be the same as well. The brazing step is described on Table 1.

Table 1 - Description of the Brazing Process

| Stage | Heating Rate [ºC/min] | Temperatures [°C] | Time [min] |
|---|---|---|---|
| SP1.1 | 4 | 25 - 675 | - |
| SP1.2 | - | 675 | 15 |
| SP2.1 | 3 | 675 - 740 | - |
| SP2.2 | - | 740 | 5 |
| SP3.1 | 1 | 740 - 795 | - |
| SP3.2 | - | 795 | 4 |

The brazing was done positioning the centre whole on the vertical direction (i.e. the brazing channels to support the fillers were in the vertical). It was chosen once it is easier to avoid greater misalignments of the components with themselves during the assemble and brazing phases.

It is important to notice that when the filler melts, by capillary action, it flows across the gap between the components, independently of the gap orientation, filling it before starting to flow to other directions. That effect had its efficiency proven later by analysing the metallography samples and by approving the specimen on the leak test.

The step after the heating cycle of the component was an inertial cooling inside the furnace.

## RESULTS AND DISCUSSION

Figure 3 presents the microstructure analysis of the Glidcop and stainless steel joint. Frame a) shows that the coatings wet efficiently both surfaces (*i.e.* there are no empty spaces between a coating and the base material). In addition, the filler alloy is well bonded to the coatings over the whole surfaces and it filled the whole gap, as desired.

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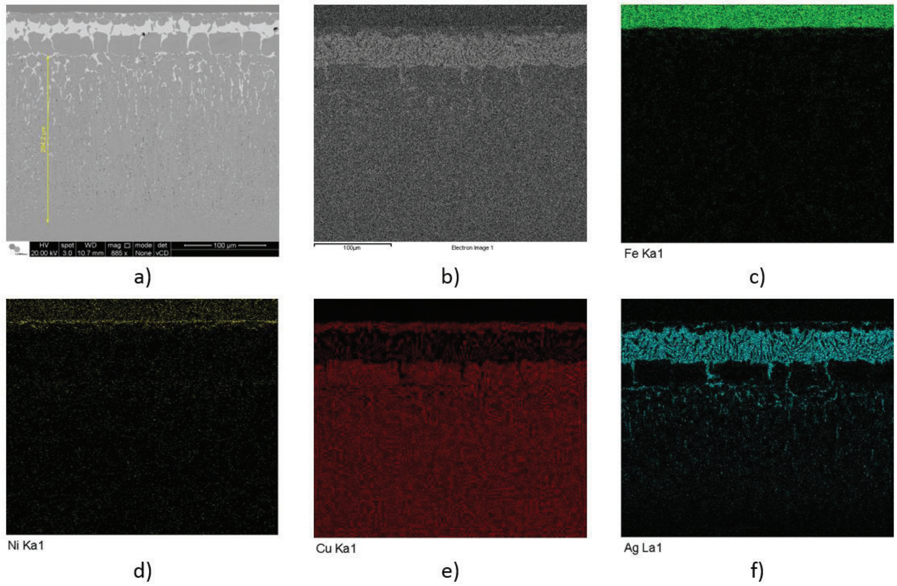


Figure 3: Glidcop and stainless steel brazing section. Frame a) shows the first section and d) the second one. An EDS analysis is show for the elements: Fe on frame b); Ni on c); Cu on e); and Ag on f).

Frame b) shows a brazing section where the EDS (Energy-dispersive X-ray spectroscopy) analysis was done. The stainless steel is on the upper side and the Glidcop on the lower.

On frames c), d), e) and f), the EDS elemental analysis are shown. Frame c) shows that only the stainless steel contains iron (Fe).

Frame d) presents the elemental analysis for the nickel (Ni). It is present in the stainless steel 304L alloy in small quantities and more concentrated on its coatings. The Glidcop's nickel coating suffered diffusion to the base material during the brazing process.

Copper concentrations are shown on frame e), which are high: on the Glidcop (base material and coating) and on the filler metal.

Finally, on frame f) it is show distribution of the silver (Ag) contained on the filler alloy. Also, it is possible to notice some diffusion of silver on the Glidcop matrix.

Some improvements on the coatings used on the Glidcop parts resulted on a reduction of this diffusion. Observing the behaviour of the filler alloy it is possible to notice that it distributed homogeneously across the gap, illustrating the uniformity of the process.

Considering the filler metal microstructure, there are two noticeable phases in it: the first rich in copper with silver in solid solution; and the second rich in silver containing copper in solid solution.

Related to the mechanical adjusts, the coatings could cover the whole part surface, accompanying the surfaces irregularities and keeping almost constant the deposition rate (apart from the corners, where there was always a concentration of coating material). The fillers alloys could also bear some minor irregularities on the base material's surface while filling the gaps between them.

Another point of analysis was the comparison between the upper and lower regions of brazing. Once the brazing was done with the specimen's longitudinal axis on the vertical direction allied to its upper half being symmetric to the lower one, it could be studied if the capillary action resulted on symmetrical joints on both sides.

Metallography analysis and leak testes were done to check both regions and it was proven that their behaviour under operational conditions were similarly acceptable.

Leak tests were conducted on the two regions of each specimen: the water chamber and the vacuum. All those regions were approved on the test with no leak detected up to $10^{-10}$ mbar.l/s, full scale and minimum leak rate of the equipment.

Afterwards, hydrostatic pressure tests were done. The operational water pressure of the components on the beamline will be eight bar. It was established that tests must be conducted on pressures 50% higher than the operational pressure to ensure the safety of the component. Hydrostatic pressure tests were conducted using pressures above 12 bar for 24 hours. In addition, a pressure of 34 bar was applied to the brazed component for a few 5 minutes to test it under super-critical conditions. It supported the test without any problems.

## CONCLUSIONS

The objective of the current study was to obtain a brazing process that could be integrated to the manufacture chain of the Sirius' power absorbers. Also, the joint needed to bond dissimilar metals and result on a leak-tight and mechanical-resistant structure. It is possible to conclude after microstructure analysis, leak tests and hydrostatic pressure tests that the developed process (based on nickel and copper coating and the Cusil filler alloy) attends the requisites imposed for its application. The components made of the combination of Glidcop and stainless steel presented satisfactory performance on the tests.

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