Microelectronic Engineering xxx (2013) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Microelectronic Engineering

journal homepage: www.elsevier.com/locate/mee

Chemical mechanical planarization of barrier layers by using a weakly alkaline slurry

Chenwei Wang [a,*], Jiaojiao Gao [a], Jianying Tian [b], Xinhuan Niu [a], Yuling Liu [a]

[a] Institute of Microelectronics, Hebei University of Technology, Tianjin 300130, China
[b] Market Information Department of CSPC Zhongqi Pharmaceutical Technology (Shijianzhuang) CO., Ltd, Shijiazhuang 050051, China

ARTICLE INFO

Article history:
Received 8 December 2012
Received in revised form 9 March 2013
Accepted 1 April 2013
Available online xxxx

Keywords:
Chemical mechanical planarization
Barrier layer
Weakly alkaline slurry
Dishing and erosion
Correction

ABSTRACT

A weakly alkaline barrier slurry (pH = 8.0) was proposed, which was free of unstable H_2O_2 and inhibitor such as benzotriazole (BTA). The polishing results of Cu, Ta and oxide blanket wafers show that the slurry has a high removal rate on oxide, while Ta has a low removal rate on Cu. The evaluation of the slurry was implemented in a way that the process conditions of Cu CMP and consumables on platen 1 and platen 2 were fixed. Copper dishing and oxide erosion have been characterized as a function of polishing time. The experiment results reveal that the barrier slurry without inhibitors has an obvious effect on the correction of dishing and erosion, and it also suggests that the slurry has a high selectivity of Ta and oxide to Cu. The sheet resistance does not exhibit any difference as polishing time increased, which indicates substantially lower copper loss.

1. Introduction

Barrier layers, such as Ta and/or tantalum nitrides, which are thermodynamically stable and have low film resistivity have been introduced in integrated circuit interconnects (ICs) to prevent the diffusion of Cu atoms into dielectrics and improve the adhesion property between the two layers [1–2]. Due to the incorporation of low-k dielectrics in device structures underlying Ta/TaN barrier layers, it is necessary for chemical mechanical planarization (CMP) of barrier at a reduced pressure ($\leqslant$1 psi) to prevent structural damage to fragile dielectric materials with low-permittivity. In addition, non/weakly alkaline slurry solutions are preferable for CMP of barrier, because many of Si-based low-k materials chemically disintegrate in high pH media [3–5]. During CMP of patterned copper wafers, two phenomena – copper dishing and dielectric erosion occur during over-polish step (which is required to ensure complete copper removal across the entire wafer).

In this paper, dishing is defined as the recessed height of a copper line compared to the neighboring oxide, and erosion is defined as the amount of recess of oxide relative to field oxide surface (As shown in Fig. 1). Dishing reduces the thickness of wide copper features, leading to an increase in the resistance and current density along the line. Thus, another major requirement for a good barrier slurry is that it can yield high selectivity of TaN: Cu as well as Ta: Cu polish rate to correct the topography [6–10].

Many efforts have been devoted to the development of barrier slurry to improve the CMP performance. However, almost all of these slurries contain H_2O_2 as oxidizer and benzotriazole (BTA) as inhibitor. As known to all, H_2O_2 is unstable and easily to be decomposed, which will deteriorate the performance of the slurry. Although BTA has been recognized as an influential inhibitor of copper corrosion in aqueous acidic, neutral, and alkaline solutions. It is reported that BTA creates post-CMP challenges such as leaving hydrophobic copper surface, increasing particle adhesion and increasing etch rate of copper during cleaning [11–17]. Recently, we have reported a kind of barrier slurry without BTA, but it was performed under a relative high pressure (2.0 psi), utilizing unstable H_2O_2 as oxider [18]. The slurry used for the CMP of barrier is a further research of our previous investigation. The composition of the slurry is different from our recent report, key feature of the slurry is free of H_2O_2 and BTA, slurry performances was evaluated in terms of dishing and erosion. Sheet resistance of the copper patterned wafer has also been studied, Finally the mechanism of barrier CMP was also discussed.

2. Experimental

Experiment was carried out on Applied Materials Reflexion LK 300 mm tool which was designed for a three-step CMP approach. Real-time profile control (RTPC) was implemented on platen 1 (P1) to provide average removal rate fluctuations and the endpoint of step one at target thickness regardless of incoming copper film. Subsequently, copper clearing was completed using full scan

---

[*] Corresponding author. Tel.: +86 022 60204914; fax: +86 022 26556455.
E-mail address: cwtjy206@163.com (C. Wang).

0167-9317/$ - see front matter © 2013 Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.mee.2013.04.001

Please cite this article in press as: C. Wang et al., Microelectron. Eng. (2013), http://dx.doi.org/10.1016/j.mee.2013.04.001

endpoint (EP) on platen 2 followed by barrier removal within the 3rd step. The purpose of this work is to evaluate the performance of the barrier slurry, thus the process conditions and consumables on platen 1 and platen 2 were fixed. The Dow chemical IC 1010TM pads with window were used on P1 and P2, Politex Regular embossed pad was used for barrier removal. A 15 min pad break-in procedure was performed to condition the pad before experiments. Process parameters in the polishing experiments are summarized in Table 1. Removal rate selectivity of different blanket wafers (including Cu, Ta and Oxide) was evaluated under the same condition of barrier CMP. Schematic of patterned copper wafer was shown in Fig. 2. Copper slurry used on P1 and P2 is a product of Tianjin Jingling Microelectronic Material limited. Barrier slurry under investigation was formulated with 10 wt.% diluted colloidal silica (20–30 nm in size), 1.5 wt.% FA/O chelating agent (it was obtained from Hebei University of Technology), 0.5 wt.% guanidine nitrate and deionized water (DIW). The pH of the slurry was then adjusted to 8.0 by using phosphoric acid. A RESMAP 463 FOUP

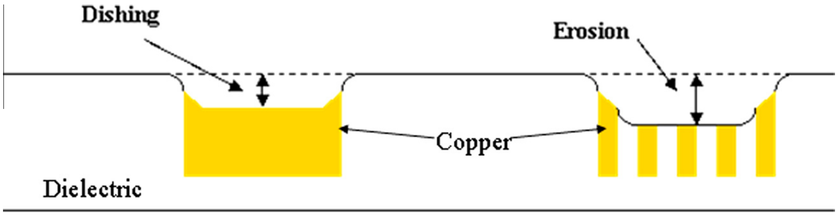

Fig. 1. Schematic representation of copper dishing and dielectric erosion.

Q2 **Table 1**
Process parameters in polishing experiments.

	P1	P2	P3
Purpose	Bulk copper removal	Copper clearing	Barrier removal
RR/Z 1–Z 5 pressure (psi)[a]	3.2/2.0/1.5/1.5/1.5/1.5	3.2/2.0/1.5/1.5/1.5/1.5	2.2/1.5/1.0/1.0/1.0/1.0
Slurry flow rate (ml/min)	300	300	300
Head rotation speed (rpm)	97	97	78
Platen rotation speed (rpm)	103	103	80
Endpoint	~2 KÅ Cu remaining	EP 45 s + OP 30 s	By time
Conditioner	3 M disc A160 pad conditioner		

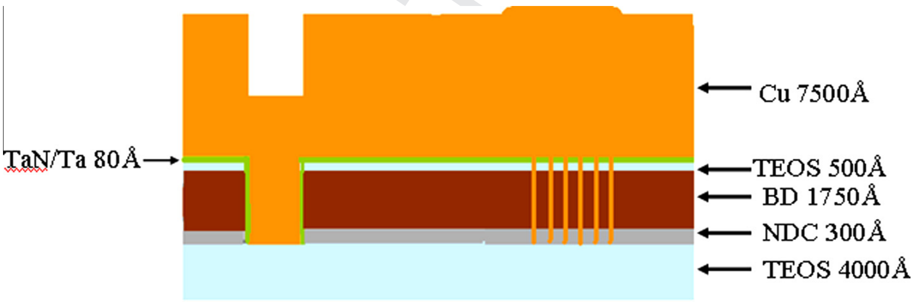

Fig. 2. The schematic of patterned copper wafer used in this experiment.

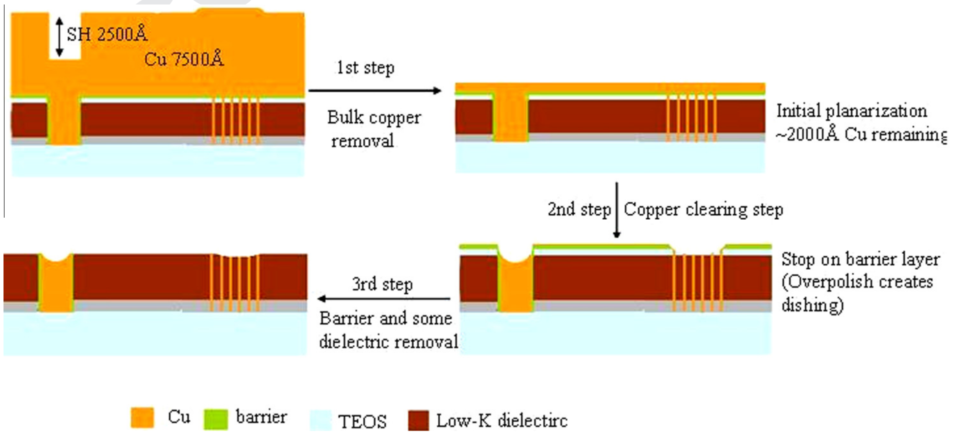

Fig. 3. Schematic illustration of copper CMP in this experiment.

Please cite this article in press as: C. Wang et al., Microelectron. Eng. (2013), http://dx.doi.org/10.1016/j.mee.2013.04.001