## 5000-µm Line-and-Space Planarization Using Chemical Mechanical Polishing

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Chemical mechanical polishing planarizes broader features than other processes, but is restricted to features less than 1000  $\mu$ m wide. We deposited thick BPSG and thin NSG films on a patterned wafer. Initial polishing removed the upper NSG level completely, exposing the BPSG, but the lower NSG level remained unpolished. BPSG polishes faster than NSG, resulting that the upper BPSG level was selectively polished. This technique enabled us to planarize 5000- $\mu$ m line-and-space patterns as well as less than 1000- $\mu$ m ones.

## Introduction

Chemical mechanical polishing can planarize much wider features than any other planarization process, but it is very difficult to planarize features more than 1000  $\mu$ m wide.<sup>1</sup> Hayashi patterned the polishing stopper layer on the lower BPSG level, which enables us to planarize wider features ( 5000- $\mu$ m wide features are often cases in VLSI circuit). This technique was, however, overweighed by adding a lithography process.<sup>2</sup> We therefore worked on planarization that would not use a lithography process.

# Experiment

# **Preparation of Samples**

In preparing our three samples (Fig. 1 (a)), we started by making 1.1- $\mu$ m-deep grooves on Si wafers using reactive ion etching (RIE). Line-and-space patterns were 10, 100, 1000, and 5000  $\mu$ m wide. We then deposited 1.25- $\mu$ m BPSG and 0.2- $\mu$ m NSG films on one grooved wafer (Sample A). On the second grooved wafer, we deposited a 1.55- $\mu$ m NSG film (Sample B), and, on the third, a 1.55- $\mu$ m BPSG film (sample C). Samples B and C were used to clarify the effects of polishing on planarization.

# **Polishing and Measurement**

The three samples were polished continuously under conventional SiO2 polishing conditions (Table 1) for 0.5 to 2.0 minutes. We then measured the step height, h, using a Taly step or a P2 (Tokyo Electron) and SiO2 (NSG and/or BPSG) thickness of the lower level, t, using a reflectometer (Fig. 1 (b)).



Fig. 1(b) line-and-space pattern

### **Results and Discussion**

Fig. 2 shows the NSG/BPSG structure planarization. The lower level thickness, t, was almost invariable during polishing independent of pattern sizes, meaning that the lower NSG was unpolished. Therefore, the decrease of step height directly corresponds to the polished thickness of the upper NSG and/or BPSG. Since the initial NSG is 0.2 µm thick, the upper NSG is completely removed after 2 minutes polishing, exposing the upper BPSG and leaving the lower NSG thickness unchanged (Fig. 3). BPSG polishes faster than NSG, and thus the upper BPSG selectively polished and the lower NSG acted as a stopper (Fig. 3). Consequently, planarization was realized almost independent of pattern sizes. After 6 minutes, all line step heights were below 0.1 µm and 0.043 to 0.122 µm of the lower NSG level was removed. The maximum removal difference was 0.079 µm for the lower NSG level for 10 to 5000-µm line-and-space features. The average removal for the lower NSG was 0.083 µm (Fig. 2).

Fig. 4 shows the NSG structure planarization. After 18 minutes of polishing Sample B, step heights for 10, 100, and 1000- $\mu$ m NSG line-and-space patterns were less than 0.1  $\mu$ m, and that of the 5000- $\mu$ m feature was 0.191  $\mu$ m. Between 0.288 and 0.425  $\mu$ m of the lower NSG was removed. The maximum removal difference of 0.137  $\mu$ m for the lower NSG level and average removal of 0.332  $\mu$ m for the lower NSG level were larger than those of the NSG/BPSG films.



Fig. 2 NSG/BPSG structure planarization

# Table 1 Polishing conditions

Slurry	SC112
Pad	IC60
Pressure	210 g/cm <sup>2</sup>
Rotation speed	60 rpm



(a) Before polishing



(b) Beginning of polishing





Fig. 3 Planarization steps: (a) NSG/BPS on a grooved wafer. At (b), the upper NSG film is completely removed. At (c), the lower NSG acts as a polishing stopper.



Fig. 5 shows the BPSG structure planarization. After polishing Sample C for 5.5 minutes, the step heights of the BPSG film line-and-space patterns were 0 to 0.302  $\mu$ m. The height reduction is smaller than for NSG/BPSG and NSG films. Between 0.256 and 0.482 of the lower BPSG was removed. The removal difference of 0.226  $\mu$ m and average removal of 0.376  $\mu$ m were larger than for NSG/BPSG and NSG films.

To compare the planarization effects of above three techniques, we evaluated the maximum removal difference for lower SiO2 and the maximum step height among various patterns at the end of polishing. Sample A (NSG/BPSG) had the lowest maximum step height and the lowest minimum removal difference for lower SiO2 (Fig. 6). These results enable us to planarize various sizes of patterns and to eliminate dummy patterns made to reduce the planarization pattern dependence. Two different film

polishing rates alone should produce the same effect. Using a SiN/NSG structure, where NSG polishes faster than SiN, might be more practical in VLSI process.

#### Conclusion

We prepared three samples --NSG/BPSG, NSG, and BPSG--on individual wafers and polished them, then studied the effects of planarization. NSG/BPSG proved to have several advantages: It enables us to planarize 5000- $\mu$ m line-and-space pattern to less than 0.1  $\mu$ m, and both the removal difference and average removal for lower SiO2 were smaller than for NSG and BPSG. Since NSG/BPSG is pattern-independent, it can be applied to many types of VLSI circuit and simplify the VLSI process.

#### References

(1) P. Renteln, M. E. Thomas, and J. M. Pierce, IEEE 7th VMIC Conf, p. 57.

(2) Y. Hayashi and S. Takahashi, Jpn. J. Appl. Phys. Vol. 32, 1060.

