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Effect of slurry pH on the defects induced during the plug isolation chemical mechanical polishing

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Abstract

In the present work, major polishing defects such as micro dishing and polishing residues induced during the landing plug isolation (LPI) chemical mechanical polishing (CMP) were quantitatively examined in slurries with different pH by combining chemical dipping test and analytical method such as scanning electron microscopy and transmission electron microscopy. From the results of the dipping test, we found that the solution alkalinity accelerates micro dishing of borophosphosilicate glass (BPSG) layer to 60 nm in value, which is responsible for preferential accumulation of polishing residue at this site. This is attributed to more rapid chemical dissolution of BPSG than that of nitride film during LPI CMP in alkaline slurry. By introducing acidic slurry, we succeed in the effective reduction in the micro dishing and total number of the polishing residue N_r, generated during CMP in conventional silica-based alkaline slurry.

Keywords: Micro dishing; Slurry; Chemical mechanical polishing (CMP)

1. Introduction

Recently, chemical mechanical planarisation (CMP) process becomes widespread to a variety of applications such as shallow trench isolation, LPI (landing plug isolation), storage node and damascene CMP processes for advanced integrated circuit devices [1–3]. Though these functional CMP processes are considered as indispensable for planarising circuit layer in device fabrication, there still exist issues such as defect, dishing and erosion originating from the simultaneous exposure of various layers having different polishing characteristics during CMP.

As primary dielectrics in LPI process, it has been widely reported that the doped silicon (Si) oxides, such as phosphosilicate glass (PSG) and borophosphosilicate glass (BPSG), are generally used for their good flow characteristic and low resistivity [4]. However, Han et al. [5] investigated that the doped silicate oxides present higher potassium and calcium contamination after scrubbing and deionized water rinse compared to undoped oxides. This occurs because the phosphorous acts as a gathering site for metal impurities on the surface.

Under this circumstance, HF immersion has attracted considerable attention to reduce the metallic contamination for undoped oxides [6,7]. HF immersion can effectively remove some metal species which are chemically adsorbed onto the oxide surface [8]. Thus, it can be stated that addition of HF in the post-CMP cleaning sequence may be able to reduce the defects formed on the PSG surface. However, the soft films such as PSG and BPSG tend to have high post-CMP defect counts after an extended HF immersion: HF can etch microscratches and thus enlarge their size so that more unexpected defects are detected after an extended HF immersion. Hence, it is necessary to develop or improve the conventional isolation CMP process for fabricating sub-micron dynamic random access memory (DRAM) by establishing novel consumables under careful consideration of unique properties and structures of each layer.

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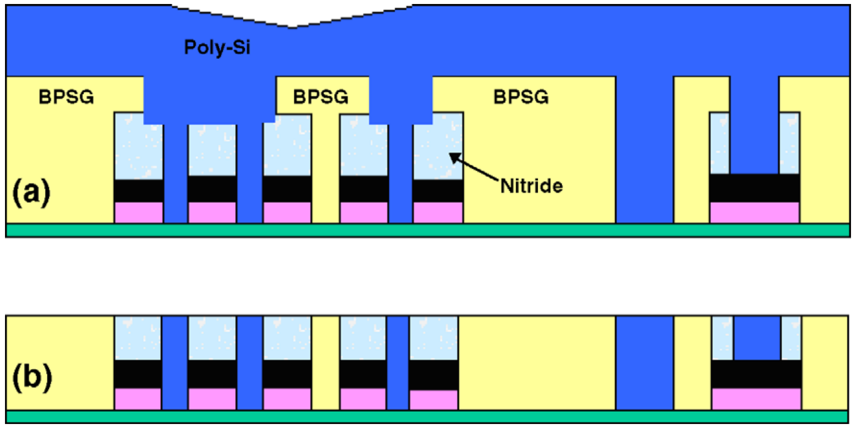

Fig. 1. Schematic cross-sectional diagram of wafer sample obtained (a) before and (b) after LPI CMP.

The present work evaluates the characteristic of conventional alkaline silica slurry in terms of the reduction of major polishing defects, such as micro dishing and the polishing residues, originating from the LPI CMP process. For this purpose, we employed the CMP technique combined with the chemical dipping test and analytical method such as scanning electron microscopy (SEM) and transmission electron microscopy (TEM) in various slurries with different pH. The experimental results lead to the success in reduction of the polishing defects by introducing acidic slurry.

2. Experimental details

For this purpose, we used a test vehicle employing 0.16 μm design rule for memory device as CMP samples. Fig. 1(a) and (b) show schematic diagram of poly-Si plug in BPSG layer on patterned nitride structure. Since the three kinds of layers such as poly-Si, BPSG and nitride layer are simultaneously exposed during LPI CMP, the effects of slurry characteristics and pad/abrasive contact on these layers are very important.

CMP process was performed using a conventional rotary type CMP tool with Rodel IC1000/SUBA4 pad. Alkaline silica slurry was obtained from Bayer Company. An AMAT MIRRA 3400 3 platen polisher system with ON-TRAK double side scrubber DSS 200, equipped with poly-vinyl-alcohol brush cleaner was used with the platen speed and carrier pressure set at 50 rpm and 7 psi, respectively.

In order to investigate the role of slurry pH in the polishing performance, we immersed blanket wafers (chemical dipping test) in the four kinds of silica-based slurry with various pHs of 2, 3, 7 and 11, adjusted by adding 0.1 M HNO_3 solution into the alkaline slurry of pH 11. After that, the patterned wafers were polished in slurries with various pHs to measure both values of micro dishing and the total number of the polishing residue, N_r, quantitatively by KLA-Tencor STEALTH system. Total defect number was counted by scanning all the patterned area in the wafer. STEALTH often included irregular reflection induced by underlying layers as defects. All the defects were classified and confirmed visually by CD-SEM (critical dimension-scanning electron microscopy, Hitachi S9260, operated at 800 V) again to measure exact defect number. Dishing was carefully analyzed by TEM (Hitachi H-7000, operated at 100 kV) with cross-sectional view. TEM specimen was prepared by the following procedures. DRAM-integrated Si wafer was cleaved into small fragments and one of them was bonded to stub. A thin specimen with less than 25 μm thickness was prepared by slicing wafer fragment-bonded

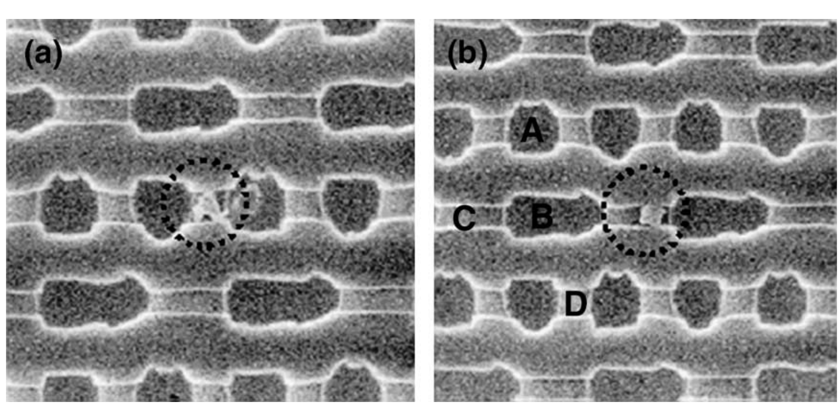

Fig. 2. SEM micrographs of the polishing residue, generated just after LPI CMP in conventional silica-based alkaline slurry, on (a) storage node contact and (b) bit line contact regions: A and B, poly-Si; C and D, BPSG.