Effect of Plasma Treatment on Double Patterning Technique

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Double patterning technique (DPT) has been developed to overcome the limitation of photolithography for sub-50nm devices. For the successful implementation of DPT process, intermixing between two photoresist (PR) layers should be prevented. Two types of plasma treatment (Ar and HBr plasma) were introduced and intermixing was effectively prevented by forming protecting layer on 1st pattern. Finally, 50nm line and space patterns were successfully transferred into the underlying carbon hard-mask layer with Ar plasma treatment.

Introduction

DPT has been reported as a promising candidate to extend lithography limit beyond 50nm node by performing the currently available lithography two times [1-3]. As you can see in Fig.1, the pitch can be reduced by a half of it as long as the misalignment between two patterns can be well controlled. However, it is difficult to prevent intermixing between two photoresist (PR) layers, which results in pattern missing as shown in Fig. 2(a). In this article, two types of plasma treatment (Ar and HBr plasma) are introduced to prevent intermixing between two PR layers and protection mechanisms of plasma treatment are also investigated.

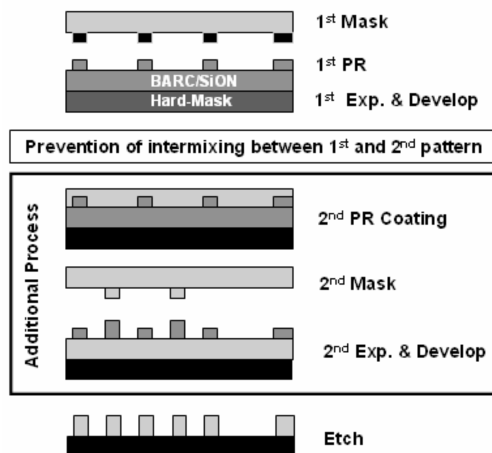

Fig. 1. A schematic diagram of double patterning process.

Experimental

About 50nm wide 1st PR line patterns are formed with 100nm half pitch ArF scanner on carbon hard-mask layer covered with SiON thin layer. After first PR patterning, plasma treatment is applied to form a protection layer surrounding the 1st PR patterns using Ar or HBr gas. Dual-frequency capacitively-coupled plasma (CCP) etcher was used for plasma treatment process. The following 2nd PR of 200nm- thick is coated for second patterning process and it is aligned with the 1st pattern. Finally, the dry etching process is performed after second patterning to define the underlying mask layer.

Results and discussion

Fig.2 shows the effect of plasma treatment on the intermixing between two PR layers. Without plasma treatment (a), the 1st pattern disappeared after 2nd photolithography process due to intermixing between 1st and 2nd PR. However, using Ar plasma treatment (b) and HBr plasma treatment (c), the 1st pattern was remained after 2nd PR patterning, indicating possible protection layer formation protecting intermixing between two PR layers.

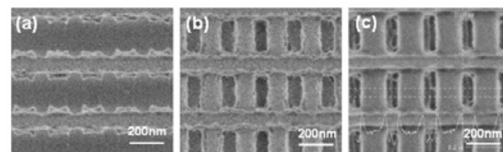

Fig. 2. Top-down SEM images after 2nd patterning with different plasma treatment conditions: (a) without plasma treatment, (b) Ar plasma treatment, (C) HBr plasma treatment

To understand the protection mechanism of plasma treatment, XPS analyses were carried out on the ArF PR before and after plasma treatment. As shown in Fig. 3, intensity

of Si increases significantly while that of F decreases. The top electrode is regarded as the source of Si sputtered by Ar^+ during Ar plasma treatment. As a result, this Si layer deposited on the PR surface protects intermixing.

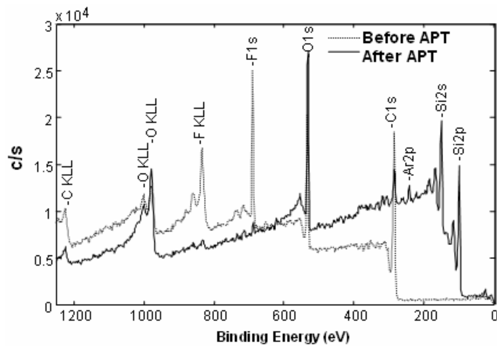

Fig. 3. XPS spectra of ArF PR before and after Ar plasma treatment (APT).

Fig. 4 shows a cross-sectional secondary electron microscopy (SEM) image after HBr plasma treatment, which shows polymer layer on the PR surface. This polymer consists of C, O, F and Br (Table 1), and it seems to protect intermixing between two PR layers. The polymer on PR is known to be hardened after plasma exposure due to cross-linking reaction of polymer. This PR hardening is believed the main mechanism for protection layer formation in HBr plasma treatment. Quartz top plate instead of Si in HBr plasma treatment exclude the possibility of sputtered Si protecting layer formation.

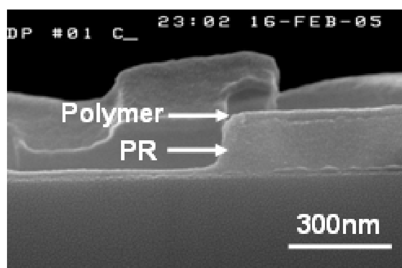

Fig. 4. Cross-sectional SEM image after HBr plasma treatment, showing polymer layer on the surface of resist.

Table 1. Relative contents of atomic elements of ArF resist with and without HBr plasma treatment (HPT) obtained from XPS analysis

	C 1s	O 1s	F1s	Br 3d5
w/o HPT	79.36	19.10	1.54	0.00
HPT 60s	36.19	59.88	0.25	3.70

Finally, with Ar plasma treatment, 50nm line and space patterns are successfully transferred into underlying carbon hard-mask layer (Fig. 4). Even though 1st and 2nd PR profiles were slightly different, 1:1 line and space pattern could be successfully obtained by controlling the PR thickness and 1st line critical dimension (CD).

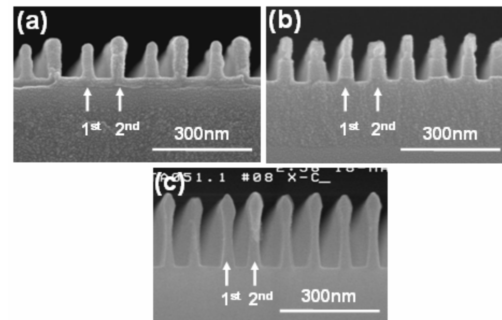

Fig. 5. Cross-sectional SEM images of 50nm line and space patterns: (a) after 2nd patterning, (b) after BARC/SiON etching, (c) after carbon hard-mask etching.

Conclusions

Plasma treatment process was studied as a key technology to prevent intermixing between two PR layers for DPT process. Protection mechanisms of plasma treatments were described with SEM and XPS analyses. With Ar plasma treatment, 50nm line and space patterns are successfully transferred into the underlying carbon hard-mask layer.

References

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