Effect of Epoxy Molding Compound Material and Leadframe Roughness to Integrated Circuit Package for Automotive Devices

Anan Sukantharat†,
Kessararat Ugsornrat, and **Chalermsak Sumithpibul**, Non-members

ABSTRACT

This research studied the effect of epoxy molding compound material and leadframe roughness of an integrated circuit package for automotive devices. In the manufacturing process, the epoxy molding compound material and leadframe roughness are the main factors that effect the coefficient of thermal expansion (CTE) and reliability for an automotive device package with no delamination in high temperature applications. In the experiment, two types of epoxy molding compound materials were studied and compared between standard and roughened leadframe for a quad flat non lead (QFN) package. For the reliability test, the epoxy molding compound materials type A and type B with different leadframe were analyzed with moisture sensitivity level 1 to observe delamination inside the packages. The results showed that the CTE mismatch of epoxy molding compound material type A is less than the CTE mismatch of epoxy molding compound material type B with both standard and roughened leadframe. Moreover, the results also found no delamination for epoxy molding compound material type A with roughened leadframe. In addition, both epoxy molding compound materials showed significant delamination inside packages with standard leadframe.

Keywords: Integrated Circuit Package, Automotive Device, Quad Flat Non Lead (QFN), Epoxy Molding Compound Material, Leadframe

1. INTRODUCTION

Integrated circuit (IC) packaging has been ramping up to use in the automotive sector. An automotive device is an electronic device used in an automobile/car such as for engine management, driver safety, air bag system, tire pressure sensor, door lock system, in-car entertainment and others [1–4] as Fig. 1. Automotive devices require IC packaging with high quality and reliable performance. Quad Flat non-Lead packages (QFN) [5–6] as in Figs. 2 and 3 used for the automotive devices also require high quality and reliability as well as safety performance. In particular, QFNs used for the engine management or under the hood [7] strongly require highly reliable performance and without defects including delamination since the area under the hood generates high temperature, which directly influences the quality and reliability of the QFN package [8]. Delamination is the main problem for IC packaging [9–14] including QFN due to the mismatch in the coefficient of thermal expansions between dissimilar materials, leading to delamination and affecting the product quality [15–19]. The adhesion between the leadframe and epoxy molding compound interfacing is a major factor that affects the quality of the product in terms of the delamination [20–22]. The coefficient of thermal expansions (CTE) of the leadframe and epoxy molding compound are the factor that affectdelamination when temperature rises in the application [23].

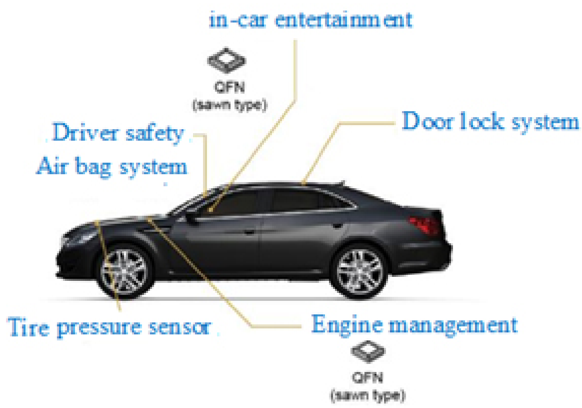

Fig.1: *Automotive devices.*

This research studied the effect of epoxy molding compound material and leadframe roughness of an integrated circuit package for automotive devices.

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The authors are with the Department of Industrial Physics and Medical Instrumentation, King Mongkut's University of Technology North Bangkok, Bangkok, Thailand.

†Corresponding author. E-mail: anansu@utacgroup.com

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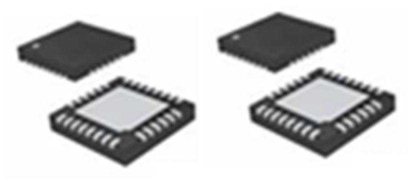


Fig.2: *QFN package.*

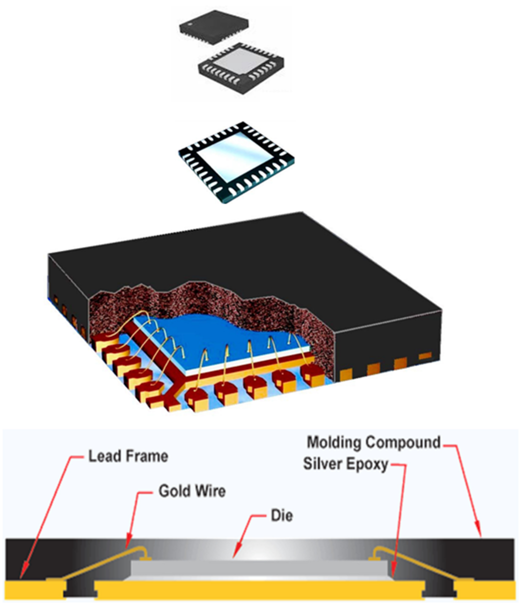


Fig.3: *QFN package and X-section.*

Two types of epoxy molding compound materials with different properties including CTE were studied and compared between standard and roughened leadframe [24] for quad flat non lead (QFN) package to see their moisture sensitivity level (MSL) performance.

2. METHODOLOGY

The QFN package was assembled using epoxy molding compound type A and type B to compare between standard and roughened leadframe as shown in Tables 1 and 2. Die area of 60 % of the die attach pad area and die thickness of 25 % of the package thickness were studied in this research, which is in line with other research and experiments [5, 12, 25]. The aluminum die was used for this experiment. The leadframe roughening is a special process and after wafer inspection the leadframe was roughened for the die attach process. The assembly process is shown in Fig. 4. The leadframe roughening was done by the additional chemical process.

The reliability assessment [26] was based on AEC-Q100 (Automotive Electronics Council) Grade 0 reliability tier including the moisture sensitivity level 1 (MSL-1), un-bias high accelerated stress

Table 1: *Matrix of epoxy molding compound use for QFN 5 mm × 5 mm × 0.9 mm.*

Condition	QFN 5 mm × 5 mm × 0.9 mm			
Leadframe	Standard	Roughened	Standard	Roughened
Epoxy Molding Compound	A	A	B	B

Table 2: *Matrix of epoxy molding compound use for QFN 7 mm × 7 mm × 0.9 mm.*

Condition	QFN 7 mm × 7 mm × 0.9 mm			
Leadframe	Standard	Roughened	Standard	Roughened
Epoxy Molding Compound	A	A	B	B

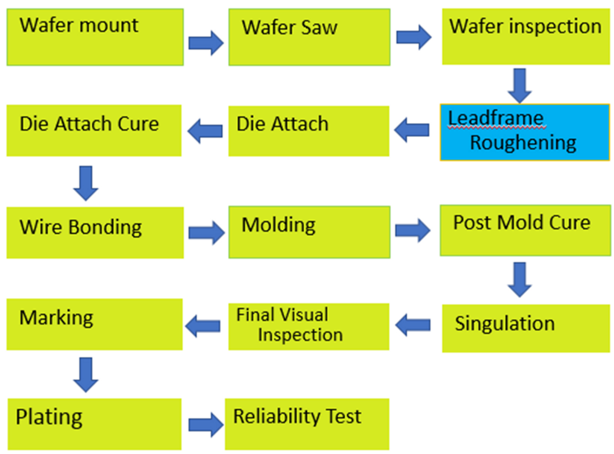


Fig.4: *Assembly process flow with special process is leadframe roughening.*

test (uHAST) and temperature cycling (TMCL). Delaminations were analyzed by scanning acoustic microscope.

3. EXPERIMENTAL RESULT

Based on the results, the standard leadframe showed delamination under all conditions for epoxy molding compound type A and epoxy molding compound type B. Both QFN 5 mm × 5 mm × 0.9 mm and QFN 7 mm × 7 mm × 0.9 mm found delamination after reliability assessment MSL-1, uHAST 96 hours, and TMCL 2000 hours with standard leadframe as in Tables 3 and 4.

The result also found the significant improvement that is no delamination of epoxy molding compound type A with roughened leadframe under all conditions for both QFN 5 mm × 5 mm × 0.9 mm and QFN 7 mm × 7 mm × 0.9 mm when completing the reliability assessment including MSL-1, uHAST 96 hours, and TMCL 2000 hours. The epoxy molding

Table 3: *Delamination result of QFN 5 mm × 5 mm × 0.9 mm.*

Delamination Result	QFN 5 mm × 5 mm × 0.9 mm			
Leadframe	Standard	Roughened	Standard	Roughened
Epoxy Molding Compound	A	A	B	B
MSL-1	Delamination	No Delamination	Delamination	No Delamination
uHAST 96 hours	Delamination	No Delamination	Delamination	No Delamination
TMCL 2000 hours	Delamination	No Delamination	Delamination	Delamination

Table 4: *Delamination result of QFN 7 mm × 7 mm × 0.9 mm.*

Delamination Result	QFN 7 mm × 7 mm × 0.9 mm			
Leadframe	Standard	Roughened	Standard	Roughened
Epoxy Molding Compound	A	A	B	B
MSL-1	Delamination	No Delamination	Delamination	Delamination
uHAST 96 hours	Delamination	No Delamination	Delamination	Delamination
TMCL 2000 hours	Delamination	No Delamination	Delamination	Delamination

Table 5: *Delamination result of QFN 5 mm × 5 mm × 0.9 mm.*

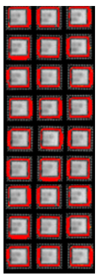
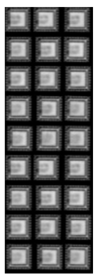
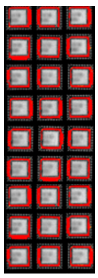
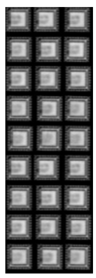
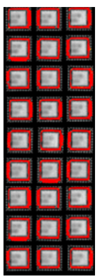
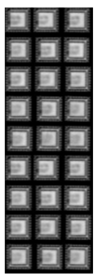
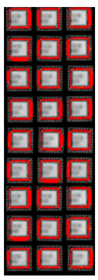
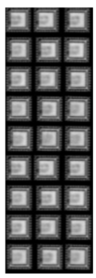
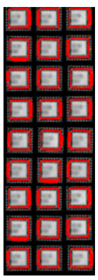
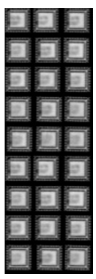
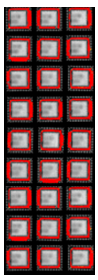
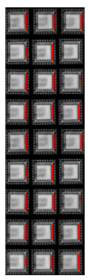
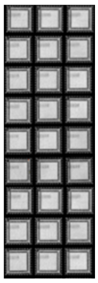
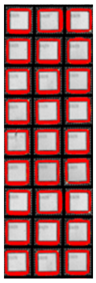
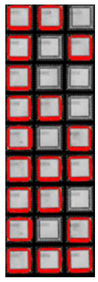
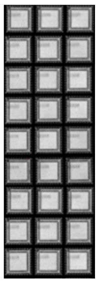
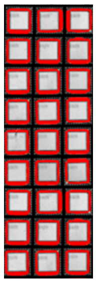
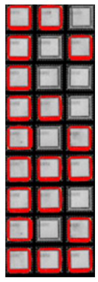
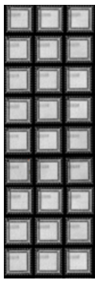
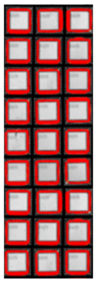
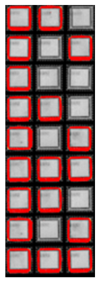
Delamination Result	QFN 5 mm × 5 mm × 0.9 mm			
Leadframe	Standard	Roughened	Standard	Roughened
Epoxy Molding Compound	A	A	B	B
MSL-1				
uHAST 96 hours				
TMCL 2000 hours				

Table 6: *Delamination result of QFN 7 mm × 7 mm × 0.9 mm.*

Delamination Result	QFN 7 mm × 7 mm × 0.9 mm			
Leadframe	Standard	Roughened	Standard	Roughened
Epoxy Molding Compound	A	A	B	B
MSL-1				
uHAST 96 hours				
TMCL 2000 hours				

compound type B with roughened leadframe shows no delamination after reliability assessment for only MSL-1 and uHAST 96 hours for QFN 5 mm × 5 mm × 0.9 mm, but found delamination after TMCL 2000 hours. Moreover, epoxy molding compound type B with roughened leadframe found delamination under all conditions for QFN 7 mm × 7 mm × 0.9 mm when completing the reliability assessment including MSL-1, uHAST 96 hours, and TMCL 2000 hours. Therefore, epoxy molding compound type A is better than epoxy molding compound type B when the roughened leadframe is applied. The delamination results and photos for all conditions are shown in Tables 5 and 6.

The results show that the roughened leadframe is better than the standard leadframe [15]. The result shows no delamination under all conditions for the roughened leadframe for QFN 5 mm × 5 mm × 0.9 mm and QFN 7 mm × 7 mm × 0.9 mm when epoxy compound type A was used and some conditions for QFN 5 mm × 5 mm × 0.9 mm when the epoxy molding compound type B was used.

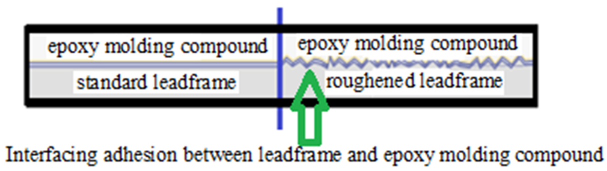


Fig.5: *The interfacing layer with inter-locking pattern.*

This is because the leadframe surface finish of a roughened type is more rough than the standard leadframe surface finish. This rougher surface can increase interfacing layer with inter-locking pattern [24] and make stronger interfacing adhesion between the leadframe and epoxy molding compound; refer to the explanation photo as shown in Fig. 5.

The surfaces of standard and roughed leadframe were analysed by Scanning Electron Microscope (SEM) and show different surface patterns as shown in Figs. 6 and 7. The roughened leadframe surface pattern is rougher when compared with the standard

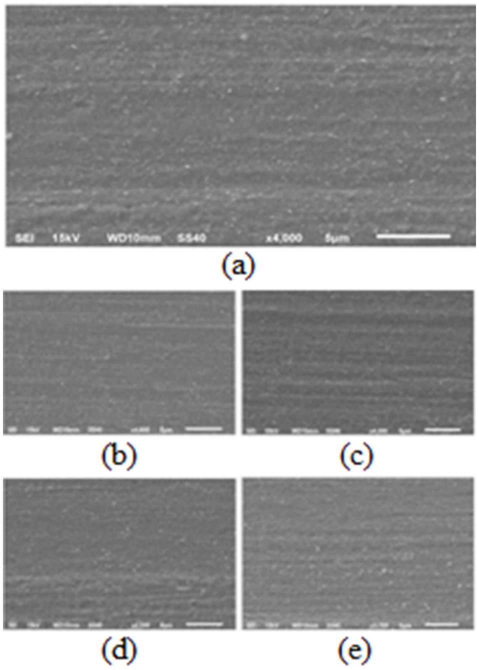


Fig. 6: *Standard leadframe surface; (a) surface position 1, (b) surface position 2, (c) surface position 3, (d) surface position 4, and (e) surface position 5.*

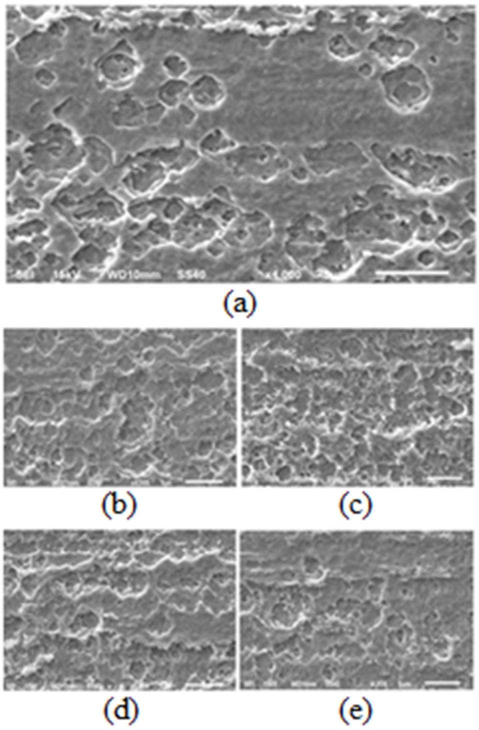


Fig. 7: *Roughened leadframe surface; (a) surface position 1, (b) surface position 2, (c) surface position 3, (d) surface position 4, and (e) surface position 5.*

leadframe pattern to around 10–20 μm in depth.

From the results, the epoxy molding compound type A is better than the epoxy molding compound

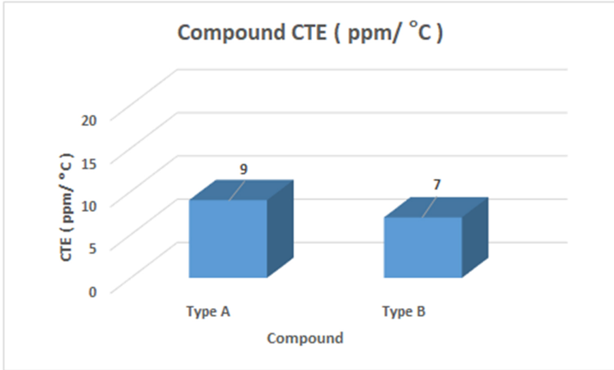


Fig. 8: *Epoxy molding compound CTE.*

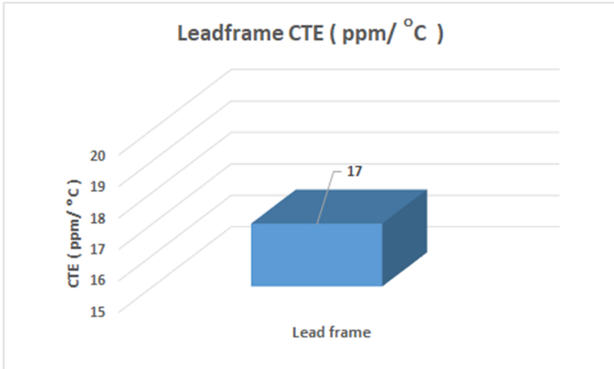


Fig. 9: *Leadframe CTE.*

type B due to the different CTE. The CTE of epoxy molding compound type A is 9 ppm/°C, which is higher than the CTE of epoxy molding compound type B which is 7 ppm/°C as shown in Fig. 8. These CTEs create a different CTE mismatch and affect package warpage which is the cause of delamination after reliability testing. Higher CTE mismatch induces more chance of delamination due to more package warpage. The epoxy molding compound type A creates CTE mismatch of 8 ppm/°C but the epoxy molding compound type B creates CTE mismatch 10 ppm/°C when interfacing with leadframe surface which has CTE 17 ppm/°C as shown in Figs. 9 and 10, respectively.

CTE mismatch of epoxy molding compound type A is lower than that of epoxy molding type B, which reduces stress and warpage of the package leading to reduced delamination inside the package [27–30]. Fig. 11 shows the mechanism of warpage when there is CTE mismatch between dissimilar materials [31–32]. Leadframe and epoxy molding compound always expand when the temperature rises but the leadframe expands more than the epoxy molding compound creating a pattern of package warpage called "Smiling". In contrast, the leadframe and epoxy molding compound always shrink when the temperature reduces but the leadframe shrinks more

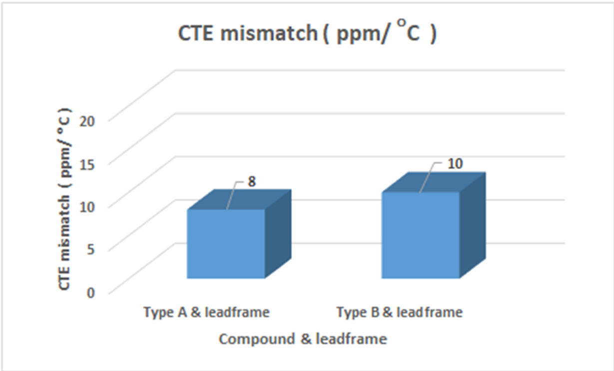


Fig.10: *CTE mismatch between epoxy molding compound type A & type B and leadframe.*

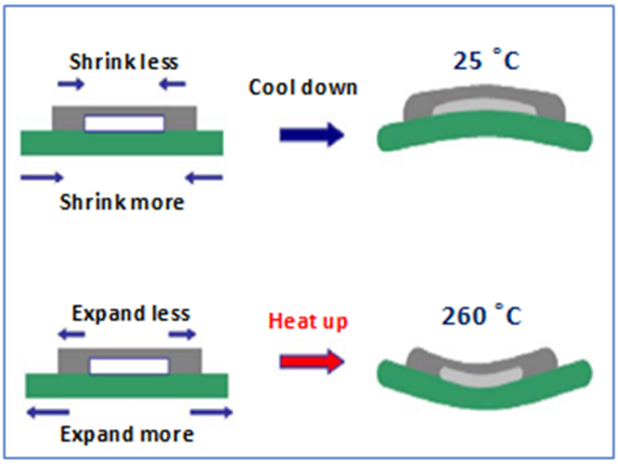


Fig.11: *Warpage pattern of smiling and crying.*

than the epoxy molding compound creating pattern of package warpage called "Crying".

The samples which showed no delamination for both epoxy molding compound type A and B after completing reliability assessment were analysed by X-section and Scanning Electron Microscope. The result shows no gap between epoxy molding compound and leadframe as in Fig. 12 for QFN 5 mm × 5 mm × 0.9 mm and Fig. 13 for QFN 7 mm × 7 mm × 0.9 mm.

Similarly, the samples which showed delamination for both epoxy molding compound type A and B after completing reliability assessment were analysed by X-section and Scanning Electron Microscope and the results show significant gaps between epoxy molding compound and leadframe as in Fig. 14 for QFN 5 mm × 5 mm × 0.9 mm and Fig. 15 for QFN 7 mm × 7 mm × 0.9 mm.

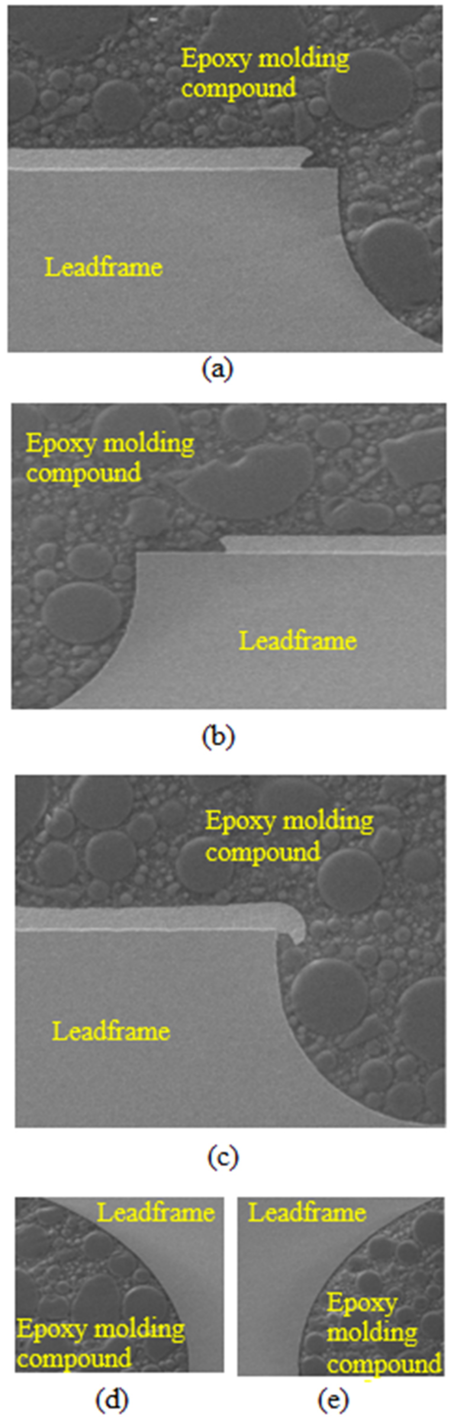


Fig.12: *X-section and SEM showing no gap between epoxy molding compound and leadframe for QFN 5 mm × 5 mm × 0.9 mm at (a) position 1, (b) position 2, (c) position 3, (d) position 4, and (e) position 5.*

4. CONCLUSION

In conclusion, this comparison studied quad flat non lead package (QFN) using different epoxy molding compounds, namely type A and type B, and also different leadframes, namely standard and roughened leadframe. Results show that the standard leadframe shows delamination under all conditions of epoxy molding compound type A and epoxy molding compound type B. The results show a

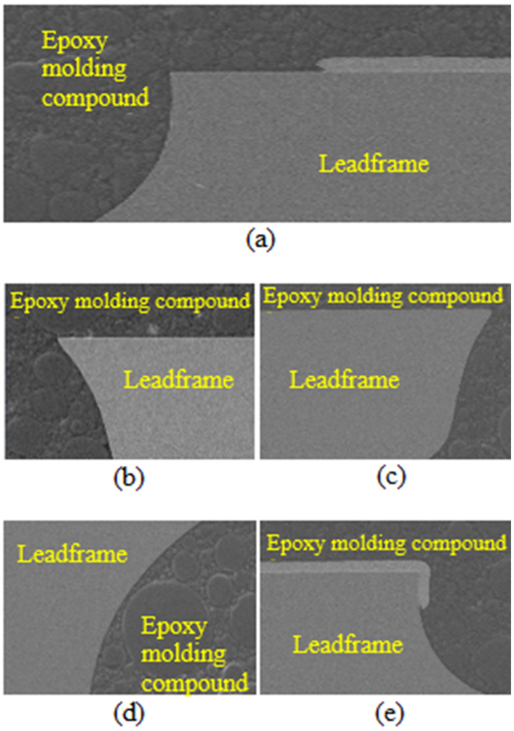


Fig.13: *X-section and SEM showing no gap between epoxy molding compound and leadframe for QFN 7 mm × 7 mm × 0.9 mm at (a) position 1, (b) position 2, (c) position 3, (d) position 4, and (e) position 5.*

significantly improvement that is no delamination of epoxy molding compound type A with roughened leadframe under all conditions for both QFN 5 mm × 5 mm × 0.9 mm and QFN 7 mm × 7 mm × 0.9 mm. The epoxy molding compound type A is better than epoxy molding compound type B due to the different CTEs. CTE mismatch of epoxy molding compound type A is lower than that of epoxy molding compound type B, which reduces stress and warpage of the package and leads to reduced delamination inside the package. Therefore, epoxy molding compound type A with roughened leadframe can be used for QFN package without delamination to qualify for the automotive devices.

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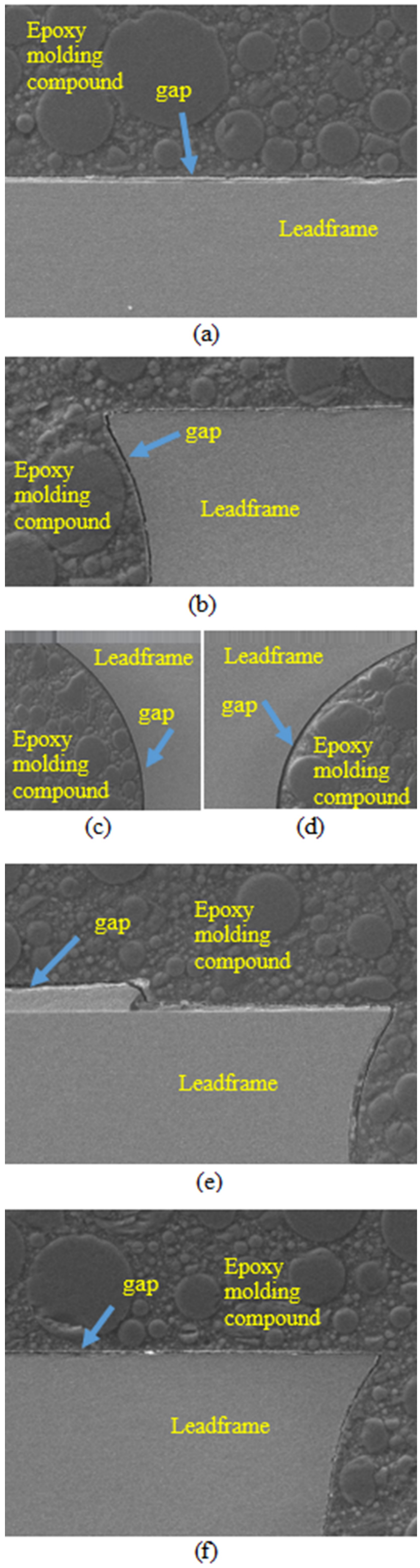

Fig.14: *X-section and SEM showing gaps between epoxy molding compound and leadframe for QFN 5 mm × 5 mm × 0.9 mm at (a) position 1, (b) position 2, (c) position 3, (d) position 4, (e) position 5, and (f) posiition 6.*

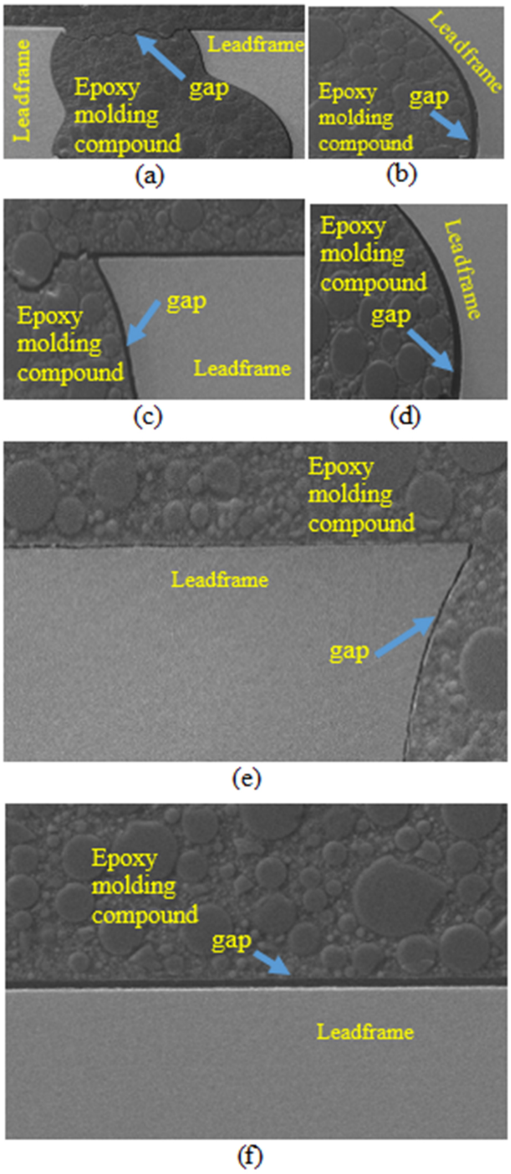

Fig.15: *X-section and SEM showing gaps between epoxy molding compound and leadframe for QFN 7 mm × 7 mm × 0.9 mm at (a) position 1, (b) position 2, (c) position 3, (d) position 4, (e) position 5, and (f) position 6.*

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Anan Sukantharat received B.S. degree in Applied Physics from King's Mongkut Institute of Technology Ladkrabang (KMITL) in 1998 , the M.S. degree in Applied Physics (Micro and Nanoelectronics Engineering) from King's Mongkut University of Technology North Bangkok (KMUTNB) in 2015. He is currently a Ph.D. candidate at the King's Mongkut University of Technology North Bangkok (KMUTNB). He has been worked for UTAC Thailand Limited in Engineering Department in charge of Process Engineering since 2000. His research interests are in area of the Integrated Circuit Packaging and Semiconductor.

Kessararat Ugsornrat received B.S. degree in Physics from Prince of Songkhla University (PSU) in 2000, the M.S. degree in Physics from Chulalongkorn University (CU) in 2004 and Ph.D. degrees in Microelectronics from Asian Institute of Technology (AIT) in 2010. From 2004–2012, She has been a lecturer at Department of Industrial Physics and Medical Instrumentation, Faculty of Applied Science, King Mongkut's University of Technology North Bangkok (KMUTNB) in Thailand. Since 2013, she has been an assistant professor. Since 2016, she was co-founder in Microelectronics Packaging Laboratory (MPAC), King Mongkut's University Technology of North Bangkok. Since 2019, she works as an associate professor. Her research interests are in the area of Micro/Nano-Electro-Mechanical Systems (MEMS/NEMS), Microfabrication, Lab-on-a-chip, Sensors and Nanosensors, Advanced Materials, Graphene and Printed Electronics, IC and MEMS Packaging. She authors more than 40 proceeding papers, 9 refereed journal papers and one textbook. Her research expertise is in Microfluidics, Lab-on-a-chip, Electrochemical sensors, Printed Sensors, and IC Packaging.

Chalermsak Sumithpibul received B.A.degree in Arts (General Management) from Suan Dusit University (SDU), Mini-MBA Certificate from the National Institute of Development Administration (NIDA), Honorary Doctorate Degree in Microelectronics Engineering from King Mongkut's University of Technology North Bangkok (KMUTNB) in 2018. From 2016–2020, he has been a lecturer at Department of Industrial Physics and Medical Instrumentation, Faculty of Applied Science, King Mongkut's University of Technology North Bangkok (KMUTNB) in Thailand. Since 2016 he was co-founder in Microelectronics Packaging Laboratory (MPAC), King Mongkut's University Technology of North Bangkok. His experience is 38 years in Integrated Circuit Packaging and Semiconductor, he is the former Vice President of Engineering in UTAC Thailand Limited.