TAIWAN SEMICONDUCTOR

AN-1007

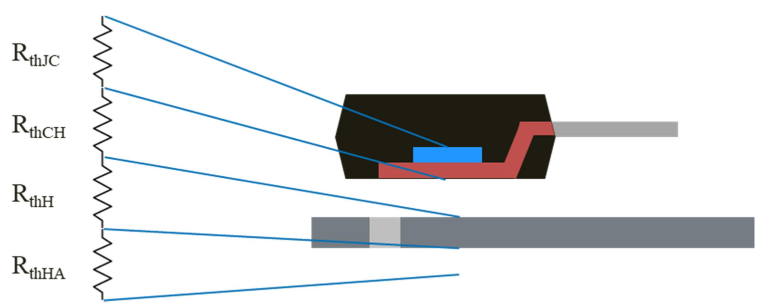
SIP package mount torque evaluation - application note

Content

1. Introduction

1.1 Purpose

Power device package thermal performance with heatsink is related to R_{thJA} (junction to ambient thermal resistance). R_{thJA} is composed of R_{thJC} (junction to case thermal resistance), R_{thCH} (case to heatsink thermal resistance), R_{thH} (heatsink thermal resistance), and R_{thHA} (heatsink to ambient thermal resistance) (Figure 1).



(Figure 1 – Thermal resistance structure)

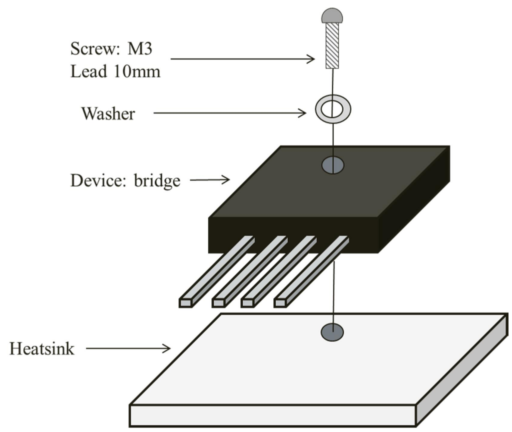
Air is the bigger resistivity interface which resistivity is $1.5\text{x}10^{14}$ Ωm, so air is a high insulator and it could increase thermal resistance. In order to let power device could have good thermal dissipation performance, adding heat sink (for example Al material resistivity is $2.82\text{x}10^{-8}$ Ωm) to increase heat transfer area to the ambient air is important. While combine device with heat sink, there might be air gap of the remaining space if combination method is not appropriate. So it is important to mount a heat sink to power device to minimizing contact thermal resistance. It could adopt a screw to fasten device and heat sink to make the contact area good seal between the two surfaces.

Axial lead package products will add additional heat sink to get better power handling capacity and excellent thermal dissipation performance by customers' application. We offer application note – which suggest the good screw torque for customer application via experiment.

We adopt 9 package of GBU, TS-6P, ITO-220, TO-220, TO-247, KBJL, D3K, TS4K(KBL), and TS6PL. Apply different screw mounting torque value on the device and monitor mechanical status, internal structure status. Even we monitor device performance via TC (temperature cycling) to monitor its environment temperature affect factor performance.

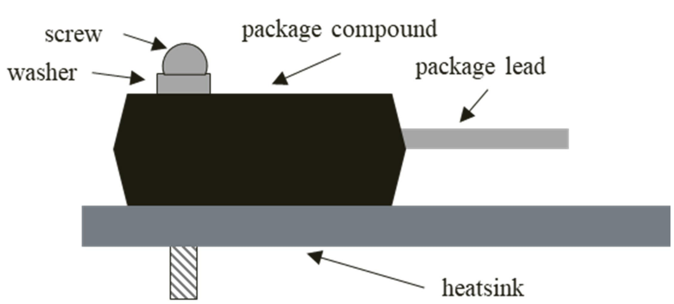
1.2 Affection of screw mounting torque

Discrete device mount in PCB assembly process, power device package will need screw to make device and heatsink combination well in order to gain good heat dissipation. Usually apply screw with washer to make device and heatsink combination (Figure 2)

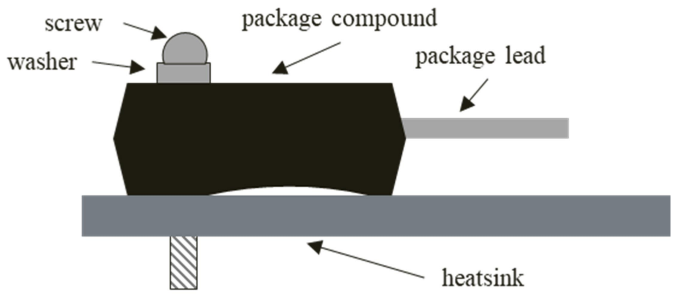


(Figure 2 – mounting method for power device)

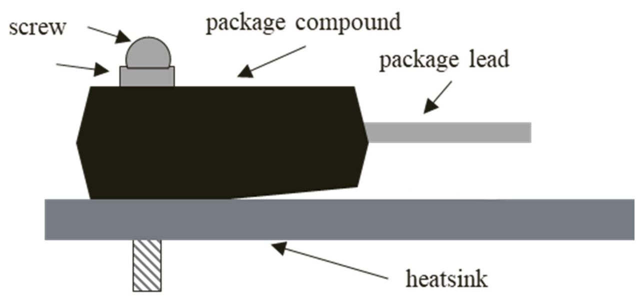
Screw mounting stress control is important. If screw torque is too loose, the device and heatsink will not be well contact and it could make thermal resistance high to have bad heat dissipation; the other hand if screw torque is too tight, the device might be lifted up heatsink and might damage device package, it could make thermal resistance high and make the electric parameters shift to be failed. (Figure 3,4,5)



(Figure 3 – Proper screw torque make device and heatsink combination well)



(Figure 4 – Loose screw torque make bad contact between device and heatsink)

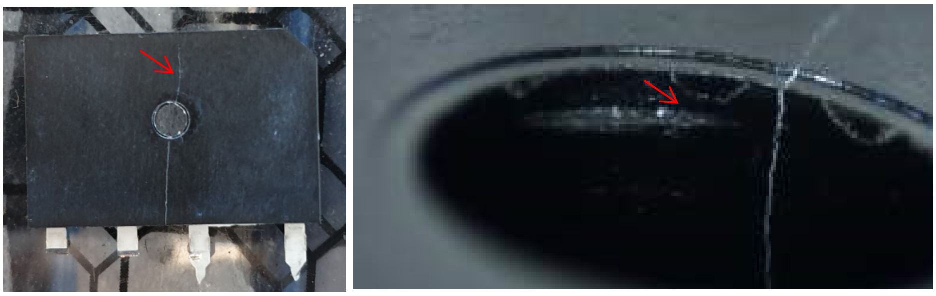


(Figure 5 – Tight screw torque make device lifted up heatsink and might damage device package)

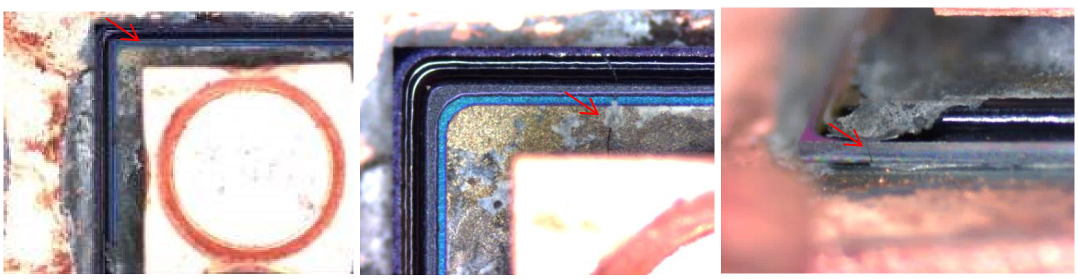
2. Improper screw mounting consequence

Screw mounting improper stress makes device molding compound crack (Figure 6), it could be observed there is die crack phenomenon after demounting molding compound and examine inner structure (Figure 7). Remove lead frame and monitor bare die, the die cracked could be discovered (Figure 8).

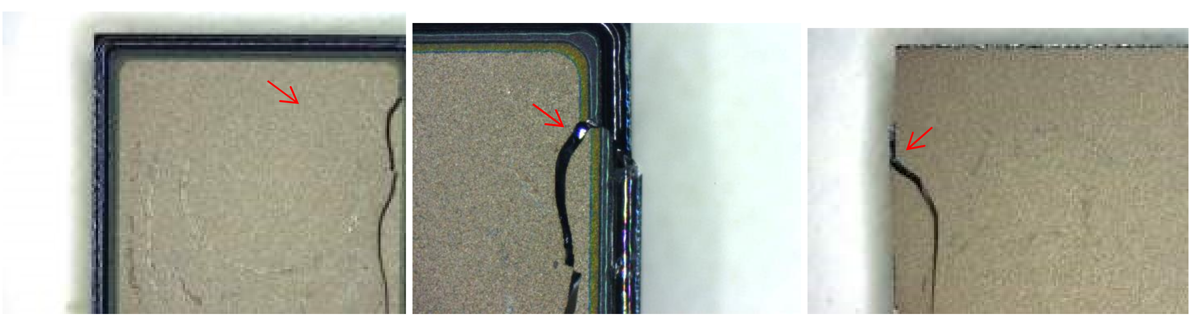
Additionally, make sure device attach to heat sink prior to device is soldered on PCB. If solder device to PCB first, the stress from the PCB fixed pad could damage device during tightening screw to combine device and heat sink.



(Figure 6 – screw torque overstress to make device appearance to suffer cracks)



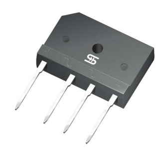
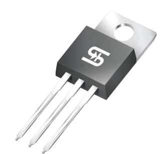
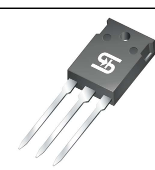
(Figure 7 – Remove molding compound to examine inner structure, there are cracks on die caused by screw torque improper stress)

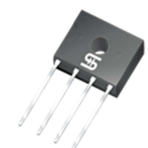
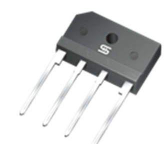
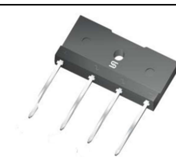


(Figure 8 – Take off lead frame and monitor bare die, the die cracked could be observed)

3. Experiment procedure

Select 9 packages of GBU, TS-6P, ITO-220, TO-220, TO-247, KBJL, D3K, TS4K(KBL), and TS6PL which includes small die and big die in order to consider die size impact factor. (Figure 9)

Package	Small die Part number	Small die size (mil)	Big die Part number	Big die size (mil)	Package picture
GBU	GBU405 NG	88mil	GBU805 NG	114mil	
TS-6P	TS6P05G NG	100mil	TS50P05G NG	180mil	
ITO-220	UGF1008G NG	57mil	MBRF30150CT-Y NG	141mil—Dual Dice	
TO-220	UG1006G NG	57mil	MBR30100CT-Y NG	122mil—Dual Dice	
TO-247	SR1640PT NG	78mil	MBR60100PT NG	150mil	

Package	Small die Part number	Small die size (mil)	Big die Part number	Big die size (mil)	Package picture
KBJL	TS6KL80 NG	88mil	TS10KL80 NG	100mil	
D3K	UR2KB100 HF	60mil	UR8KB80 HF	95mil	
TS4K (KBJ)	TS4K80 N	82mil	TS10K80 N	100mil	
TS6PL	T10JA07G-K HF	95mil	T15JA07G-K HF	110mil	

(Figure 9 – Device list to evaluate torque experiment)

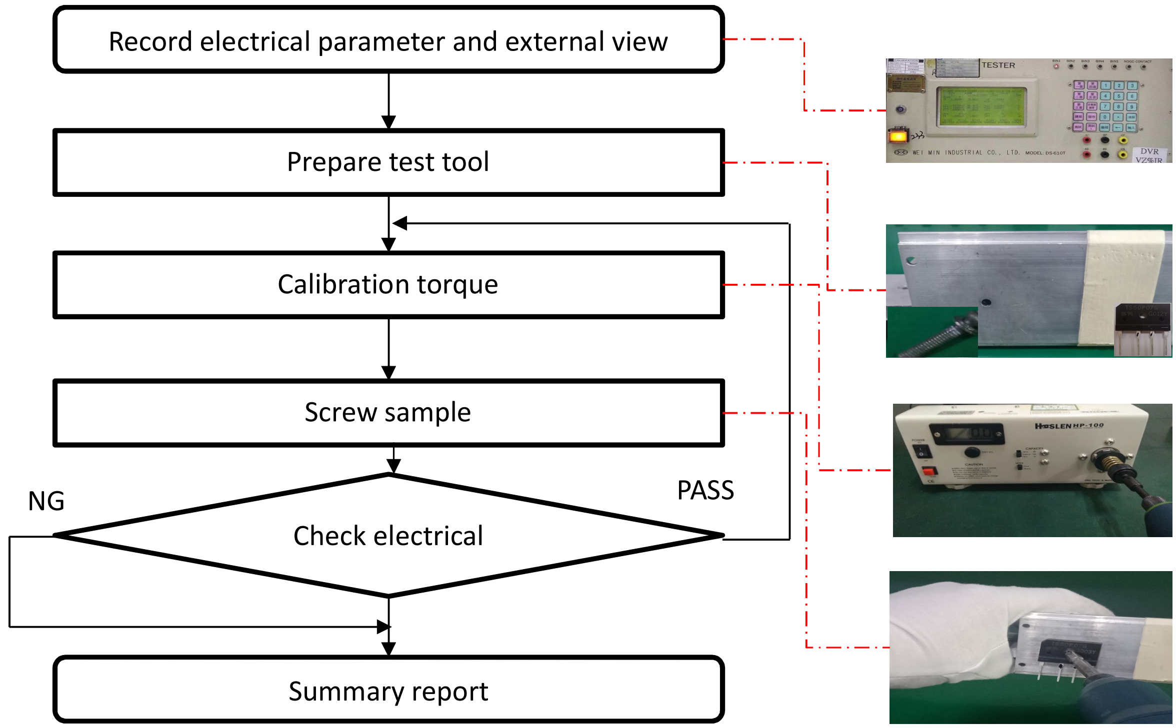
3.1 Experiment flow

We apply this experiment flow includes 1- prepare device under test samples. 2- CSAM. 3- electrical parameters test. 4- apply torque to screw bridge and heatsink. 5- CSAM. 6- electrical parameters test. 7- thermal resistance measurement. 8- TC (temperature cycling). 9- CSAM. 10- electrical parameters test.

3.2 Torque test flow

We apply screw torque to screw device and heatsink, we increase the screw torque until making the device package broken. Got the maximum torque value and adopt three torque values (1 Nm, 0.9Nm, 0.8Nm) to do the experiment. The applying screw torque procedure is as (Figure 10).

Torque test flow：



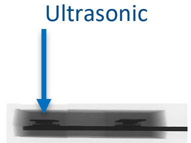
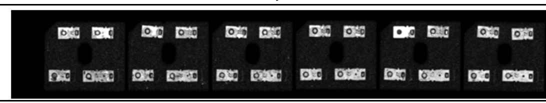
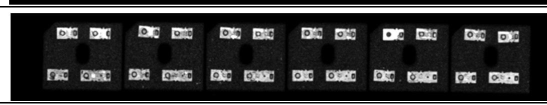
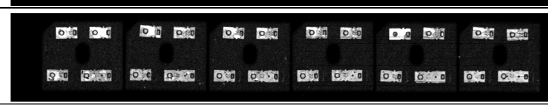
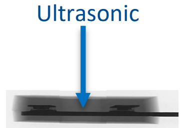
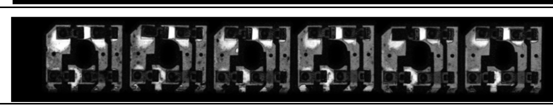
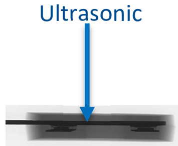
(Figure 10 – Torque test method and flow)

4. Experiment result

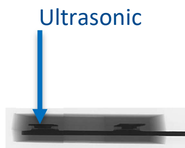
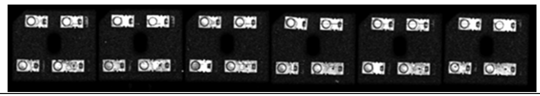
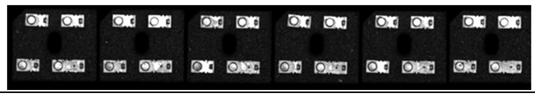
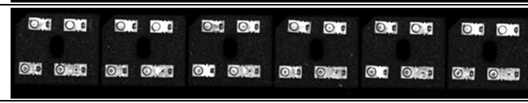
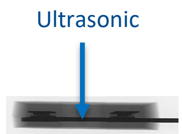
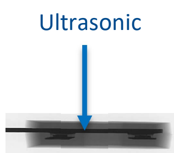
Check device influence after screw torque applied, test before and after electrical parameters variation. In order to go a step further to examine if any minor damage after screw torque applied devices and may be not discovered, we do TC (temperature cycle) to let device under -55°C/15minutes to 150°C/15minutes circumstance 1000 cycles to verify device further. CSAM (scanning acoustic microscope) could verify if device layers occur delamination after screw torque and TC applied. We also test devices Z_{thjC} (junction-to-case thermal impedance) to see if different torque would make device structure damage then making thermal impedance increase to abnormal.

4.1 CSAM result

GBU package device includes big die and small die parts, applied CSAM to examine if any delamination growth among initial, after applied screw torque and after applied TC. There is no delamination growth between these experiments (Figure 11) (Figure 12).

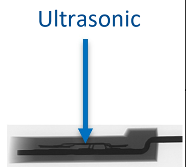
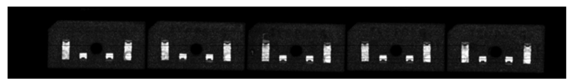
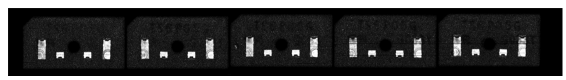
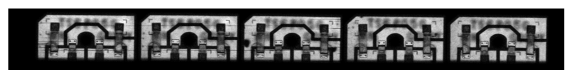
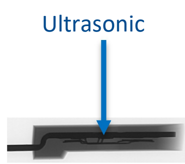
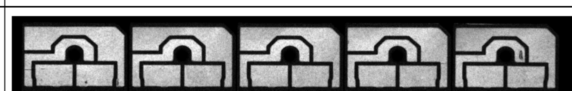
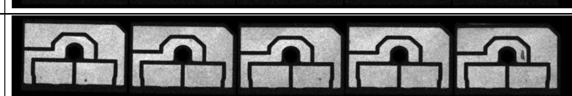
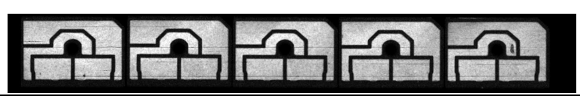
Package	Part number	Scan layer	Stage	CSAM picture
GBU	GBU405 NG	interface of compound and clip Ultrasonic 	initial	
			After apply torque	
			After TC	
		interface of compound and pad Ultrasonic 	initial	
			After apply torque	
			After TC	
		interface of compound and back pad Ultrasonic 	initial	
			After apply torque	
			After TC	

(Figure 11 – GBU package small die device CSAM result no delamination growth)

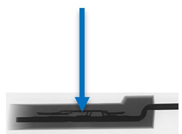
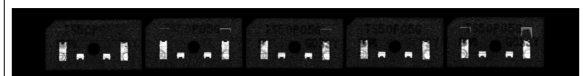
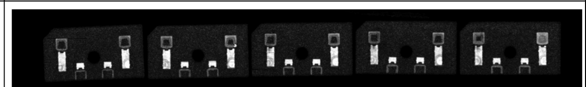
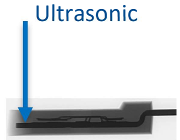
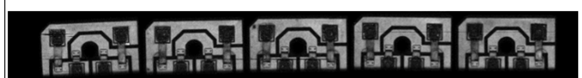
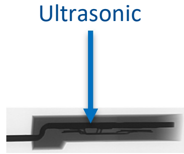
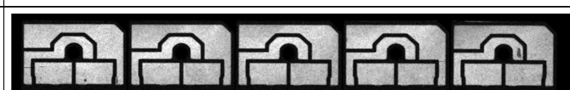
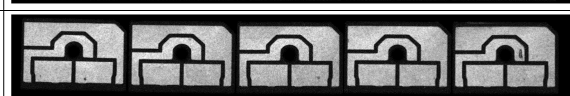
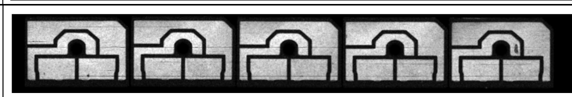
Package	Part number	Scan layer	Stage	CSAM picture
GBU	GBU805 NG	interface of compound and clip 	initial	
			After apply torque	
			After TC	
		interface of compound and pad 	initial	
			After apply torque	
			After TC	
		interface of compound and back pad 	initial	
			After apply torque	
			After TC	

(Figure 12 – GBU package big die device CSAM result no delamination growth)

TS-6P package device includes big die and small die parts, applied CSAM to examine if any delamination growth among initial, after applied screw torque and after applied TC. There is no delamination growth between these experiments (Figure 13) (Figure 14).

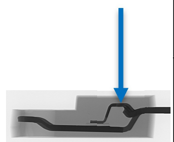
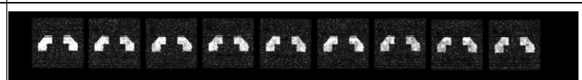
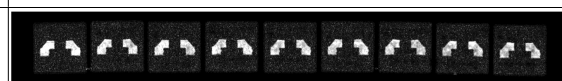
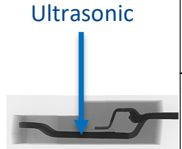
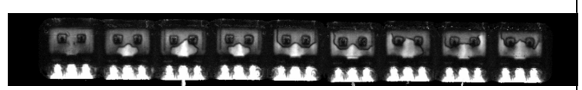
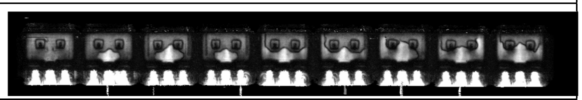
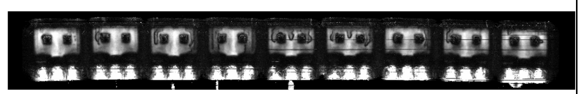
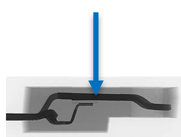
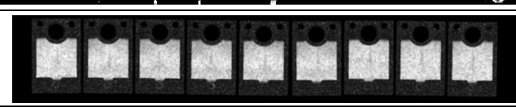
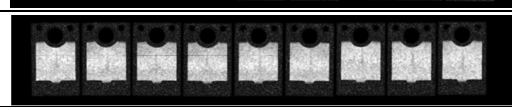
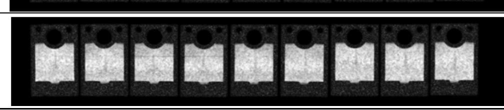
Package	Part number	Scan layer	Stage	CSAM picture
TS-6P	TS6P05G NG	interface of compound and clip 	initial	
			After apply torque	
			After TC	
		interface of compound and pad 	initial	
			After apply torque	
			After TC	
		interface of compound and back pad 	initial	
			After apply torque	
			After TC	

(Figure 13 – TS-6P package small die device CSAM result no delamination growth)

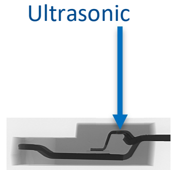
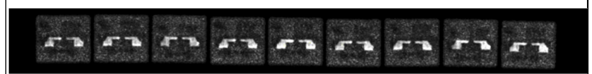
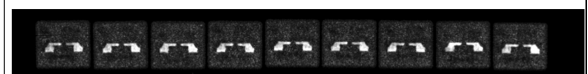
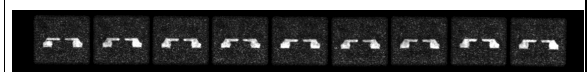
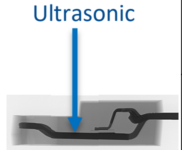
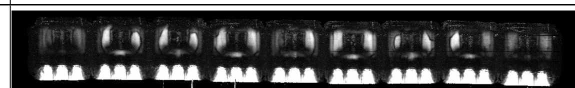
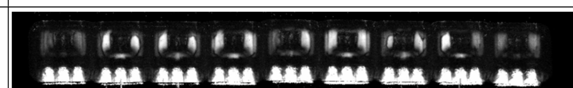
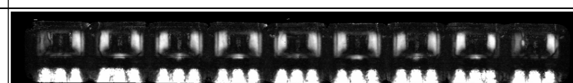
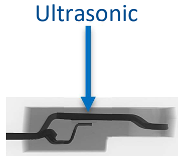
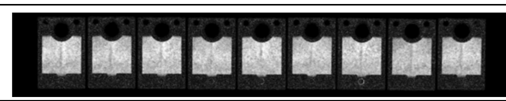
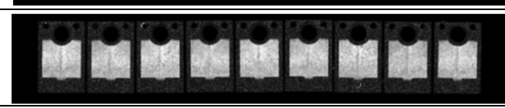
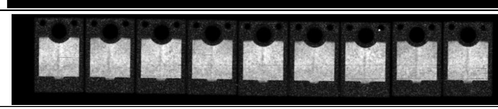
Package	Part number	Scan layer	Stage	CSAM picture
TS-6P	TS6P05G NG	interface of compound and clip Ultrasonic 	initial	
			After apply torque	
			After TC	
		interface of compound and pad Ultrasonic 	initial	
			After apply torque	
			After TC	
		interface of compound and back pad Ultrasonic 	initial	
			After apply torque	
			After TC	

(Figure 14 – TS-6P package big die device CSAM result no delamination growth)

ITO-220 package device includes big die and small die parts, applied CSAM to examine if any delamination growth among initial, after applied screw torque and after applied TC. There is no delamination growth between these experiments (Figure 15) (Figure 16).

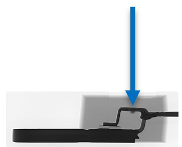
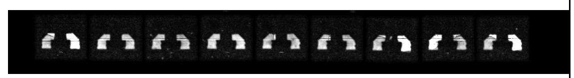
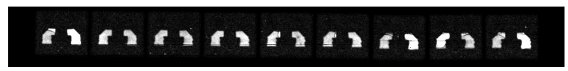
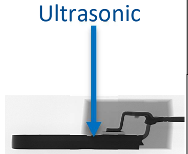
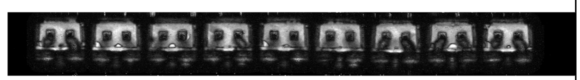
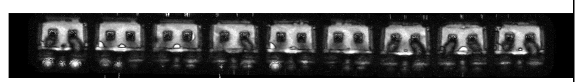
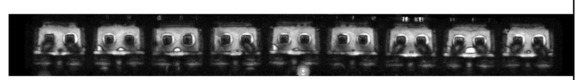
Package	Part number	Scan layer	Stage	CSAM picture
ITO-220	UGF1008G NG	interface of compound and clip Ultrasonic 	initial	
			After apply torque	
			After TC	
		interface of compound and pad Ultrasonic 	initial	
			After apply torque	
			After TC	
		interface of compound and back pad Ultrasonic 	initial	
			After apply torque	
			After TC	

(Figure 15 – ITO-220 package small die device CSAM result no delamination growth)

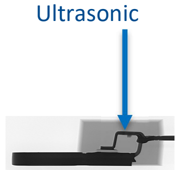
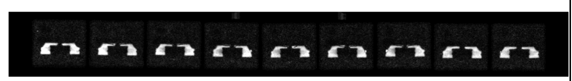
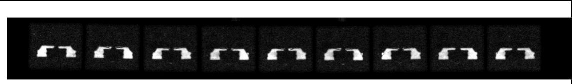
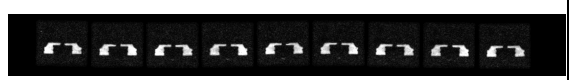
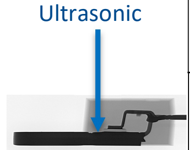
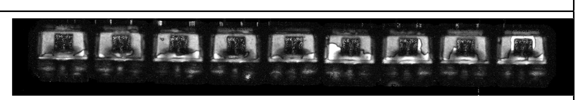
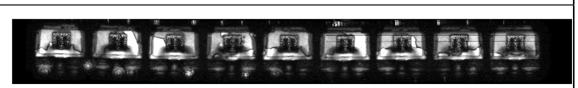
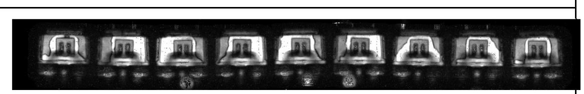
Package	Part number	Scan layer	Stage	CSAM picture
ITO-220	MBRF30150CT-Y NG	interface of compound and clip Ultrasonic 	initial	
			After apply torque	
			After TC	
		interface of compound and pad Ultrasonic 	initial	
			After apply torque	
			After TC	
		interface of compound and back pad Ultrasonic 	initial	
			After apply torque	
			After TC	

(Figure 16 – ITO-220 package big die device CSAM result no delamination growth)

TO-220 package device includes big die and small die parts, applied CSAM to examine if any delamination growth among initial, after applied screw torque and after applied TC. There is no delamination growth between these experiments (Figure 17) (Figure 18).

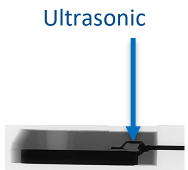
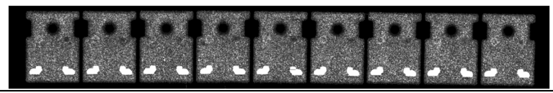
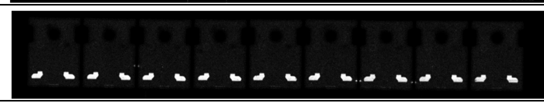
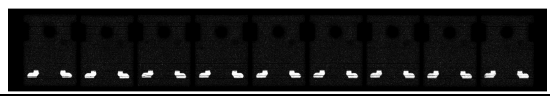
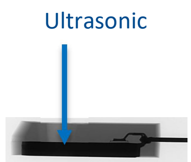
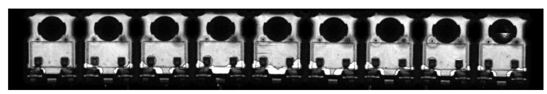
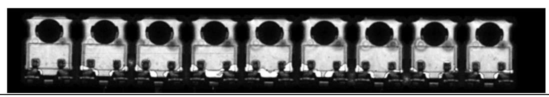
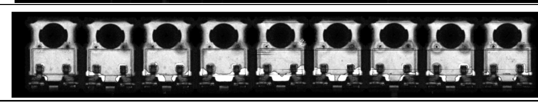
Package	Part number	Scan layer	Stage	CSAM picture
TO-220	UG1006G NG	interface of compound and clip Ultrasonic 	initial	
			After apply torque	
			After TC	
		interface of compound and pad Ultrasonic 	initial	
			After apply torque	
			After TC	

(Figure 17 – TO-220 package small die device CSAM result no delamination growth)

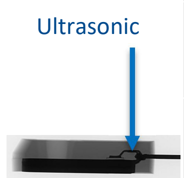
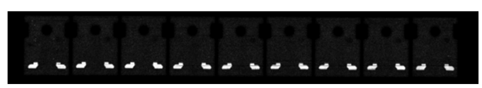
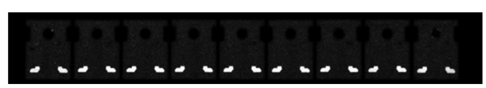
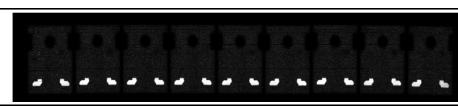
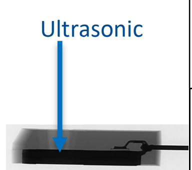
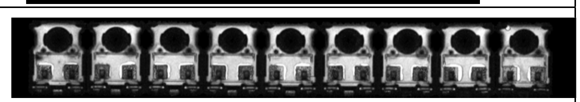
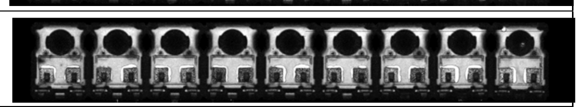
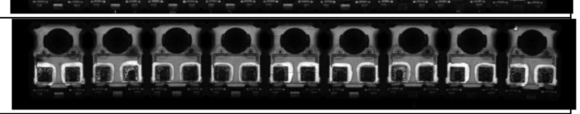
Package	Part number	Scan layer	Stage	CSAM picture
TO-220	MBR30100CT-Y NG	interface of compound and clip Ultrasonic 	initial	
			After apply torque	
			After TC	
		interface of compound and pad Ultrasonic 	initial	
			After apply torque	
			After TC	

(Figure 18 – TO-220 package small die device CSAM result no delamination growth)

TO-247 package device includes big die and small die parts, applied CSAM to examine if any delamination growth among initial, after applied screw torque and after applied TC. There is no delamination growth between these experiments (Figure 19) (Figure 20).

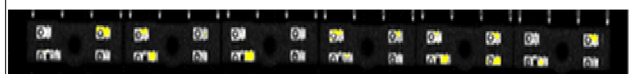
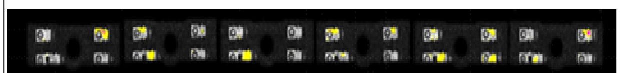
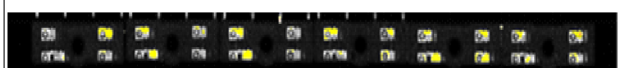
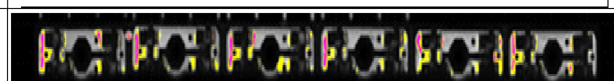
<table>
<tr><th>Package</th><th>Part number</th><th>Scan layer</th><th>Stage</th><th>CSAM picture</th></tr>
<tr><td rowspan="6">TO-247</td><td rowspan="6">SR1640PT NG</td><td rowspan="3">interface of compound and clip
</td><td>initial</td><td></td></tr>
<tr><td>After apply torque</td><td></td></tr>
<tr><td>After TC</td><td></td></tr>
<tr><td rowspan="3">interface of compound and pad
</td><td>initial</td><td></td></tr>
<tr><td>After apply torque</td><td></td></tr>
<tr><td>After TC</td><td></td></tr>
</table>

(Figure 19 – TO-247 package small die device CSAM result no delamination growth)

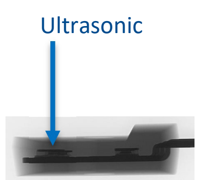
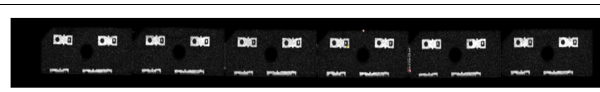
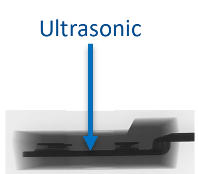
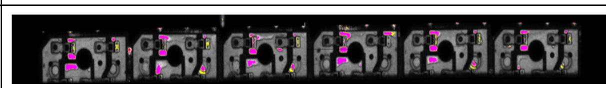
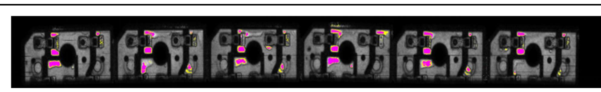
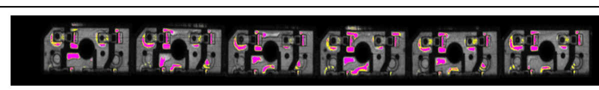
<table>
<tr><th>Package</th><th>Part number</th><th>Scan layer</th><th>Stage</th><th>CSAM picture</th></tr>
<tr><td rowspan="6">TO-247</td><td rowspan="6">MBR60100PT NG</td><td rowspan="3">interface of compound and clip
</td><td>initial</td><td></td></tr>
<tr><td>After apply torque</td><td></td></tr>
<tr><td>After TC</td><td></td></tr>
<tr><td rowspan="3">interface of compound and pad
</td><td>initial</td><td></td></tr>
<tr><td>After apply torque</td><td></td></tr>
<tr><td>After TC</td><td></td></tr>
</table>

(Figure 20 – TO-247 package big die device CSAM result no delamination growth)

KBJL package device includes big die and small die parts, applied CSAM to examine if any delamination growth among initial, after applied screw torque and after applied TC. There is no delamination growth between these experiments (Figure 21) (Figure 22).

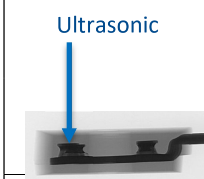
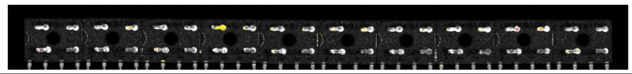
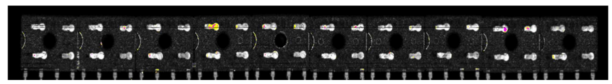
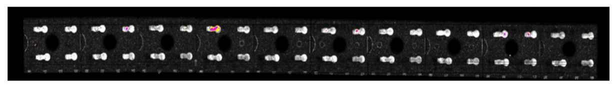
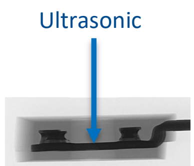
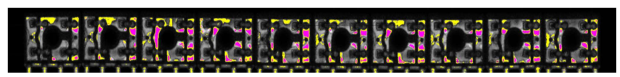
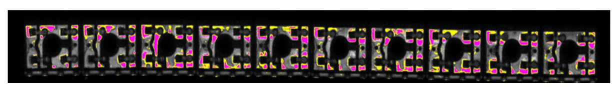
Package	Part number	Scan layer	Stage	CSAM picture
KBJL	TS6KL80 NG	interface of compound and clip 	initial	
			After apply torque	
			After TC	
		interface of compound and pad 	initial	
			After apply torque	
			After TC	

(Figure 21 – KBJL package small die device CSAM result no delamination growth)

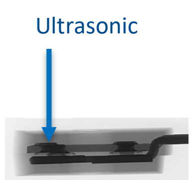
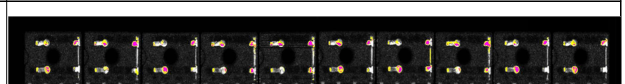
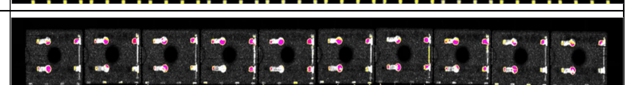
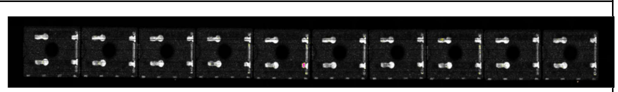
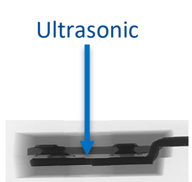
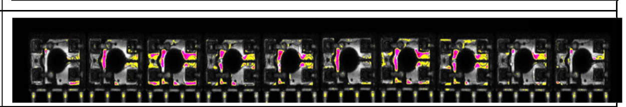
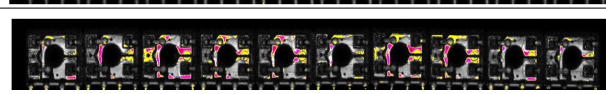
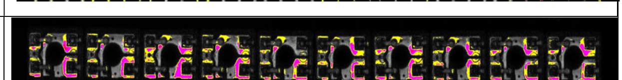
Package	Part number	Scan layer	Stage	CSAM picture
TS4K (KBJ)	TS4K80 N	interface of compound and clip 	initial	
			After apply torque	
			After TC	
		interface of compound and pad 	initial	
			After apply torque	
			After TC	

(Figure 22 – KBJL package big die device CSAM result no delamination growth)

D3K package device includes big die and small die parts, applied CSAM to examine if any delamination growth among initial, after applied screw torque and after applied TC. There is no delamination growth between these experiments (Figure 23) (Figure 24).

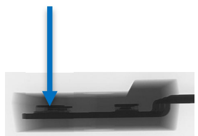
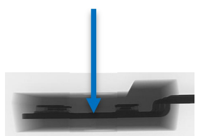
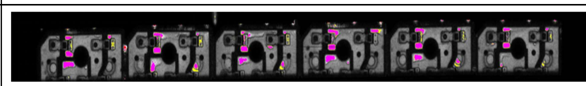
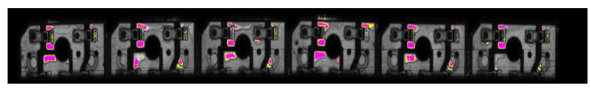
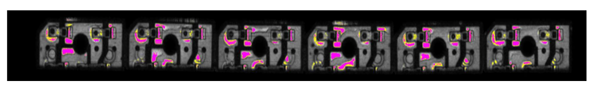
Package	Part number	Scan layer	Stage	CSAM picture
D3K	UR2KB100 HF	interface of compound and clip 	initial	
			After apply torque	
			After TC	
		interface of compound and pad 	initial	
			After apply torque	
			After TC	

(Figure 23 – D3K package small die device CSAM result no delamination growth)

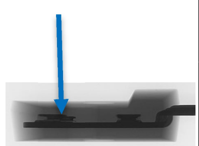
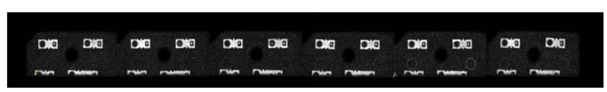
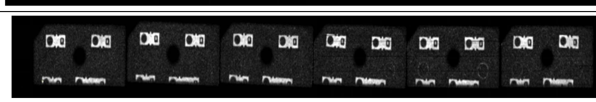
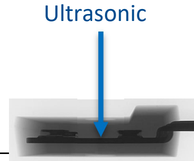
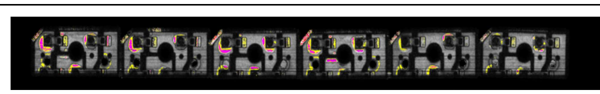
Package	Part number	Scan layer	Stage	CSAM picture
D3K	UR8KB80 HF	interface of compound and clip 	initial	
			After apply torque	
			After TC	
		interface of compound and pad 	initial	
			After apply torque	
			After TC	

(Figure 24 – D3K package big die device CSAM result no delamination growth)

TS4K(KBJ) package device includes big die and small die parts, applied CSAM to examine if any delamination growth among initial, after applied screw torque and after applied TC. There is no delamination growth between these experiments (Figure 25) (Figure 26).

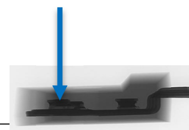
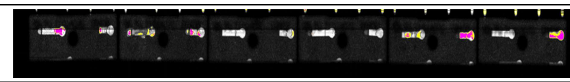
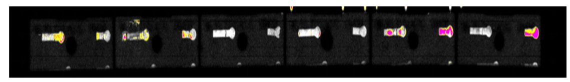
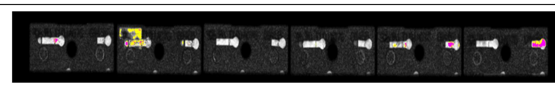
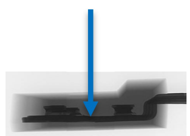
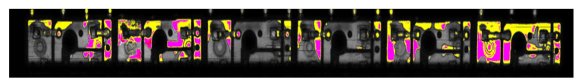
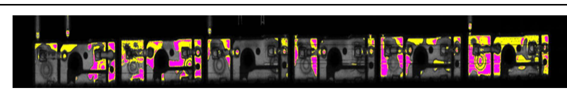
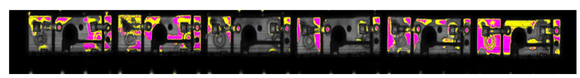
Package	Part number	Scan layer	Stage	CSAM picture
TS4K (KBJ)	TS4K80 N	interface of compound and clip Ultrasonic 	initial	
			After apply torque	
			After TC	
		interface of compound and pad Ultrasonic 	initial	
			After apply torque	
			After TC	

(Figure 25 – TS4K(KBJ) package small die device CSAM result no delamination growth)

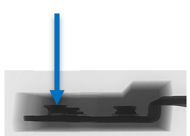
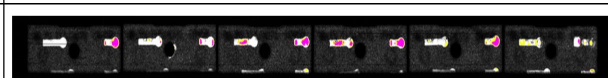
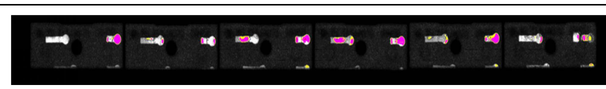
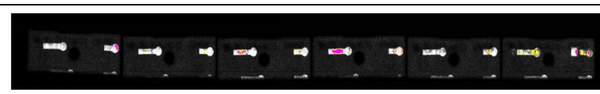
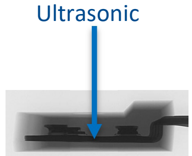
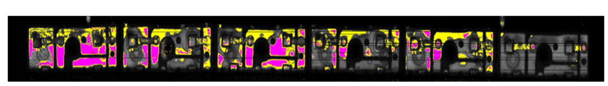
Package	Part number	Scan layer	Stage	CSAM picture
TS4K (KBJ)	TS10K80 N	interface of compound and clip Ultrasonic 	initial	
			After apply torque	
			After TC	
		interface of compound and pad Ultrasonic 	initial	
			After apply torque	
			After TC	

(Figure 26 – TS4K(KBJ) package big die device CSAM result no delamination growth)

TS6PL package device includes big die and small die parts, applied CSAM to examine if any delamination growth among initial, after applied screw torque and after applied TC. There is no delamination growth between these experiments (Figure 27) (Figure 28).

Package	Part number	Scan layer	Stage	CSAM picture
TS6PL	T10JA07G-K HF	interface of compound and clip Ultrasonic 	initial	
			After apply torque	
			After TC	
		interface of compound and pad Ultrasonic 	initial	
			After apply torque	
			After TC	

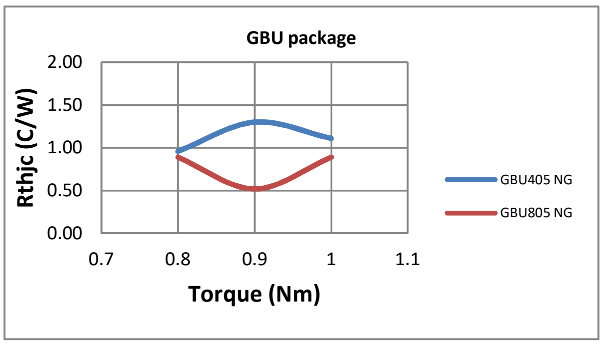
(Figure 27 – TS6PL package small die device CSAM result no delamination growth)

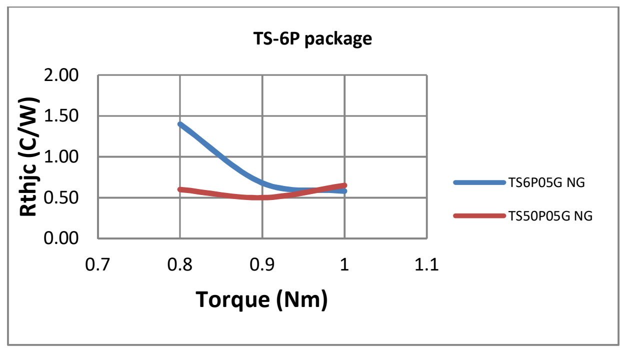
Package	Part number	Scan layer	Stage	CSAM picture
TS6PL	T15JA07G-K HF	interface of compound and clip Ultrasonic 	initial	
			After apply torque	
			After TC	
		interface of compound and pad Ultrasonic 	initial	
			After apply torque	
			After TC	

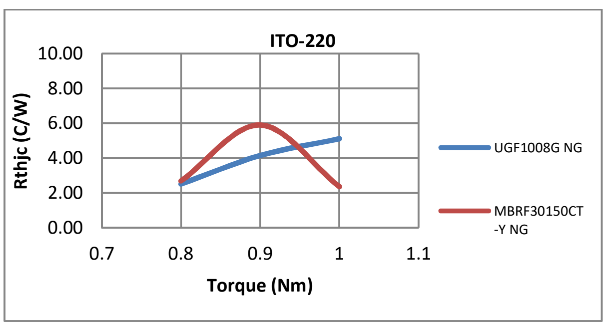
(Figure 28 – TS6PL package big die device CSAM result no delamination growth)

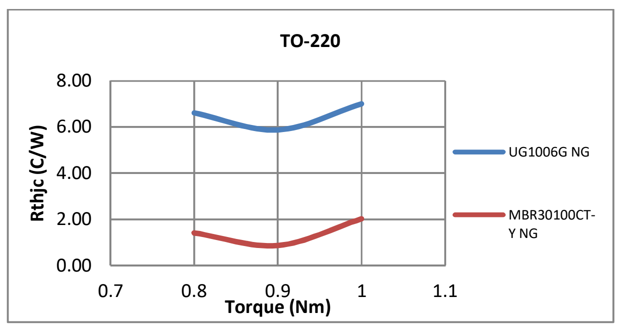
4.2 Junction-to-case thermal impedance result

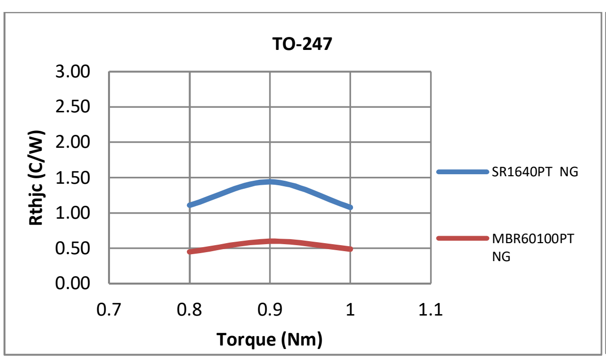
Z_{thjC} (junction-to-case thermal impedance) measured of 9 package - GBU, TS-6P, ITO-220, TO-220, TO-247, KBJL, D3K, TS4K(KBL), and TS6PL that after fastening by three torque values (1 Nm, 0.9Nm, 0.8Nm). The thermal impedance of each package applied by three torque values are similar (Figure 29).

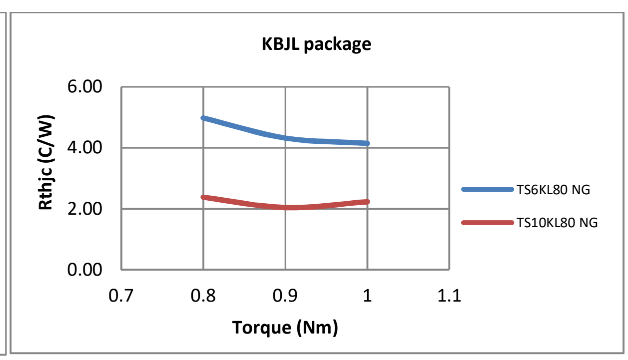


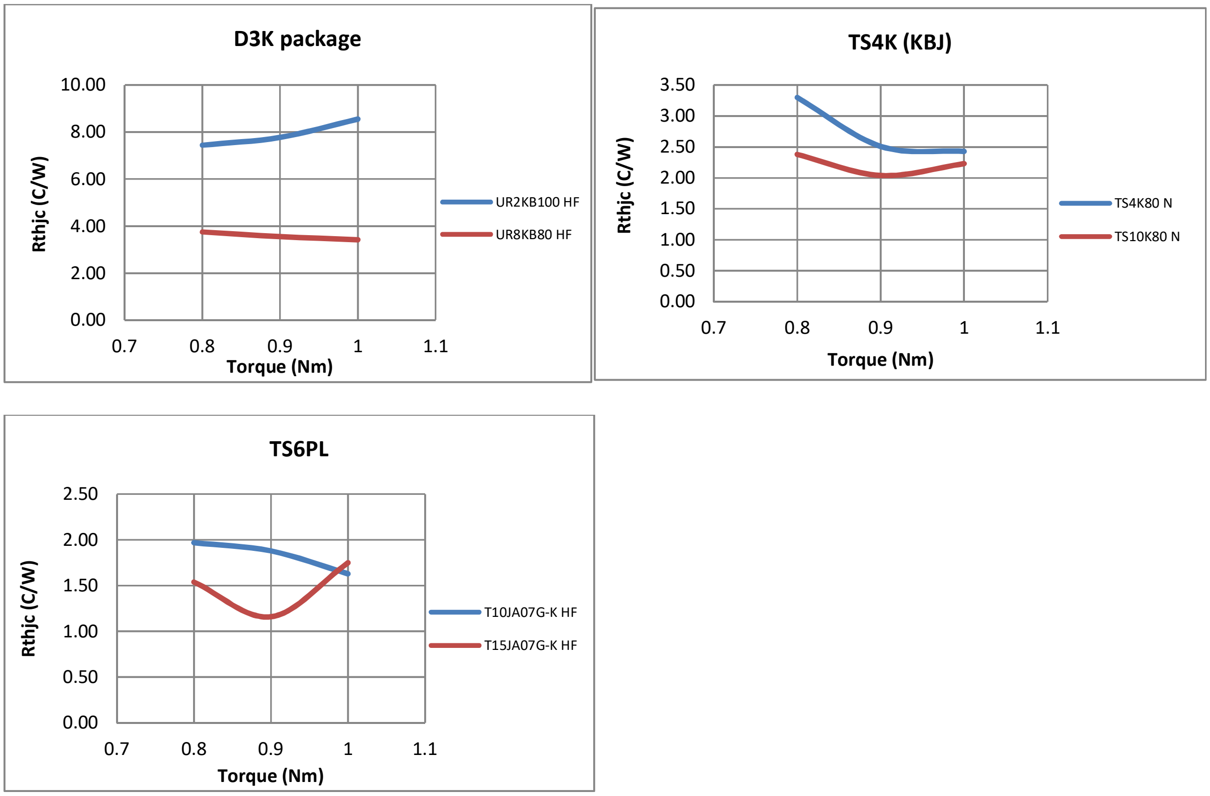












(Figure 29 - The thermal impedance of each package applied by three torque values are similar)

5. SUMMARY

9 package - GBU, TS-6P, ITO-220, TO-220, TO-247, KBJL, D3K, TS4K(KBL), and TS6PL devices after fastening three torque values (1 Nm, 0.9Nm, 0.8Nm). The electrical parameters performance show no variation, CSAM before and after results have no delamination growth and thermal impedance of each package devices are similar. We recommend the torque value 0.9Nm could be the optimum thermal contact and prevent mechanical damage to the 5 package - GBU, TS-6P, ITO-220, TO-220, TO-247, KBJL, D3K, TS4K(KBL), and TS6PL devices.

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Notice

This application note information is for reference only based on this experiment and limited quantity of samples, please follow datasheet specification or inquire contact windows before you using in application.

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