Abstract #2056, 224th ECS Meeting, © 2013 The Electrochemical Society

Fabrication and Characterization of Grain growth in Electroplated Cu for 3D IC interconnect Applications

Tao-Chi Liu*, Shing-Ru Wang and Mike Corey
Global Semiconductor Applications Center, Enthone Inc.
No.10, Lu-hsing Street Lu-chu Township, Taoyuan, Taiwan.

Abstract

As the limits of very-large-scale integration (VLSI) in ICs manufacturing, the development of three dimensional integrated circuits (3D ICs) is under way in the micro-electronics industry. With respect to scale the electrical joint on a chip surface to achieve low RC delay and large bandwidth speed, microbump, through silicon via (TSV) and through substrate hole (TSH) had been developed enabling the short and dense electronic circuit with a thinned substrate. Since the 3D ICs consists of the stacking of multiple microprocessor and memory chips, the heat dissipation is crucial, leading to early failure and low reliability.

Copper possesses a low electrical resistivity of 1.7 $\mu\Omega$ with a very high thermal conductivity of 401 W m^{-1} K^{-1} at room temperature. Therefore, it has been adopted as the major underbump-metallization (UBM) material and TSH in interposer of 3D IC, which performed by electroplating[1-5]. It is reported that the microstructure and orientation can significantly dominate the mechanical and electrical properties. For instance, nanotwinned Cu possesses high mechanical strength and ductility, while it maintains almost the same conductivity as bulk Cu. nt-Cu also has high electromigration resistance. The grain growth and design can be controlled by plating speed and organic additives [6]. In other words, the grain structures are also evidences that the additives influence the electrochemical reaction. In this study, we propose a novel crystallography characterization method using FIB polishing/milling directly after the cross-sectioned electroplated samples, as illustrated in Fig. 1. This method enables to analyze a specific area while crystallographic information at that location is critical [7]. Therefore, the crystal growth by additives can be controlled and monitored precisely. The electroplating bath was high-purity Copper sulfate solution composed of 60 g/L copper cations and 40 ppm hydrochloric acid. Surfactant and Enthone Cuprostar THF-100 additives are applied to modified the crystal microstructure and through hole filling of organic interposer. Highly oriented (111) grains and densely packed nt-Cu microbump can be fabricated at high current densities and high stirring speeds.

Fig. 2 presents the cross-sectional FIB image for the nt-Cu grain deposited which current density was fixed at 8ASD. According to the nucleation-coalescence growth mechanism, the columnar textures come from the competing growth among adjacent grains. During the cathodic reduction, the copper cations prefer to be reduced on a low surface energy grain rather than the high energy one. Fig. 3. Shows the cross-sectional FIB image of THs in an organic interposer using butterfly plating. In essence, butterfly plating is intended to bring hydrodynamics control and leveler altering the current density distribution together. Significantly, the FIB image demonstrates that there are at least three phase change locations in the filled THs, indicating that the dimple-free filling is caused by leveler replacing the remaining accelerator on the area above the THs. Hence, Cuprorstar THF-100 additive results in excellent filling capability.

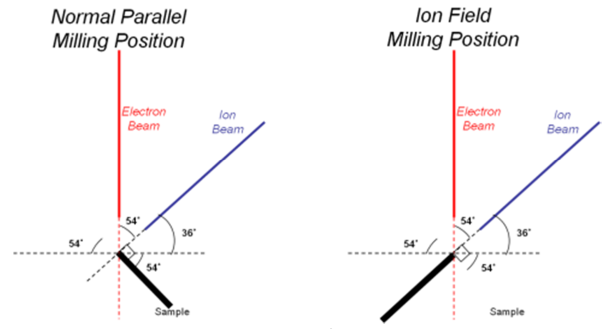

Fig. 1. Schematic illustration of the FIB milling procedure of (a) Surface polishing and (b) direct ion beam milling.

Fig. 2. FIB image of electroplated nanotwinned Cu after ion beam polishing.

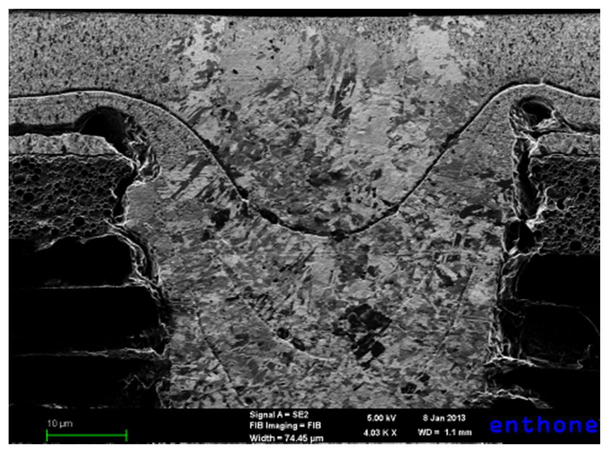

Fig. 3. FIB image of THs after butterfly plating. The cross-sectional surface was milled by ion beam.

References

1. Wei-Ping Dow, De-Huei Liu, Chun-Wei Lu, Chien-Hung Chen, Jhih-Jyun Yan,Su-Mei Huang, Electrochemical and Solid-State Letters, 14(1), D13 (2011)
2. Wei-Ping Dow, De-Huei Liu, Chun-Wei Lu, Chien-Hung Chen, Jhih-Jyun Yan, Su-Mei Huang, Electrochemical and Solid-State Letters, 14(6), D63 (2011)
3. Wei-Ping Dow, Hsiang-Hao Chen, Ming-Yao Yen, Wei-Hsiang Chen, Kao-Hsuang Hsu, Po-Yao Chuang, Hiroshi Ishizuka, Nobuo Sakagawa, Ryoichi Kimizukad, Journal of The Electrochemical Society 155(12), D750 (2008)
4. Hsiang-Yao Hsiao, Chien-Min Liu, Han-wen Lin, Tao-Chi Liu, Chia-Ling Lu,Yi-Sa Huang, Chih Chen, K. N. Tu, Science 336, 1007 (2012).
5. Tao-Chi Liu, Chien-Min Liu, Hsiang-Yao Hsiao, Jia-Ling Lu, Yi-Sa Huang, Chih Chen, Cryst. Growth Des. 12,5012 (2012)
6. Tao-Chi Liu, Chien-Min Liu, Yi-Sa Huang, Chih Chen, King-Ning Tu, Scripta Mater.68, 241 (2013)
7. Tao-Chi Liu, Chih Chen, Kuo-Jung Chiu, Han-Wen Lin, Jui-Chao Kuo, Materials and Characterization 74, 42 (2012).