AuSn Preform Thickness's Effect on Thermal Management in Semiconductor Laser Applications

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Abstract
For the plethora of applications that require a high-melting die-attach solder, 80Au/20Sn is a great choice to ensure good performance and reliability, especially when used in one of its most highly demanded applications: semiconductor laser die-attach. However, difficulty managing thermal heat transfer has prevented the widespread use of semiconductor lasers. When the operational heat of these devices increases, their longevity and potential become limited. One option to improve thermal transfer is to use a thinner 80Au/20Sn preform in the bondline, which allows the heat to transfer to the heat-sink more quickly and efficiently. The creation of voiding hot spots—due to the lack of solder volume—is a perceived concern when using a thinner preform in the solder joint, which then contradicts the original intention. Voiding percentages were defined for several 80Au/20Sn preform thicknesses—ranging from 0.002″ to 0.00035″ thick—allowing for conclusions to be drawn on the effect of 80Au/20Sn preform thickness on thermal transfer in semiconductor laser technologies.

Key words
Laser die-attach, semiconductor lasers, thermal management, voiding percentage

I. Introduction
Thermal requirements of semiconductor laser technologies often mandate the use of a high-melting die-attach solder. 80Au/20Sn is a great choice to ensure good performance and reliability due to its eutectic melting point of 280°C. One of the most highly demanded applications for 80Au/20Sn is in semiconductor laser die-attach, which is due to recent advancements that have made lasers an economical option for a multitude of new products. 80Au/20Sn is commonly used with high output lasers because of its good thermal conductivity, high shear, yield, and tensile strength, excellent wettability, and resistance to corrosion.

However, a key challenge with semiconductor lasers is thermal management as these devices generate a significant amount of heat. Controlling the heat produced by semiconductor lasers is the main barrier that prevents their widespread use since the laser performance will decrease as temperature increases, limiting its potential. Any improvement in thermal release from the die to the substrate directly improves the overall operational efficiency and performance of the device. One method to help facilitate thermal transfer from the die to the substrate is to reduce the bondline thickness by using thinner 80Au/20Sn preforms. By using a thinner preform in the bondline, the heat is transferred away from the die more quickly, increasing the longevity and potential of the die.

With the use of a thinner solder material in the bondline, there is a perceived concern of a possible increase in voiding due to the lack of solder volume. Potential voiding hotspots within the solder joint would negate the intent of using a thinner solder material in the bondline, retaining, instead of releasing, the heat from the semiconductor laser device more efficiently. Several 80Au/20Sn preform thicknesses were tested for voiding percentages, ranging from 0.002″ to 0.00035″ thick. The voiding percentages across the different 80Au/20Sn preform thicknesses will be defined, allowing for a conclusion to be made.

II. Experimentation and Results
The experiment began by assembling 80Au/20Sn preforms at X/Y dimensions of 0.285″ x 0.521″ and thicknesses of 0.002″, 0.001″, 0.0005″, and 0.00035″ between two Alumina 92% black coupons coated with 50µin Ni/50µin Au with a bonding surface of 0.285″ x 0.521″ (Fig. 1). Twenty packages per 80Au/20Sn thickness were assembled

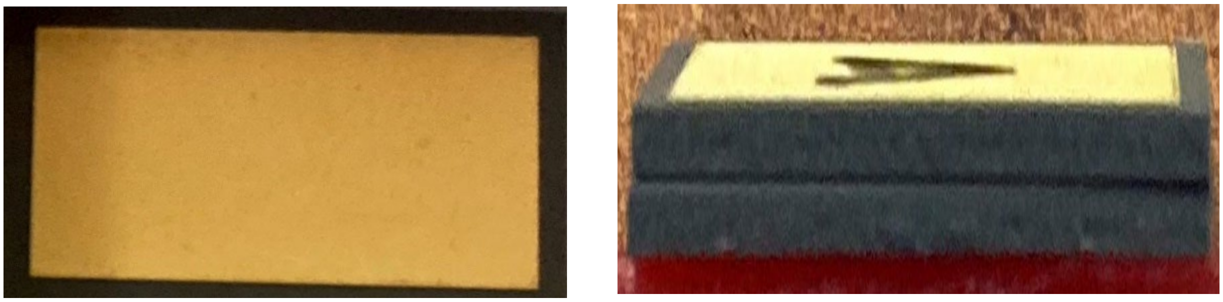


Fig. 1. Coupon Assembly (left: top view; right: side view)

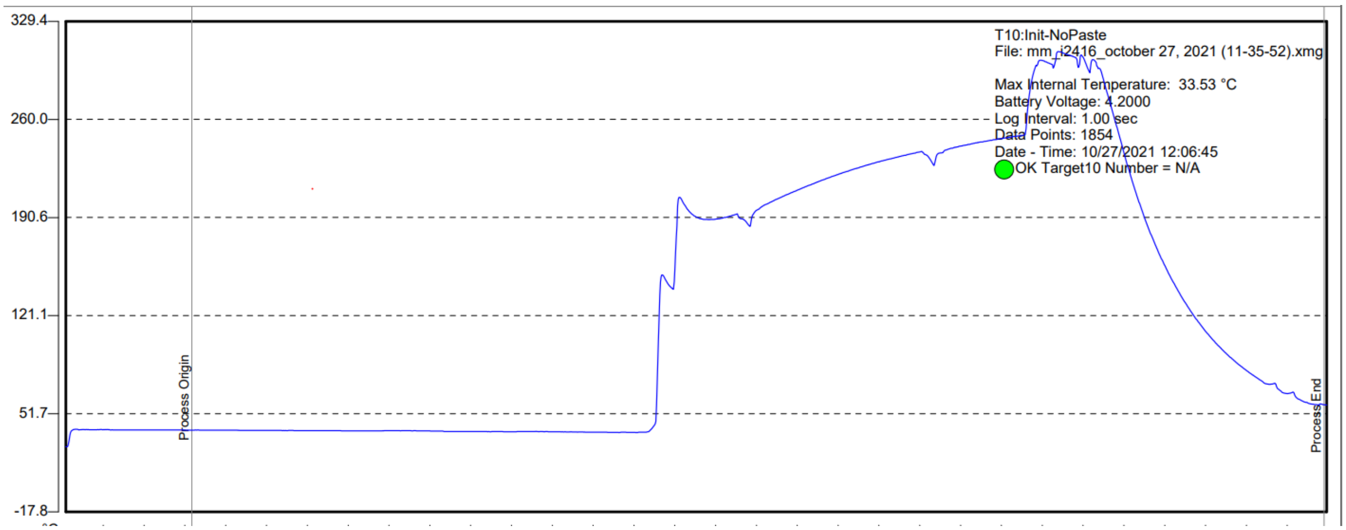


Fig. 2. Reflow Profile

and reflowed in a PINK oven in a nitrogen environment with formic acid and with a standard AuSn profile (Fig. 2) at a peak temperature of 306°C for approximately 51s TAL. A YXLON X-ray machine was used to image the coupons, and voiding was measured using the ImageJ WEKA program.

Voiding percentages (Fig. 7 and Table I) were calculated at 6.26%, 8.99%, 23.17%, and 28.95% for thicknesses of 0.002″, 0.001″, 0.0005″, and 0.00035″, respectively (Figs. 3–6).

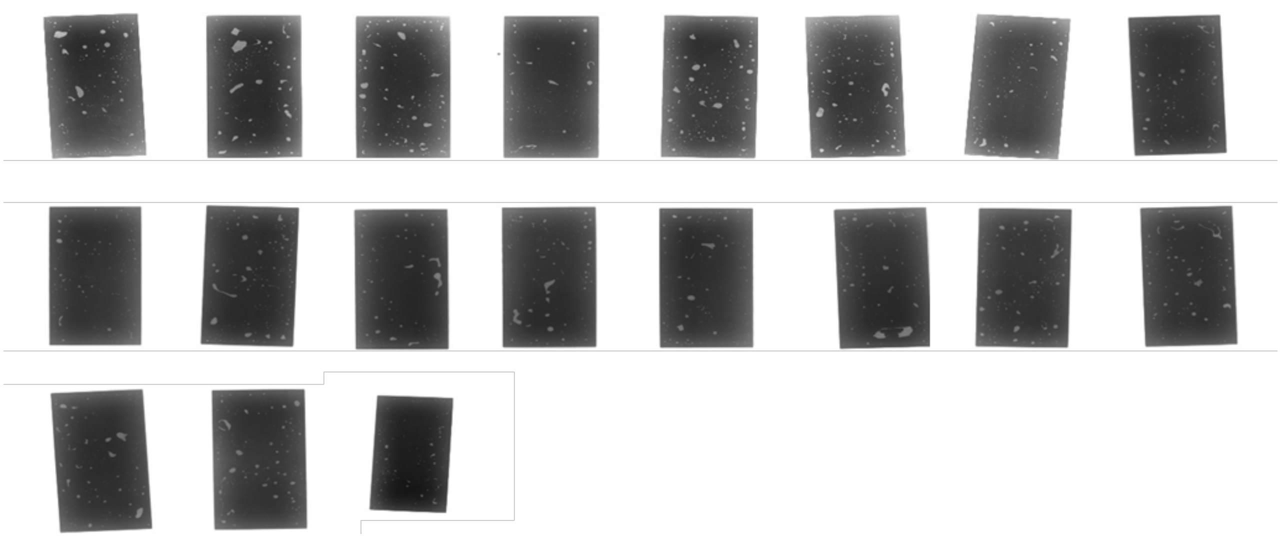


Fig. 3. X-ray Images of Preforms: 0.002″

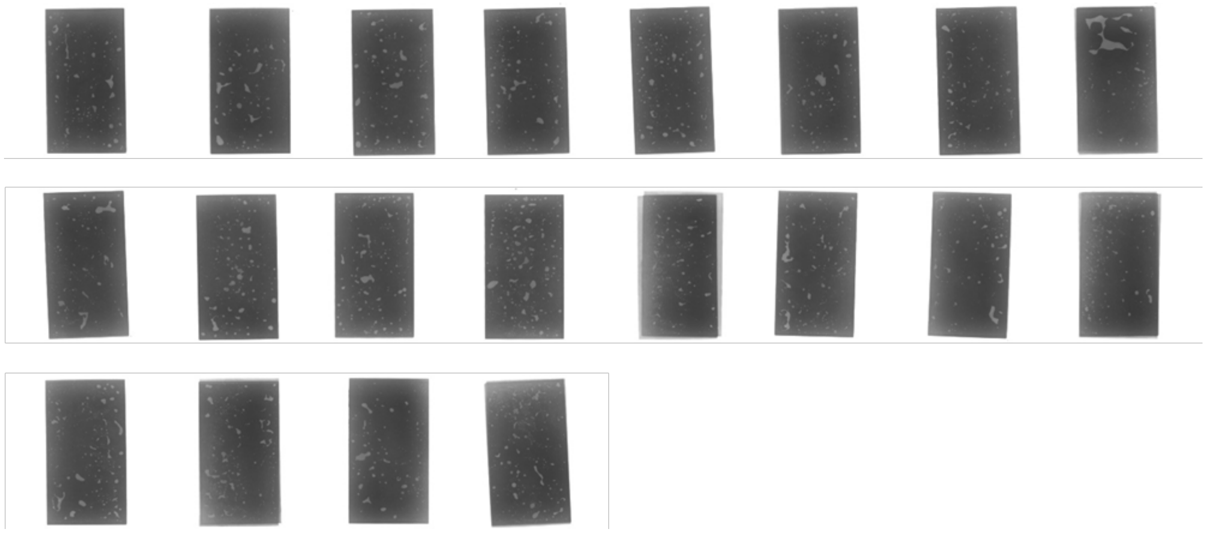


Fig. 4. X-ray Images of Preforms: 0.001″

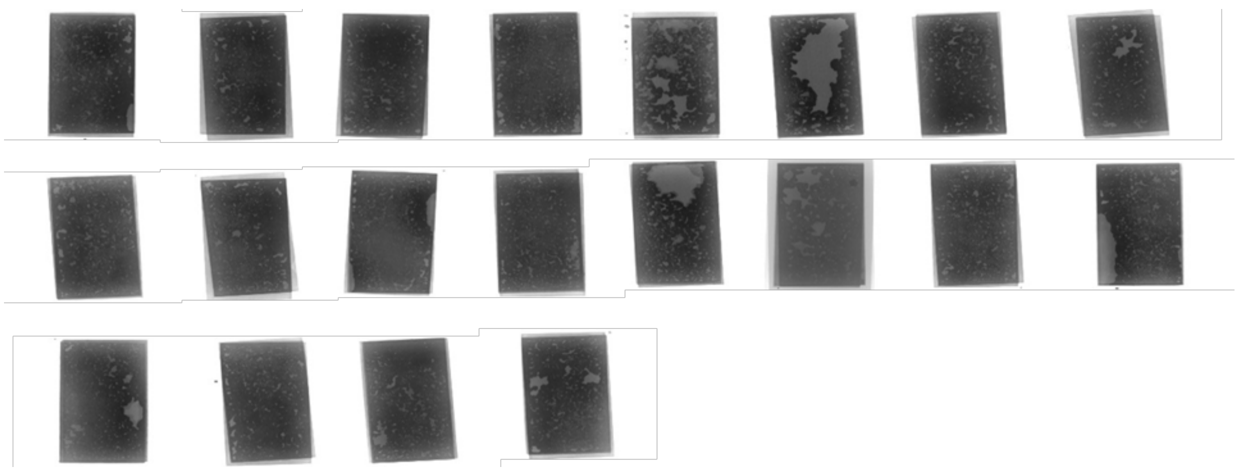


Fig. 5. X-ray Images of Preforms: 0.0005″

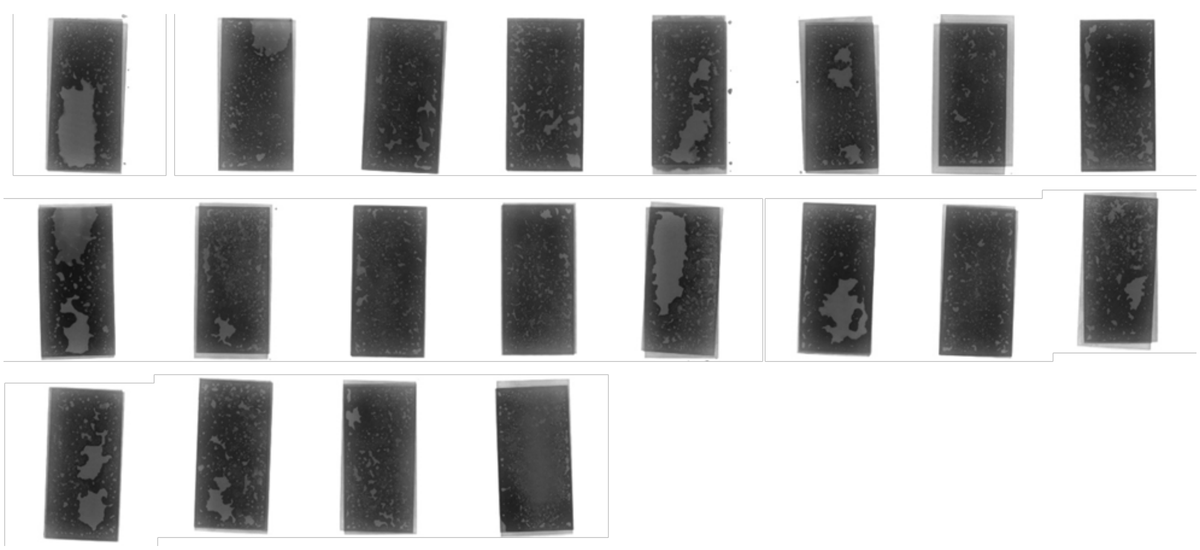


Fig. 6. X-ray Images of Preforms: 0.00035″

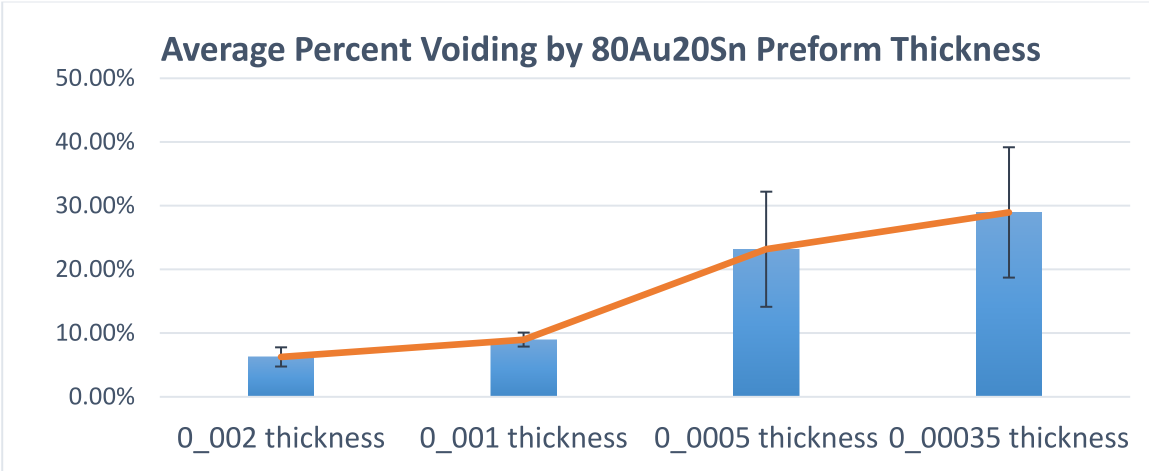


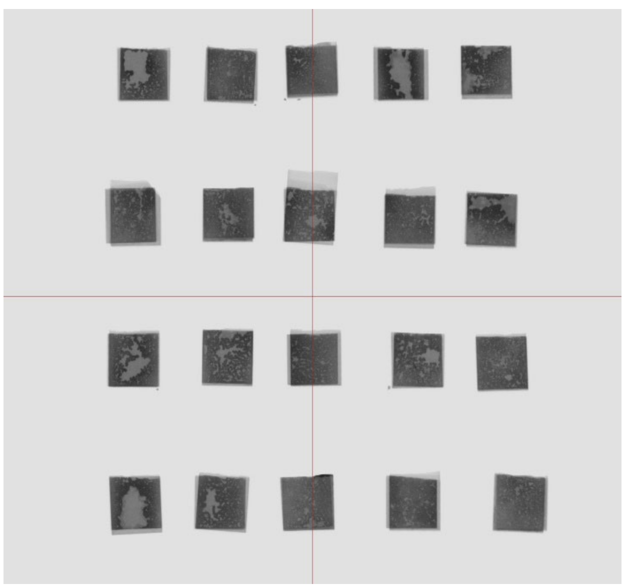
Fig. 7. Average Percent Voiding by 80Au/20Sn Preform Thickness

Table I. Voiding Percentages

Thickness	# of Voids	STD	Area% of Voids	STD	Largest Void	Max Area% of Voids	Min Area% of Voids
0.002″	387.84	85.78	6.26%	1.51%	5.48%	9.87%	4.30%
0.001″	519.50	130.84	8.99%	1.10%	3.91%	11.00%	6.27%
0.0005″	1129.35	286.37	23.17%	9.04%	32.73%	44.02%	14.79%
0.00035″	980.55	396.06	28.95%	10.23%	31.17%	50.26%	15.71%

A second round of experimentation was performed using 80Au/20Sn preforms at X/Y dimensions of 0.285″ x 0.260″ and thicknesses of 0.0005″ and 0.00035″ between two Alumina 92% black coupons coated with 50µin Ni/50µin Au with a bonding surface of the same X/Y dimensions.

Twenty packages per 80Au/20Sn thickness were assembled, reflowed, and imaged in the same manner. Voiding percentages were calculated at 23.54% and 19.73% (Fig. 10 and Fig. 11) for thicknesses of 0.0005″ and 0.00035″ (Fig. 8 and Fig. 9), respectively.



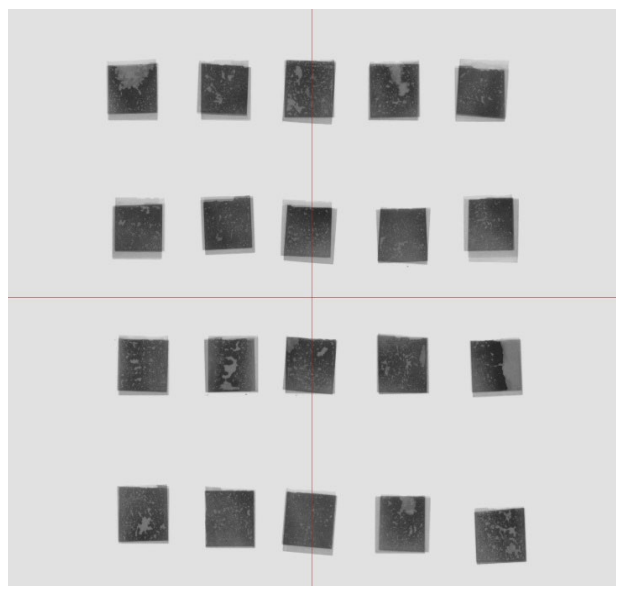


Fig. 8. X-ray Images of Preforms: 0.00035″

Fig. 9. X-ray Images of Preforms: 0.00035″

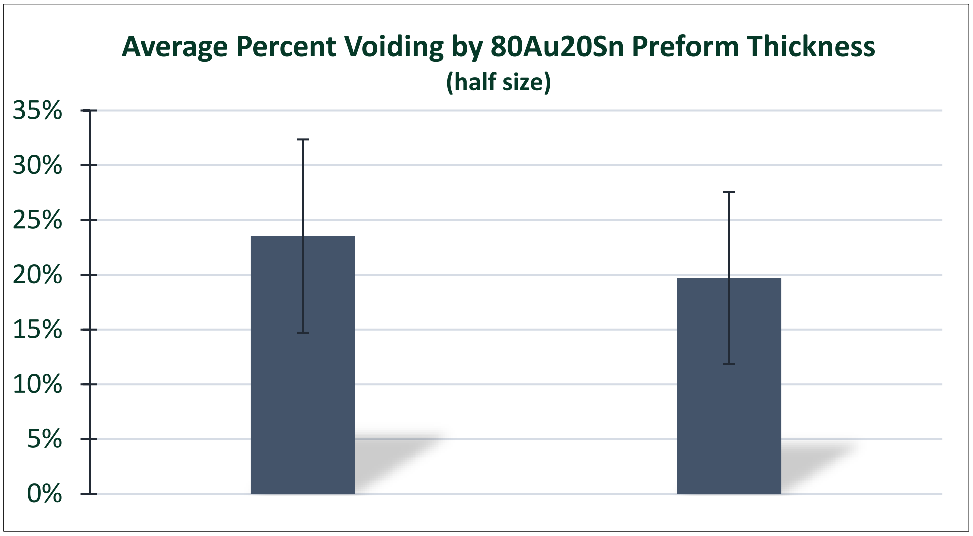


Fig. 10. Average Percent Voiding by Preform Thickness

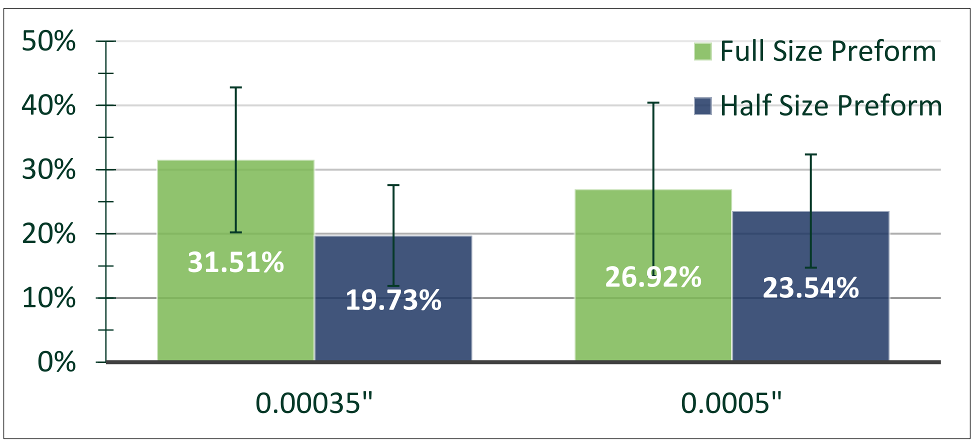


Fig. 11. Percent Voiding by Preform Size

III. Conclusion

Initially, there was a direct relationship between the thinner the solder material used in the bondline and the percentage of voiding in the solder joint. Furthermore, 80Au/20Sn preform thicknesses of 0.0005″ and 0.00035″ presented large starvation voids as there was not enough solder volume to wet the entire bonding area of the Alumina 92% black coupons coated with 50µin Ni/50µin Au. A greater voiding area within the solder joint will retain, instead of release, the heat from the semiconductor laser device more efficiently. The original intention of using a thinner solder material in the bondline is to transfer heat away from the die more quickly, and thus increase the longevity and potential of the die. However, with the appearance of these voiding hotspots, the use of a thinner solder material in the bondline negates this. Since X/Y dimensions of 0.285″ x 0.521″ are quite large for what is normally seen in die-attach, a secondary round of experimentation was performed using both 80Au/20Sn preforms and Alumina 92% black coupons coated with 50µin Ni/50µin Au at half the length of the original experiment to determine if a smaller die-bonding area would have any effect on overcoming the lack of available solder when using thinner 80Au/20Sn preforms, and therefore, impact voiding.

While starvation voids were still present, it can be established that wetting distance is tied to the volume of material. Even with the reduction of the length of the solder preforms and Alumina 92% black coupons, 0.285″ x 0.260″ is still larger than is normally seen in die-attach, so there is opportunity to continue studying the relationship of AuSn preform thickness on thermal transfer to determine the maximum allowable component size with regards to solder volume. Continuing to define the voiding percentages across the different 80Au/20Sn preform thicknesses can determine the effect on thermal transfer in semiconductor laser technologies.