Inorganic ARC For Use in Microlithography

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Abstract- **In this study silicon nitride has been seen to be an effective anti-reflective coating for use at wavelengths from 190 to 436nm. The report discusses effects of the film such as index of refraction, extinction coefficient, thickness, and stoichiometric composition for the application of ARC in microlithography.**

I. INTRODUCTION

As advances in microlithography continue into 0.35µm resolution and below; conventional resists, anti-reflective coatings (ARC's), and other methods to obtain high aspect ratios will be needed. With respect to anti-reflective coatings, the traditional organic ARC's may be rendered incompatible with new processes due to narrow cure temperature windows and undercutting during resist development. [1] Therefore, new inorganic ARC's may be needed that simplify the photolithography process and contribute to increases in resolution through elimination of standing wave and notching effects as shown in Fig. 1.

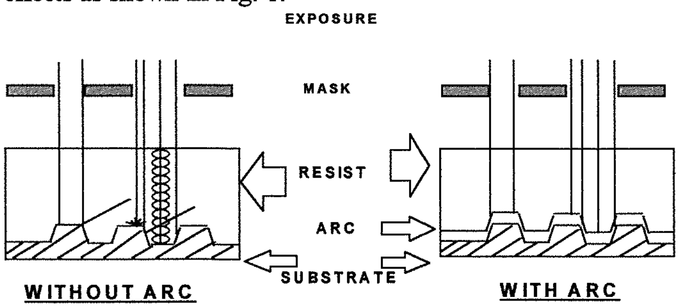

Fig. 1. Diagrams illustrating effects of light reflectance (standing waves, reflective notching, and back scattered light) with and without ARC.[2]

II. PROCESS TECHNOLOGY

Both silicon and titanium nitrides have been investigated for use as anti-reflective coatings. Films of different stoichiometric compositions were deposited on fused silica substrates by reactive sputtering of elemental targets. Thin films of silicon nitride were deposited utilizing a RF sputterer at a power of 500 Watts, a base pressure of 5E-7 Torr, and a sputter pressure of 7mT. Titanium nitride films were deposited by DC sputtering using a CVC 601 sputterer at 390V, a current of 4A, and a base pressure of 7E-6 Torr. Different film compositions were achieved by varying the chamber gas flow of nitrogen in both systems. The film thicknesses ranged from 800 Å to 2000 Å.

The films were characterized for optical properties with a PERKIN-ELMER Lambda 11 UV/Vis Spectrophotometer. Transmission and Reflectance curves were ascertained from a wavelength range of 240 to 900 nm (Figure 1). Further analysis of the curves was accomplished using solutions to the Fresnel equations; which after adjusting for the silica plate, thickness, and other factors, gave the index of refraction (n) and extinction coefficient (k) of the films. Utilizing the films optical properties, we are then able to simulate the films usefulness as an ARC with PROLITH®. This software creates a plot of substrate reflectivity versus film thickness for all imaging wavelengths.

III. RESULTS AND DISCUSSION

A. Silicon Nitride

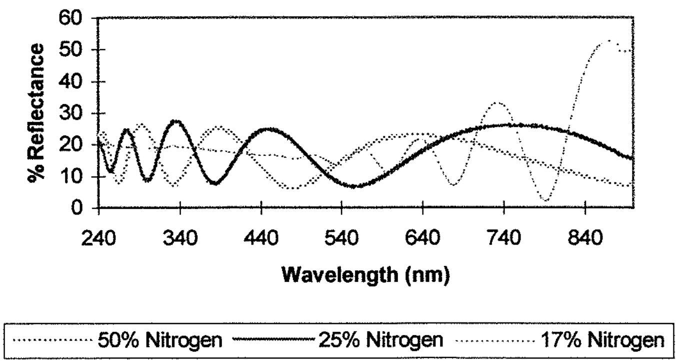

Fig. 2. Reflectance vs. wavelength for silicon nitride films

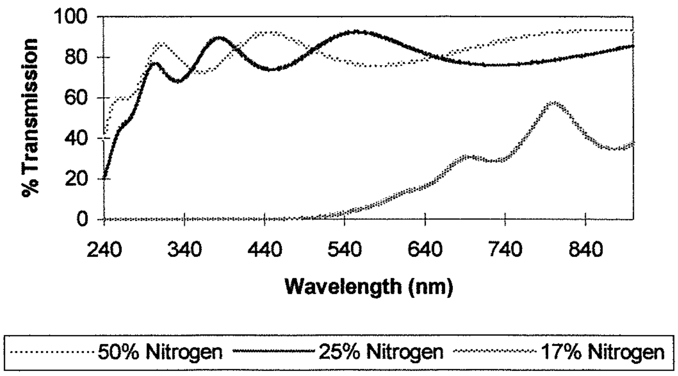

Fig. 3. Transmission vs. wavelength for silicon nitride films

Reviewing Fig. 2 and Fig. 3 for silicon nitride ARC films, It has been found that decreasing the amount of nitrogen in the deposition flow causes both the reflectance and transmittance curves to be shifted towards higher imaging wavelengths.

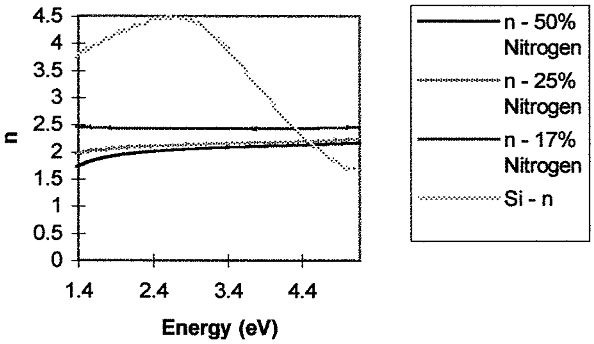

Fig. 4. Index of refraction for silicon nitride films of different sputtering gas compositions

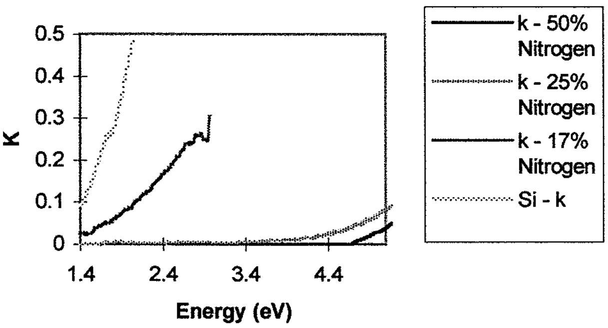

Fig. 5. Extinction coefficient for silicon nitride films of different sputtering gas compositions

Through observation of the optical properties of silicon nitride, the effects of nitrogen depletion are seen. As in Fig. 4., a nitrogen decrease causes the index of refraction to increase toward the value of silicon at imaging wavelengths. This shows that stoichiometric composition of the film is changing and the layer is becoming more silicon rich. Fig. 5. also verifies this result as the k values approach that of silicon with decreases of nitrogen in the sputtering ambient.

Nitrogen Ambient	436nm n	436nm k	405nm n	405nm k	365nm n	365nm k	248nm n	248nm k	193nm n	193nm k
50%	2.05	0.00	2.07	0.00	2.08	0.00	2.16	0.03	2.29	0.31
25%	2.10	0.00	2.10	0.00	2.15	0.00	2.20	0.10	2.30	0.40
17%	2.40	0.30	2.40	0.30	2.40	0.30	2.50	0.25	2.50	0.20

Table 1. Silicon nitride film properties by composition and wavelength (gray areas are acceptable for ARC's.)

Once the index of refraction and the extinction coefficient was obtained, the film usefulness was determined by simulation. As is shown in Table 1, functional anti-reflective coatings were found for imaging wavelengths from 190nm to 436nm (presented in gray.) Revisiting Figs. 2 and 3, reflectance values of ~20% and transmission values of ~0% give the optical properties necessary for the ARC.

Optimum film thickness was also calculated through simulation. As is shown in Table 2, effective film coatings ranged in thickness from 100Å to 590Å for different imaging wavelengths and film compositions.

Nitrogen	436nm	405nm	365nm	248nm	193nm
50%					560
25%				361	590
17%	131, 220	121 200	180, 250	118, 171	172 208

Table 2. Simulated silicon nitride ARC thickness, in Å, over the imaging wavelengths.

To verify the simulation, a silicon nitride ARC was deposited on both silicon and aluminum substrates. A thickness of 260Å was achieved. This sample was measured for reflectance at imaging wavelengths (with the tool calibrated to the reflectance of aluminum.) As illustrated in Fig. 6., the film reduced the reflectivity of both substrates to 3%. The 3% reflectance can be explained by the thickness variation from simulated values. Additionally, it was found that a thickness change of 40Å (17% nitrogen film) was enough to shift the zero reflectance point from 365nm to 436nm.

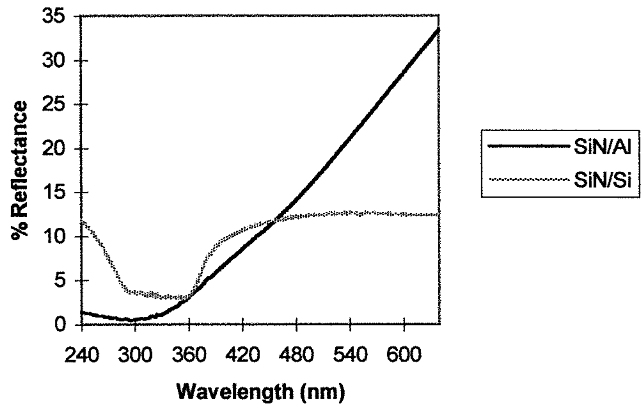

Fig. 6. Silicon nitride (17% nitrogen, 260Å) - reflectivity vs. wavelength on various surfaces

B. Titanium Nitride

Reflectance and transmission curves were obtained for the titanium nitride samples produced by DC sputtering. In opposition to the effect seen in silicon nitride, no predictable shifts occurred in those curves. However, in relation to 248 nanometer measurements, a 17% chamber composition produced a transmission of ~0% and a reflectance of ~21%. As shown in silicon nitride, these are two primary indicators

of a practical ARC. The optical properties were not determined for this film.

IV. SUMMARY

This study has presented a functional inorganic anti-reflective coating for use in microlithography. In addition, It is proved that silicon nitride reduces the reflectance of aluminum and silicon over all current and future imaging wavelengths.

ACKNOWLEDGMENT

This project would not have been possible without the guidance and assistance of B. Smith in determining the optical properties of the materials. In addition, the PERKIN-ELMER spectrophotometer used in this experiment was provided to Rochester Institute of Technology by SRC.

REFERENCES

[1] H. Tompkins, J. Sellers, and C. Tracy, “An inorganic ARC for use in microlithography,” J. Appl. Phys., p.3932, 1993
[2] S. Jones, B. Dudley, D. Koester, C. Peters, and S. Bobbio,"Anti-reflective coating for deep UV lithography process enhancement," Polymer Eng. and Sci., p.1579, 1992