SiH_4 Soak Effects for Optimization of Tungsten Plug Deposition on TiN Barrier Metal

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Abstract

The SiH_4 soak step is widely used during the CVD Tungsten(W) plug deposition process on the Ti/TiN barrier metal to prevent the WF_6 attack to the underlayer metal. We tried to reduce or skip the time of SiH_4 soak process to optimize W-plug deposition process on Via. The electrical characteristics including Via resistance and the structure of W film are affected according to SiH_4 soak time. The elimination possibility of SiH_4 soak process was confirmed in the case of that the CVD W film grows on the stable Ti/TiN underlayer.

Key Words : SiH_4 Soak, CVD(chemical vapor deposition), WF_6 attack, W-plug, TiN barrier metal.

1. Introduction

In the CVD Tungsten(W) plug deposition process into contact and Via on the Ti/TiN barrier metal, WF_6 can react with Al, Si, Ti. WF_6 can be reduced by the underlayer Al and Ti through $WF_6 + 2Al \rightarrow W + 2AlF_3$ or $2WF_6 + 3Ti \rightarrow 2W + 3TiF_4$ on Via when the underlayer TiN are unstably formed. In order to minimize the incubation time, W deposition with a nucleation layer formed by the reaction of WF_6 by SiH_4 is applied. The nucleation layer has a high bulk resistivity, poor step coverage, and increased surface roughness compared with the H_2 reduction process. We compared the Via Rc and the W film structure according to SiH_4 soak time, and evaluated the exclusion possibility of the SiH_4 soak step on Via contact hole of 0.33 ㎛ size.

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2. Experiments

With the TEOS based IMD(inter-metal dielectric) on bare wafer, CVD W was deposited on TiN/Ti barrier metal to confirm the effect of reaction suppression between WF_6 and Ti. We evaluated electrical characteristics of sheet resistance(Rs), Rs non-uniformity(NU), resistivity and reflectance after deposition of W on TEOS. The Via Rc data was achieved on 0.33 ㎛ size. W CMP process was applied to remove W on IMD except Via, and metal interconnects structure is Ti/TiN/AlCu/top TiN. W structure was analyzed by SEM and EDS.

3. Results and Discussion

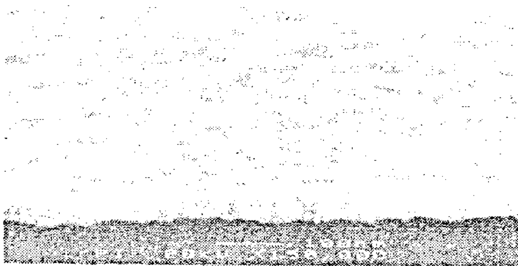
The SiH_4 soak time in the CVD W deposition process was splited, and it was displayed in table 1. The Rs, resistivity and reflectance values are decreased by the drop of SiH_4 soak time, and the no SiH_4 soak condition shows best result. We think the Si in SiH_4 react with WF_6, and the compound of SiH_4 increase Rs. Reflectance

non-uniformity(Ref. NU) increase according to decrease of SiH_4 soak time. The surface morphology of W nucleation layer were compared by SEM in Fig. 1.

Table 1. The comparison of Rs and reflectance data.

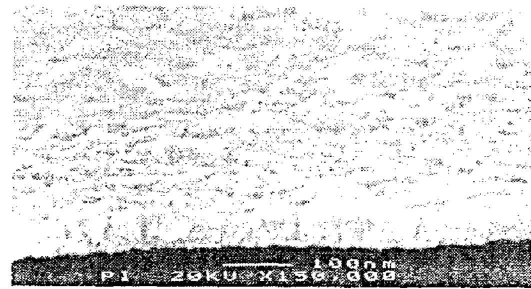
Soak Time	Rs (Ω/□)	Rs NU (%)	Reflectance (%Si)	Ref. NU (%)	Resistivity (μΩ-cm)
No	2.63	2.31	122.65	0.87	11.81
5 (sec)	3.29	2.75	126.19	0.35	14.82
10 (sec)	3.31	2.68	127.43	0.33	14.89
15 (sec)	3.29	2.90	127.60	0.23	14.80

(a) No SiH_4 Soak



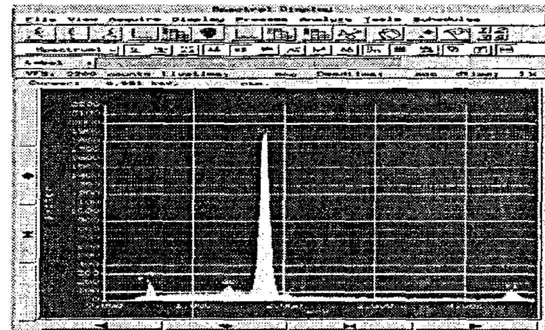
(b) SiH_4 Soak Time : 5 sec

(c) SiH_4 Soak Time : 10 sec



(d) SiH_4 Soak Time : 15 sec

Fig. 1. The surface structure comparison of W nucleation film by SEM.



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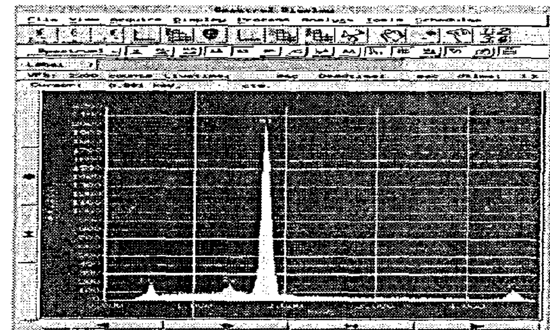

(b) SiH_4 Soak Time : 5 sec

Fig. 2. The surface element analysis of the W nucleation film by EDS.

The shrinkage of SiH_4 soak time increase grain size of W film and reduce reflectance and resistance. We confirmed the cross sectional structure by SEM, and the damage of Ti and TiN layer were suppressed in all conditions

including none SiH_4 soak time. TiF_3 formation after W film deposition on Ti/TiN barrier films was confirmed by the surface analysis of the W nucleation film. There aren't any F peak on all samples like Fig. 2. It means that WF_6 attact to Ti/TiN layer in spite of soak skip dose not appear in the case of the barrier structure that are safely deposited. SiH_4 soak skip condition has lower and safe Via Rc profile, and it is showed in Fig. 3.

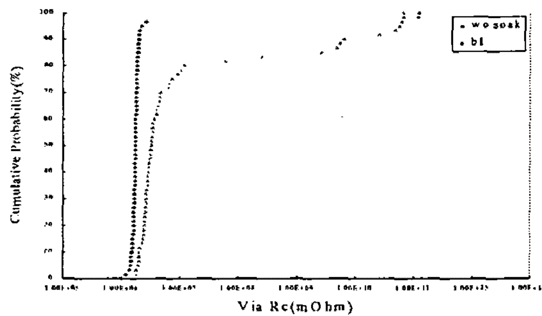

Fig. 3. Normalized Via Rc as a function of SiH_4 Soak time.

4. Conclusion

SiH_4 soak process is used to suppress WF_6 attack into barrier metal. But, the condition of no SiH_4 soak during W film deposition process has superior electrical characteristic and film structure in this test. So, it is confirmed the throughput improvement and Via Rc progress are possible by optimization of the barrier metal structure. We can decrease the process time about 10% by skip of the soak step.

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