CHARACTERIZATION OF ARC

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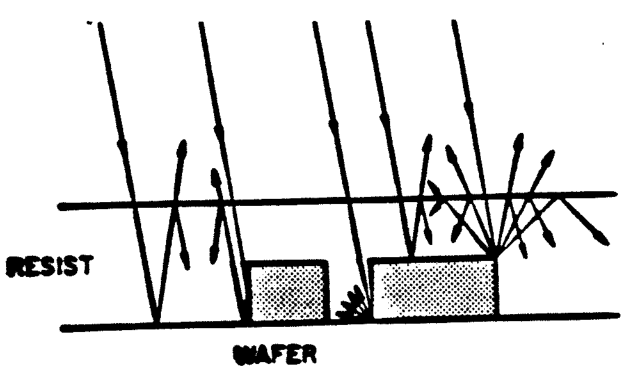
ABSTRACT

Two Anti-reflective coatings (ARC), ARC-XL and ARC-PN2, were studied for process latitude. Temperature bake and exposure dose were varied and their effect on 5.0um line/space pairs was evaluated. Using the software package RS1 a full factorial experiment with centerpoints was designed. The two ARCs used, did reduce notching and the manufacturer's processing ranges were verified. However, to establish the process latitude a wider range of exposure doses needs to be evaluated.

INTRODUCTION

Anti-reflective coatings (ARC) improve the performance of single layer resists with respect to resolution, tolerance, and linewidth control over topography. Also, as geometries become smaller and smaller it becomes important to avoid notching. Notching is usually a result of reflections from topographical features, especially from inside corners as shown in Figure 1a [1]. The interference between incident and reflected exposure light and light scattering from neighboring patterns can lead to differential light absorption across pattern steps [2].



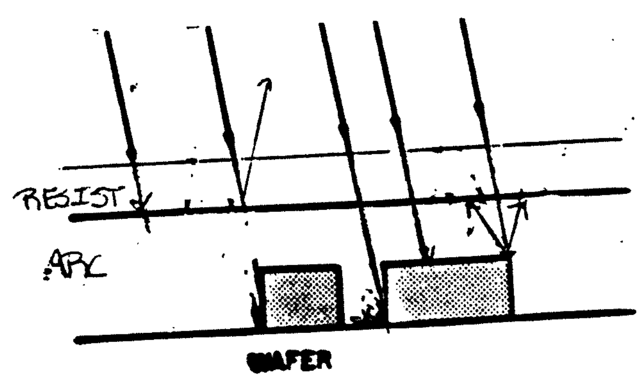


FIGURE 1: (a) without ARC (b) with ARC

ARC has many features that make it part of a viable bilayer process. ARC products have greater adhesion to aluminum substrates than positive photoresists due to their resin structure. ARC is compatible with most major positive photoresists and PMMA planarization layers and is developed in positive resist developer simultaneously with exposed resist. The only additional processing steps are the ARC spin coat and bake.

ARC also has advantages over dyed photoresists. Under certain conditions, dyed resist may be plagued by scumming due to standing waves, whereas ARC eliminates all standing waves [3]. ARC gives a better contrast and does not require a change in the development process. It is also easier to implement and does not require a post-exposure bake.

Experiments were designed to study the ARC under varying bake temperatures and exposure doses. The experiments were designed for both Brewer Science Incorporated's ARC-XL and ARC-PN2. Both ARC-XL and ARC-PN2 were formulated to do the same thing. However, ARC-PN2 has a larger process latitude in the bake temperature and to give better development properties in deep channels. ARC-XL is the latest formulation from Brewer Science, Inc. ARC-XL has an increased absorbance and a greater shelf life than previous ARCs. This increased absorbance allows for processing in the mid-UV to deep-UV exposure regions and thus allows for better resolution.

EXPERIMENTAL DESIGN

An experiment was designed on RS1 using a full-factorial design that includes centerpoints. The full factorial design with center points requires relatively few runs per factor studied and it is easy to analyze. The design is based on an interaction model, which includes the effects of the variables independently, and together. The design allows for two runs to be replicated, to determine the variability of the experiment and its validity.

When using ARC it is the bake temperature and the exposure dose that are most critical to the process [2]. The bake temperature and exposure dose for the ARC were varied within the manufacturer's ranges in order to study process latitudes. Some secondary factors, such as, humidity and temperature of cleanroom were not directly incorporated into the design, but were monitored during processing. Development time and temperature were kept constant. The 5.0um line/space pairs were used for evaluation on wafers with and without ARC, since 5.0um geometries for IC fabrication is being developed at RIT. The response, latitude, will be in terms of a number; 1, 2, or 3 for undercutting, "normal", and scumming results. The two experiments are given in Tables 1 and 2.

TABLE 1: EXPERIMENT FOR ARC-PN2

WAFER ID	BAKE TEMPERATURE (C)	EXPOSURE DOSE (mJ/cm2)
ARC1	168.0	85
ARC2	174.0	95
ARC3	162.0	75
ARC4	168.0	85
ARC5	162.0	95
ARC6	168.0	85
ARC7	174.0	75

TABLE 2: EXPERIMENT FOR ARC-XL

WAFER ID	BAKE TEMPERATURE (C)	EXPOSURE DOSE (mJ/cm2)
ARC8	170.0	85
ARC9	145.0	85
ARC10	170.0	65
ARC11	158.0	75
ARC12	145.0	65
ARC13	158.0	75
ARC14	158.0	75

In a process with KTI 820 positive resist applied with a spin speed of 5000 rpm the base dose is usually 55 mJ/cm2. Without the ARC, the reflected light from the substrate is partially responsible for the exposure. With ARC there is a greater absorbance of the energy and this needs to be compensated for by increasing the base dose.

For the exposure process, the RIT ETM mask was used. The ETM mask is a mask used by RIT in lithography courses, and contains a series of line/space pairs, and test targets which can be used for evaluating focus and resolution.

The wafers were cleaned and oxide was grown to obtain a thickness of 5000 A. To pattern the SiO2, the wafers were coated with HMDS and KTI 820 positive photoresist using the hand-spinners. The wafers were baked, exposed, and developed. The wafers were etched in buffered, ashed in the Plasmaline and cleaned. Aluminum was evaporated onto the wafers using the CVC evaporator.

The control wafers, those without the treatment of ARC, were coated on the Wafertrac, using an inhibited scrub and no HMDS. The wafers were exposed and aligned on the Kasper Aligner. The wafers were developed on the Wafertrac using KTI 934 developer in a 1:1 dilution and were then etched in aluminum etch heated to 40C. The wafers were then ashed in the Plasmaline.

Wafers ARC1 through ARC14 were processed according to the experiment designed by RS1. The ARC was coated on the hand-spinners for 60 seconds at 5000 rpm. The wafers were then individually baked on the CEE electric hotplate for one minute at the temperature specified. The wafers were coated with photoresist on the Wafertrac, without a scrub nor HMDS prime. All the wafers were exposed on the Kasper aligner at the dose specified by RS1 and then developed. The wafers were etched in aluminum etch heated to 40C. Finally, the photoresist was stripped using the Plasmaline. The 5um line/space pair was examined and measured using the stage micrometer.

RESULTS/DISCUSSION

In examining the results it is apparent that many of the line/space pairs do not total 10.0um, since the user's judgment is required when reading the stage micrometer. The results for ARC-PN2 are shown in Table 3. It appears that the best equal line/space pairs were obtained at a bake temperature of 162C and an exposure dose of 75 mJ/cm2.

TABLE 3: EXPERIMENT FOR ARC-PN2

WAFER ID	BAKE TEMP(C)	DOSE(mJ/cm2)	LINE/SPACE(um)	STAND DEV (um)
ARC1	168.0	85	3.96/7.62	0.386/0.373
ARC2	174.0	95	3.05/5.08	0.254/0.285
ARC3	162.0	75	4.22/5.58	0.340/0.332
ARC4	168.0	85	3.66/7.11	0.495/0.505
ARC5	162.0	95	3.56/5.46	0.439/0.427
ARC6	168.0	85	3.20/6.09	0.340/0.382
ARC7	174.0	75	3.10/5.84	0.417/0.400

The ARC-XL results are given in Table 4. ARC-XL gave the best equal line/space pair at a bake temperature and exposure dose of 145C and 85 mJ/cm2, respectively.

TABLE 4: EXPERIMENT FOR ARC-XL

WAFER ID	BAKE TEMP(C)	DOSE(mJ/cm2)	LINE/SPACE(um)	STAND DEV(um)
ARC8	170.0	85	3.30/5.58	0.597/0.623
ARC9	145.0	85	3.64/5.08	0.227/0.223
ARC10	170.0	65	3.05/4.57	0.358/0.364
ARC11	158.0	75	3.35/6.35	0.455/0.501
ARC12	145.0	65	3.20/4.06	0.663/0.636
ARC13	158.0	75	3.05/7.37	0.312/0.348
ARC14	158.0	75	3.10/7.37	0.300/0.336

From examining the replicated runs, the experiment for ARC-XL had better reproducibility than the experiment for ARC-PN2. In measuring the line/space pair of 5.0um it was

apparent that the spaces, for both ARCs, were bigger than the lines. There did not appear to be any scumming nor undercutting. This did verify the manufacturer's ranges, however, there were no results to enter into RS1. The procedure that should have been undertaken was to start at extreme exposures and work inwards towards the manufacturer's guidelines. This would have produced process latitude charts and allowed RS1 to predict what would happen at bake temperatures and exposure doses not tested.

At the larger linewidths in the wafers without ARC, the lines did not appear to have an scumming nor undercutting. However, at the smaller linewidths, there was not enough exposure in the valleys and too much exposure in the peaks. This is the result of notching.

CONCLUSIONS

Anti-reflective coatings, ARC-XL and ARC-PN2, were studied and compared as a means of controlling reflection and standing wave effects within a positive photoresist. ARC helped to improve the performance of KTI 820 by preventing notching in the metal lines over the topography. The manufacturer's ranges for bake temperature and exposure dose were verified.

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