CU CORE COLUMN ENABLES FINE PITCH & HIGH-DENSITY 3D PACKAGING

Lewis Huang, Hiroki Sudo, Daisuke Soma, Hiroshi Okada
Senju Metal Industry Co., Ltd.
Tokyo, Japan
lewis@senju.com

ABSTRACT
As the next-generation interconnection materials, Cu core column is a kind of cylindrical-shaped copper core with Ni and solder plating. It could replace ordinary solder balls, Cu core balls and even Cu plated posts and has become the focus of attention. Cu core columns have innately ability to control and maintain a consistent standoff height, and can achieve excellent electrical and thermal conductivity due to the excellent physical properties of copper.

It is known that the Cu core column can exhibit sufficient performance compare with solder balls and Cu core balls. In this study, after experiment we know Cu core columns with lower aspect ratio and small core diameter is better for drop test. Cu core columns with higher aspect ratio and less solder amount is better for Thermal Cycle Test.

Key words: Cu core column, Cu cored solder joint, Fine pitch, High density, Package on Package, 3D packaging.

INTRODUCTION

The industry requires devices to be thin, light, short, small form factor and highly performance, resulting in fine-pitch and high-density packaging as inevitable means. However, in order to achieve complete industrial realization, many characteristics need to be improved, such as heat dissipation, electrical conductivity, thermal conductivity, and the dimensional accuracy. In addition, in 3D package assembly structures especially like Package-on-Package (PoP), solder bumps may collapse because of the weight of top package. Several years ago, in the industry there have been introduced Cu core solder balls to improve these problems. As the name implies Cu core solder balls made of spherical copper as a core in the center and then with Ni and solder plating outside [1]-[2]. Ni plating is effective to prevent the diffusion between Tin and Copper. Cu core solder balls inherently have excellent conductivity characteristic and a stand-off height merit to control and keep a consistent room to prevent bump collapsing between packages. Besides this, there are three physical properties of Cu: high melting temperature (1083 deg.C), high electrical conductivity, and high thermal conductivity.

Recently, Cu core columns are cylindrical copper core materials with Ni and solder coatings. Because this merit they are very suitable for narrow-pitch package design, and they take advantage of the ideal properties of Cu-core solder balls, they had attracted attention and potentially become next generation interconnection materials. It is also considered to be installed by a conventional solder ball mounter, which not only could replace conventional solder balls or Cu-core solder balls, but also can be used for copper-plated pillars and even TSVs (through-silicon vias). Using this new advanced material can significantly reduce manufacturing time and costs.

However, due to its cylindrical shape, it is unclear whether it can be mounted as stably as an ordinary solder ball or not. For copper-core solder balls, previous studies [3] have demonstrated heating rates in the molten solder temperature range; 483-501 (K) of the reflow profile affects the Cu balls' position in Cu-cored solder bumps. Slower solder melting will affect the copper balls to maintain its center position. We observed Cu core columns tilt after reflow process, due to alignment force generated by the molten solder surface tension. This may potentially lead to non-wetting issues or downgraded package-level reliability during package assembly. In addition, the non-wetting problem is mainly attributed to the warpage of the PKG and the PCB substrate, but if the amount of solder in the Cu core ball is insufficient, previous studies [4] reported that it may lead to abnormal failure modes. After the reflow process, the intermetallic compound (IMC) layer on the nickel-plated surface is exposed on top of the Cu core ball bumps, which will obstruct wetting and cause non-wetting problems during assembly.

According to previous research [5], it has been proved that Cu core column is superior to traditional solder ball and Cu core ball in the Drop reliability & heat stress resistance. Therefore, in this paper we further study how the diameter, length, and aspect ratio of the Cu core columns will affect the Drop & TCT reliability and how to optimize the dimensions of the Cu core column.

METHODOLOGY

The Cu core columns' SPECs are shown in Table 1. We done the electrolytic plating for Ni plating 2um and SAC305 plating to four types of Cu core columns. Total size and SAC305 plating thickness of these four are different. Each Cu core column illustration was shown in Figure 1.
First step, we did Cu core column mounting to Test PKG. SRO size was set as φ0.24mm and pad surface finish as Cu-OSP. The size of package was 12x12x1.1mm with 0.5mm pitch. Water soluble flux Product A (internal product) was printed with stencil mask with the hole of φ0.24mm, then Cu

core columns was put on the test PKG. Total 25 PKGs per each test leg was prepared.
Second step we did reflow process that used the high temperature observation equipment. The reflow peak temperature was at 245 deg. C, the ramp up rate from room temperature to peak temperature was 1 deg.C/sec and the O_2 concentration was at under 100ppm.

Table 1. Specification of Cu core columns.

Leg no.	Core Size (mm)	Ni Plating Thickness	Solder Plating Thickness	Total Size (mm)
1	φ0.18×L0.25	2um	8um	φ0.2×L0.27
2	φ0.18×L0.45	2um	5.5um	φ0.195×L0.465
3	φ0.18×L0.45	2um	15.5um	φ0.215×L0.485
4	φ0.15×L0.45	2um	8um	φ0.17×L0.47

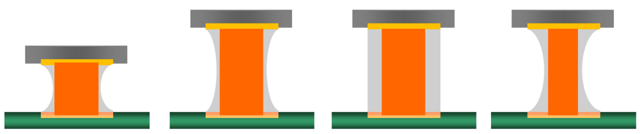

Figure 1. Cu core column leg illustration.

Third step we did SMT assembly that the SRO size of test PCB substrate was set as φ0.24mm and pad surface finish was Cu-OSP. Daisy chain has designed in 0.8mm-thickness PCB substrate. SMT assembly was reflowed by Product B reflow furnace (internal product) and used profile was shown in Figure 2, under air atmosphere.

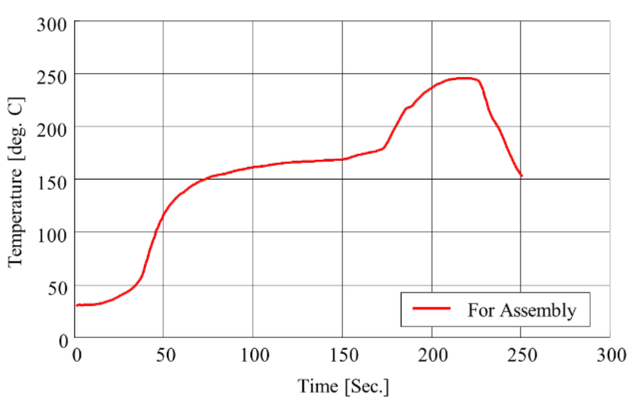

Figure 2. Reflow profile for SMT assembly.

Fourth step drop test and thermal cycle test (TCT) was performed. Sample sizes N=10 for drop test, N=15 for TCT was set per each test leg. We set 1500G as impact acceleration of drop test. We implemented TCT by thermal shock chamber and the condition of thermal cycle test was shown in Figure 3. Next procedure we checked the numbers of drop and thermal cycle, when the resistivity surpassed the criteria of breaking down, for drop test 1.5 times of initial resistivity and for TCT 15Ω was set.

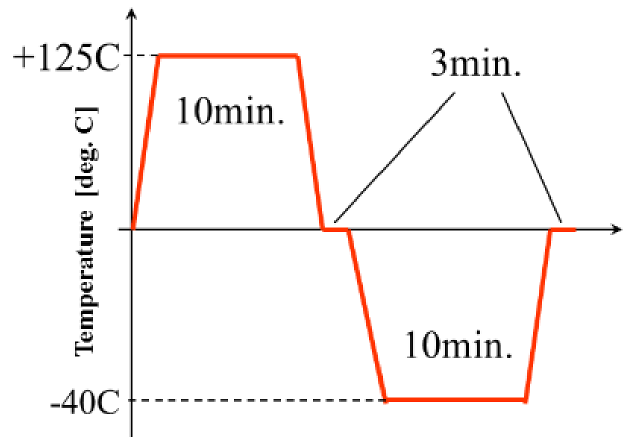

Figure 3. Thermal cycle test condition.

RESULTS

Drop test results are shown in Figure 4. In this case, Cu core columns leg no.1 total size φ0.20mm x L0.27mm show the best drop reliability. Second was leg no.4 φ0.195mm x L0.465mm, third was leg no.3 φ0.215mm x L0.485mm and last one was leg no.2 φ0.17mm x L0.47mm.

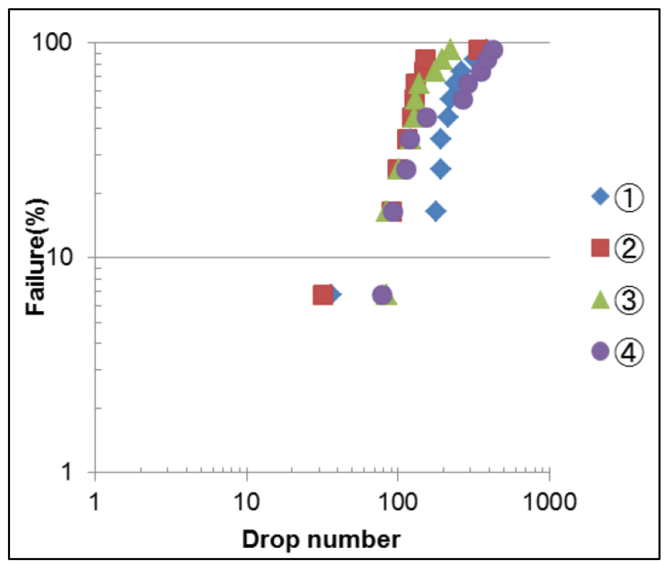

Figure 4. Drop test result.

TCT results are shown in Figure 5. In this case, Cu core column leg no.4 φ0.195mm x L0.465mm show the best Thermal Cycle Test reliability. Second was leg no.2 φ0.17mm x L0.47mm, third was leg no.3 φ0.215mm x L0.485mm and last one was leg no.1 total size φ0.20mm x L0.27mm.

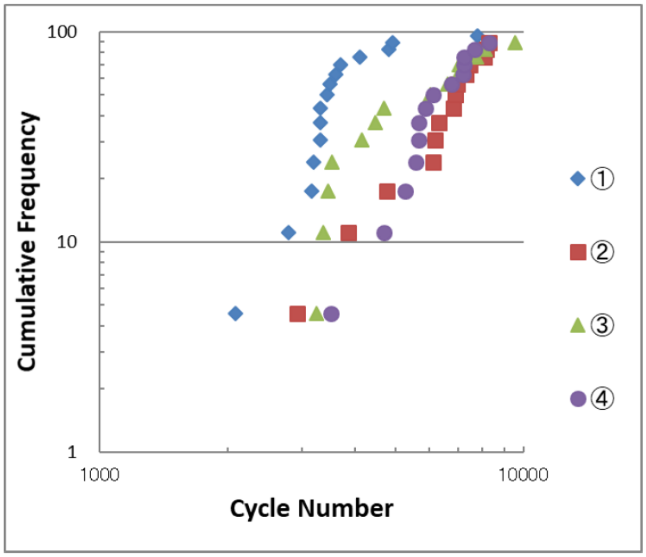

Figure 5. Thermal cycle test result.

CONCLUSION

According to our previous research report, Cu core columns can replace traditional solder balls and Cu core balls, which can effectively realize fine pitch, high density and high performance packaging assembly.

In this report, it is more certain that when using Cu core column in the industry in the future, we must carefully consider the characteristic requirements for reliability (Drop or TCT), and must reach the optimization of the overall package design by aspect ratio, solder amount, and core diameter.

From these results, we can summarize that Cu core columns with lower aspect ratio and small core diameter is better for drop test. Cu core columns with higher aspect ratio and less solder amount is better for Thermal Cycle Test.

REFERENCES

[1] S. Sakatani, T. Saeki, Y. Kohara, K. Uenishi, K. F. Kobayashi, and M. Yamamoto, *Solderability of BGA joints between Cu core solder balls with Sn/Ag multi plating and Ni/Au coated pads.* Japan Institute of Electronics Packaging, vol. 6, pp. 509-515, 2003.

[2] K. Tanaka, N. Kurashima, H. Iizuka, K. Ooi, Y. Machida, S. Shiraki and T. Koyama, *Thinner and Miniaturization Embedded Device Package, MCeP, for PoP and Module Application.* International Symposium on Microelectronics. Fall 2012, Vol. 2012, No. 1, pp. 001010-001017

[3] H. Kawasaki, T. Hattori, T. Roppongi, D. Soma, I. Sato, and Y. Kawamata, *Cu balls and Cu-core balls for 3D packaging.* 2013 IEEE CPMT Symposium Japan (ICSJ). doi:10.1109/ICSJ.2013.6756080

[4] J. Y. Son, S. G. Lee, Y. W. Lee and S. B. Jung, *Mechanical property and plated solder volume effect of Cu core ball*, 2018 20th Electronics Packaging Technology Conference,

[5] H. Sudo, D. Soma, and H. Okata, *Cu core Column application for fine pitch 3D Mounting*, 2019 52th International Microelectronics Assembly and Packaging Society