Influence of Belt Furnace on Glass-to-Metal Seal Process

Introduction

The glass, under suitable conditions, will bond well to a wide variety of metals and alloys which has led to the development of many useful technologies. One of them is Glass-to-metal seal (GTMS) technique. GTMS becomes a popular and low cost method to hermetic sealing, which is an important part of design of many products today. The GTMS is a fusion bonding technique; glass is heated to a molten state and bonds to the metal. Bonding occurs through wetting and chemical reactions between the metal and the glass. In addition to providing seal, the glass acts as an insulator between one pin to another and housing.

The GTMS has a lot of advantages, such as effective hermeticity; resistance in harsh environments e.g. against corrosive material, vibrations, serious temperature fluctuations; long-term, reliable protection of the packaged component. A large number of products use GTMS technology for its excellent value. The applications include Electronic and photonic package, aerospace, automotive, battery feed through, high vacuum, medical, military and sensor housing. Soft glass is the appropriate bulb or tube material for incandescent and fluorescent lamps. Figure 1shows some components using GTMS.

Figure 1: Glass-to-metal seal products

There are majorly two types of seal, one is compression seal and the other is matched seal. The compression seal is designed to exert concentric compressive stress on the glass in the available temperature range, while considering the thermal expansion coefficients of the metal and glass. The matched seal type is majorly designed to seal Fe-Ni-Co alloy (Fe: 54%, Ni: 28, Co: 18%), known as Kovar, with glass. The thermal expansion coefficient of Kovar synchronizes with that of glass over a wide range of temperatures. The matched seal type can be used to make a variety of terminals with comparatively few restrictions on the terminal shape. At the same time, it provides high air-tightness and electrical insulation. So most application, from light bulbs to electronic packaging, are using matched seal type.

Process of Glass-to-Metal Seal

A typical glass-to-metal seal consists of the following elements: 1) A metal bulk head (or body) with a hole in it; 2) A pin conductor in the center of this hole; 3) A piece of glass pre-formed to fit between the pin and the bulk head.

During GTMS processing, these three components are placed on a fixture which holds them in position. The components are assembled with the glass in the form of small items placed in or around the metal parts. The components are placed in a furnace configured to maintain a controlled atmosphere in the firing chamber. During the components go through the furnace, they are heated to appropriate temperatures for the particular set of materials, which the intention is to let the glass soften just sufficiently. At the sealing temperature, the glass melts and flows gently into place to fill the space between the pin and the bulkhead, making a good seal to the metal. The assembly is then cooled. The temperature of the process should be specific controlled for good qualified products. Figure 2 shows a schematic of GTMS process of belt furnace.

It is significant for the glass not to become too runny, nor stay too stiff. A carrier may be used to take a lot of little parts through the belt furnace at once. Generally, the whole process is nearly continuous when moving through the furnace and the temperature would change gradually during the pass. Once the temperature can get the crucial glass bits, the glass can fill the adjacent metal well.

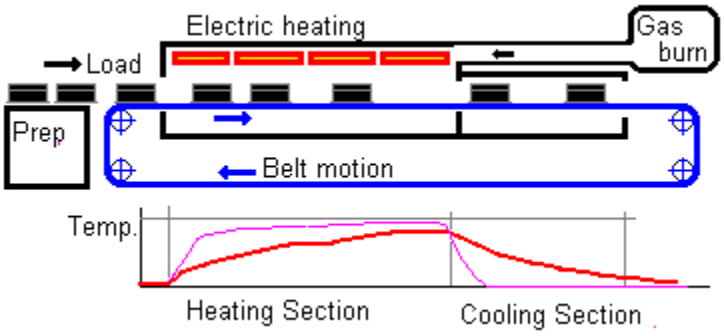

Figure 2: Schematic of a typical GTMS of belt furnace.

The Properties of Glass for GTMS Process

The quality glass-to-metal seal is pretty influenced by the glass. As an engineering material, glass is unique. Two of the most significant properties that make it so, one is the mechanical strength, and the other is viscosity. Glass is a brittle material but one that is truly elastic with no plastic deformation to failure.

The intrinsic strength of glass is extremely high and certain experiments have substantiated. Glass, at room temperature, actually is a viscous material and it has not true melting points. But its viscosity will reduce when temperature increasing, and the viscosity reduction is approximately exponential with temperature. The significant viscosity reduction zone is between 500°C and room temperature. So during the GTMS process, the temperature heating in furnace is significant.

Volume resistivity of glass at ordinary room temperature varies widely with the composition from as low as 108 to as high as 1019 ohm centimeters. During the GTMS process, the volume resistivity of glass decreases with increasing temperature, Figure 3. Consequently, we have to take this issue into account when considering operations at elevated temperature by furnace.

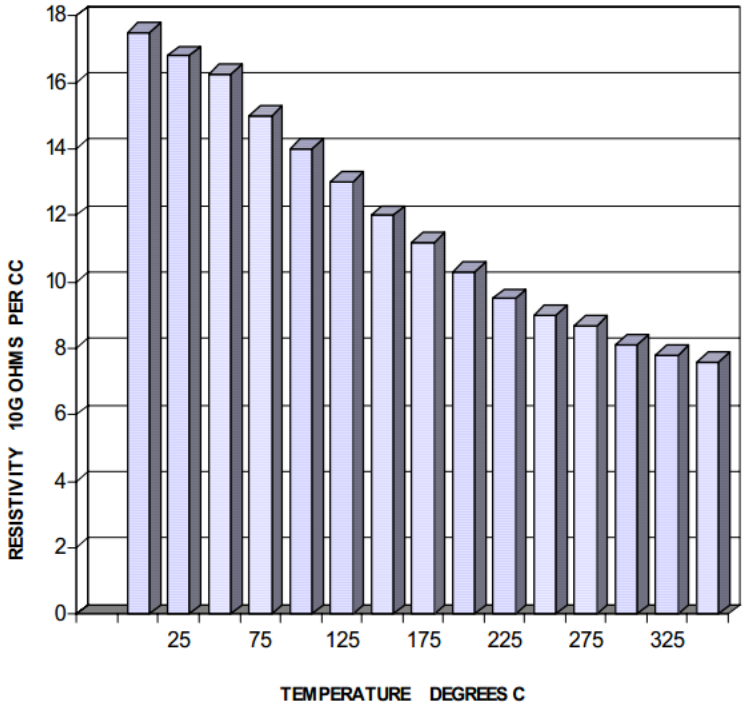

Figure 3: Change in glass resistivity with temperature

Improved Glass-to-Metal Seal Through Furnace Control

The ultimate goal of making the matched glass-to-metal seal is to produce a consistently reliable end product which will retain its hermeticity throughout its useful life. The hermeticity and strength directly influence the reliability of the components of which they are a part and can cause or prevent potentially catastrophic component failure. To improve the hermeticity of GTMS process and produce a more reliable product at higher levels of consistency majorly relies on more precise control over furnace atmosphere composition.

As former study recommended, a consistent 2.0-6.5 μm residual intergranular oxide, which is tighter control by the preoxidation, is best for the performance. And the preoxidation is deeply influenced by the composition of H_2 and N_2. All of these operations can be performed on a continuous mesh-belt furnace and require a protective atmosphere of some type. As the preoxidation is significant for sealing process, a precise control through the use of humidified H_2-N_2 furnace atmosphere should be applied. This process control could offer consistently produce desired oxide depths. A schematic of the control system for belt furnace is depicted in Figure 4.

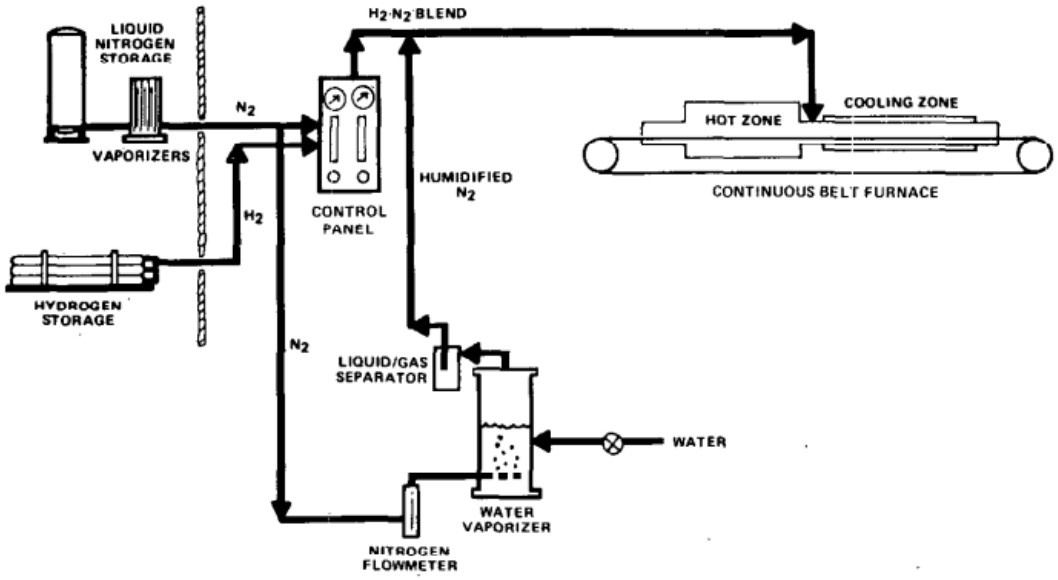

Figure 4: Schematic of H_2-N_2 atmosphere system of belt furnace

By blending H_2, N_2, and H, O people can exercise the process control necessary for the production of consistently reliable seals. Precise blending of the furnace atmosphere does allow repeatable formation of intergranular oxide within acceptable limits. This is the basis for producing matched glass-to-metal seals which have the durability to meet the necessary specifications continually.

Furnace for Glass-to-Metal Seal

The HSA series belt furnace is well designed for glass-to-metal seal process, Figure 5. This furnace uses ceramic heater boards to achieve elevated temperatures. The HSA series furnace comes with a refractory heating chamber equipped with ceramic fiber heating board. The heating works to give fast thermal response. The furnace is equipped with temperature profiling system and computer monitoring system. Moreover, it can achieve good atmosphere control including hydrogen, nitrogen, and oxygen by dew point monitoring and oxygen monitoring system. Consequently, HSA series furnace can serve an excellent GTMS process.

Forced air or water cooling is used in the cooling section of the furnace. The muffle design located within the furnace helps with control of atmospheric conditions and also helps in maintaining a cleaner environment inside the furnace. As a standard feature, this furnace is equipped with a steel brush for cleaning the conveyor belt; however, ultrasonic belt cleaning is available as an extra option. It is a really clean environment application furnace.

Figure 5: Hengli HSA series belt furnace

The HSA series furnace has a microprocessor based PID controller to control the furnace. Type K thermo-couples are used in determining the zone temperatures and the controls are located on the right hand side of the furnace which can be viewed from the entrance. The central processing unit (CPU) is located at the exit table and is primed with a Windows operating system for ease of use. The computer system is pre-installed with a program for controlling the furnace parameters, including the belt speed, zone temperatures, and atmospheric conditions. Temperature profiles can be stored and retrieved as well for future purposes. The furnace already has programs in the software for capturing/storing, displaying, and printing out the furnace profile. Thermocouple ports are located at the entrance table for connecting the profiling thermocouple directly into the microprocessor. This feature allows for the monitoring and recording of actual temperatures experienced by the part. Additionally, the furnace is equipped with a redundant overheat safety protection system which incorporates an additional type “K” thermocouple in the center of each controlled zone and the multi-loop alarm. The specification of a HSA7503-082N belt furnace is listed in Table 1.

Specification	HSA7503-08ZN
Rate Temperature	900 deg. C max, Normal operating: 850 deg C
Belt Width	30" (750mm)
Effective Above Belt Clearance	1" (25mm)
Control Zones	8
Conveyor Speed	2-8 IPM (40-200mm/min)
Loading Table	59" (1500mm)
Unloading Table	59" (1500mm)
Belt	Balanced V Weave, SUS314
Heating Elements	FEC Heater Board
Insulation	High quality ceramic fiber
Temperature Controller	Intelligent PID Shimaden Controller
Alarm	Thermocouple, Over Temp, Belt Stop. Audio and Visual Alarm
Atmosphere	6 pipes of dry clean air or N2. 2-6 m3/h, 1.1-3.3 CFM
Cooling	Forced Air cooling
Across Belt Temperature Uniformity	+/- 4 deg C
Overall System Width	60.5" (1540mm)
Overall System Length	343" (8705mm)
Overall System Height	54" (1,350mm)
Net Weight	2500kg
Power	Three-phase, 480VAC, 60Hz, 38 KVA MaxNormal operating power draw is about 15 KVA

Table 1: Specification of HSA7503-082N belt furnace

Conclusion

To improve GTMS process should consider a great number of conditions. The proper temperature control and precise time control are fundamental of a good GTMS furnace. Moreover, the atmosphere composition of GTMS process is always vital for the effective GTMS process and excellent quality of product. By blending the H_2, N_2, and H, O, we can get an ideal environment for GTMS process. The efficiency and quality will increase when the belt furnace can handle these requirements well.