Evaluation of post etch residue cleaning solutions for the removal of TiN hardmask

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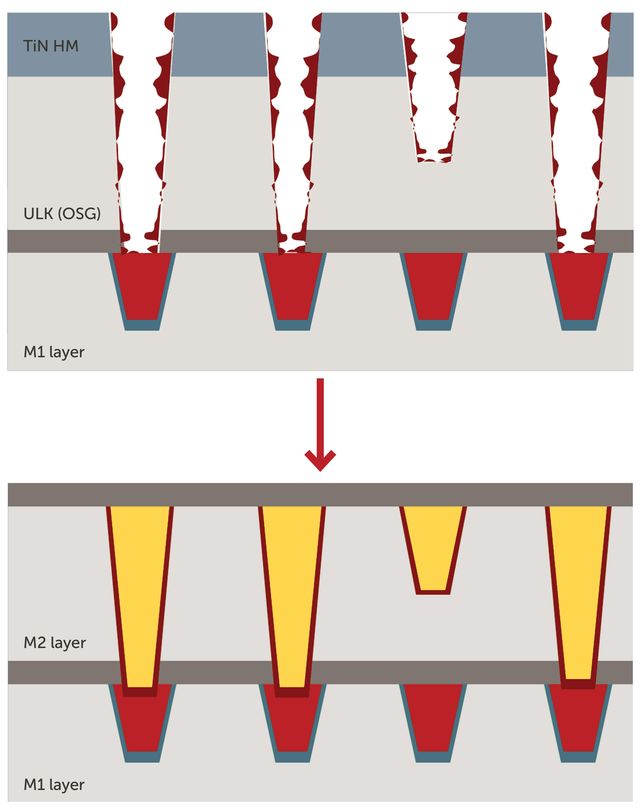
INTRODUCTION

In the back-end of line (BEOL), dielectric materials are patterned by a dry etch process using a fluorocarbon based plasma, which leads to fluorinated polymer deposition on the dielectric sidewalls. Subsequent metallization requires removal of this polymer to achieve good adhesion between the metallization stack and dielectric and to prevent voiding. The required post-etch residue removal (PERR) wet cleaning step needs to be compatible with a variety of new materials that are introduced in advanced interconnect technology. Formulated cleans have been developed to address the complexity of having exposed dielectric, barrier, liner and line materials and to have a tunable TiN removal rate. In this work we evaluate two types of formulated PERR cleans from Entegris, Inc.: the first with compatibility to tungsten and the second with compatibility to copper.

SCOPE

PERR cleans must etch the TiN hardmask to decrease the aspect ratio of the structure for conformal fill with the contact metal, and remove the residue on the sidewall of the via and trenches to get good adhesion of the contact metal, while being compatible with the exposed liner, barrier, dielectric and contact metal. At the ≤10 nm node, W is often used in the M1 layer, while Cu is used as the contact metal at every other layer. The potential/pH diagrams for W and Cu (not shown here), make evident that compatible cleans that also etch TiN will need to be in opposite ends of the pH scale. TK10-X4 is an acidic clean that will be evaluated for W, while TK9C is an alkaline clean targeted at Cu compatibility.



METHODS

Material compatibility. Blanket and patterned wafer testing for TK10-X4 was performed on the SCREEN SU3200, a 300 mm single wafer tool, at 60°C at a flow rate of 1.5 L/min. For TK9C, the concentrate was mixed with 30% H_2O_2 at a dilution ratio of 1:9 by mass to a total mass of 250 g and heated to 50°C in a beaker with agitation (300 rpm). In both cases, a two-minute deionized water (DIW) rinse, three-minute IPA rinse and N2 blow dry is performed after exposure to the process chemistry. The thickness of the tungsten and electroplated copper blanket films, before and after the experiments, was measured by calibrated XRF. Spectroscopic ellipsometry was used for measuring the thickness of the low-κ material and TiN. The low-κ material used in this work was an orthosilicate glass (OSG) type of material with a target κ-value of 2.4 (~20% open porosity). The film etch rates were compared to a dilute aqueous hydrofluoric acid (dHF) solution with an HF concentration of 0.05% by weight. The dHF mixture was processed in a beaker at 25°C for comparison to TK9C and TK10-X4.

Cleaning performance. To assess the performance on patterned structures, a 45 nm ½ pitch test structure was used. Coupons were immersed in TitanKlean® 10-X4 at 60°C for two minutes in a beaker with agitation (300 rpm), followed by two minutes DIW overflow rinse, three minutes IPA rinse and N2 dry. The cleaning performance was then evaluated by SEM.

Electrical performance. The electrical performance and yield for TK10-X4 was evaluated using a 45 nm ½ pitch test structure with OSG 2.55 dielectric, where the via contact and meander line resistances were measured. The electrical performance and yield for TK9C was evaluated at two different hydrogen peroxide dilutions using a 22 nm ½ pitch test structure, where Cu line thicknesses varied from 22 nm to 32 nm.

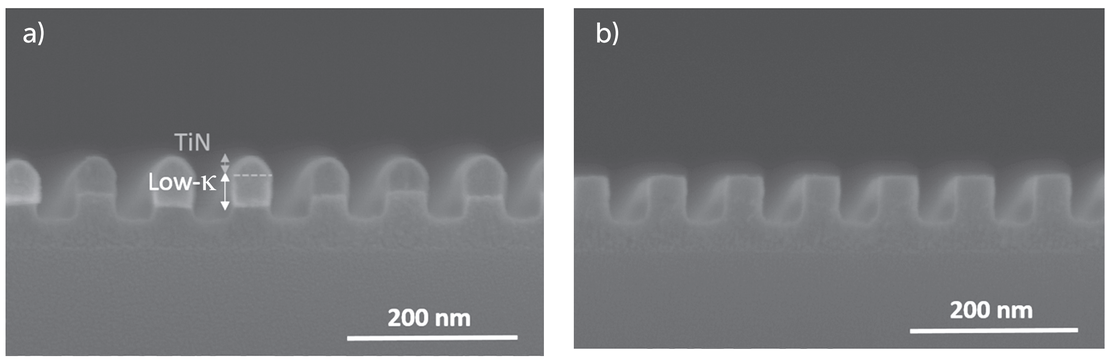
RESULTS

Compatibility

	ETCH RATE (nm/min)	
Film type	**0.05% HF**	**TK10-X4**
Plasma-exposed W	0.09	0.12
Plasma-exposed OSG 2.4	0.27	0.09
TiN	0.7	19.7

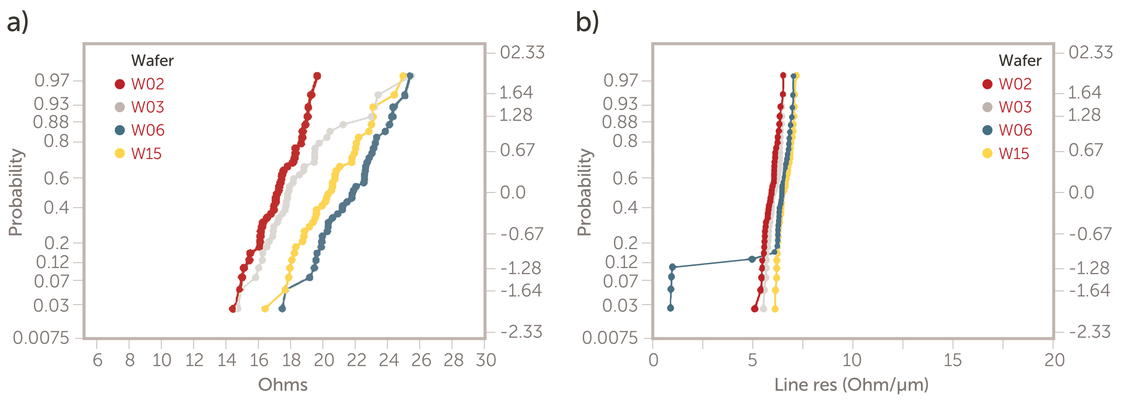
	ETCH RATE (nm/min)	
Film type	**0.05% HF**	**TK9C**
Plasma-exposed Cu	0.2	<0.1
Plasma-exposed OSG 2.4	0.3	0.4
TiN	0.7	12.9

TiN Removal/Cleaning Performance



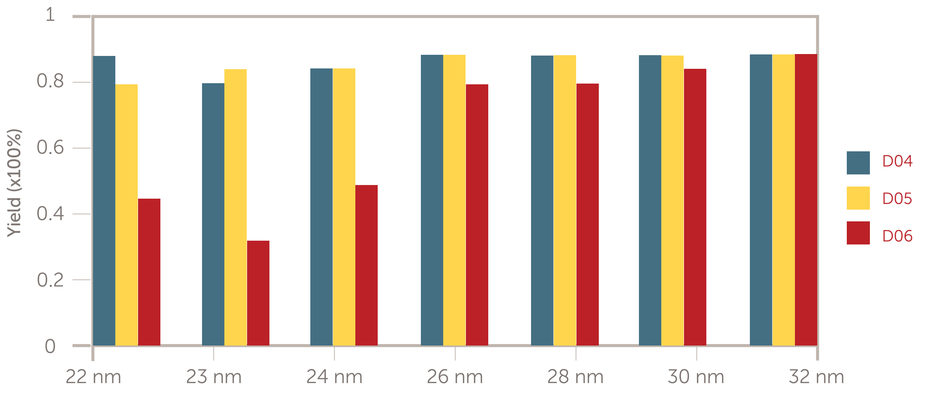
X-section SEM image of a) 90 nm pitch patterned wafer with TiN hard mask and low-κ before cleaning; b) after cleaning with TK10-X4

Electrical Performance – TK10-X4



Electrical results for TitanKlean 10-X4 using a 90 nm pitch test structure, highlighting a) via contact resistance and b) meander line resistance. Four wafers were processed with the same conditions.

Electrical Performance – TK9C



Electrical results for TitanKlean 9C using a 45 nm pitch test structure with CD lines of 22 nm and more. Significant yield improvement for D04 (TitanKlean 9C:H_2O_2 1:3, 50°C, two minutes) and D05 (TitanKlean 9C:H_2O_2 1:9, 50°C, two minutes) vs. no clean D06 (no clean): 90% vs. 50% for CD lines of 22 nm.

SUMMARY

The performance of formulated PERR cleaners, TitanKlean 10-X4 and TitanKlean 9C, developed for ≤10 nm interconnects have been evaluated. The solutions were specifically developed for W and Cu compatibility, respectively. They show compatibility to OSG 2.4, excellent residue removal, as well as tunable TiN hardmask removal. Electrical evaluation of both formulations shows a yield of >90% on the structures tested, a significant improvement over unprocessed wafers.