# The Impact of AuSn Preforms Thickness on Solder Joint Reliability

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**Abstract**

*A hurdle that prevents widespread use of semiconductor lasers is that their performance is negatively impacted by thermal management. New products like stack layer diodes have a large number of lasers that work all at once in the condense area. When semiconductor laser dies' operational heat increases, the power of the laser decreases. A technique that is helping users overcome this hurdle is the application of a thinner 80Au20Sn solder joint for the die-attach to aid in thermal transfer to copper heat sinks.*

*The paper looks at a variety of different preform thicknesses, ranging from 0.0002" to 0.0015", and it also reviews voiding percentages. Our study tested shear strength and looked at how preform thickness impacts joint integrity. Further, we took a more in-depth look at the intermetallic thickness on ultra-thin preforms and observed how it affected the solder joint strength. Finally, we looked at other factors like surface tension and at what thickness preform this starts to impact voiding and performance.*

*The paper will help engineers gain insight into what preform thickness will be the optimal choice for laser diode applications as well as other die-attach applications.*

**Keywords:** preform, laser, semiconductor, die-attach, intermetallic, ultra-thin, solder, and joint strength

## Introduction

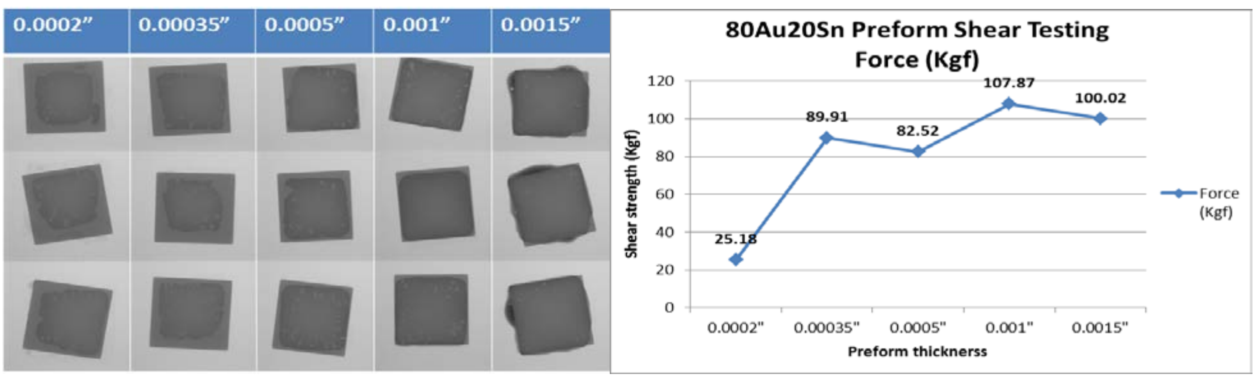
80Au20Sn preforms are a popular soldering option for high-reliability die-attach applications, including semiconductor laser devices. Recent advancements in semiconductor laser technology have made lasers an economical option for a multitude of new products in laser cutting, photonic devices, and lidar sensing. A key challenge with semiconductor lasers is thermal management. These devices generate a significant amount of heat, and any improvement in thermal release from the die to the substrate directly impacts the overall operational efficiency and performance of the device.

One method to help facilitate thermal transfer from the semiconductor die to the substrate is reducing the bond line thickness (BLT) through use of thinner 80Au20Sn preforms. Typical preform thickness is in the range of .0005" to .001," but there is an increased demand for preforms under 0.0005" thick. However, there are some perceived challenges with using thinner preforms. For instance, there is the possibility that voiding will increase and shear strength may be sacrificed with reduced solder volume. For this reason, it is important to understand the impact preform thickness could potentially have on the die-attach process, thermal performance, and integrity of the solder joint.

This study investigated the impact solder preform thickness (and therefore solder volume) has on solder joint shear strength, voiding, and the final intermetallic (IMC) layer formation.

## Experimentation

The first experiment looked at shear strength. The test used 0.250" square Cu coupons on a 1.50" square Cu base. In the images below, the voiding created around the outside was due to a lack of solder volume. The preform thickness for the testing ranged from 0.0002" to 0.0015" thick. The coupons were reflowed with no weights to aid in void reduction. The Cu coupons and substrates were used in shear testing due to Cu’s ability to dissolve easily into most solder containing Sn. This can be seen in the low-voiding results on the sample coupons. The outside voiding was caused by the cupping of the coupon from the stamping process. One drawback to this process is that when it creates an IML, it is not created evenly. Instead, it forms in pockets from the Cu bonding surface which extend into the solder joint, thereby creating weak spots. During reflow, the coupons were liquidus for roughly one minute, creating an IMC of Au5Sn(Cu) in the interface, which has a weaker shear and tensile strength than when bonded to Ni plating [1].




**The Results from Shear Testing**

The 0.0002” thick sample was the only one to have a part fail and come off the test substrate, but those remaining 0.0002” thick coupons still had strong solder bonds (25.18Kgf). The 0.0002” and 0.00035” are similar in the x-ray images, but the 0.00035” sample is 64.73Kgf stronger. This shows how the additional solder impacts the bond strength. From the thickness of 0.00035”, strength continues to trend up to a 0.0015” thickness slightly.

**The Impact of Preform Thickness on Voiding**

The objective for semiconductor die-attach is to increase the thermal transfer by decreasing the bond line thickness. Any voiding will create hotspots, hurting the thermal transfer and decreasing the laser output. This test examined if preform thickness impacts solder joint voiding. The voiding test used Alumina 92% black with 0.285” x 0.521” coupons with 50µin Ni and 50µin Au. The goal of testing was to see if the preform thickness impacts the voiding percentage. The sample construction for the testing was to sandwich the 80Au20Sn preforms between two coupons. The ceramic coupons were ideal because they had a flatness spec of 0.002” over an inch. The same coupon material was also used on the top and bottom so as not to create any CTE mismatches that would result in voiding from delamination. During reflow, the coupons were held together with a paperclip to apply pressure. It was reflowed in a nitrogen atmosphere in the BTU belt furnace with a peak temperature of 306°C.

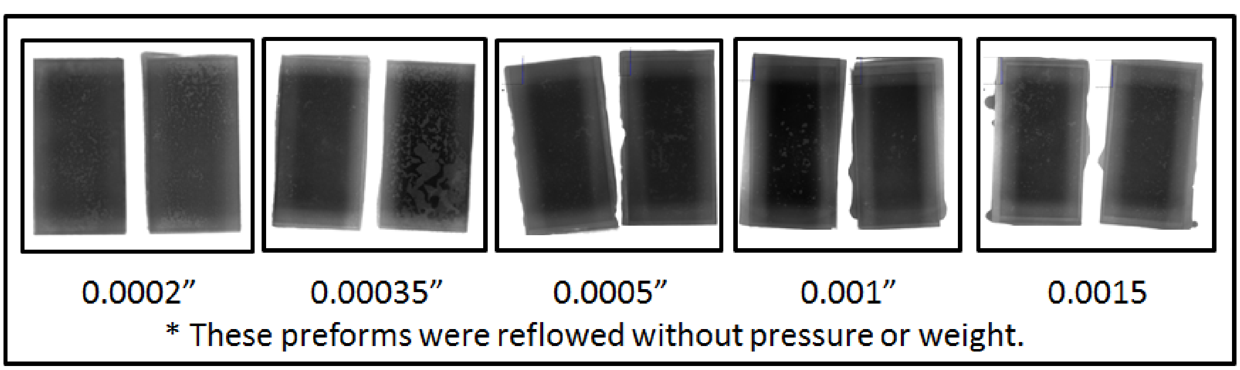



**Figure A (Reflowed in a BTU Furnace with Nitrogen)**

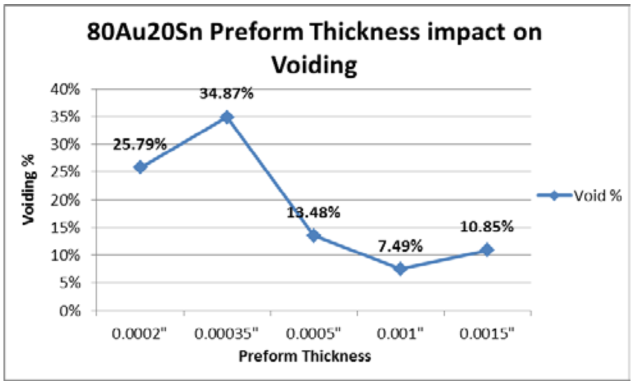



**Figure 1: The Results from Figure A Void Testing**

**Results from the Void Testing**

The benchmark for determining an acceptable solder joint is 15% by area or less. Those preforms that were0.0005" or thicker performed well. The 0.0002" and 0.00035" performed well with a limited amount of solder in the joint.

During the testing, different furnaces were used with different amounts of time over liquidus. Below are results from a bell jar furnace with forming gas 15%H2/85%N2 and an induction coil for a heat source.

manufacturers wanting to use thinner preforms to improve thermal transfer, a thick IML will grow based on time over liquidus. The Sn in the preform dissolves Au and Ni plating into the solder IMC at the interface.

**Intermetallic layer (IML)**

The <0.0005" preforms are mainly used in semiconductor laser die applications and reflowed in very short reflow profiles with a scrub reflow process with 15-seconds over liquidus. The InGaAsP/InP die bonding surfaces have 50µin of Au plating on the substrate.

For this test, an electronic microscope was used with cross sections on ceramic coupons from figure A to look at samples that used 0.0002", 0.0005", and 0.0015" thick 80Au20 Preforms. The coupons from figure A have 50µins of Au plating on the Ni.

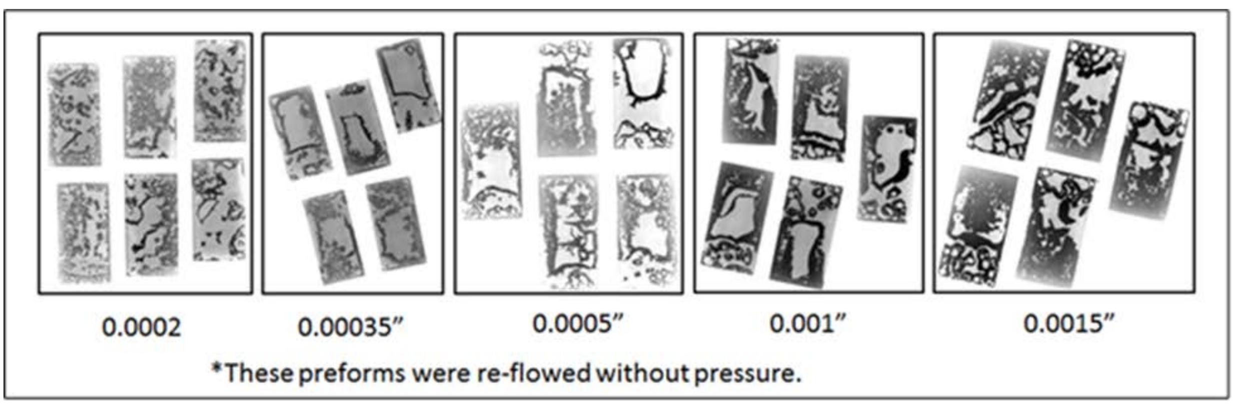
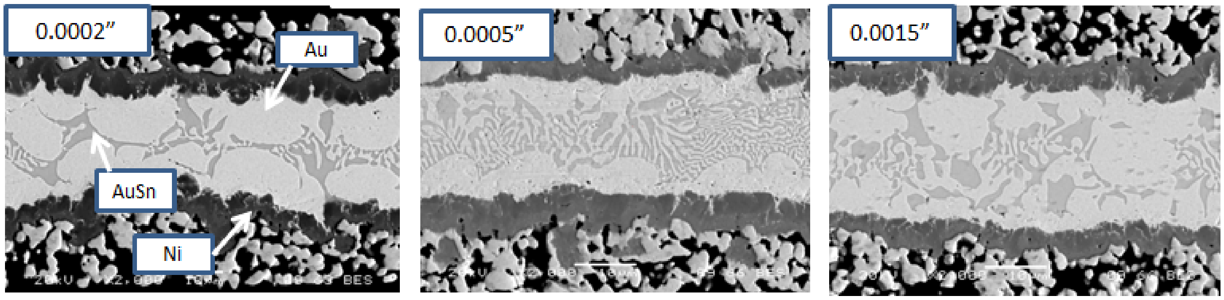



**Figure B (Reflowed in a Bell Jar Furnace with Forming Gas)**

The main difference between figure A and B is the amount of time over liquidus. The sample reflowed in Figure B, saw time over liquidus between 30-45 seconds compared to figure A which was 51 seconds over liquidus.

One of the factors revealed by this is that Au plating thickness plays an important role in the length of the liquidus period. In Figure (A), voiding was significantly less and showed better wetting. With

Cross-section Images of the Ceramic coupons



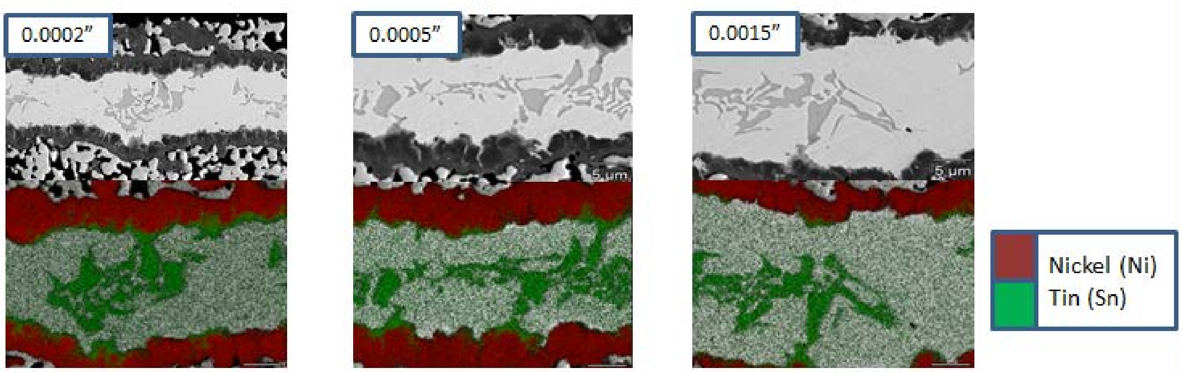

Reflow A: 51 seconds over liquidus w/ peak of 306°c
80Au20Sn preform thickness 0.0002”, 0.0005”, and 0.0015”

The IML is only between the Au plating and the 80Au20Sn preform. It is clear that the Sn migrated into the Au plating, but never made it to the Ni layer.

An additional reflow test was done with an increased time over liquidus to 90 seconds and a peak temperature of 330°C. The goal of this test was to better understand why the first test didn’t create an AuSnNi IMC. Was the time over liquidus too short? Was there not enough Sn to bring the Au in solution to get to the Ni, or was it just confined by the layering of the Au rich areas to the Ni from the interface?

second test increased the time over liquidus to 90 seconds to see if an AuSnNi IMC would be created at interface. Based on the 0.002” preform test coupon cross section images, all of the Au plating was absorbed into the solder joint, and a layer of Sn on the Ni interface created an IMC. The 0.0005” and the 0.0015” thick preform coupons still have small areas that are Au-rich, as shown by the white areas on the Ni. Based on samples, it is evident that 0.0002” preforms brought Au plating into the solution and started creating an IMC before the 0.0005 and 0.0015” preforms. This was most likely caused when the 0.0002” thick preform went to liquidus slightly

Cross-section Images of the Ceramic coupons




Reflow was over 90 seconds with peak 330°c

To answer these questions, the second test run was performed with the same ceramic coupons. The

quicker than the 0.0005” and 0.0015”. These findings support those semiconductor laser manufacturers who want to use thinner preforms less than 0.0005” thick.

There are two other considerations in designing these solder joints in reviewing IML. Typically, IML's are weaker than the solder alloys, so a 2-3 microns-thick IML is needed to get good adhesion and limit weak IML's. The IML is a poor conductor because the grain structures don't run together, but in pockets created by different interphase of IMC alloy. As the pockets are made up of different alloy percentages, they solidify at different times, creating sporadic grain boundaries that create resistance [1]. The goal for these applications is to create a thin IML to give the solder joint strength and limit the impact of electrical conductivity. It is very important when scaling-up a process to first review the bond line thickness and adjust the furnace reflow profile.

**Conclusion**

The main goal for this testing was to better understand the impact 80Au20Sn solder preform thickness has on solder joints. The shear testing showed that the 0.0002" preforms still provide a strong solder joint at 25.18kgf, while0.00035" provides the best thickness to shear strength ratio. The void testing showed that 0.0005" or thicker preforms performed well and had voiding less than <15%. The testing on both shear and voiding were set up to show ability to solder and reduce the impact of CTE and flatness on ceramic coupons for the void testing. The conclusion from the testing is that manufacturers using preforms will still have a strong solder joint and could optimize their reflow process by reviewing the intermetallic layer to ensure that the solder joint is seeing sufficient time over liquidus.

**Resources**

[1] Hongqun Dong, "Design of the Contact Medializations for Gold-Tin Eutectic Solder-A Thermodynamic-Kinetic Analysis," retrieved from: https://pdfs.semanticscholar.org/7089/3e78122e0277 0ff2c7c0ae59d242b895e9ce.pdf, 2016.