SV Microwave, an Amphenol Company

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Thermal Effects of Solder Reflow on RF PCB Connector Design

Summary

This report explores the changes that different dielectric materials undergo during a standard PCB solder reflow process. The dielectrics examined are PTFE, Torlon, PEEK, Ultem, and Corning #7070 glass. The connectors used for the testing are all male SMP surface mount connectors. The connectors were soldered using Sn96 solder and tested electrically. Mating end dimensions were taken after reflow as well as measurements to determine how evenly the connectors were soldered to the board.

Introduction

From past experience and customer feedback we know that PTFE insulators undergo major dimensional changes when exposed to the temperatures required to reflow solder on printed circuit boards. Sn96 solder melts at around 221-225°C, though this figure depends on the exact composition of the solder being used and the reflow oven profile selected. This elevated temperature causes the PTFE to expand inside the connector and potentially extrude out of the connector and disrupt its seating on the board. It can also move the center contact and push it beyond the allowable tolerance for the mating end specification.

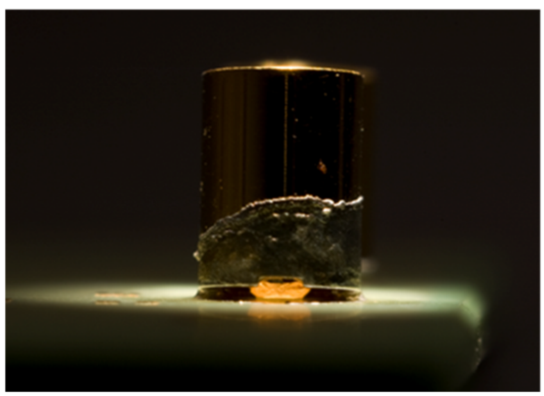

Figure 1: Common RF PCB connector design showing PTFE insulator growth after reflow process

These changes have forced us to either make sacrifices to electrical performance by setting the end of the insulator well short of the bottom of the connector, or design in different dielectrics with better thermal properties and higher dielectric constants.

Experiment and Results

The connectors used in this experiment were modeled after SV PN 1211-20016 which is the glass seal control connector (it is known that Corning #7070 glass will not reflow at these temperatures). PNs SK-3397-3400 were designed to use the same footprint, and they all have a similar construction. The connector part number and dielectric used can be found below in Table 1.

Part Number	Dielectric Material
1211-20016	Corning #7070
SK-3397	PTFE
SK-3398	Ultem 1000
SK-3399	Torlon
SK-3400	PEEK 1000

Table 1: Connector part numbers and corresponding dielectric material

Each connector was soldered to the sample board SK-3412 using Sn96 solder paste and a reflow oven. The heating profile used for these tests is shown below in Figure 2. The max temperature of the profile is quite a bit higher at 250°C because there are other objects in the oven soaking up heat, so the board and the solder don't see that max temperature.

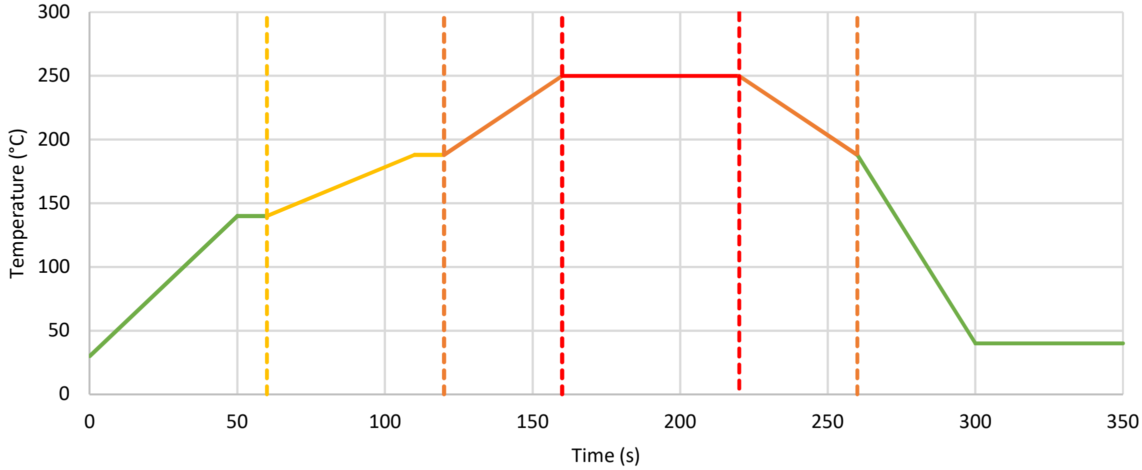

Figure 2: Sn96 Reflow oven temperature profile

The connectors were tested electrically, plots are shown and discussed below. The connectors' mating end dimensions, the height of the pin from the reference plane ('RP', shown below in Figure 3) were measured before and after reflow, the average of 5 samples is shown in Table 2 below.

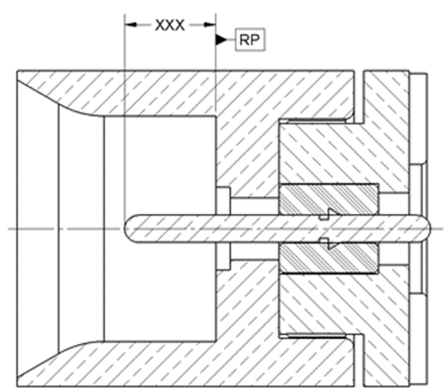

Figure 3: Cross section of SK-3397 (PTFE) showing Mating End Dimension (XXX)

PN	Dielectric	Average Mating End Dimension Before Reflow	Average Mating End Dimension After Reflow	Change in Pin Height
1211-20016	Corning #7070	.0511"	.0510"	-.0001"
SK-3397	PTFE	.0513"	.0508"	-.0004"
SK-3398	Ultem 1000	.0509"	.0513"	+.0004"
SK-3399	Torlon	.0507"	.0499"	-.0008"
SK-3400	PEEK 1000	.0512"	.0515"	+.0003"

Table 2: Connector Mating End Dimensions before and after reflow

The largest difference between the pin height before and after reflow is -.0008", which is best attributed to measurement error. A .0008" change in the pin height is not substantial enough to cause mechanical or electrical failure in this application. Measurements were also taken around the rim of the connector using a drop gauge to measure how flat the connectors were sitting on the board after reflow. The measurements were only taken after reflow for fear that the drop weight of the drop gauge would skew the data or displace the connector in an unintended manner. The measurements were taken according to Figure 4, where location 1 was the reference point. The measurements are shown in Table 3.

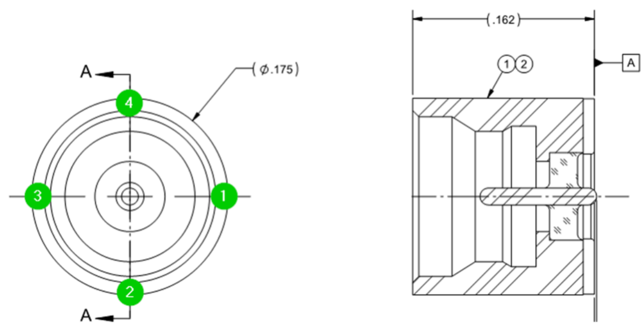

Figure 4: Schematic showing where flatness measurements were taken

Part Number	Dielectric	Location 2	Location 3	Location 4
1211-20016	Corning #7070	+.0004	+.0005	+.0005
SK-3397	PTFE	0.0000	+.0003	0.0000
SK-3398	Ultem 1000	+.0002	0.0000	-.0003
SK-3399	Torlon	+.0005	-.0004	0.0000
SK-3400	PEEK 1000	+.0009	+.0001	+.0001

Table 3: Connector Mating End Dimensions Before and After Reflow

The connectors were placed in the reflow oven with a block of Ultem on top of them to achieve flatness in the final product. The block is approximately 3.5" x 3" x 0.75" and weighs about 4 oz and covers the entire eval board. At most, one side of the connector was .0009" off of the reference measurement, indicating that the connectors are sitting very flat on the boards.

Finally, cross-sections of the soldered connectors were taken, and are shown below in Figures 5-9. As indicated by the stability of the pin height during reflow, there is minimal deformation of the insulators. The one exception is the PTFE insulator (which is about .004” longer in length than the drawing specification) that is bulging into the air line section of the connector. The growth was even on both sides and did not seem to greatly affect electrical performance, though SK-3397 did have worse performance in the lower frequency band. It is unclear whether this is growth from the elevated temperature or from when the pin was pressed into it.

It should be noted that the designs tested were optimized for the reflow process by moving the insulator bottom surface away from the PCB. This was done by including an impedance optimized airline section between the PCB surface and the bottom plane of the insulator.

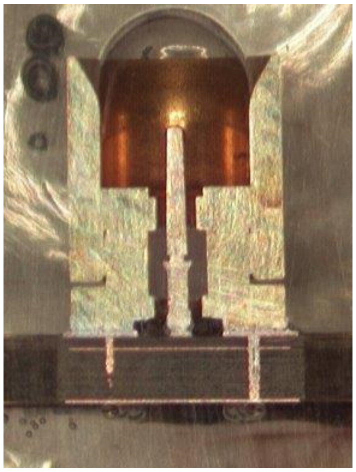

Figure 5: Cross-Section of SK-3397 (PTFE)

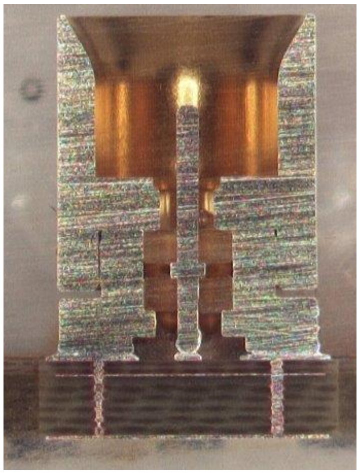

Figure 6: Cross-Section of SK-3398 (Ultem)

Figure 7: Cross-Section of SK-3399 (Torlon)

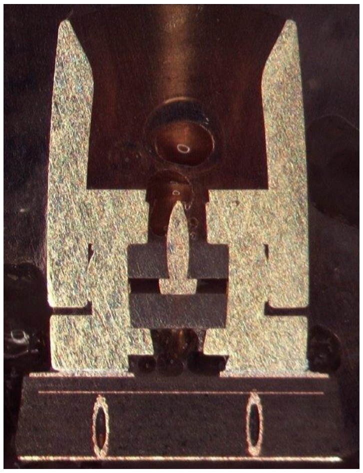

Figure 8: Cross-Section of SK-3400 (PEEK)

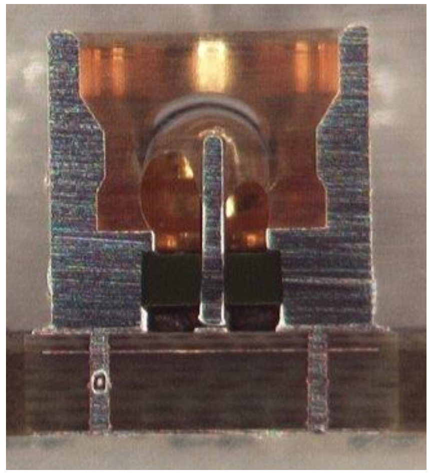

Figure 9: Cross-Section of 1211-20016 (Corning #7070)

The final measurements taken were of the height of the RP from the surface of the board and the final thickness of the solder on the board, these measurements are shown below in Table 4. The RP height was measured using a drop gauge and the solder thickness was measured using an optical inspection tool on the cross-sections shown above.

The stencil used to lay the solder paste was .0035”. The reason 1211-20016 sits so low is because the construction of that connector is different from the plastic dielectrics. These measurements were taken in an effort to understand what happens to the height of the connector when solder is added. The data suggests that the solder does not “expand” or “rise”, but rather remains at the same thickness or is “squished” by the connector.

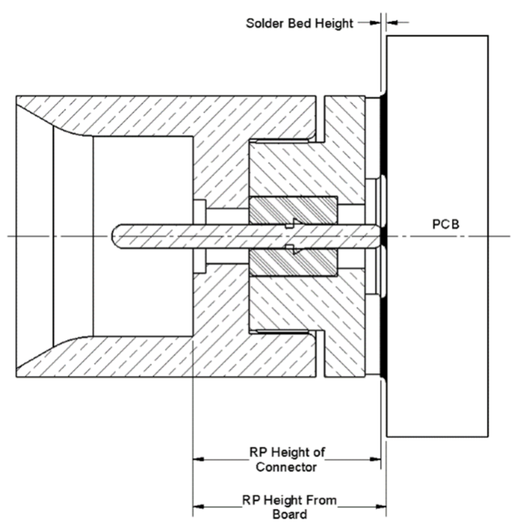

Figure 10: Connector RP Height and Solder Thickness

Part Number	Dielectric	RP Height From the Board	Nominal RP Height of Connector	Solder Thickness
1211-20016	Corning #7070	.0545”	.0520”	.0031”
SK-3397	PTFE	.1184”	.1170”	.0015”
SK-3398	Ultem 1000	.1199”	.1170”	.0034”
SK-3399	Torlon	.1202”	.1170”	.0027”
SK-3400	PEEK 1000	.1219”	.1170”	.0035”

Table 4: Connector RP Height and Solder Thickness

Electrical Test Results

Electrical measurements were taken and are shown below. Figures 10 and 11 show VSWR and Insertion Loss respectively. The measurements were taken using two of each connector on SK-3412, the sample board. The measurements are ungated and the connectors perform fairly well through about 18 GHz.

The performance across the different dielectrics is consistent, though the 1211-20016 with a glass bead had a markedly better VSWR than the others. The difference in electrical performance may be due to the fact that the board design was based on that connector, and the other connectors were designed as best as possible around the board. Perfect electrical performance was not the goal of this analysis, but is shown here to demonstrate that the performance was consistent and to show drastic differences, if there were any.

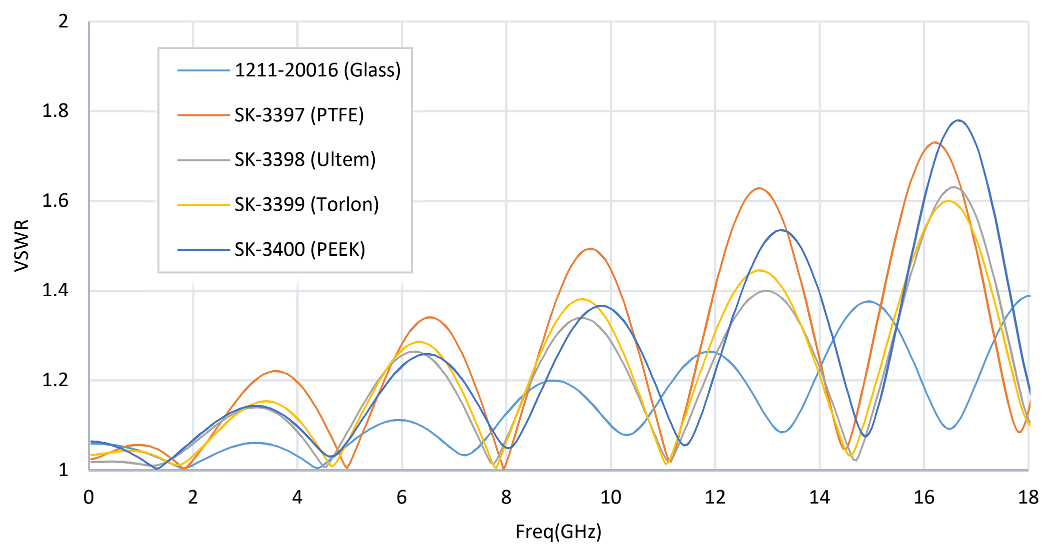

Figure 10: VSWR vs frequency of each connector type

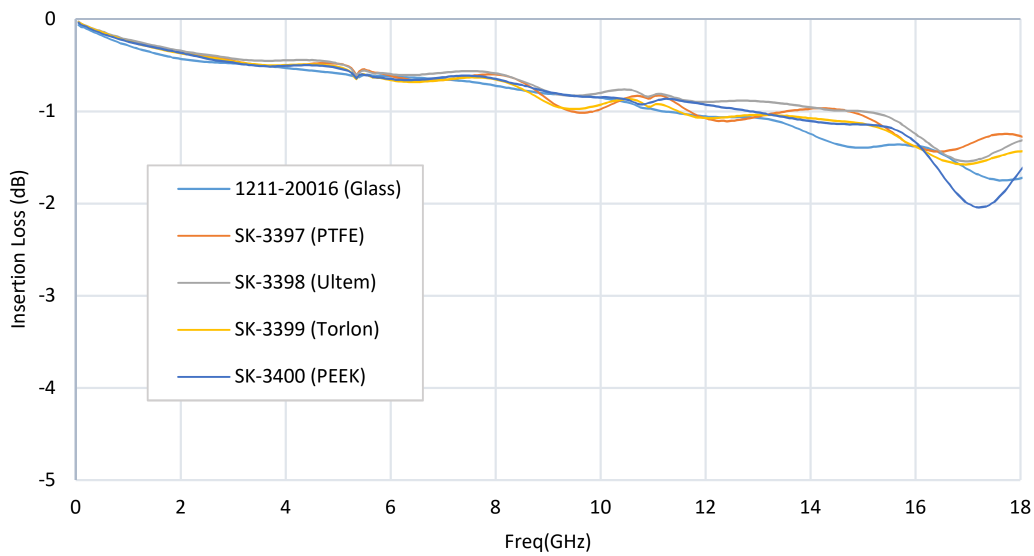

Figure 11: Insertion Loss vs Frequency of Each Connector Type

Conclusion

It was found that this reflow profile had negligible effects on the shape and dimensions of the dielectrics in the connectors studied. We attribute this to the connector design which is optimized for Sn96 reflow temps by moving the bottom plane of the insulator away from the surface of the PCB, and using an impedance controlled air gap, mechanical shoulders within the connector ID and custom insulator design to allow for minor dielectric reflow.

The flatness measurements of the connector reference plane and mating end dimensions showed negligible change (within the error of measurement) from before to after the reflow process. We also confirmed that a small amount of weight on the connector during reflow did not significantly change the final solder height and consistent solder thicknesses were achieved. Per the results shown in this report, we expect soldered connectors to sit approximately .001 below ±.001 into the solder paste.

Our results confirmed that all insulator types evaluated in this experiment are viable candidates for this type/size of connector and reflow profile. We recommend proper connector design, that takes dielectric growth into consideration, for applications where dielectric growth during reflow is of concern.

For additional information, please contact marketing@svmicro.com