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The Control of Sidelobe Intensity with Arrangement of the Chrome Pattern (COSAC) in Half-Tone Phase-Shifting Mask

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A new half-tone phase-shifting mask(HT-PSM) with COSAC, which has the two-layer structure of chrome and half-tone films, is successfully developed. With this technology, the depth of focus(DOF) is enhanced to 1.5μm for dense 0.35μm contact hole at 1.0μm pitch. The problem of the resist thickness loss which is generated in printing with normal HT-PSM is solved by the control of sidelobe. In HT-PSM with COSAC, the intensity of sidelobe is reduced by chrome pattern on half-tone film, while the phase-shifting effect is maintained.

1.Introduction

A HT-PSM is the technology proposed to enhance the DOF and resolution in advanced photolithography, and it has been developed mainly for patterning contact hole 0.35μm diameter and beyond. In a HT-PSM, the sidelobes are generated in profile of light intensity in the position of the interference between 1st-order diffracted light and the leak light which passes through half-tone regions.[1][2] When contact holes are placed densely and closely, plural sidelobes interfere with one another and the light intensity increases several times as high as an isolated contact hole. The resist thickness loss which is generated around contact holes due to the light intensity of sidelobe obstructs to achieve enhanced lithographic resolution and DOF. In this paper, a new method is proposed to control the intensity of sidelobe with the arrangement of chrome patterns on reticle, without decrease of DOF.

2.Mask fabrication

Fig.1 shows printed result of dense 0.35μm contact holes at 1.0μm pitch with normal HT-PSM. Two sidelobes interfere with each other in the position 'A', and four sidelobes interfere with one another in the position 'B'. The resist thickness loss is generated in the position where the light intensity due to interference of plural sidelobes exceeds the sensitivity of the resist. The position of resist thickness loss is limited to the center position between contact holes, and it can be easily replaced with the position on a reticle. Further, as the sidelobe intensity can be reduced by decrease of the leak light which passes through half-tone regions, the method in which the chrome patterns are placed on half-tone film is adopted as the countermeasure of resist thickness loss.

Fig.2 shows the process flow of HT-PSM with COSAC. The blank reticle consists of the two layers of chrome and half-tone film. In electron beam writing process after resist coat, the patterns for the half-tone layer are exposed first, and the patterns for the chrome layer are exposed subsequently. In doubly-exposed regions, the resist is fully removed by development, and contact hole patterns are formed after etching. Singly-exposed regions with only the second one, result in half-tone patterns after ashing and subsequent chrome etching. Unexposed regions result in chrome patterns, and function as opaque layer to reduce the light intensity of sidelobes.

3.Result and Discussion

High alignment accuracy(±0.005μm) of chrome patterns with respect to contact holes is achieved in the present mask process. Fig.3 shows the array of contact holes and chrome patterns in the HT-PSM with COSAC. Chrome patterns are placed in the positions where four sidelobes interfere with one another and the light intensity becomes highest.

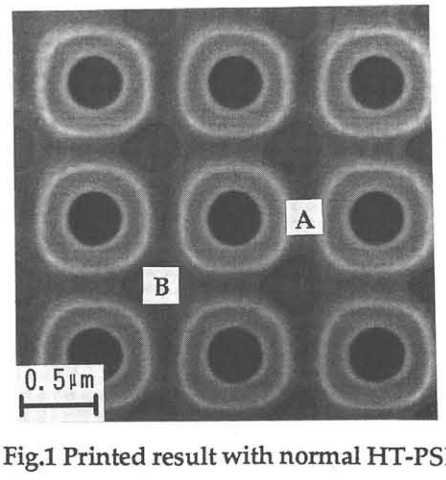


Fig.1 Printed result with normal HT-PSM

Fig.4 shows the cross sectional structure and the optical characteristics of the HT-PSM with COSAC. The light intensity at a wafer is calculated for dense 0.35μm contact holes at 1.0μm pitch with and without COSAC. The square chrome patterns of 0.2μm are placed in the HT-PSM with COSAC, the sidelobe intensity is reduced without decline of contrast on light intensity.

Lithographic performance was estimated on a bare-Si wafer coated with 1μm thick positive resist by using a NA=0.57, σ =0.3 i-line stepper. Both prevention of resist thickness loss and the DOF were estimated with the method in which the arrangement of the chrome patterns and mask bias combine. In this experiment, the DOF in which critical dimension(CD)±10% is achieved without resist thickness loss is defined as 'DOF1', and the DOF in which CD±10% is achieved with one is defined as 'DOF2'. Fig.5 shows CD characteristics and generation of resist thickness loss as a function of defocus and mask bias in the normal HT-PSM. 'A' and 'B' in Fig.5 indicate the positions of resist thickness loss in Fig.1. As mask bias becomes bigger, suitable exposed dosage becomes lower, and the resist thickness loss is prevented in order from where the sidelobe intensity is low. The mask bias in which all the resist thickness loss is prevented is 0.142μm, and then DOF2(=DOF1) decreases to 0.9μm. But the mask bias in which only the position 'A' of resist thickness loss is prevented is 0.120μm, and the DOF2 of 1.5μm is obtained. The HT-PSM with COSAC was estimated by using 0.120μm in mask bias. Fig.6 shows printed result of dense 0.35μm contact hole at 1.0μm pitch in defocus with and without COSAC. The resist thickness loss around contact holes is prevented by COSAC.

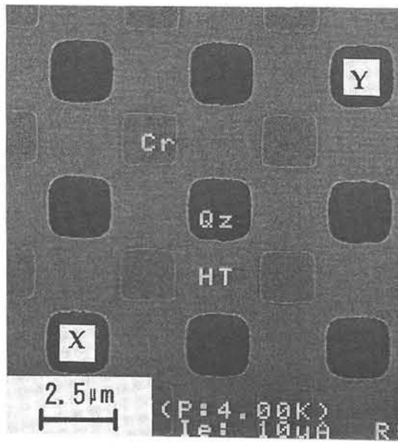


Fig.3 SEM picture of the HT-PSM with COSAC

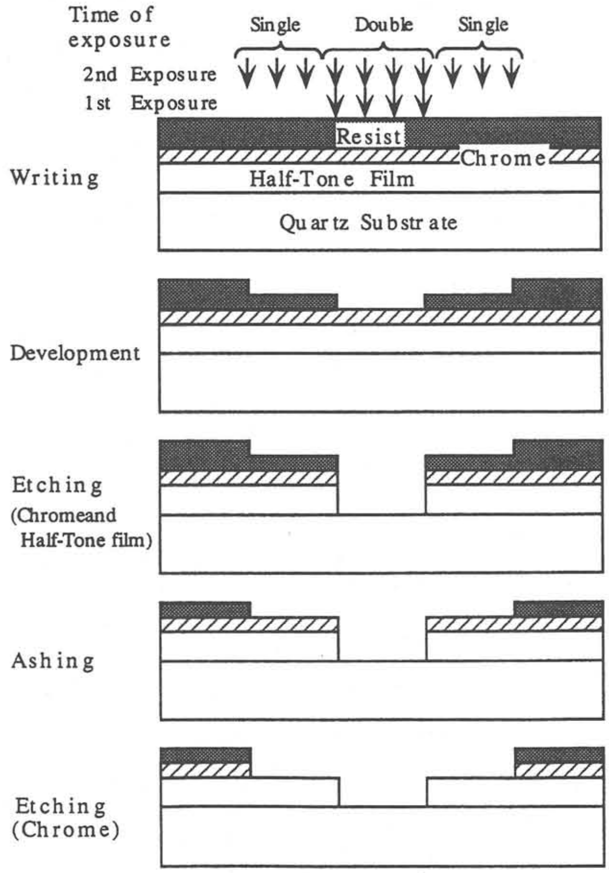
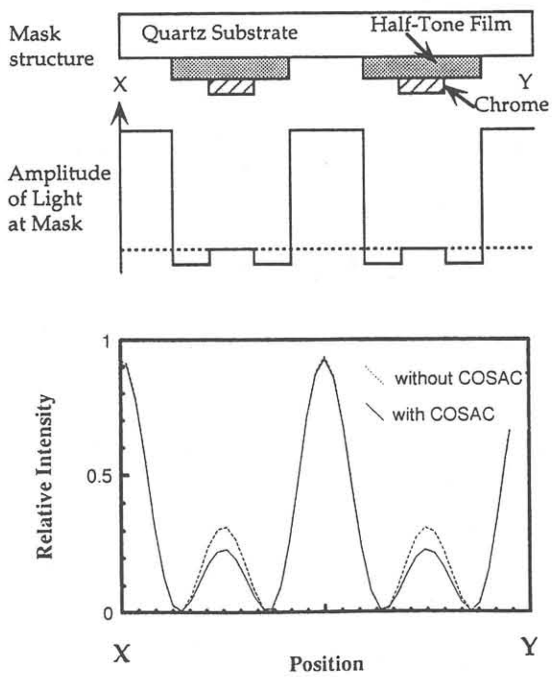


Fig.2 Process flow of the HT-PSM with COSAC



NA 0.57, λ 365nm, σ 0.3
Transmittance 8.0%, Best focus

Fig.4 Cross sectional structure and the optical characteristics of the HT-PSM with COSAC.

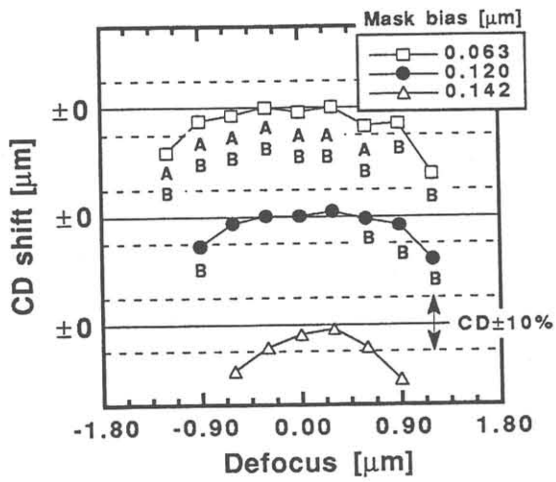


Fig.5 Dependence of DOF and resist thickness loss on mask bias

Fig.7 shows the DOF as a function of the chrome pattern size. The nearer to 0.1μm chrome pattern size approximates, the bigger the effect which reduces the intensity of sidelobe becomes. Consequently, the resist thickness loss which was generated in the position 'B' in defocus is prevented and DOF1 is enhanced. When the chrome pattern size is between 0.10μm and 0.30μm, both the control of sidelobe intensity and the phase-shifting effect are stable. The DOF1, which was 0.9μm in normal HT-PSM, is enhanced to 1.5μm. When the chrome pattern size is more than 0.3μm, the percentage of the area of half-tone region becomes smaller, and the DOF2 is reduced by the decrease of the phase-shifting effect. Further, the peak of the diffracted light due to Fresnel's diffraction at the edge of chrome pattern approaches the position 'A' of the interference between two sidelobes. Consequently, the resist thickness loss is generated in that position and DOF1 is largely reduced. It is possible to control sidelobe intensity, phase-shifting effect and diffracted light at the chrome pattern by changing size and arrangement of chrome pattern in HT-PSM with COSAC.

4.Conclusion

A new HT-PSM with COSAC, which has the two-layer structure of chrome and half-tone films, is successfully developed. With the present technology, high resolution and wide DOF are achieved for dense and closely-spaced(0.65μm) contact holes. The present technology is promising for fabricating quarter micron device and beyond.[3]

Acknowledgement

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(a)

(b)

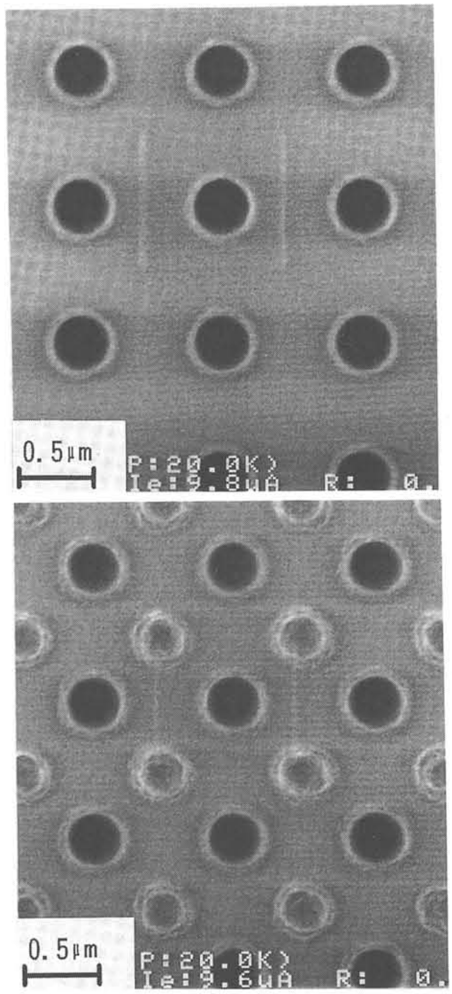
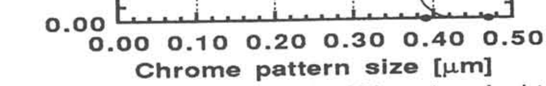


Fig.6 SEM picture of 0.35μm contact holes
(a) Printed result with COSAC
(b) Printed result without COSAC



DOF1 : CD±10% preventing the thickness loss of resist
DOF2 : CD±10%

Fig.7 Dependence of DOF on chrome pattern size in the HT-PSM with COSAC (0.35μm contact holes)

References
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