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CVD Method of Anti-Reflective Layer Film for Excimer Laser Lithography

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A new anti-reflective layer (ARL) film for KrF excimer lasers, which makes the excimer laser lithography applicable to mass production of devices to a tighter design rule than 0.35μm, was developed. The ARL, which is composed of SiOxNy:H, was used to fabricate a 16MSRAM gate structure. The SiOxNy:H film with optimal refractive indices was easily deposited by varying the SiH_4/N_2O ratio as a PECVD parameter. Using the SiOxNy:H film, variations in photoresist absorption was significantly reduced.

1. Introduction

KrF excimer laser lithography has not been applicable to the manufacture of devices requiring a tighter design rule than 0.35μm because when exposure light of ever shorter wavelengths is used to obtain high resolution, reflection from the interface between the photoresist and substrate becomes increasingly stronger. A high-performance anti-reflective layer (ARL) for excimer laser lithography would solve the problem. It has been proposed that a-C:H [1] and SiCx [2] could be adapted to ARL for KrF excimer laser lithography (248nm). However, residual carbon contamination in the gate structure may be a problem, when self-aligning contact with offset oxide film is used, because an ARL is formed between WSix and the offset oxide film. Therefore, we investigated ARLs without carbon, and found that SiOxNy:H film satisfied anti-reflective conditions for KrF excimer laser lithography [3].

In this paper, we describe a method of controlling the refractive indices of SiOxNy:H film by varying the SiH_4/N_2O ratio as a PECVD parameter.

2. Experimental

Figure 1 shows the real (n) and imaginary (k) refractive indices of various materials at 248nm. There are no materials without carbon which satisfy the anti-reflective conditions, but SiOx, SiNx, SiOxNy did satisfy the anti-reflective conditions. The "n" value of SiO_2 and Si_3N_4 is as almost the same as that of Si, and the "k" value of SiO_2, Si_3N_4 and that of Si are very different. Therefore, SiOx, SiNx, SiOxNy may have a value between the refractive indices of Si and SiO_2 or Si_3N_4. We expected that the refractive indices of these materials were be able to be easily varied by changing the composition (x, y). A parallel plate PECVD system with SiH_4/N_2O was used for the SiOxNy:H deposition, because PECVD can vary the composition of SiOxNy:H more widely than thermal CVD.

Film thickness and "n" and "k" were measured by a spectroscopic ellipsometer, and the composition of SiOxNy:H was measured by RBS.

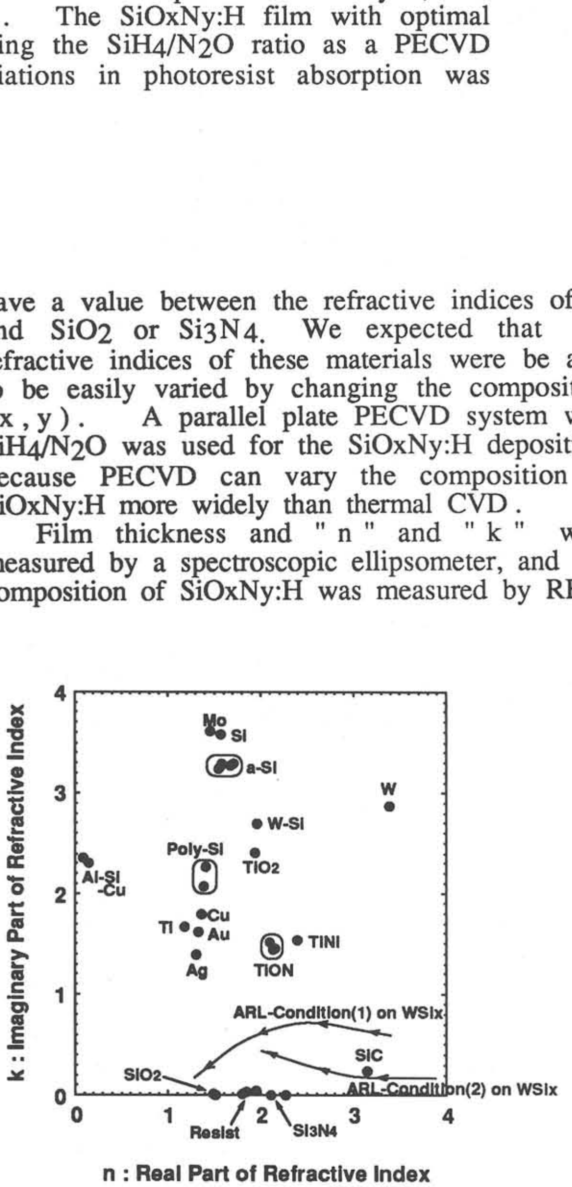

Fig. 1 Refractive indices of Various materials at 248nm. Plotted curves are simulated anti-refractive n and k values on WSix.

3. Results and Discussion

The SiH_4/N_2O ratio was widely varied to control the refractive indices of the SiOxNy:H film. Figure 2 shows the variation of " n " and " k " values at 248nm with SiH_4/N_2O ratio from 0.5 to 2.0 . The SiOxNy:H film was deposited with a higher SiH_4/N_2O ratio than in with conventional PECVD conditions, which caused optical absorption . With an increasing SiH_4/N_2O ratio, the " k " value increases while the " n " value remains almost constant . Figure 1 suggests that the " n " values of a-Si and SiO_2 or Si_3N_4 are almost the same . Consequently, ARL film with the optimal thickness and " k " value can be easily deposited . Figure 3 and 4 show the wavelength dependence of " k " and " n " values, respectively, with variations of SiH_4/N_2O ratio as a parameter . As the wavelength becomes shorter, " k " increases at any SiH_4/N_2O ratio, and the increasing ratio of " k " becomes larger according with an increasing SiH_4/N_2O ratio . In the low SiH_4/N_2O region, " n " increases monotonically with a decreasing wavelength . On the other hand, in the high SiH_4/N_2O ratio region, wavelength dependence of " n " has maximum value . This is the reason " n " at 248nm is less dependent on the SiH_4/N_2O ratio .

We expected that the composition of SiOxNy:H would become Si-rich with an increasing SiH_4/N_2O ratio . We can see in Fig.5 the increase in [Si] and decrease in [O] with an increase in the SiH_4/N_2O ratio, while [N] and [H] is almost constant . The increase of " k " is attributed to the increase in [Si] in the ARL . This is also expected from Fig.1, in which " k " relationship of Si is high, while " k " is zero for SiO_2 and Si_3N_4 .

Figure 6 shows the simulation results of the anti-refractive effect with and without SiOxNy:H film on the gate structure for self-aligning contact which has offset SiO_2 on WSix . The simulation suggest that the optimal ARL conditions are $n = 2.12$, $k = 0.54$, $d = 29nm$. Using SiOxNy:H, it is expected that the variation of photoresist absorption will be reduced from ±21% to ±1% . We applied these simulation results to fabricate a 0.35μm device for 16MSRAM . SiOxNy:H film with optimal optical conditions was obtained by the PECVD with a $SiH_4/N_2O = 1.14$ ratio . Figure 7 shows the photoresist pattern with and without ARL film on the gate structure which has 200nm LOCOS steps and is covered with 170nm offset oxide . A KrF excimer laser stepper, Canon FPA-3000EX1, and a Wako WKR-PT1 chemically amplified positive resist were used . With this ARL film , a gate pattern can be resolved without halation or scum .

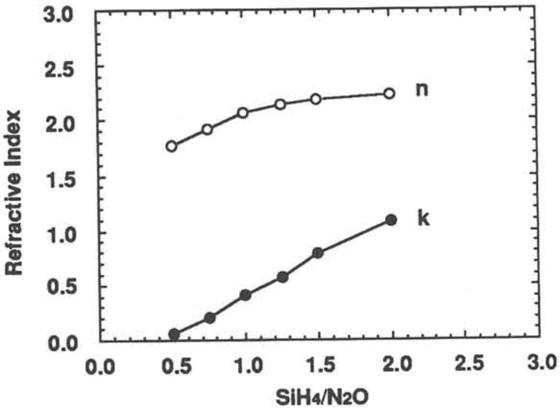

Fig. 2 SiH_4/N_2O ratio dependence of n and k at 248nm .

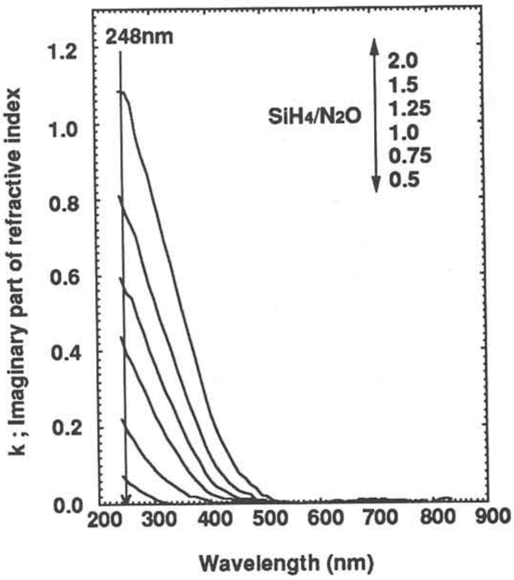

Fig. 3 Wavelength dependence on imaginary part of refractive index (k) .

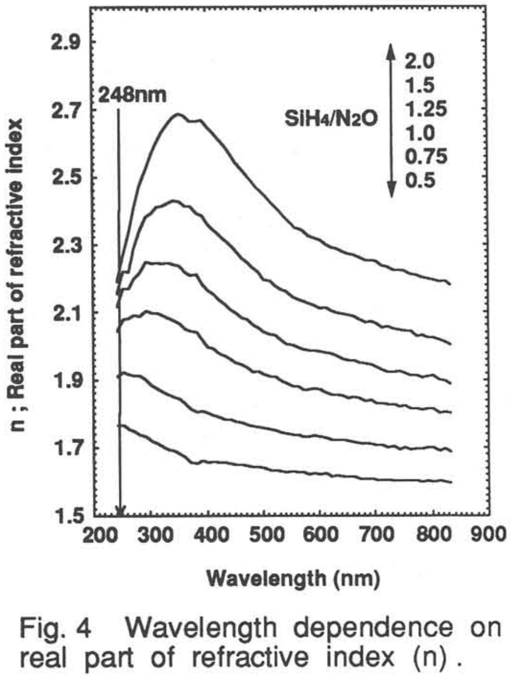

Fig. 4 Wavelength dependence on real part of refractive index (n) .

4. Conclusion

It is clear that the SiOxNy:H is an effective anti-reflective material for KrF excimer laser lithography. Refractive indices of this film can be widely varied with the SiH_4/N_2O ratio in PECVD conditions. This film has a dependence on the SiH_4/N_2O ratio in which " k " is strongly varied by the ratio while " n " remains almost constant. We applied this film to an actual device and found that variations of photoresist absorption were greatly reduced.

5. Acknowledgements

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6. References

1) Y.Suda, T.Motoyama, H.Harada, M.Kanazawa, SPIE, vol.1674, 1992, p350-361
2) T.Ogawa, M.Kimura, Y.Tomo, T.Tsumori, SPIE, vol.1674, 1992, p362-375
3) T.Ogawa, M.Kimura, T.Gocho, Y.Tomo, T.Tsumori, SPIE, 1993, to be published.

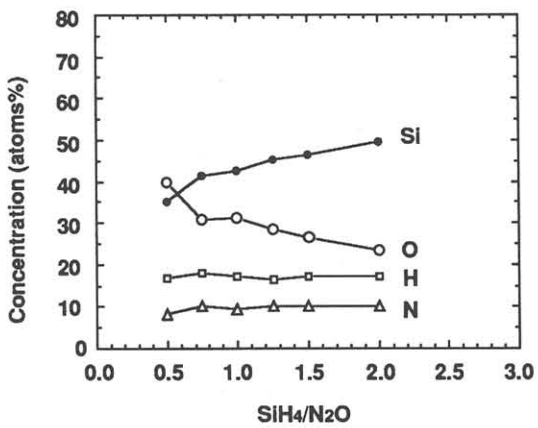


Fig. 5 SiH_4/N_2O ratio dependence on concentration of Si, O, H and N.

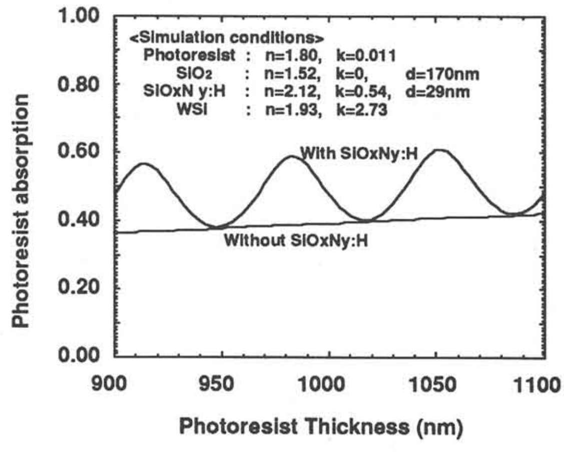
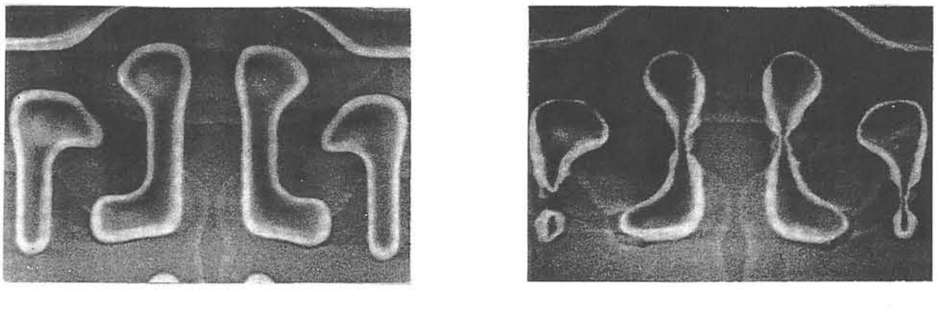


Fig. 6 Simulated photoresist absorption with and without SiOxNy:H for WSix substrate.



(a) ; with SiOxNy:H film

(b) ; without SiOxNy:H film

Fig. 7 Resist pattern on 0.35μm rule 16MSRAM gate structure with SiOxNy:H film (a) and without SiOxNy:H film (b).