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PII: S0167-9317(17)30400-8
DOI: doi:10.1016/j.mee.2017.12.002
Reference: MEE 10674

To appear in: *Microelectronic Engineering*

Received date: 2 June 2017
Revised date: 9 November 2017
Accepted date: 4 December 2017

Please cite this article as: R. Yim, C. Perrot, V. Balan, P.-Y. Friot, B. Qian, N. Chiou, G. Jacob, E. Gourvest, F. Salvatore, S. Valette , Chemical/mechanical balance management through pad microstructure in CMP. The address for the corresponding author was captured as affiliation for all authors. Please check if appropriate. Mee(2017), doi:10.1016/j.mee.2017.12.002

Chemical/Mechanical Balance Management through Pad Microstructure in CMP

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Abstract

CMP is a complex process that combines the synergistic effect of a chemical action performed by the slurry and a mechanical one done by the pad and the abrasive particles of the slurry. The pad plays a key role in the CMP process as it contributes to both chemical and mechanical actions. In this paper, we focused on the pad pores, which act on the two sides of the chemical/mechanical balance. Pads with different porosities were investigated. The effect of pad microstructure on CMP performance were studied. A 3D confocal microscope was used to analyze pad roughness parameters, height distributions and asperities properties. Silicon blanket wafers were polished using different pads and were then characterized in order to extract surface roughness, removal rate and defect level. The surface quality of the wafer post process presents a direct correlation with pad topography. A smaller pad pore size (i.e. smooth surface) shows a beneficial effect on the wafer roughness.

We further discuss the effect of pore size on pad topography by studying asperities properties and volume available for slurry transportation. The consequences of pore characteristics are then correlated to CMP performance. This study allows us to understand how we can manage the chemical/mechanical actions through the pad microstructure.

Keywords
Chemical mechanical planarization; CMP; Pad roughness; Pores; Asperities; Wafer roughness; Removal rate, Defect level

1. Introduction

Chemical Mechanical Planarization has become a crucial step in the semiconductor manufacturing. CMP has enabled 3D device manufacturing, for both 3D transistors and 3D stacked integrated circuits through wafer bonding [1]. Surfaces quality, from the wafer level (millimeter scale) to the very local one, including the diameter of electrical contacts and the material roughness (atomic scale), is more and more critical to ensure good electrical properties as well as to provide good bonding performance [2].

The CMP process involves both chemical and mechanical effects [3]-[6]. For the silicon removal, Liu et al. [7] proposed a mechanism that includes two dynamics processes. Firstly the active components of the slurry attack the silicon atoms of the wafer surface resulting in the cleavage of silicon bonds. Secondly the reaction products are carried away by the abrasive particles and the polishing pad. The balance and synergistic effects of these two steps define the total removal rate and the quality of the final polished surface.

Polishing pad is a key consumable in the process and numerous studies have looked into the effect of pad on CMP results: groove designs have shown an impact on pad surface temperature, coefficient of friction and removal rate in interlayer dielectric (ILD) and copper CMP processes [8], [9]. The relationship between the pad microstructure and the polishing performance has also been investigated: parameters such as asperities properties and surface texture have shown an impact on removal rates and planarization efficiency [10], [11]. Y. Li [12] has found that the presence of pores in the pad can change the planarization efficiency, the within wafer non-uniformity, and the pad lifetime. Recently S. Choi et al. [13] have shown that the