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# Brief Review on Corrosion of Palladium Coated Copper Wire Bonds under High Temperature Storage Stress Test

Chan Lam Cha[1,3], Kok-Tee Lau[2,4*] and Muhammad Zaimi[2,4]
[1)] Infineon Technologies (Malaysia) Sdn. Bhd., Melaka, Malaysia
[2)] Fakulti Teknologi Kejuruteraan, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[3)] Fakulti Kejuruteraan Pembuatan, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[4)] Carbon Research Technology Research Group, Advanced Manufacturing Centre, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

*Corresponding e-mail: ktlau@utem.edu.my

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**ABSTRACT** – Palladium coated copper (PCC) wire is replacing gold and bare copper (Cu) wire because of its superior mechanical properties, better reliability and manufacturing yield. However, the PCC wire bonding in automotive devices experience corrosion problem under high temperature storage stress (HTS) test. Literature review indicated copper sulfide that involved in corrosion on PCC wire is originated from mold compound of semiconductor packages. It is proposed that a change to the mold compound formulation (by removing the sulfur base adhesion promoter) and an improvement of the PCC wire's corrosion resistance through the usage of new alloying element.

## 1. INTRODUCTION

Palladium-coated Copper (PCC) wire is emerging as an alternative to Copper wire as the former performs better in manufacturing yield and reliability stress than bare Cu wire [1-2].

However, acceptance of PCC wire for automotive device is still low due to the stringent requirement by AEC Q100 and Q006 standard. Previous works shown dominant failure of PCC wire happened after HTS stress especially at temperature of 175°C [3-5]. Corrosion was observed on 1$^{st}$ and 2$^{nd}$ bonds causing severe degradations in the ball shear and wedge pull values.

Robert Bosch, a major automotive player reported in 2014 the PCC wire has an intrinsic degradation beyond 1000h@150°C under high temperature storage stress [3], even concluded application of PCC wire in automotive device is not recommended (Figure 1).

However, the root cause and failure mechanism was not discussed. Thus, the actual limitation and the physical failure mechanism of the degradation on PCC wire bond at high temperature are not well understood at that time.

This paper intends to give a short review on corrosion issues of PCC wire bond in Quad Flat Package (QFP)-type semiconductor package under HTS stress test for AEC Q100 and Q006 standard. The review covers microstructure and elemental analysis, corrosion mechanism and research gap on the corrosion issue.

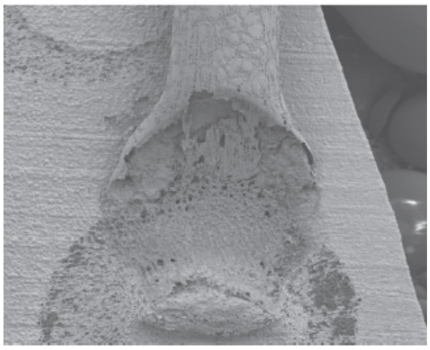

Figure 1 SEM micrographs of 2$^{nd}$ (i.e. stitch) bonds underwent 26h@250°C after decapsulation [3]

## 2. MICROSTRUCTURE AND ELEMENTAL ANALYSIS

An elemental analysis through Energy Dispersive X-ray (EDX) Analysis revealed presence of sulfur element at void surrounding of the first and second bond interface region [4,6]. It was suspected that sulfur (S) is the root cause of the void formation. Cu void formation becomes more severe for mold compound with higher S content [6].

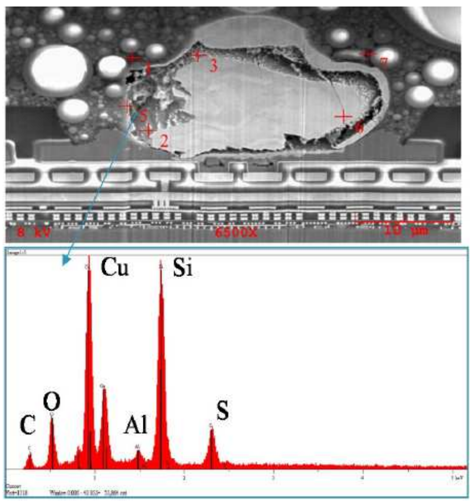


Figure 2 FIB image on 1$^{st}$ (ball) bond after HTS at

1008h@175°C and EDX analysis on Cu void region [6]

## 3. CORROSION MECHANISM

The corrosion only happened on PCC wire but not on bare Cu wire under same HTS stress condition [4,6]. The study showed corrosion on PCC wire was not observed when the device was not encapsulated with mold compound [3]. It confirmed that the mold compound contains S element, which was the foundation block of adhesion promoter of the compound. The promoter function is to enhance the adhesion between mold to lead frame surface.

We propose corrosion mechanism model based on galvanic corrosion. Under this mechanism, palladium (Pd) from the wire acts as cathode, while the underneath copper (Cu) is the anode (i.e. Cu is less noble than Pd). Sulfur from the mold compound was released during HTS to become hydrogen sulfide ($H_2S$). $H_2S$ was acted as electrolyte species of galvanic corrosion cell of Cu and Pd. Then, Cu reacted with ion sulfur to form copper sulfide compounds (i.e. $Cu_2S$ or CuS). The compounds are chemically stable, thus are easily detected by EDX analysis. Galvanic corrosion of Cu was sustained with the continuous supply of $H_2S$. This chemical reaction lead to Cu voids formation in PdCu ball bonds [6]. Illustration of anode and cathode participations in the galvanic corrosion is shown in Figure 3.

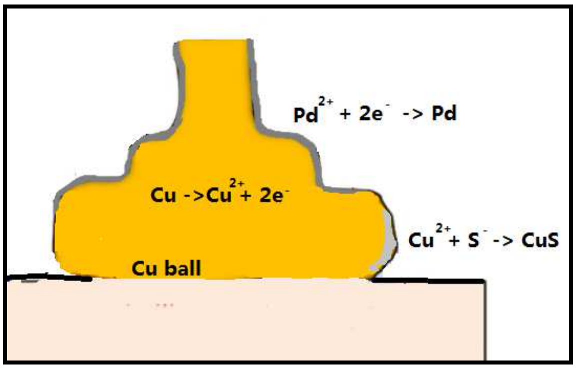


Figure 3 Cu corrosion mechanism by sulfur species on Pd-coated Cu of 1st bond

## 4. RESEARCH GAP

Although weakness of PCC wire was due to severe degradation of 2nd bond after HTS stress, understanding on the issue is still not clear mainly due to the following reasons:

1. The failure mechanism model discussed mainly is galvanic corrosion. However, the galvanic corrosion requires the presence of an electrolyte. It is not clear how $H_2S$ (i.e as electrolyte) participates in the galvanic corrosion and whether water moisture is involved during the mechanism.
2. Few studies shown the corrosion only happened on PCC wire but not on bare copper wire. The function of the palladium in the corrosion mechanism need further study.
3. Most of the investigations only focus on 1st bond but not on 2nd bond. Technically, 2nd bond is more critical than 1st bond as the bonding area and contact area on 2nd bond is smaller.
4. Chemical interaction between different materials (i.e. Pd and Cu of PCC wire bond, S of mold compound and etc) inside the enclosed region of molded semiconductor packages during HTS was not fully understood. Predominant factor of the interaction is sulfur ppm level (i.e. concentration) from the the mold compound, where a higher S ppm leads to a higher Cu bond's corrosion rate. Nevertheless, the investigation of the interaction between these components need to be expanded to other package bonding design such as ball grid array (BGA) type.

## 5. CONCLUSION

PCC wire demonstrates a superior performance during manufacturing process compare to bare Cu wire. However, PCC wire experienced corrosion process by sulfur (S) from mold compound.

We would like to propose a change in the mold compound formulation (by removing the S content). This approach had showed good result as quoted by few research papers. Furthermore, we suggest usage of new alloying element to substitute Pd plating on the current PCC wire. It is to eliminate the role Pd as catalyst for the Cu bond corrosion.

Further work to identify other sources of S content in QFP and BGA types packages is underway. This is to ensure current PCC wire is suitable for different automotive packages.

## 6. REFERENCES


[1] B.Y. Lim, C.K. Chang, O. Yauw, B. Chylak, C.L. Gan, and Z. Chen, *Microelectronics Reliability*, vol. 54, no. 11, pp. 2555–2563, 2014.

[2] S.C. Tey, K.-T. Lau, and M.E.A. Manaf, *Proceeding of the 16th International Conference on Electronic Packaging Technology (ICEPT) 2015*, 2015, pp. 114–117.

[3] J.C. Krinke, D. Dragicevic, S. Leinert, E. Friess, and J. Glueck, *Microelectronics Reliability* 54(9–10), pp. 1995–1999, 2014.

[4] M. Han, M. Wang, L. Zhang, B. Yan, J. Li, M. Song, and V. Mathew, *Proceeding of IEEE 18th Electronics Packaging Technology Conference (EPTC)*, 2016, pp. 797–800.

[5] H. Xu, I. Qin, H. Clauberg, B. Chylak, and V.L. Acoff, *Acta Materialia*, vol. 61, pp. 79–88, 2013.

[6] C.-C. Lee, T.A. Tran, V. Mathew, R. Ibrahim, and P.-L. Eu, *Proceeding of IEEE 66th–Electronic Components and Technology Conference*, 2016, pp. 606–613.