GLASS SEALING MIM BOXES FOR FIBER OPTIC AND ELECTRONIC PACKAGES

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ABSTRACT

Metal Injection Molded (MIM) materials have been shown to exceed the industry standard for hermeticity in fiber optic and electronic packages. The next property requiring study is the glass sealing of parts into MIM boxes. These parts include glass, leads, windows, and ceramics. For two decades, processes have been developed to glass seal parts into wrought metal boxes. Glass sealing depends on several material properties including thermal expansion, surface condition, wetting, surface oxidation, and microstructure. Successful glass sealing will result in exceeding the current industry standard. This research focused on measuring the effect that several glass sealing processes have on the hermeticity of MIM boxes. The results demonstrated that MIM boxes could be successfully glass sealed and the hermeticity of the MIM box does depend on the glass sealing process.

Key words: MIM, Glass Sealing, Hermeticity, Metal Injection Molding, Leak Rate, Box, Package

INTRODUCTION

The introduction in the 1980's of microelectronics, cable, and fiber optics technologies resulted in the growth of new metal products. These technologies are integrated into many products such as computers, HVAC systems, entertainment systems, automobiles, digital communications, and others. The metal components enclose and protect the electronics and fiber optic components.

Production of Metal Boxes

In the beginning, metal components were machined from wrought metal. Several generations of these components were produced from wrought metal. Recently, it was proven that metal parts produced via the Metal Injection Molding (MIM) process exceed the industry specification for hermeticity.[1] MIM parts are establishing a foothold in these markets due to the potential cost reductions as compared to wrought metal components. In some cases, the cost reduction is 90%.

Wrought metal components production is outlined in Figure 1.[2] The process involves casting the ingot from molten metal. After casting, the ingot is cut and rolled into bar stock. The bar stock is then purchased by the firm that will machine the component. The machinist will cut, grind, drill, and mill the bar stock into a component such as a box. After machining, it will be cleaned to remove cutting fluids and lubricants. The cleaned box is then sent to the glass sealer to seal the leads into the box. These leads connect the device inside the box to other components or the network. The quality of the glass seal is checked via hermeticity testing. Lastly, the box is plated. During the machining process approximately 40 to 80% of the bar stock is turned into scrap.

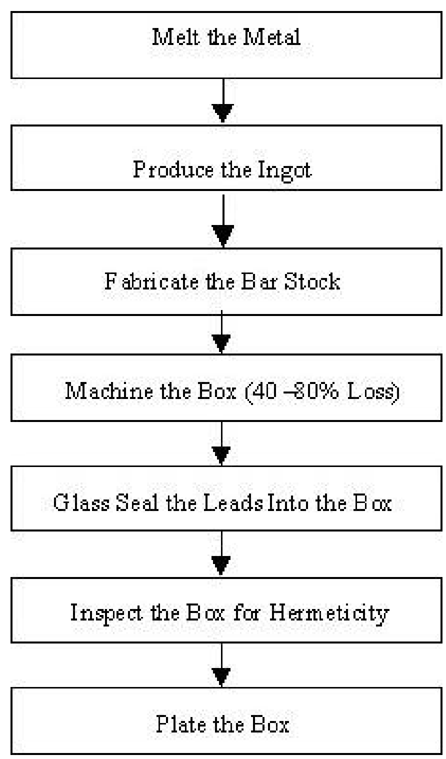


Figure 1. Process outline for the production of wrought metal components.

MIM component production is outlined in Figure 2.[3] The MIM process begins with the atomization of metal powder from molten metal. The metal powder is then mixed with binders to produce a feedstock. Then, the feedstock is placed in an injection molder, heated, and shot into a mold to form a green box. The binder is removed from the green box during debinding. Thermal debinding and solvent debinding are the most common processes to debind green MIM box. The debound box is then sintered to form a high density metal. Sintering occurs at high temperatures, up to 2400^oF (1316^oC), under a controlled atmosphere or vacuum. After sintering, the box is cleaned. Scrap is eliminated or significantly reduced since machining of the box is usually not necessary. The cleaned box is then sent to a glass sealer to seal the leads. The quality of the glass seal is checked via hermeticity testing. Lastly, the box is plated.

Machining of the MIM box after sintering is generally not necessary since it is usually sintered to the final dimensions. During injection molding straight through holes, tapped holes, chamfers, radii, and other features can be formed. The forming of these features eliminates machining of the MIM box. The elimination of milling, grinding, drilling, and scrap are the fundamental reasons MIM boxes are lower in cost than wrought metal boxes.

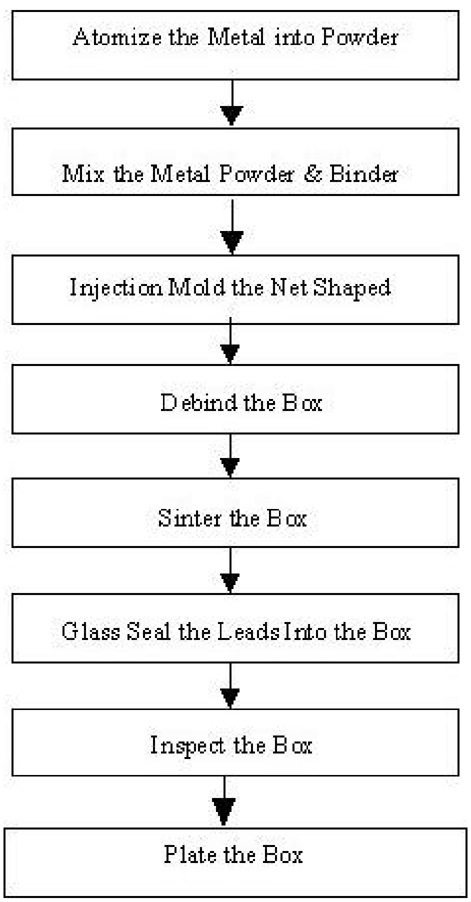


Figure 2. Process outline for the production of MIM components.

Prior to assembly of the electronics package, the leads are glass sealed into the MIM box. After assembly of the electronics package, the lid is laser welded onto the MIM box. This step seals the box to protect the electronics. Without sealing, the components would be exposed to air/water and the performance of the package could be compromised.

Glass Sealing

Glass Sealing is the process used to bond various components into the box. These components include electrical leads, mirrors, windows, and connectors. Glass is used to bond the components to the box because glass is an insulator of heat, an insulator of electricity, and can bond dissimilar materials. These dissimilar materials comprise metals, ceramics and glass.

If the glass sealing process is done correctly, the components inside the box will not come in contact with the environment. There are many parameters of the glass sealing process that affect the quality of the seal. A partial list of the parameters is:

1. The composition and thermal expansion of the metal;
2. The composition and thermal expansion of the glass;
3. The surface roughness of the box, the cleanliness of the box and glass, the wetting of the glass to the box;
4. The wetting of glass to the component, the atmosphere of the glass sealing furnace;
5. The temperature cycle for glass sealing, configuration of the component;
6. The configuration of the feedthrough holes in the box.

There are some rules-of-thumb for the glass sealing process such as the thermal expansion coefficient mismatch between the metal and the glass. As the components are heated during the glass sealing process, the metal components expand and the glass melts. After the glass is melted to create the seal, the box is cooled. The glass and metal constituents contract during cooling. If the difference in thermal expansion between the components is too great, the contraction of the constituents could create tensile, compression, or shear forces that could crack the glass or break the bond between the glass and metal.

The glass sealing process is too complex to devise a universal model for glass sealing. Most glass sealing firms use a combination of experience and experimentation to develop a process to bond the specific arrangement of MIM box, glass, and component. Hermeticity is the term used by the industry to measure the quality of the glass seal.

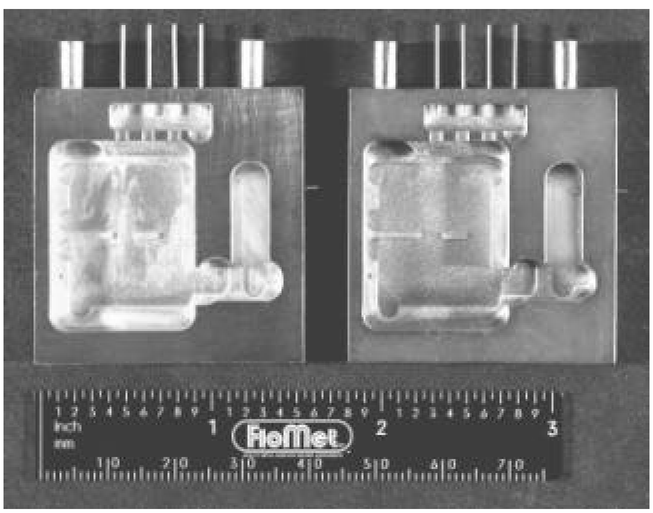
This paper will review the effect that the glass sealing process has on the hermeticity of MIM boxes.

RESULTS and DISCUSSION

Description of the MIM Box

The MIM box used in this study is illustrated in Figure 3. The boxes were composed of Alloy 49. The composition by weight of alloy 49 is 51% Fe and 49% Ni. The typical density of the alloy 49 MIM box used in this study is 7.93 g/cc or 97.3% of theoretical density. At this density all of the porosity in the part will be closed, see Figure 4. As the micrograph demonstrates there is no open porosity in the microstructure of the MIM box. All of the pores are isolated from each other. This microstructure prevents the atmosphere from pemeating through the wall of the MIM box.

Although the composition of wrought and MIM boxes are the same, the microstructure of the material can be different. The density, pore size distribution, and grain size are some of the differences in microstructure between wrought parts and MIM parts. For example, the density of wrought alloy 49 is 8.18 g/cc or 99.9% of theoretical density. These differences could affect the hermeticity of the glass seal of the MIM box to the components, as compared to the wrought box.



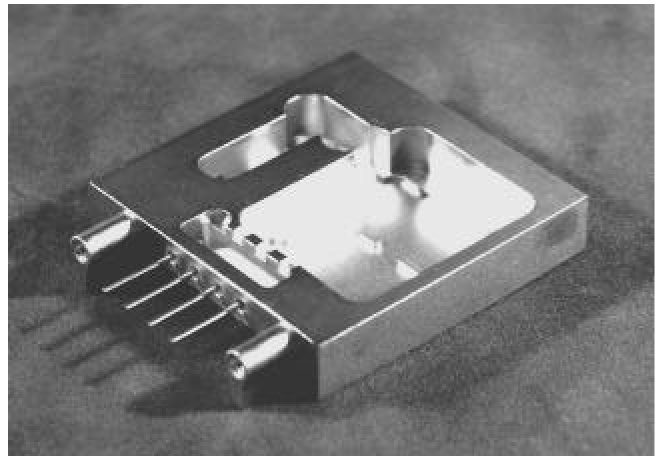


Figure 3: Alloy 49 MIM Box produced the glass sealing study. The boxes are shown after the Kovar leads have been glass sealed into the box.

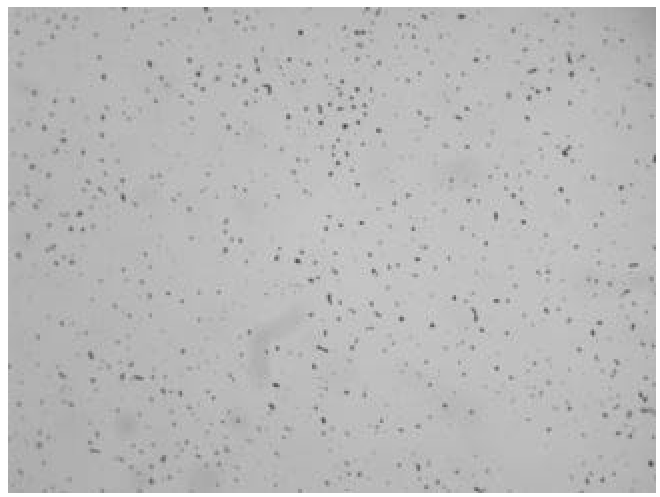


Figure 4: Typical polished microstructure of MIM Alloy 49 Box, 400X magnification.

Glass Sealing Processes

In this study, three glass sealing processes were examined. Each process was conducted at a different firm, designated A, B, and C. In general, glass sealing firms do not disclose details of their process. The lack of disclosure is due to the complex nature of the glass sealing process and proprietary process parameters of each firm's glass sealing process. The only information revealed by the glass sealing firms was the atmosphere of the furnace during glass sealing. Firm A and Firm B use an oxidizing atmosphere during glass sealing. Firm C uses a non-oxidizing atmosphere during glass sealing.

Microstructure of the Glass Seal

The purpose of the microstructure analysis was to determine if there were any defects that could affect the hermeticity of the glass seal. The defects could be located in the glass, in the metal, or at the boundary between the glass and the metal box or Kovar leads. The defects could include open porosity in the metal, cracks in the glass, or no wetting between the glass and the metal box. The microstructure of the glass seal was examined for the wrought alloy 49 box glass sealed by Firm A (Figure 5), the MIM alloy glass sealed by Firm A (Figure 6), the MIM alloy glass sealed by Firm B (Figure 7), the MIM alloy glass sealed by Firm C (Figure 8).

Figure 5: Typical polished microstructure of the wrought Alloy 49 Glass Seal. The glass is the dark area and the white area is the metal. 250X magnification.

Figure 6: Typical polished microstructure of the MIM Alloy 49 Glass Seal produced by Firm A. The glass is the dark area and the white area is the metal. 250X magnification.

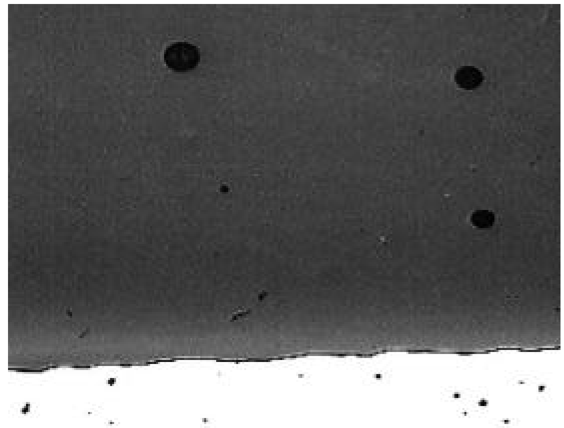


Figure 7: Typical polished microstructure of the MIM Alloy 49 Glass Seal produced by Firm B. The glass is the dark area and the white area is the metal. 250X magnification.

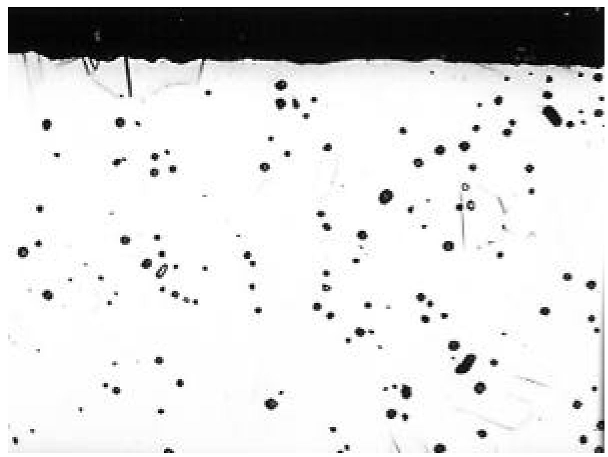


Figure 8: Typical polished microstructure of the MIM Alloy 49 Glass Seal produced by Firm C. The glass is the dark area and the white area is the metal. 250X magnification.

The microstructural examination of the metal boxes glass sealed by Firm A, Firm B, and Firm C showed no material defects in the metal that would affect the hermeticity of the glass seal. The wrought box did show significantly less porosity than the MIM boxes. The MIM boxes showed no evidence of open porosity. This was expected.

The microstructural examination of the metal boxes glass sealed by Firm A, Firm B, and Firm C showed no material defects in the glass that would affect the hermeticity of the glass seal. There were some small bubbles in the glass; but this is a normal situation. There is no evidence of cracking or crazing of the glass that could affect the hermeticity of the box.

The microstructural examination of the metal boxes glass sealed by Firm A, Firm B, and Firm C showed no material defects in the boundary between the glass and the metal box that would affect the hermeticity of the glass seal. All the areas examined illustrated good wetting of the glass to the metal box and Kovar leads. There is no evidence of a crack at the boundary between the glass and metal that could affect the hermeticity of the box.

Measuring the Hermeticity of Alloy 49 MIM Boxes

The electronics and fiber optics industry specification for hermeticity is 1.0×10^{-8} atm cc/sec leak rate. 1 cc is approximately the volume of 3 dimes.[4] This standard was adopted by NASA during the 1960s. A leak of 1.0×10^{-8} atm cc/sec leak rate will fill 1 cc in 1.7×10^{6} minutes or 3.2 years. This is equivalent to a leak rate of 0.32 cc in 1 year. The reliability of the components in the box is dependent on sealing the box. If the components come in contact with the atmosphere, it can compromise the functioning of the components. Therefore, the sealed box must achieve the specification for hermeticity to prevent the performance of the components in the box from degrading. If the microstructure of the box produces a leak rate lower than 1.0×10^{-8} atm cc/sec, then the sealed package will exceed the industry specification for hermeticity.

The hermeticity of wrought alloy 49 boxes and the MIM alloy 49 boxes produced by Firm A were measured by Firm A. Firm A's test equipment was capable of determining if the hermeticity of the glass sealed metal box passed or failed the industry standard. Their equipment is not capable of quantitatively measuring the hermeticity of the glass sealed metal box.

An independent contractor measured the hermeticity of the MIM alloy 49 boxes glass sealed by Firm B and Firm C. The contractor is certified to do leak check testing. A Level II technician performed the testing. The testing on the MIM alloy 49 boxes glass sealed by Firm B was performed on a Varian Model 959 Helium Mass Spectrometer Leak Detector. The detection limit of the instrument is a leak rate of 2×10^{-9} atm cc/sec. The testing on the MIM alloy 49 boxes glass sealed by Firm C was performed on a Varian Model 938-41 Helium Mass Spectrometer Leak Detector. The detection limit of the instrument is a leak rate of 2×10^{-10} atm cc/sec. The procedure to measure the hermeticity of the boxes was designed to yield quantitative results. The procedure was:

1. Calibrate the instrument.
2. Clean the surface of the part.
3. Place the part onto the test fixture.
4. Activate the Helium Mass Spectrometer Leak Check Detector.
5. After the instrument stabilizes, take background reading for the instrument.
6. Let 99% pure He gas flow over the part for 30 seconds.
7. Wait 30 seconds and take the final reading.
8. Subtract the final reading from the background reading to determine the leak rate of the part.
9. Repeat steps 2 to 8 for each successive part measured.

The results of the testing are summarized in Table 1. Firm A glass seal process was developed to glass seal wrought metal boxes. The firm measured at least 50 glass sealed wrought metal boxes and 50 MIM boxes for each process condition. They reported that over 95% of the glass sealed wrought boxes passed the industry specification for hermeticity. However, only 7% of the alloy 49 MIM boxes passed the industry specification for hermeticity. Firm A had no explanation for the low level of acceptable parts. They modified their glass seal process. This resulted in 93% of the MIM boxes passing the industry specification for hermeticity. Unfortunately, the modified glass sealing process is not an economically viable process.

Firm B glass seal process was developed to glass seal wrought metal boxes. The contractor measured 12 alloy 49 MIM glass sealed MIM boxes. All the boxes passed the industry specification for hermeticity. In 42% of the glass sealed MIM boxes the hermeticity of box was leak rate was lower than the capability of the leak detector to measure.

Firm C glass seal process was developed for greater flexibility with respect to the surface condition of the metal box. The contractor measured two glass sealed MIM boxes. All the boxes passed the industry specification for hermeticity. In 100% of the glass sealed MIM boxes the leak rate was lower than the capability of the leak detector to measure.

Based on the hermeticity data, the glass seal process does affect the quality of the glass seal in a MIM box. Firm A was not able to develop an economically viable process to glass seal alloy 49 MIM boxes. Firm B has a process to glass seal alloy 49 MIM boxes. However, only 42% of the glass sealed metal boxes exceeded a leak rate of 2.0×10^{-9} atm cc/sec. Firm C has a process to glass seal alloy 49 MIM boxes. 100% of the glass sealed metal boxes exceeded a leak rate of 2.0×10^{-10} atm cc/sec.

CONCLUSIONS

Based on the data there are three conclusions:

1. Glass sealed MIM boxes exceed the industry specification for hermeticity;
2. Differences in the glass sealing process will affect the hermeticity of the glass sealed MIM box.
3. Manufacturing the box via MIM can eliminate machining of metal boxes.

Therefore, glass sealed MIM boxes can be used for electronics and fiber optic packages without compromising the reliability of the package. Finally, since MIM can be used to produce the box, a cost savings of 60% or greater can be realized.[5]

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Table I. Results of the Hermeticity Testing of Glass Sealed Alloy 49 Boxes

Glass Seal Firm	**Leak Rate (atm cc/sec)**	**Pass/Fail Hermeticity Specification (1×10^{-8} atm cc/sec)**
Firm A – Wrought Alloy 49 Box	Not Available	95%+ Pass
Firm A – MIM Alloy 49 Box	Not Available	7% Pass
Firm A – MIM Alloy 49 Box*	Not Available	93% Pass
Firm B – MIM Alloy 49 Box	$<2.0 \times 10^{-9}$	Pass
Firm B – MIM Alloy 49 Box	4.0×10^{-9}	Pass
Firm B – MIM Alloy 49 Box	$<2.0 \times 10^{-9}$	Pass
Firm B – MIM Alloy 49 Box	4.0×10^{-9}	Pass
Firm B – MIM Alloy 49 Box	8.0×10^{-9}	Pass
Firm B – MIM Alloy 49 Box	6.0×10^{-9}	Pass
Firm B – MIM Alloy 49 Box	$<2.0 \times 10^{-9}$	Pass
Firm B – MIM Alloy 49 Box	$<2.0 \times 10^{-9}$	Pass
Firm B – MIM Alloy 49 Box	4.0×10^{-9}	Pass
Firm B – MIM Alloy 49 Box	$<2.0 \times 10^{-9}$	Pass
Firm B – MIM Alloy 49 Box	2.0×10^{-9}	Pass
Firm B – MIM Alloy 49 Box	6.0×10^{-9}	Pass
Firm C – MIM Alloy 49 Box	$<2.0 \times 10^{-10}$	Pass
Firm C – MIM Alloy 49 Box	$<2.0 \times 10^{-10}$	Pass

* - Modified Glass Seal Process

Tekna Seal Oxide-Free results