NOCOLOK® News #2-2023

November, 2023

Head of the NOCOLOK® Competence Centre - Dr. Sebastian Gutmann

Dr. Sebastian Gutmann holds a diploma in chemistry from the University of Oldenburg, Germany and a PhD from the University of South Florida, USA. He joined Solvay's Specialty Chemicals business in 2012, where he held various positions in Research & Innovation in Hanover, Germany and Seoul, Korea. As a project and team leader, he contributed to the development of materials for electronic applications (displays, photovoltaics), insulation and batteries, before assuming technical responsibility in the NOCOLOK® business.

With the retirement of Dr. Hans-Walter Swidersky, Dr. Gutmann took over the role of Manager of the NOCOLOK® Competence Centre, where he now heads the technical service (Hannover) and research activities (Bad Wimpfen) for the NOCOLOK® flux aluminium brazing technology. The NOCOLOK® Competence Centre focuses on product and process improvement as well as application testing and analytical services for the NOCOLOK® product portfolio.

After a passive phase, Dr. Swidersky officially retired in December 2023. We would like to take this opportunity to thank Dr. Swidersky for his many years of outstanding contribution to the NOCOLOK® business and wish him all the best in his well-deserved retirement.

Bad Wimpfen celebrates 40 years of NOCOLOK® production in Germany

NOCOLOK® was developed in the early 1980s as an alternative to traditional aluminium brazing methods. Traditional methods required high temperatures which resulted in distortion, corrosion and other quality defects. NOCOLOK® not only improved product quality, but also reduced production costs and energy requirements in the manufacture of aluminium parts such as car radiators and air conditioning systems. Unlike the development samples, these were not yet brazable and had to be mixed with potassium cryolite. Continuous development resulted in a product that is now the standard brazing agent for aluminium parts in the automotive industry. Other variants like NOCOLOK® Cs Flux, Li Flux or Zn Flux for special applications have been developed and are still produced in Bad Wimpfen.

As part of the company celebrations on 14 July 2023, we celebrated "40 years of NOCOLOK® production" by presenting the production team with a new anniversary plaque and polo shirts. On the same evening, the new plaque was installed on the building.

Gränges Technical Seminar 2023

Solvay was proud to co-sponsor this year's Gränges Technical Seminar, which was held from September 19 – 21, 2023 in Suzhou, China. About 250 registered participants from the thermal management industry joined the event. After several years of limitations to meet during the Covid period, it was a great opportunity for face-to-face meetings and exchanges at the NOCOLOK® booth. The event focused on "Low carbon enabler, path to green aluminium" with discussions on sustainable development of the upstream and downstream industrial chains of thermal management. Dr. Sebastian Gutmann gave a talk about "NOCOLOK® flux brazing technology for New Energy Vehicles", outlining the bright future and many opportunities of NOCOLOK® flux technology for brazing of battery cooling plates. The talk was well received and triggered a large interest and requests from the participants.

NOCOLOK® and carbon footprint

Sustainability and circular economy is one of the most important trends of our time. This is why all industries, including the automotive industry, are making great efforts to achieve carbon neutrality within the next few decades. A key building block is the calculation of the CO_2 equivalent value of the materials produced, based on Life Cycle Assessment studies that comply with international ISO standards. Such studies are a cradle-to-gate approach that includes all process steps from raw materials through the process itself to the final product.

All NOCOLOK® based products, powders, pastes and fluxes, are calculated with such resulting CO_2 equivalent values and a declaration can be provided under NDA agreements.

New NOCOLOK® Video on YouTube

NOCOLOK®, the world's leading flux for aluminium brazing, is not only produced in various grades at the Solvay plant in Bad Wimpfen, but is also continuously developed and optimised for new applications. The relocation of the NOCOLOK® Research &

Innovation (R&I) pilot plant and laboratories from Hannover to Bad Wimpfen has been successfully completed.

Take a look at our new video on YouTube

Solutions for brazing challenges in battery coolers

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Abstract

Thermal management of electric vehicles is faced with challenges, as batteries need to be kept at a defined temperature range between 15 and 35 °C in order to function at peak performance throughout the life of a vehicle. The manufacture of such battery cooling systems involves controlled atmosphere brazing technology using noncorrosive flux. OEMs develop different battery cooler designs that require adapted fluxing methods. In this paper, selected cases of fluxing and brazing challenges in the manufacturing of battery cooling systems will be presented. Brazing experts will provide guidelines for fluxing and brazing of battery coolers.

1 Introduction

Batteries currently used in electrical vehicles [EV] can operate within temperature between -30°C and 50°C; however at temperature extremes, their performance is reduced and also battery life time suffers quite significantly. At high temperatures above 70°C, a chain reaction can occur causing destruction of the battery pack. Also during fast charging, batteries must be cooled down. High current going into the battery produces heat that must be removed. EV batteries perform the best at temperature between 20°C and 25°C [1].

EV batteries can be cooled using air cooling or liquid cooling. Liquid cooling is the method of choice to meet modern cooling requirements.
Air cooling systems use air to cool the battery and exists in the passive and active forms. Passive air cooling uses air from the outdoor or from the cabin to cool the battery. It is usually limited to a few hundred watts of heat dissipation. Active air cooling gets its air intake from an air conditioner, which includes an evaporator and a heater to control the air's temperature. It is usually limited to 1kW of cooling and can be used to cool or heat the cabin.

Liquid cooling is the most popular cooling technology. It usually uses a liquid coolant such as water mixed with ethylene glycol and a corrosion inhibitor. Components carrying the liquid prevent direct electrical contact between the cells and the liquid coolant.
Like in air cooling, passive and active systems exist. Active liquid cooling is more complex and expensive but provides better performances for propulsion and charging power and the cooling results are much more reliable, thus nowadays, most batteries for EV are liquid cooled using active cooling, despite the fact that the active cooling is more expensive since it includes more components, such as a heat pump, a heat exchanger, a circulating pump, valves, and multiple temperature sensors [2].

Types of EV battery water coolers

An aluminium component is surrounding the battery cells. The component is filled with liquid coolant, which carries the heat to another location, such as a radiator. There is no direct electrical contact between the cells and the liquid coolant. The cooling component is usually located at the bottom of the car cabin.

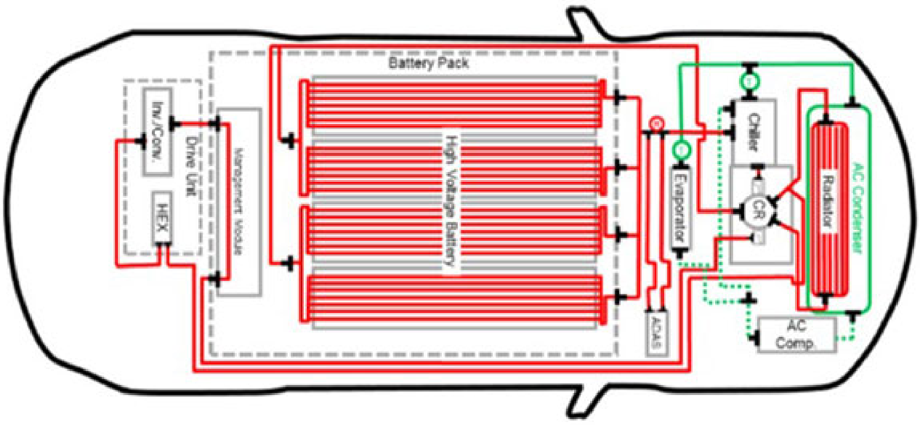

Figure 1. *Exemplary location of the battery cooling system in an EV [3]*

One type of the cooler design is based on Multiport Extrusion tubes [MPE]. It has been patented by Tesla [4]. In this design the flat MPE is slightly bent around battery cells. Brazing is required only for joining the MPE tube with the collector. Such joint is quite easy to braze and so far no information about brazing problems connected with this type of battery coolers have been known to the authors.

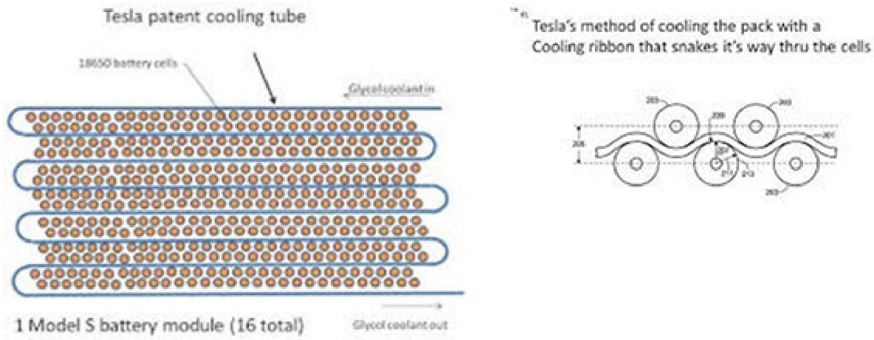

Figure 2. *Concept of battery cooler made with MPE tubes [4]*

A second type of the battery cooler design is based on two flat plates usually of large size (up to about 2 meters). The plates are brazed together by some kind of inner dimples or dikes formed in one plate. The dimples/dykes provide resistance to inner pressure of the coolant and make the coolant flow turbulent.

Figure 3. *EV battery cooler design [5]*

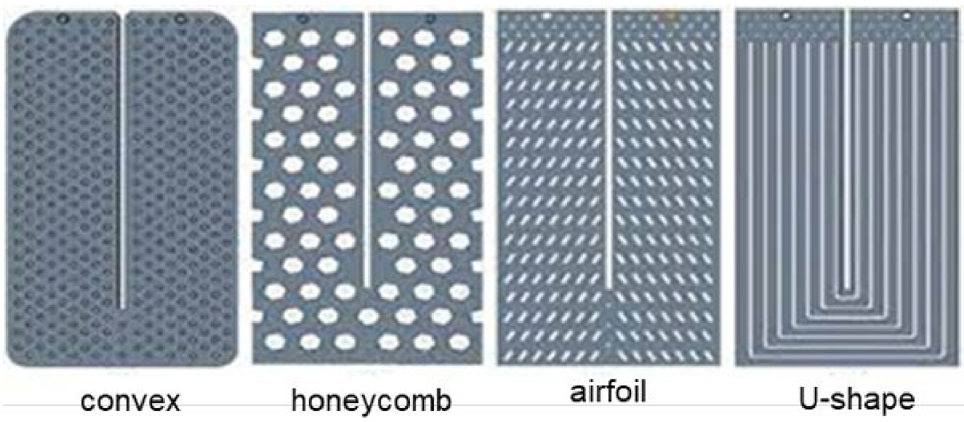

Figure 4. *Different designs of connectors between the two plates of an EV battery cooler [6]*

2 Methodology of brazing fault analysis

Brazing as any other technical process is controlled by several parameters. These are: temperature, flux load and its uniformity, furnace atmosphere, joint geometry, filler metal availability, cleanliness. When each of these parameters is within the optimal limit, 100% successful brazing is guaranteed. Thus, when investigating a brazing fault one should concentrate on checking the values of the above parameters during brazing. This is not a straightforward process since there are no technical means to measure them directly during the brazing process (except the furnace atmosphere). It means that by examining the faulty parts one should define which of the brazing parameter was not met. This examination could be quite simple (just visual observation) or may require using more sophisticate technics like optical and/or electron microscopy. [7]

3 Not-brazed dikes/dimples

Not-brazed dikes/dimples is the most common brazing problem. The battery coolers must have a perfectly flat surface from one side due to the fact that the batteries are positioned on that surface. When some of the inner dimples are not properly brazed, a small deformation (bulge) of the initially flat surface are formed during pressure leak test. Such parts are therefore scrapped.

Case 1

A cut out from a plate battery cooler with bulged surface (not-brazed dikes) has been analysed by optical microscopy and scanning electron microscopy (SEM).

Figure 5. *Cut out from a large cooler plate with slightly bulged surface*

During investigations a few metallographic cross sections were prepared both across flat surface of the plate and across the bulged area.

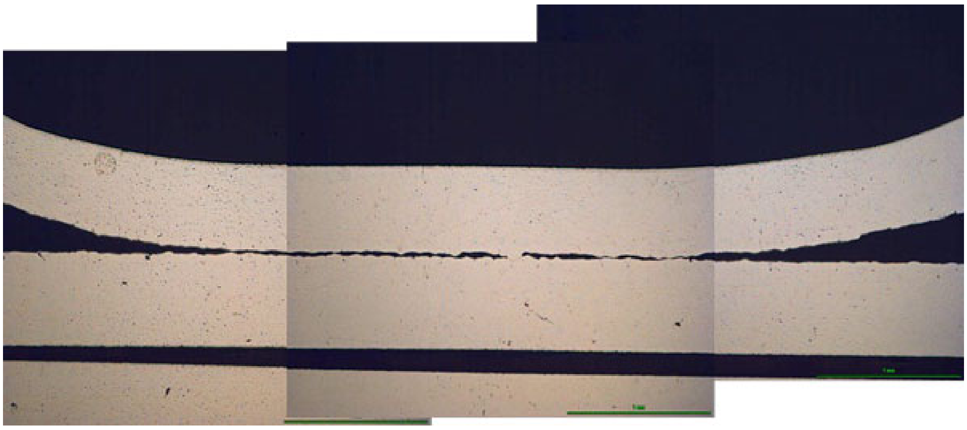

Figure 6. *Cross section through slightly bulged area*

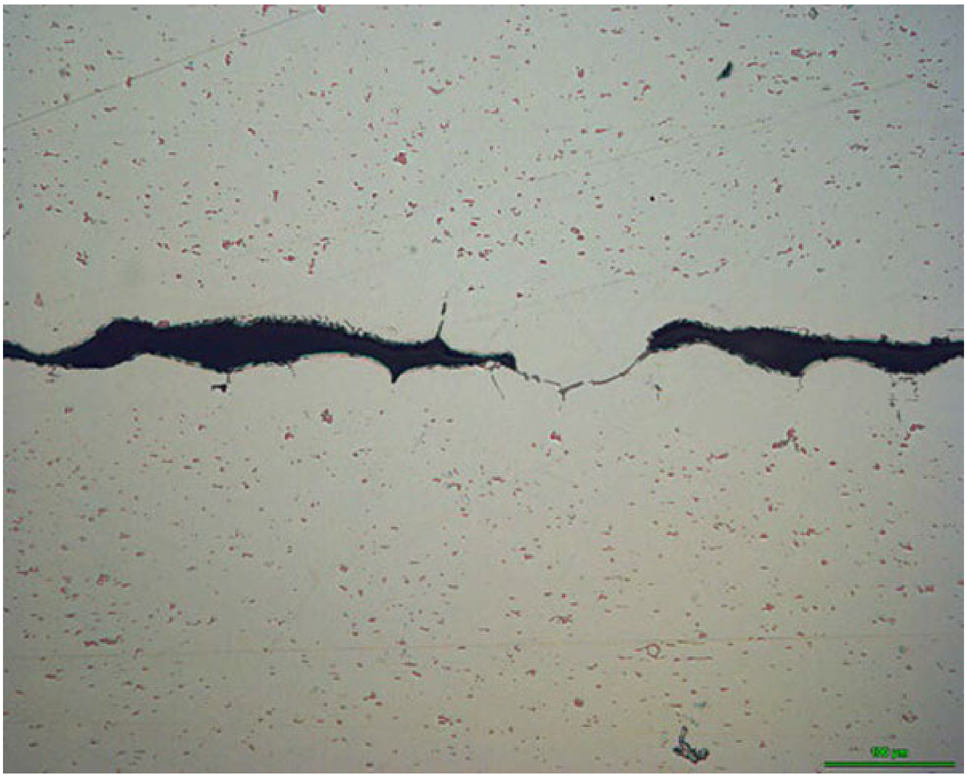

Figure 7. *Cross section through slightly bulged area; high magnification*

The above pictures allowed for elimination of joint geometry (gap size) and temperature as possible reason for the braze failure. The plate material was clad with 4343 alloy. Observation of the joint at high magnification reveals presence of whitish ribbons, which are free of precipitates. This is a witness mark of the 4343 clad, which must have been liquid during the brazing cycle (wavy like character of the surface). No silicon precipitates are seen since it must have diffused into the bulk of the material during the brazing cycle. This observation suggests that the brazing temperature must have been correct during brazing, but the liquid clad did not wet the opposite side of the joint. Thus possible reason for the braze failure are: lack of flux, bad furnace atmosphere and/or cleanliness. Those parameters can be investigated by SEM.

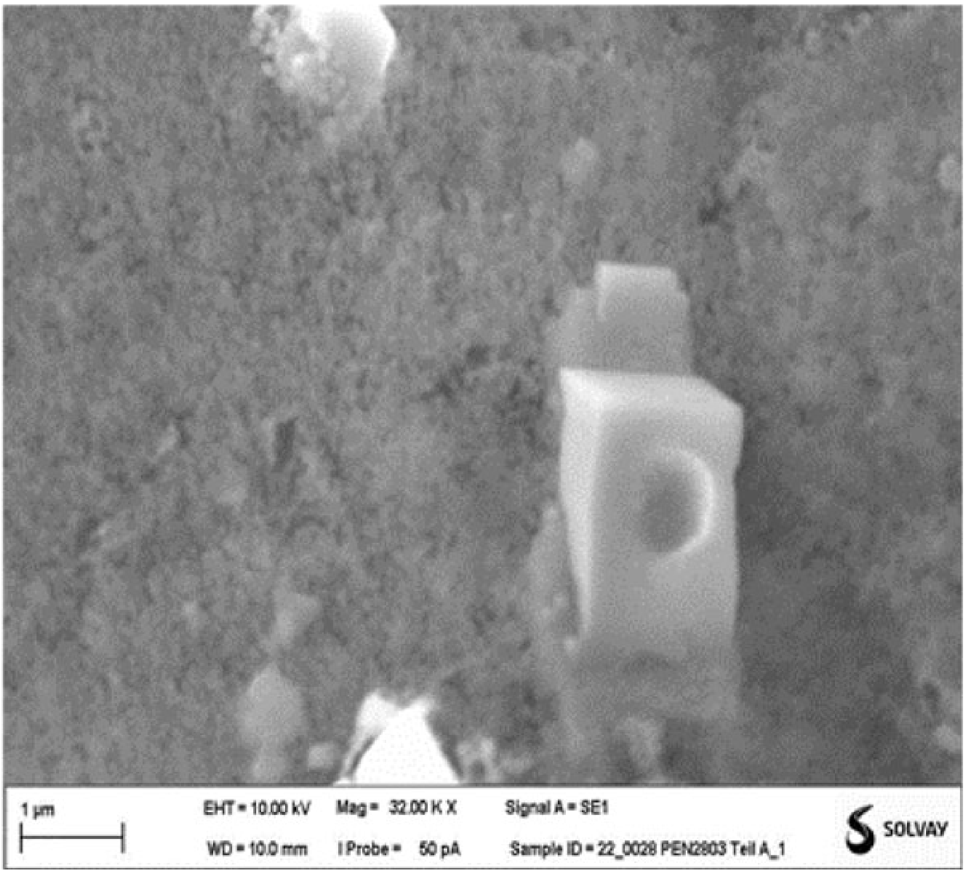

Figure 8. Surface morphology of the not-brazed joint. Case 1

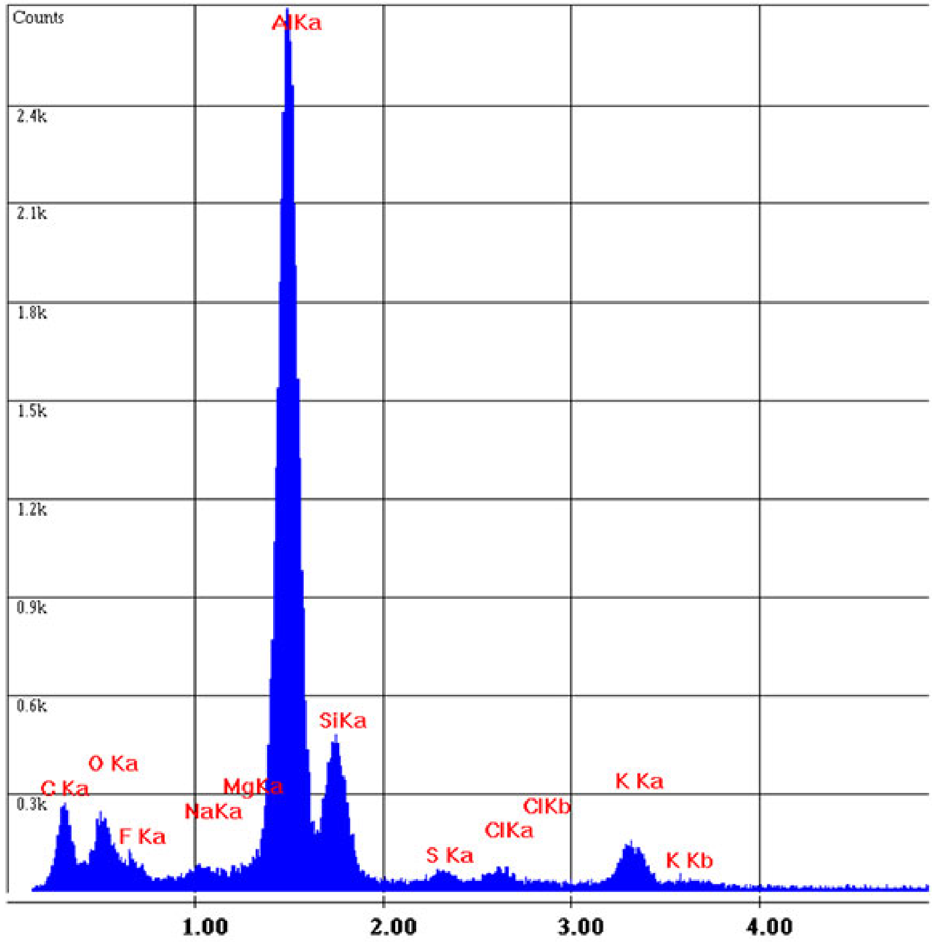

Figure 9. *EDX diagram from the surface of not-brazed joint*

Observation of the surface morphology of the not-brazed joint showed presence of only few crystals of flux residue. The observed crystals have rectangular character (no high level of moisture – correct furnace atmosphere [8]). This observation were confirmed by the energy dispersive x-ray (EDX) diagram, which showed very weak signals from flux (fluorine and potassium), very low level of oxygen and also no traces of contaminants (carbon) were found. Thus one can conclude low level of flux deposit was responsible for the failure of brazing. It is not within the scope of this work to discuss the precise method of fluxing, as this is confidential information by the manufacturer.

Case 2

A similar design as in Case 1 was investigated. The difference was such that a much wider area of not-brazed dikes appeared in this case. Similarly as in Case 1, a not-brazed surface of the dike was observed under SEM.

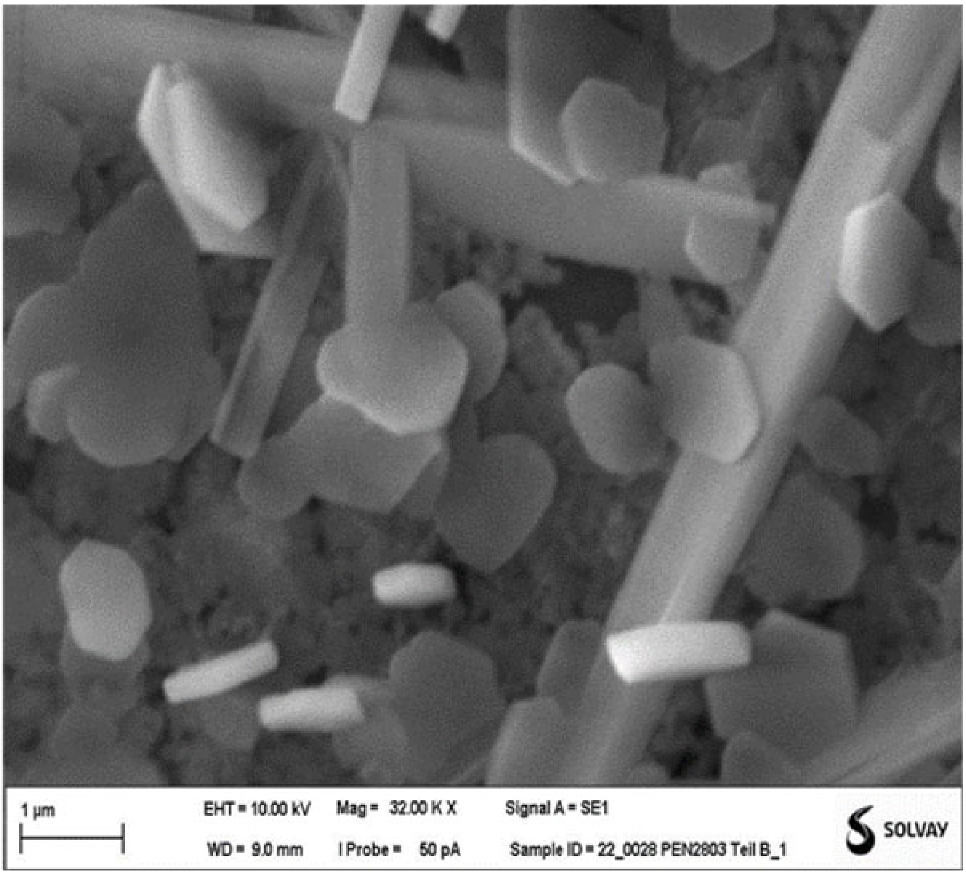

Figure 10. *Surface morphology of the not-brazed joint. Case 2*

The not-brazed surface is characterized by presence of hexagonal flux crystals. This indicates the presence of moisture in the furnace atmosphere during the brazing cycle [8]. This situation was caused either by insufficient removal of organic binder from the flux paint and/or by incomplete drying of the plates.

Case 3

Similar cut outs as discussed in Case 1 and 2 were analysed by optical microscopy and SEM; however the inner channels are not formed by dikes but by single dimples. Mechanically opened up not-brazed dimples are shown in figure 11.

Figure 11. *Not-brazed dimples. Plate mechanically opened up after the brazing*

When analysing under optical microscope a contact between the flat plate and a spherical cone like dimple, one must realize that the distance between these two surfaces is a function of the observation plane location. Only when the observation plane runs exactly through the apex of the dimple, definite conclusions about the joint gap can be drawn. Unfortunately, determining the exact location of the observation plane in the relation to the dimple apex is quite difficult and during a standard optical observation it is not usually performed. However one rule should be always observed; the observation plane should be parallel to the line determined by the dimples tips. In this way when observing different gap size at the dimples located next one to each other one can conclude that the plate were not perfectly flat. In the performed investigation all the observation planes were parallel to the dimples tips.

Figure 12 present two dimples located one next to the other where one is brazed and the other one is not. The distance between the dimple surface and the flat tube is about the same for both cases. Thus it is rather not justified to ascertain that the lack of brazed is caused by lack of contact. However, in the vicinity of the not-brazed joint one can observe an agglomeration of the filler alloy shown in Figure 13 at higher magnification. This would suggest that for some reason the flow of the filler was somewhat restricted.

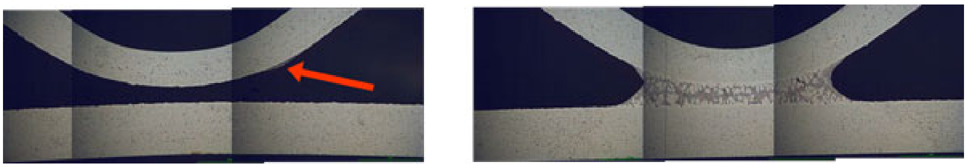

Figure 12. *Brazed and not-brazed dimples located one next to each other*

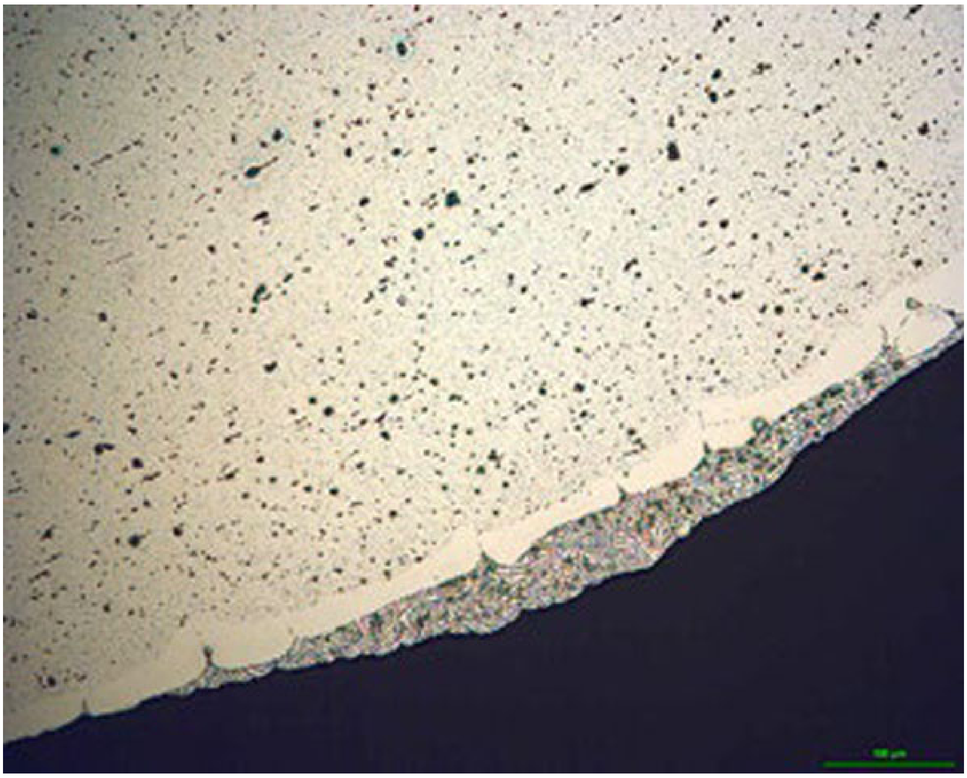

Figure 13. *Agglomeration of the filler alloy on the not-brazed dimple surface. Spot mark with red arrow in Figure 12*

The flow of the molten filler on the joint surface can be supressed by oxidation caused by bad furnace atmosphere, lack of flux and/or contamination of the substrate surface. To determine which of those potential root causes were responsible in this particular case the joint surface must be analysed under SEM.

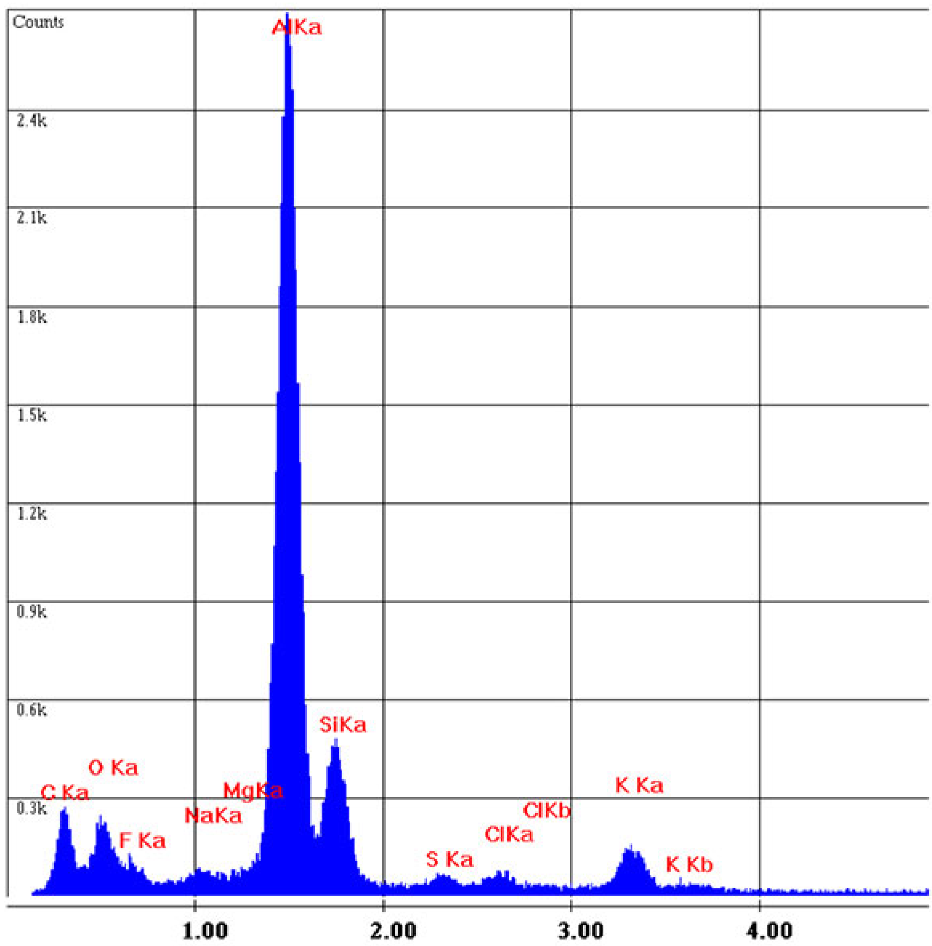

Figure 14. *EDX diagram of the not-brazed dimple surface. Case 3*

The EDX diagram reveals that the level of flux was quite low and at the same time, there is a higher level of carbon and oxygen. Most likely carbon and oxygen comes from not removed binder at lower temperature (fluxing was done with paint flux, which means that the flux slurry contained organic binder).

It should be worth mentioning that the design of the single dimple is extremely unfavourable for securing the contact between the brazed surfaces. Since the contact is done only in one point even a slight deviation from flatness will cause that some dimples are not touching the opposite surface, which results in lack of braze. This situation can be somewhat improved by applying a dead weight on the surface of the part providing the weight is uniformly distributed over the whole surface of the part.

4 Fluxing methods

For brazing of aluminium in a protective atmosphere furnace, surfaces to be brazed need to be covered with flux, which role is to remove the protective aluminium oxide layer from the joint surfaces. There are various flux application methods; however the important point is that regardless of application method it is the final load of flux and its uniformity which decides about success or failure of brazing. The goal is to obtain a uniform flux layer of minimum load (3 to 5 g/m2) or deposit flux only in the actual joints to be brazed [9].

The most common method of flux application is using flux in form of liquid slurries which can be applied to the parts by spraying, dipping or atomized spraying. This method secures reliable flux coverage and usually provides high capacity of the process; however the flux coating does not adhere well to the surface and it can be easily removed by simply touching, which could be a problem during handling the parts before brazing. The problem of weak adhesion is usually solved by using slurries with organic binders (Paint Flux), but the organic binder must be removed before brazing (evaporation at higher temperatures) which sometimes could be troublesome particularly for enclosed spaces.

Flux can also be applied using thick pastes. In this process, flux is applied only to the spots to be brazed, but if it is used for larger number of fluxing points, it may not have the required capacity. This method is recommended when low level of Post Brazed Flux

Residue [PBFR] is required [10].

When talking about flux application methods, one should also mention fluxing methods which secure excellent adhesion, but do not involve any organic binders. One of the technologies is called Trillium, where the flux is embedded into the filler alloy clad already at the stage of ingot casting. Brazing sheet obtained by such methods yields excellent brazing results [11], but the drawback of this technology might be connected to a higher cost.

A second fluxing method which secures very good adhesion is based on a spray of flux particles where the flux grains hit the coated aluminium surface with a supersonic speed. This method has not yet been industrialized, though laboratory brazing experiment proved to be quite successful [12].

5 Conclusions

Major brazing problems for flat battery coolers are not-brazed internal dikes/dimples. This issue is most often caused by mistakes done in fluxing and by design of the inner turbulators. The convex design (single dimples) is extremely unfavourable for securing the contact between the brazed surfaces. Since the contact is done only in one point even a slight deviation from flatness will cause that some dimples are not touching the opposite surface which results in lack of braze.

There is a variety of fluxing coating methods, however it is the final flux load that is important for the final brazing result regardless the application method. In some cases, brazing problems could be caused by insufficient removal of the organic binder used for securing adhesion of the flux coating. Therefore, choosing a fluxing method should always be considered individually dependently on particular design, volume of production, existing equipment and acceptable structural cost of manufacturing.

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NOCOLOK® NEWS
Presents information for NOCOLOK® users.

Publisher:
Solvay Fluor GmbH
Hans-Böckler-Allee 20 • 30173 Hannover, Germany
Place: Hannover
Register: Hannover HRB 58647
Managing Directors: Christoph Meurer, Norbert Haas

Editorial:
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Production:
klartxt GmbH, Hannover
www.klartxt.de