PFAS free, High Reliability and Multisurface die attach for QFN packages

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Abstract— Like many other industries, semiconductor packaging is also being impacted by increasing regulation around used of Perfluoroalkyl and Polyfluoroalkyl substance (PFAS) based materials in their supply chain. There have been increasing concerns over the years regarding hazards posed by PFAS. The regulatory bodies across the globe have taken notice and are acting on regulating the use of this chemical. On the other hand, semiconductor manufacturing has seen lot of advances in the recent years to keep pace with emerging requirements for power devices. With technology developing at rapid pace in consumer electronics and automation taking a dominant role in automotive and industrial sectors, the semiconductor devices that power these end applications need to demonstrate high performance and reliability. This high-performance requirement translates to the components and materials that are used to manufacture these devices since any weak link in the architecture of the semiconductor packages will lead to premature failure or low reliability of the device. This dual dynamics of PFAS-free regulation coupled with higher performance requirements has led to urgent demand for high performance PFAS-free material solutions.

Keywords—PFAS-free die attach, high reliability, QFN, multisurface die attach, void free

I. INTRODUCTION

Die attach adhesive is an integral part of devices that are manufactured using wire bond technology. Although considered as a legacy technology due to its presence for many decades, wire bond packages still constitute majority of the semiconductor packages manufactured today. Quad Flat No lead (QFN) semiconductor packages are one of the steadiest growing types of chip carriers fueled mainly by their low profile, condensed form factor, high I/O. These packages are predicted to continue growing as chip designers intend to pack more functionality in limited space [1].

The recent trend in regulation has prompted demand for PFAS-free solutions for high volume and high yield manufacturing of devices. PFAS has been used effectively in die attach adhesives to impart robust performance and high reliability. However, there are environmental impacts with use of PFAS. PFAS chemicals are known to be persistent in environment and can bioaccumulate in organisms [2]. Avoiding PFAS helps semiconductor manufacturers to minimize their environmental footprint and meet the ever evolving and stringent environmental regulations. Naturally, there is an increasing demand for PFAS-free die attach solutions that provide similar or better performance to meet the ever-evolving needs of semiconductor packaging [3].

PFAS free die attach materials are designed by using alternate chemistries to achieve high performance without compromising on the benefits required for high performance. This paper will outline a case study detailing benefits of using high performance PFAS-free die attach material to achieve highest reliability on a multitude of surfaces commonly used in QFN packages. This multi-surface, multi-package capability allows OSATs and IDMs to consolidate their die attach products used across various packages into a single material leading to process efficiencies and overall lower cost of ownership.

II. HIGH PERFORMANCE DIE ATTACH SOLUTION FOR NEXT GENERATION PACKAGES

Various performance attributes are required from a die attach material to meet current and emerging needs from high performance power packages such as QFN [4].

A. Resin Bleed Out (RBO)

RBO, also sometimes call epoxy bleed out or EBO, is a common issue encountered with silver filled epoxy die attach adhesives [5]. It is an indication of separation of component(s) from the resin system and can manifest either right after dispensing or after cure. RBO is often caused by the characteristics of the surface, like surface energy and surface roughness, on which the die attach is dispensed. RBO can lead to performance issues related to contamination and delamination (due to lack of adhesion in the area where there is RBO). On the other hand, RBO presents a design challenge for package designers that are

increasingly targeting high density packages that provide high I/O counts which implies tight keep out zones between adjacent die in the package. Historically, PFAS additives have been used in die attach adhesives in regulating the amount of RBO to prevent it from spreading to critical areas [3].

The fig. 1 below illustrates an example of a compatible PFAS-free die attach solution that does not have RBO on a roughened Cu Lead frame (R-Cu LF) surface. On the other hand, the right image demonstrates the challenge faced with some traditional die attach paste material that are not suited for this type of LF surface.

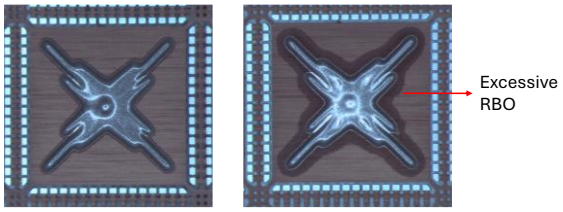

Fig. 1 RBO control (left image) with PFAS-free die attach adhesive indicates good compatibility of the adhesive on a R-Cu LF.

B. Adhesion

In order for a wire bonded package to have high reliability, it is imperative that the die attach adhesive creates a strong bond between the die and the substrate – i.e. good adhesion to the surfaces that it attaches to. Die shear strength (DSS) is an often-used measurement technique to assess the adhesion of die attach material. Fig 2. illustrates an example of a high-performance die attach adhesive with good adhesion to Au BSM (Gold back side metallization) die as well as Si die.

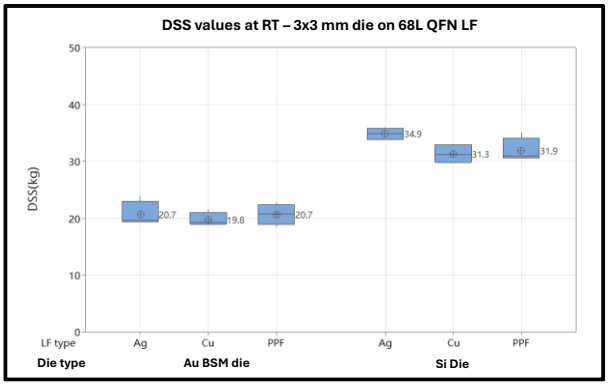

Fig. 2 High performance die attach adhesive with ≥ 20 Kg DSS on a variety of 68L QFN LF surfaces

C. Void-free

In a rapidly evolving end use application for electronics especially in consumer and automotive space, semiconductor packaging is moving towards smaller and thinner form factors. This is to accommodate higher power density. In such scenario, defects in semiconductor packages can provide weak points for failures. Voiding in the die attach joint pose critical challenges for package reliability [6]. Presence of voids can influence failures in die attach material under stress and can lead to delamination. Moreover, voids can also have a negative impact on adhesive strength of die attach. Hence it is important to have a void free die attach joint to effectively satisfy key functional requirements from a die attach i.e. good thermal, electrical and mechanical performance. Fig 3. below demonstrates void-free die attach joints possible with a high-performance die attach adhesive.

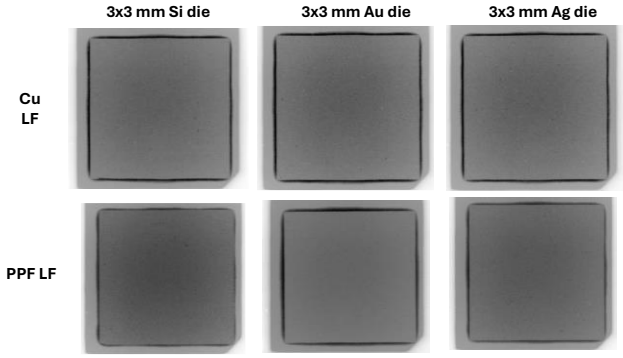

Fig. 3 High performance die attach adhesive with robust non-voiding performance in the die attach joint

D. Workability and Process stability (staging time and open time)

Along with reliable performance and functional attributes like thermal and electrical conductivity, a viable die attach solution for any package has to meet certain workability requirements. These include consistent dispensing, have good coverage underneath the die as well as controlled fillet height along the walls of the die, as shown in fig 4 below. This is important for ensuring consistent package reliability during production as good coverage underneath the die and controlled fillet [7] provide the necessary protection to the assembled package when exposed to stress conditions.

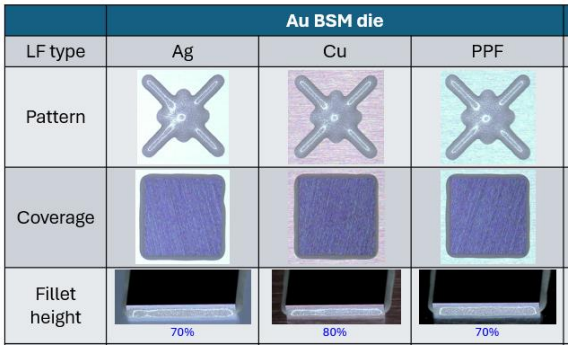

Fig. 4 High performance die attach adhesive with good die coverage and controlled fillet height (good control at ~ 70-80% of die thickness)

In a production environment, process delays and interruptions are bound to happen. The die attach adhesive needs to have robustness over a wide process window to be able to absorb these delays and still provide consistent performance. Two such relevant scenarios where there could be delays are either right after material is dispensed before die bonding (called as open time) or right after die bonding but before the part is put for curing in an oven (called as staging time).

Figs 5a and 5b are an example of a die attach adhesive with a wide staging time window up to 48 hrs. as indicated by good and consistent die coverage, no RBO before and after cure as well as no drop in adhesion as measured with high temperature (@ 260°C) DSS.

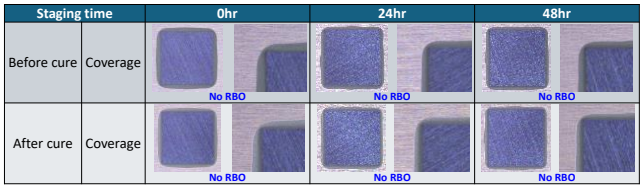

Fig.5a. Die attach adhesive with 48 hrs. of staging time process window

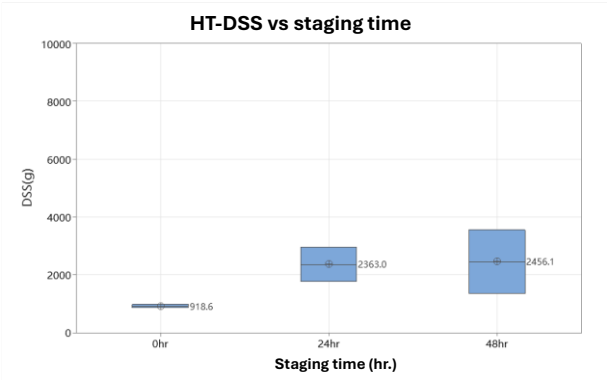

Fig.5b. No drop in high temperature DSS (HT-DSS) up to 48 hrs. of staging time

Similarly, open time in a die attach adhesive can be assessed by consistency in dispensing pattern, die coverage, ability to control fillet height as well as adhesion in terms of HT-DSS. Fig. 6a and 6b. demonstrates performance of a die attach adhesive that has an open time up to 7 hours. This indicates robustness in performance and wide process window in terms of reactivity in the resin chemistry.

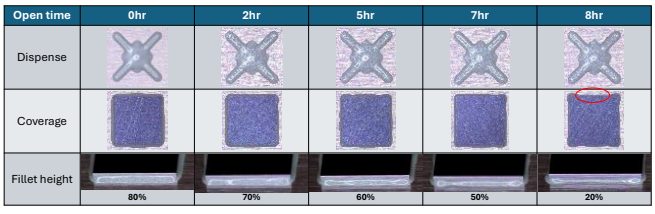

Fig.6a. Die attach adhesive with up to 7 hrs. of open time process window. At 8 hrs. of open time, inadequate die coverage and filler height observed.

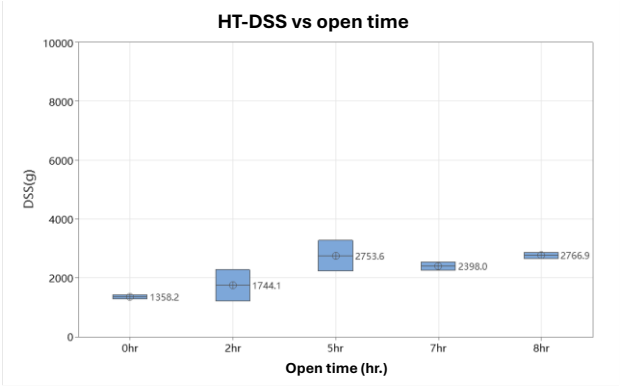

Fig.6b. Robust HT-DSS performance for open time up to 7 hrs.

III. Multisurface Solution - Reliability in QFN Packages

There is a clear trend in current electronic products that they continue to develop in the direction of smaller size and lighter weight. The QFN package is specially made available for any application that requires size, weight and function owing to its small measurement and light weight [8]. Due to various design and cost considerations, current and future packages will deploy multiple surfaces [9]. For example, it is common to find package designers making a choice between Cu, PPF and Ag surfaces for the lead frames. Additionally, higher performance requirements from chip are pushing designers to use different means at their disposal for power and thermal management. This includes use of back side metallization (BSM) layer on the traditional Si die back side that is attached to a metal Lead-frame substrate in a wire bonding process. In such cases, adhesion to various surfaces is paramount to establish a versatile die attach material that can be used across various package designs and associated surfaces. Fig 7. shows HT-DSS (high temperature DSS) with a 3x3 mm Au BSM die on 4 different LF (lead frame) surfaces. A multisurface die attach solution has comparable and high adhesion across the different surfaces tested whereas an industry standard die attach shows higher adhesion on roughened (R- Cu and R-PPF) lead frame surface.

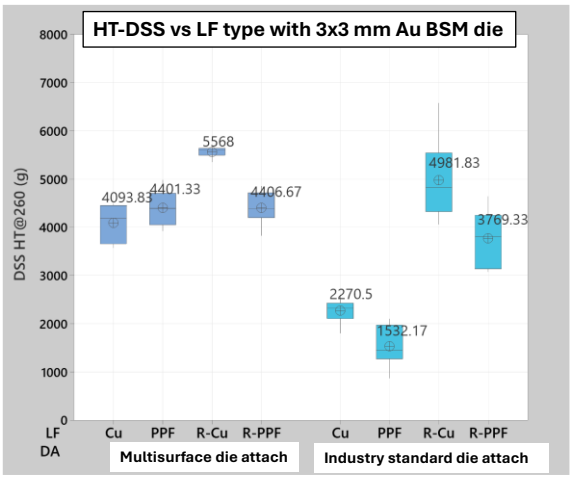

Fig.7. Multisurface Die attach adhesive with robust adhesion on multiple surfaces

In terms of reliability assessment, MSL (moisture sensitivity level) test is a standard test protocol used to probe the moisture sensitivity of a die attach adhesive. There are various levels as defined by JEDEC industry standards. The most aggressive exposure is MSL-1 and is indicative of highest standard of reliability. Figures 8, 9a and 9b. below demonstrate a multisurface solution can achieve this high level of reliability performance across various lead frame (LF) and die surfaces.

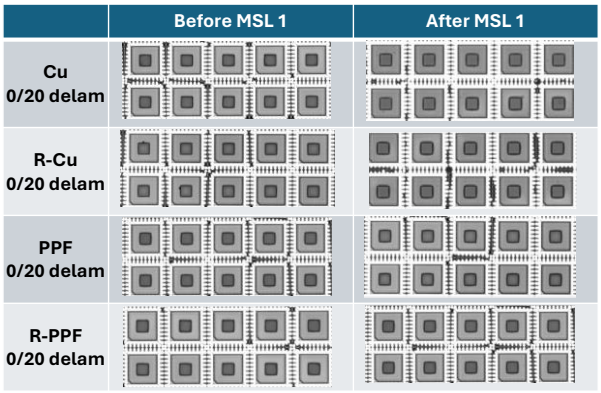

Fig.8. No delamination after MSL-1 exposure indicating high reliability of die attach adhesive on a 3x3 mm Au BSM die on 4 different lead frame surfaces.

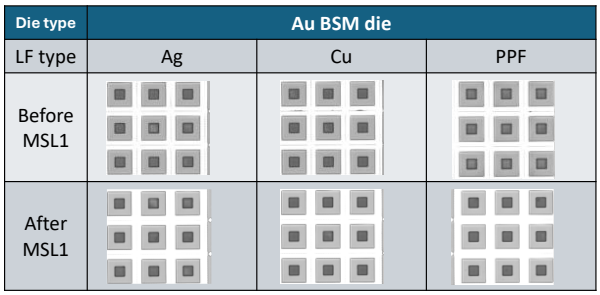

Fig.9a. No delamination after MSL-1 exposure on a 3x3 mm Au BSM die on 3 different lead frame surfaces.

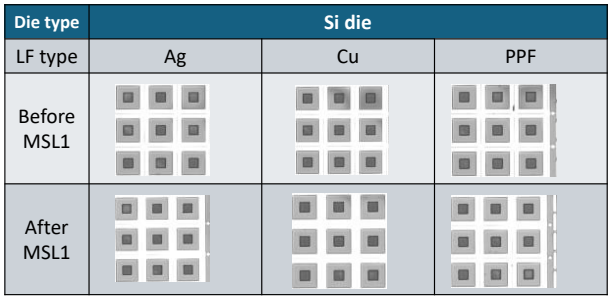

Fig.9b. No delamination after MSL-1 exposure on a 3x3 mm Si die on 3 different lead frame surfaces.

IV. Conclusion

PFAS -free initiative is gaining strength and momentum across semiconductor packaging. Manufacturers are engaging with die attach suppliers in transitioning to PFAS-free solutions to future-proof their products against evolving regulation, avoid potential supply chain disruptions and enhance their sustainability credentials without compromising performance.

A multisurface die attach material demonstrates all the key performance attributes for a die attach material on a variety of surfaces to provide high reliability and consistent performance. A good measure of performance robustness of die attach material is its ability to withstand stress environment encountered during reliability testing (e.g. MSL-1) without showing deterioration in its performance. Moreover, a robust die attach material can demonstrate good workability in terms of achieving desired die coverage and filler height even in scenarios where there are long open time and staging times. Such high-performance die attach solutions will address the current and emerging needs with Next Generation packages.

V. References

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