# Cu Dual Damascene 배선 공정에서의 DCV 배선구조의 EM 특성 연구

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# Electromigration Characteristics Stduy DCV Interconnect Structures in Cu Dual-Damascene Process

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**Abstract :** We investigated the effect of a Ta/TaN Cu diffusion barrier existence on the reliability and the electrical performance of Cu dual-damascene interconnects. A high EM performance in Cu dual-damascene structure was observed the BCV(barrier contact via) interconnect structure to remain Ta/TaN barrier layer. Via resistance was decreased DCV interconnect structure by bottomless process. This structure considers that DCV interconnect structure has lower activation energy and higher current density than BCV interconnect structure. The EM failures by BCV via structure were formed at via hole, but DCV via structure was formed EM fail at the D2 line. In order to improve the EM characteristic of DCV interconnect structure by bottomless process, after Ta/TaN diffusion barrier layer in via bottom is removed by Ar+ resputtering process, it is desirable that Ta thickness is thickly made by Ta flash process.

**Key Words :** Cu Dual-damascene, DCV, Electromigration.

## 1. Introduction

Recently, one of the advantages of using Cu interconnect for ULSI circuits is higher EM resistance and lower resistivity. The EM reliability become more important with the device improvement use of Cu interconnect. In this paper, we studied how each of Ta/TaN Cu diffusion barrier existence on the EM performance and the reliability of Cu interconnect. And propose a DCV structure improvement.

## 2. Experimental

Fig. 1 shows the via structure by BCV and DCV structure using TEM analyzer. The DCV via structure completely removed than BCV via structure to remain Ta/TaN barrier layer at via bottom. To calculate the sheet resistance measured by 4-point probe kelvin. The electron flow conducts a test upstream mode. D2 line width of upstream flow pattern is 0.2um of design size.

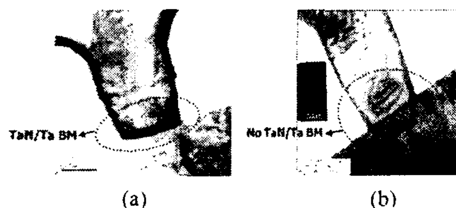



**Fig. 1.** The comparison of interconnect structure using TEM in via; (a) BCV structure (B) DCV structure.

The via size was fixed as 0.18um and test current density was 1.0, 1.5, 2.0MA/cm2, and the measurement temperature was 300, 325, 350℃, respectively. From EM test, activation energy and current density for EM compared. The test structures are examined in plan view using SEM, FIB, TEM analyzer.

## 3. Results and Discussion

### A. Electrical property of the interconnect structure

Fig. 2 shows the via chin resistance for each D2 interconnect structure. In the case of via size 0.18um, we found that BCV structure twice increase than DCV structure. It knows that the DCV structure is more advantage than BCV structure, in high speed device.

### B. The EM lifetime of the interconnect structure

Fig. 3 shows the EM lifetime distribution for the upstream interconnect structure. The results of measuring the EM life time are known MTTF variation against a current density. Figure 4 represents EM lifetime distribution by EM test temperature and interconnect structure to calculate activation energy to decide via EM mechanism. The results of the via EM in BCV interconnect structure does not become a problem over current density in BCV via interconnect structure.

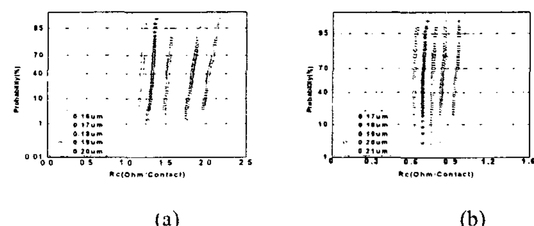
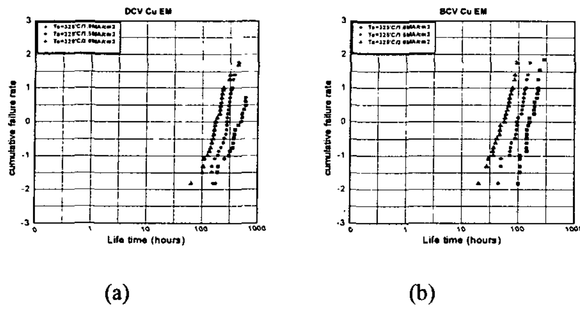
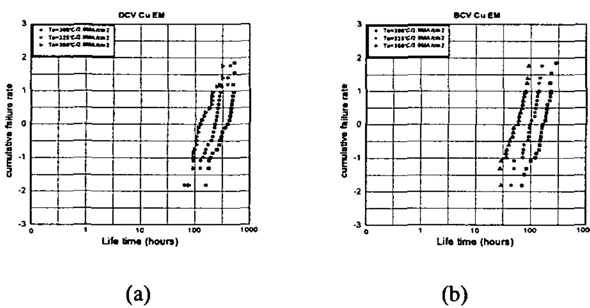



**Fig. 2.** Comparison of via resistance by interconnect structure: (a) BCV structure: (b) DCV structure.



(a) (b)

**Fig. 3.** Cumulative failure data of via EM lifetime as a function of intercomnect structure and current density; (a) upstream EM by DCV structure; (b) upstream EM by BCV structure.



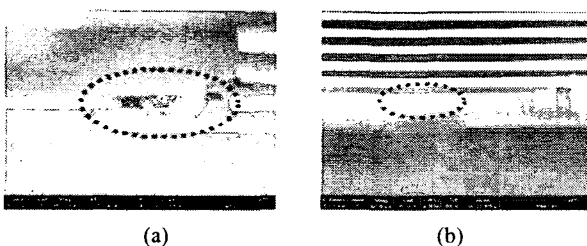
(a) (b)

**Fig. 4.** cumulative failure data of via EM lifetime as a function of intercomnect structure and test temperature; (a) upstream EM by DCV structure; (b) upstream EM by BCV structure.

However, DCV via interconnect structure does not satisfy in current density. This is considered due to activation energy difference. It analyzed failure mode by via interconnect structure to investigate the difference in a result of EM test.

#### C. EM failure mode of the interconnect structure

Fig. 6 shows that failure analysis using FIB analyzer was tested on the upstream mode via EM. Most failure of BCV structure is observed in via hole. However, DCV structure shows that DCV structure appears a EM failure at the D2 interconnect of critical design. It is consider that difference of EM failure mode is very close to Ta/TaN barrier layer existence as shown in Fig 1.



(a) (b)

Fig. 6 Failure analysis using FIB of upstream via EM: (a)BCV structure ; (b)DCV structure

## 4. Conclusion

The electric characteristic for each D2 interconnect structure showed that DCV structure showed lower resistance than BCV structure to remained barrier layer of Ta/TaN in via bottom. But the result of via EM test known that BCV intercomnect structure is superior via EM performance more than DCV interconnect structure applying bottomless process because BCV interconnect structure have bigger current density than DCV interconnect structure. It was assumed that the difference of EM characteristic is because the barrier layer of via bottom function as back stress restraining migration of Cu atom. In conclusion, In order to improve the EM characteristic of DCV interconnect structure by bottomless process, after Ta/TaN diffusion layer barrier layer in via bottom by Ar+ resputtering process removals, it is desirable that Ta thickness is thickly made by Ta flash process.

## 감사의 글

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