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# Through-Silicon-Via (TSV) filling by the electrochemical deposition of Cu with modified microstructures by ultra-fast pulsed current

Sanghyun Jin, Geon Wang, and Bongyong Yoo
Department of Metallurgy and Materials Engineering, Hanyang University, Ansan 426-791, Korea

TSV interconnection provides the three dimensional interconnection between the two-dimensional silicon based integrated-circuits. Especially, the electrochemical deposition of Cu was core process in the TSV interconnecting process. However, several issues were still critical such as the formation of the void which could cause electrical and mechanical problems, a thermal extrusion of Cu, and high cost [1].

In this study, TSV filling by ultra-fast pulsed current was investigated to control the microstructure, filling behavior and filling rate. The pulsed current was consisted with -high peak current density(~450mA/cm$^2$) and ultra-fast on time (~1μsec). An off time was adjusted for controlling the average current density. The direct current deposition with adjusted current density from -1mA/cm$^2$ to -2.5mA/cm$^2$ was also performed to compare with ultra-fast pulsed current deposition.

As a result, filling rate was improved up to 10% compare to DC electrochemical deposition (fig. 1), and the thermal extrusion was decreased significantly by using of ultra-fast pulsed current. Also, TSV filling without a void was available by adjusting the average current density.

The faster filling rate could be achieved by the higher average current density and change of filling behavior by applying the pulsed current.

Reduced thermal extrusion might relate with the variation of microstructure by using pulse current. When ultra fast pulse current was applied, sub micrometer sized grains with large density of nanotwin were observed (Fig.2). Nanotwin structure in Cu showed drastically high mechanical strength without the degradation of electrical resistivity, because of its coherent boundary condition [2]. Such enhanced mechanical properties and reducing grain size significantly reduced the thermal extrusion of Cu from TSV holes (Fig.3).

## Reference

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[2] Lei Lu, Yongfeng Shen, Xianhua Chen, Lihua Qian, K. Lu, J. Science 304 (2004) 422.

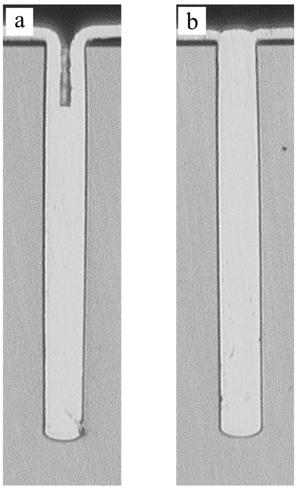

**Fig. 1** The comparison of deposition rate of TSV Cu electrochemical deposited by direct current (a) and ultra-fast pulsed current (b) with the same current density and deposition time

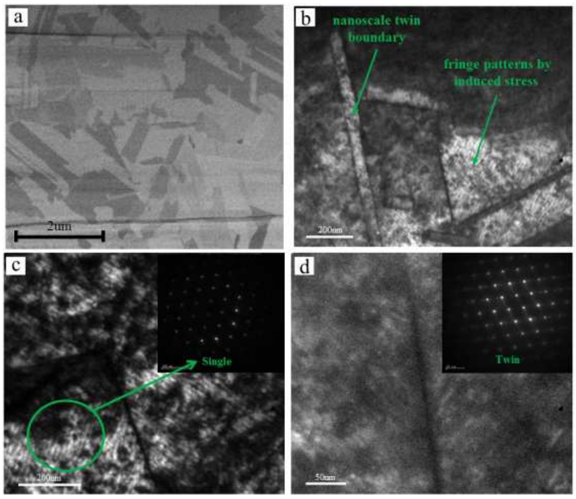

**Fig. 2** SEM (a) and HR-TEM (b), (c) and (d) images of filled Cu in the TSV electrochemical deposited by ultra-fast pulsed current.

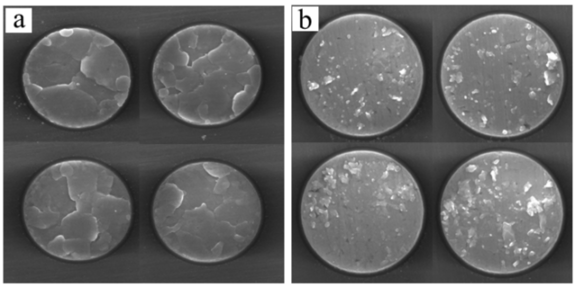

**Fig. 3** The surface morphologies of TSV Cu electro-chemical deposited by direct current (a) and ultra-fast pulsed current (b).