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Influence of Polymeric Gas on Sidewall Profile and Defect Performance of Aluminum Metal Etch

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As the semiconductor industry moves to 65nm node and beyond, Al metal etch has become more challenging for its insufficient amount of photo-resist (PR) protection to achieve the desired sidewall profile and keep the corrosion free performance simultaneously. In this paper, we focus on the selecting appropriate polymeric gas and identifying the effect of various etch polymeric gases on Al metal sidewall profile and their corrosion defect performance. Three typical gases including N2, CHF3 and CH4 are selected in this paper. The observations from scanning electron micrographs indicate N2-based recipe is apt to form the severely tapering sidewall profile while CHF3-based recipe has loose polymer protection over the sidewall, thus leading to much worse corrosion defect performance. As expected, CH4-based recipe outperforms the two above polymeric gases. It not only shows the acceptable sidewall profile but also delivers the defect performance of free corrosion.

Introduction

Aluminum (Al) and Aluminum alloys have been extensively utilized as chip wiring materials in the fabrication processes of Cu interconnects. As the dimension of devices continues to scale down, Al metal tends to become thicker for the concern of adverse effect of high resistance connection on reliability. This poses the great challenge for Al metal etch process because it's tough for the insufficient amount of photo-resist (PR) to realize the desired sidewall profile and achieve free corrosion performance simultaneously (1~3). Such issue will exacerbate for higher transmission rate case. N2 and CHF3 are two typical polymeric gases widely used in Al metal etch. However, both of them could not fully satisfy the tightened process requirements caused by the inherent insufficiency of PR thickness. In this paper, we employed CH4 in Al metal dry etch process as the additive polymeric gas. The performance of all three polymeric gases is evaluated on the sidewall profile of Al metal line and the corresponding corrosion defect performance at the side-wall of Al-metal pad.

Experiment

Al metal etch was conducted on typical LAM-2300-Versys-Metal chamber. Three kinds of polymeric gas N2, CHF3 and CH4 were examined in this work. Their percentage was optimized based on our previous researches and ranges from 5%~10% in main etch and over-etch step, respectively. The same flow rate of Al metal main etch gas, Cl2 and BCl3, are applied for all three cases. In order to compare, we also employed the same source power and bias power in three polymeric gas splits. Detailed scaled Al metal etch recipes are shown in Table.1. The thickness of Al metal is 14um. The transmission rate of this Al metal etch process is about 85%. This means only 15% area is covered by photo resist before etch. Scanning electron microscope (SEM) was used to monitor the sidewall profile of Al-line. Defects performance was inspected after etch and wet clean process by KLA defect scan and review tool.

Table I. Summary of scaled Al metal etch recipes for different polymeric gas conditions

Split Condition	Polymerci Gas type	Etch Step	Pressure (mT)	Source power (W)	Bias power (W)	CL2 (sccm)	BCL3 (sccm)	Polymeric Gas usage (sccm)	Process time
1	N2	Main Etch	a	b	c	d	e	f	End point (151sec)
2	CHF3	Main Etch	a	b	c	d	e	f	End point (117sec)
3	CH4	Main Etch	a	b	c	d	e	f	End point (135sec)

Results and Discussion

Fig.1 shows the polymer performance at Al-pad side-wall and Al-line top view comparison under three different polymeric gases. Clearly, N2-based polymeric gas leads to more tapering profile. This can be attributed to that N2 gas brings heavier polymer during etch process and significantly slows down Al metal etching rate.This can be also noticed from that N2-based recipe features the longest endpoint in the main-etch of Al metal etch among three splits (Table.1). Longer etch time inevitably results in more photo

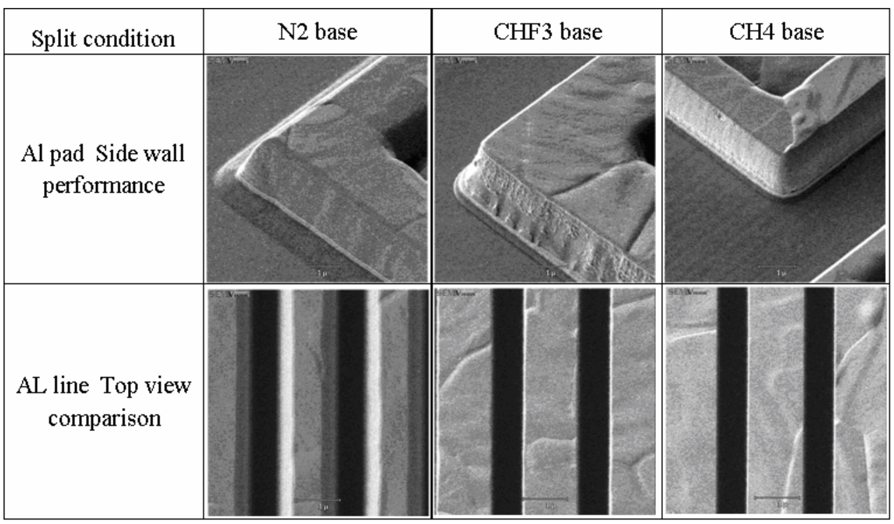

Fig.1 Al pad side wall and Al line top view comparison among three different polymeric gases

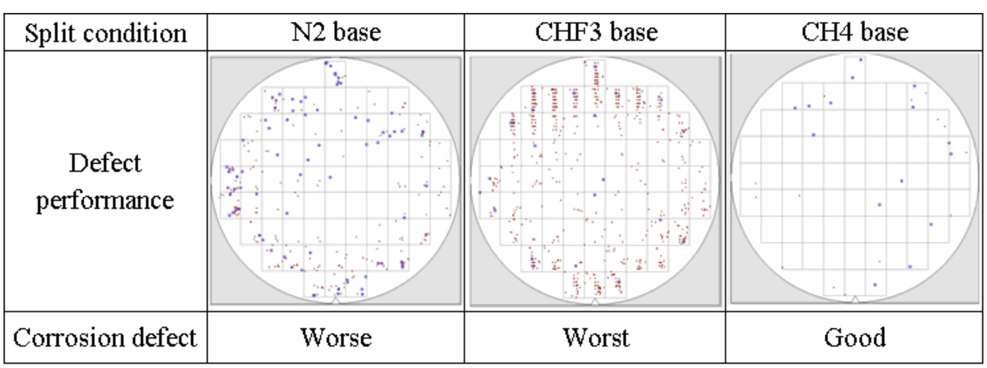

Fig.2 Corrosion defect comparison among three different polymeric gases

resist (PR) consumption. The remained PR cannot withstand physical bombardment in etch process. Coupled with heavy polymer, it finally caused much tapering profile of Al-pad and the top damage of Al line (trapezium top-profile). In contrast, CHF3-based split possesses the shortest end-point time of Al metal main etch. This indicates it's capable of generating much less polymer. In SEM picture, its roughest sidewall performance can be observed even with some Al metal grains exposed. As expected, CH4-based recipe provides the suitable polymer condition not only for Al-pad side-wall protection but also for the achievement of vertical Al-line profile.

The corresponding corrosion defect performance is summarized in Fig 2. As is well known (4-7), the corrosion defect performance can be ascribed to the side wall protection that is formed by polymer or by-product during Al metal etch process. Side wall protection mainly comes from the function of polymeric gas utilized in etch processes. Appropriate side wall protection can remarkably prevent Al metal from being attacked in the subsequent wet clean process and atmosphere environment, thus delivering the desired corrosion defect performance. In brief, CH4-based split is superior to other two kinds of polymeric gases from the point view of either Al-line profile or corrosion defect at Al-pad sidewall. While CHF3-based split demonstrates the worst corrosion defect because of its weak side wall protection.

Conclusions

In this paper, we investigated the impacts of the polymeric gas on the sidewall profile of Al-line and corrosion defect performance of Al-pad. Three typical polymeric gases include N2, CHF3 and CH4 are compared. The results show N2 gas causes the heaviest polymer, thus forming the severely tapering sidewall profile of Al-line while CHF3-based split provides the relatively loose polymer protection against the sidewall and leads to much worse corrosion defect performance. CH4-based split outperforms two other polymeric gases. It not only shows the vertical sidewall profile of Al-line but also delivers the defect performance of free corrosion at Al-pad.

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