Application of chemically amplified positive resist PSR for advanced mask making

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1. Introduction

Advanced technologies like phase-shift and modified illumination make it possible to delineate deep-submicron patterns by optical lithography. However these advanced optical technologies require precise mask fabrication technology. The development of electron beam resists is one of the key issues for advanced mask fabrication. Electron beam resists for the fabrication of precise masks must have both fine patterning capability and dry etching durability.

Chemically amplified positive resist PSR (Positive resist by Solubility Reversal) has been developed for direct wafer writing.¹⁾ In this work, the application of PSR for mask writing is investigated.

2. Experiment

The e-beam resist used in this experiment is a three-component chemically amplified resist, consisting of an acid generator, novolak resin and tetrahydropyranyl-protected polyvinylphenol (THP-M) as a dissolution inhibitor. In the case of delineating insulating layers, such as a phase shifter layer, a water soluble conducting polymer ESPACER100 (Showa Denko Co.) was spun on top of the e-beam resist to prevent any charging problem.

The e-beam exposure system used in this work is HL750D (Hitachi Ltd.) with 50 kV acceleration voltage. The current density and maximum shot size are 7 A/cm² and 2 μ m square, respectively.

3. Results

The sensitivity and resolution of chemically amplified resists are strongly dependent on the soft-bake and post-exposure-bake (PEB) conditions. In this experiment, two sets of baking conditions were adopted. To prevent an intermixing layer formation between the resist and the top-coating ESPACER100, a high soft-baking temperature of 125°C and a PEB temperature of 110°C were adopted. A low soft-baking temperature of 80°C and a PEB temperature of 80°C were adopted for delineation of the Chromium layer (TL-Cr). Figure 1 shows the sensitivity curves of these two baking conditions.

Fig.1 Sensitivity Characteristics of PSR

(a) Relationship between Line Pattern Size and Dose on $0.5 \mu\text{m}$ Line/Space Patterns

(b) Pattern Size Accuracy of Isolated Patterns

Fig.2 Pattern Size Accuracy

Fig.3 SEM Photographs of SOG after Dry Etching

Fig.4 Stability of the Pre-Coated Film

After etching the TL-Cr layer, pattern width was measured by LAMPAS Iii and pattern details were observed by SEM. Figure 2 shows the electron beam dose dependence of pattern size and pattern size change from the designed value. The sensitivity for a 0.5 μm line/space pattern is around 3 $\mu\text{C}/\text{cm}^2$ as shown in Fig. 2. Pattern size accuracy can be controlled within 0.1 μm in the range of 1.2 to 10 μm . As shown in Fig. 2(a) 10% change in the exposure dose causes only 0.026 μm change in the 0.5 μm line/space patterns.

In order to delineate the phase shifter layer, the dry etching durability of PSR was investigated. Film thickness of the shifter layer (SOG layer) was 0.4 μm , which corresponds to a 180° phase-shift at the i-line. Figure 3 shows cross-sections of the dry-etched phase-shifter. This experiment used a microwave plasma etching system using a mixture gas of $\text{C}_4\text{F}_8/\text{CH}_2\text{F}_2$. The etching rate ratio of PSR to SOG was 1 to 2 under these conditions. Due to the strong etching resistance, very straight sidewalls can be obtained.

The delay time effect of chemically amplified resist is a serious problem. Especially for mask-making application, the stability of sensitivity in pre-coated resist film is important. Figure 4 shows the exposure dose change needed to maintain constant pattern size during store time. When a pre-coated resist film is stored in a clean-room atmosphere, some change in sensitivity is observed. However, when it is stored in dry nitrogen, the change can be negligible for at least 4 weeks of storage. It is also found that top-coated resist with ESPACER100 is stable even in a clean-room environment.

4. Conclusion

The chemically amplified positive e-beam resist PSR was investigated for use in the mask-making process. Patterns of 0.5 μm critical dimension can be obtained with 3 $\mu\text{C}/\text{cm}^2$ at 50 kV. Dry etching durability was also confirmed. To prevent sensitivity variation in PSR pre-coated film, a dry nitrogen atmosphere or over coat is necessary for long term storage. These results show that PSR is a promising positive e-beam resist for mask writing in the deep-submicron range.

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Reference

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