Experimental Results using a High Vacuum Soldering and Brazing Hood Furnace

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Nowadays many components, for example devices used in electron microscopes, satellites or aircrafts, have to withstand challenging environments such as vacuum or extremely high temperatures. To manufacture reliable components like these a connection between dissimilar materials is often required.

Connecting Dissimilar Materials

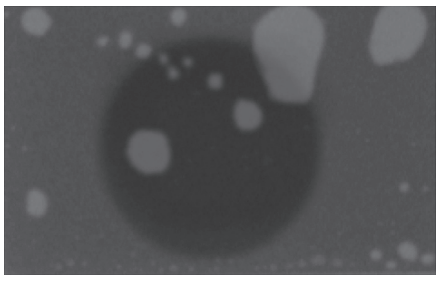
This connection can be metal-to-metal or even insulator-to-metal. It has to be strong, high temperature resistant and suitable for use in vacuum, as outgassing of flux material is not acceptable. The purpose of flux material is to remove remaining oxides and to reduce the surface tension in order to promote wetting of the dissimilar materials' surfaces. However, if exposed to vacuum or a high temperature environment, the effects of the flux on the electronic component are harmful. The flux material, which contains acid and salts, changes into the gaseous phase due to its high vapour pressure. The resulting condensation of the flux material on the insulators may produce conductive paths causing a leakage current. This process will destroy the expensive component. Unfortunately, the most active (and therefore corrosive) fluxes also form the strongest connections. Some material properties, for example vacuum resistance, cannot be obtained when manufacturing under conventional atmosphere conditions. One other problem with conventional atmospheres is that gas impurities are always embedded in the connecting surface.

Examples of electronic components

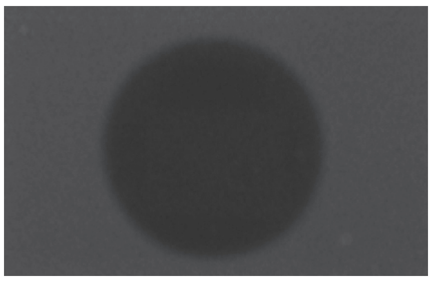
- Components for EDX devices
- Soldering of transmitting tubes / laser tubes
- Aircraft engines and components
- Radiators attached to anodes and collectors
- Circuit boards in jet planes
- Electron tubes

The solution to this problem is high vacuum soldering and brazing. For both processes the connection between the two dissimilar materials is made by a third metallic material, the so called solder or brazing filler material. The exact distinction between soldering and brazing is that in the case of soldering (reversible) adhesion is predominant, whereas brazing (irreversible) produces diffusion of the materials, leading to a much stronger connection. The complete process takes place in a high vacuum (HV) or even ultra high vacuum (UHV) environment. These environments prevent oxidation and allow the use of a solder made of flux-free material. The requirements for components used in a vacuum environment are fulfilled.

To produce components which need to withstand extreme conditions, a furnace with special features is required. **The furnace needs to be completely sealed to permit heat treatment in a vacuum environment**. Depending on the materials and the solder involved, the temperature has to be adjustable **up to approximately 1200°C with superior temperature homogeneity and stability** throughout the entire sample. Data logging is another important factor: the dissimilar materials, for example, must have a certain temperature before the filler turns into a liquid. Therefore, the furnace should permit controllable and reproducible data logging.



Conventional connection: gas impurities are clearly visible



Connection with high vacuum soldering and brazing: hardly any impurities

Image source: EADS Deutschland GmbH

All these requirements can be fulfilled by a metallic furnace such as the Carbolite Gero HBO hood furnace which is based on tungsten or molybdenum for vacuum applications (HV or UHV) with a usable volume of 10, 25 or 60 l. Depending on the customer's vacuum requirement the leakage rate can be reduced (down to < 10^{-3} mbar l/s) and a high vacuum pumping system is attached.

In vacuum the heat transfer is only possible by heat radiation (Planck's radiation law) which yields the best temperature homogeneities, i.e. a temperature gradient in the hot zone of ± 3°C.

The thyristor-controlled power supplies of the heating zones provide superior temperature stability, i.e. a variation with respect to time less than ± 1°C. Vibration-free operation is ensured to achieve a bright connection interface free of any distortion.

The automated up and down movement of a furnace hood facilitates loading and unloading and makes the sample easily accessible. The furnace body and the current feed-throughs are water-cooled and each water outlet is temperature controlled for increased safety. The operator enters a step program in a program table. The table is then loaded into the stored program control and the process runs fully automatically without user supervision. Before every start-up the furnace automatically runs through a short start routine which involves a test for major leaks and checks whether the required pressure is achieved.

HBO hood furnaces are equipped with a turbo molecular pump in combination with a pre-pump as standard. The vibration of the pumping system is decoupled from the furnace body. Before loading and unloading the furnace is vented with inert gas for particularly pure atmospheres.

The Improved HBO 60 MO/13-1G and first Experimental Results

For the production of devices needed for EDX analysers in electron microscopes, Carbolite Gero recently developed the HBO 60 MO/13-1G. As the maximum temperature for the soldering and brazing process is 1200°C, the installed power was adjusted for a maximum temperature of 1300°C. The achievable maximum heating rate is 1200 K/h allowing for a fast heat up rate. The system was combined with a water cooling chiller. As cycle time plays an important role for industrial processes with highest possible throughput, the cool down time is the limiting factor of the system. With the implementation of the water chiller control into the PLC system of the furnace, it is now possible to control the cooling water temperature between 10°C and 25°C. During the cool down of the system, the cooling water's temperature can be reduced to its lowest value. Before opening the furnace, the cooling water's temperature can be increased to prevent the humidity of the ambient atmosphere condensing on the water cooled vessel.

This integration is a very cost efficient solution to reduce the cycle time for soldering and brazing processes in industrial production. Throughput can be increased by the high heat up rate and the fast cool down option of the newly developed HBO.

Whilst pumping down the furnace, the pressure falls below 1 x 10^{-4} mbar after only 4 minutes and below 1 x 10^{-5} mbar after only 36 minutes. The vacuum receiver undergoes a special polishing procedure, and a special cleaning step as well as the large CF type vacuum flanges. A turbomolecular pump with a pumping speed of 1200 l/s is attached to the system. The measured leakage rate is below 5 x 10^{-3} mbar l/s.

Application Example

Navigation systems are increasingly used in cars, mobile phones and other electronic devises. Speed measurement and a positioning accuracy of a few meters are common features of these systems. The data for the Global Positioning System (GPS) on which most navigation systems are based is provided by satellites. In 2015 as many as 31 satellites are moving in their orbit around the earth. At a height of 20,000 km the satellites are exposed to vacuum and extreme temperatures and the electronic devices which are part of the satellite need to withstand this environment. High vacuum soldering and brazing is the most effective method for producing electronics that meet these demands.

Schematical drawing of the HBO 60 MO/13-1G. The usable volume has a diameter of 400 mm and a heated height of 500 mm. The maximum temperature is 1300°C. Argon can be used to flood the furnace in partial pressure mode.

The HBO 60 MO/13-1G with automatic software control and high vacuum pumping unit.