The Effectiveness of sub 50 nm Filtration on Reduced Defectivity in Advance Lithography Applications

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Abstract

Defectivity in the lithography area has become more critical to maintain the competitive edge for semiconductor manufacturers. Improved detection capabilities of metrology instrumentation, increased wafer sizes, newer chemistries and shrinking geometries have all contributed to the complexity of this problem. The adoption of sub 0.05 µm hydrophilic filters can play a significant role in reducing these defectivity issues.

High defectivity issues have complicated the implementation of 193 nm lithography on a production scale. These issues have forced process and lithography engineers to focus their efforts on chemical filtration instead of process development. Post etch defects have complicated the effort to reduce this problem. The implementation of filtration below 50 nm with existing dispense systems raises concerns as the filter's pore size at such fine filtration ratings approaches the size of large molecular weight components of the photoresist. This paper provides a fundamental understanding of how implementation of sub 50nm filtration, can positively reduce defectivity in BARC, and 193nm chemistries.

The work concludes that the implementation of finer filtration did not negatively impact the chemistry's functionality. Rather, significant defectivity improvements were observed. In addition, installing finer filtration in small capsule configurations did not adversely affect pump performance.

Introduction

The trend toward more complex and narrower line-width circuitry has put an increasing burden on contamination control in every aspect of the Microlithography process. Each step introduces the possibility of deleterious particulate contamination, micro bubbles, void defects, and metallic contamination on the wafer surface. Removal of particles that are smaller than the feature size is imperative to prevent circuit failure.

The utilization of 193nm lithography has enabled the production of advanced memory and logic devices with feature sizes of 100 nm and below. The photoresists designed for use at these wavelengths operate on complex pH based chemical amplification chemistry, which can be extremely sensitive to external influences. Complicating matters further, line edge roughness makes defect inspection difficult. Bottom anti-reflective coatings also offer their own set of complications. Resist / BARC interaction can be blamed for some defectivity. Micro mask defects which can only be detected after etching the wafer may be blamed on the etch process and not attributed to the photolithography step.

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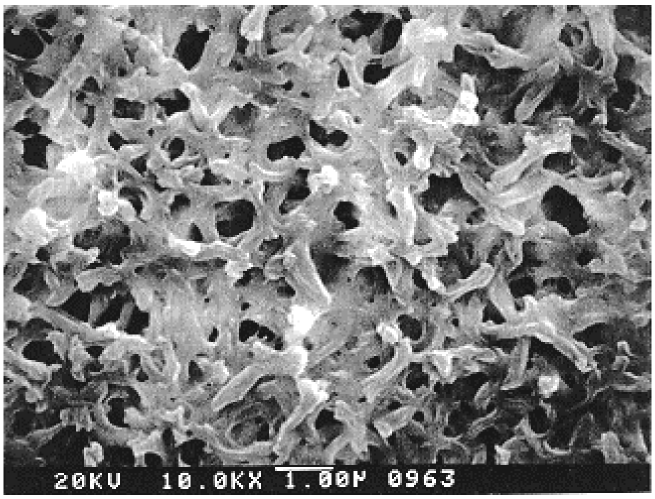
Current filtration technologies are typically composed of hydrophobic media at the 0.05 µm filtration level. With the implementation of finer filtration several concerns arise, including polymer shear, stripping of large molecular weight components, increased differential pressure, and reduction in service life of the filter. Prior studies have shown the finer filtration does not have deleterious effects on resist performance (1). Complicating matters, newer pump technology designed to reduce filter hold up volume and filter purge time has adopted capsules with less filter area than previous technologies. This further complicates the concern about differential pressure and life expectancy.

Filter Construction

The filters evaluated are constructed with a pleated membrane, with appropriately designed support and drainage layers. The support material, utilized upstream and downstream of the membrane, provides support and venting for the filter membrane, and improves flow characteristics. Hardware materials, including cage, core, and end caps, provide a rigid structure to facilitate handling. The testing includes filters with membranes constructed of nylon 6,6. These membranes are isotropic, providing a dense, high voids volume, uniform filtration structure. Such a structure provides consistent particle removal, and high removal efficiency. Figure 1 illustrates a typical nylon 6,6 membrane. Hardware and support materials are all high density polyethylene, HDPE.

Figure 1: Nylon 6,6 filtration membrane



193nm Chemistries

With the adoption of acrylate based 193nm photoresists, there have been widespread incidences of micro-bridge trench defects. These defects have been observed in different formulations from different manufacturers. These resists, which utilize chemical amplification to greatly enhance photosensitivity, are based on a deblocking reaction catalyzed by photogenerated acid in exposed areas. This results in a solubility difference between the exposed and unexposed regions of the photoresist.

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The various functional groups joined on to the acrylic polymer backbone, which provide etch resistance, acid decomposition, adhesion promotion and hydrophilicity, seem to contribute to this defectivity. The nylon 6, 6 membrane filtration materials chosen for this installation have demonstrated effective reduction in these defects by removal of low solubility oligomers of non-functioning polymer components. It is hypothesized that an affinity for these undesired materials is effecting the improvements. Because a high voids, high surface, dense nylon 6,6, structure has been shown to have an affinity for these low solubility components of the resist, a 0.04 µm rated filter was chosen to address this defect.

Figure 2 illustrates typical trench bridging defects.

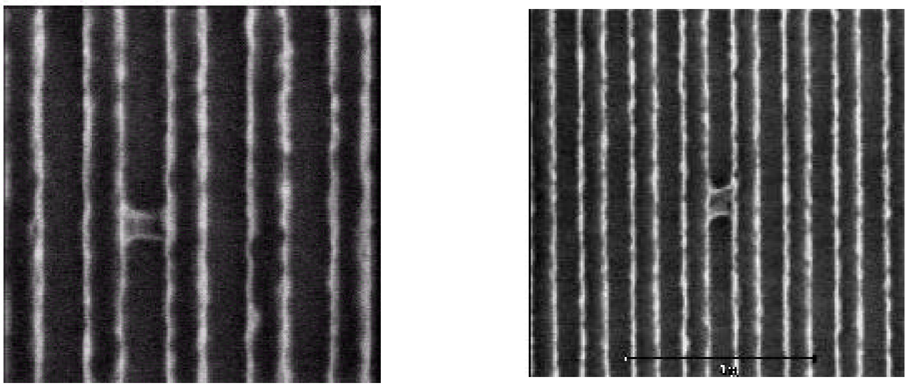

Figure 2: Typical trench bridging defect

BARC Chemistries

Bottom Anti-Reflective Coatings (BARC) are organic polymer films or Inorganic films (IARC) with absorptivities and refractive indexes that match the photoresist film at the wavelength employed. Organic films are spun onto the wafer to suppress reflections from the substrate.

A source of early failure rate (EFR) failures can be from cone defects seen at the Cobalt Silicide (CoSi) step. These defects are seen on the Organic BARC process. These defects have also been seen on the hard mask or IBARC process technologies. These defects are spires of small blocked poly etch that are typically less than 0.1um, and evade detection at Gate poly etch inspection. It takes subsequent processing from the sidewall nitride deposition and CoSi formation to decorate these small spires to make them visible to the scan tool, and to also give them their characteristic appearance; aka a "cone". During the course of investigating these defects, we have found several ways to modulate their levels. Different factors that affect their number are filter type, frequency of filter change, resist batch etc. This paper discusses ongoing projects to understand and detect the root cause(s) and/or event(s) that cause these defects.
As the defect originated from etch leaving 500A spires of poly, the initial defect from the BARC materials was assumed to be extremely small so a filter of comparable pore size

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was selected. Therefore, for this installation a 0.02 µm rated nylon 6,6 filter was used. Since the cause of these defects is extremely small, and exists pre etch, a removal rating utilizing such fine pores is required in order to remove defects sufficiently small to capture the pre etch defect before it can act as a micro mask forming the cone shaped signature.

A typical cone defect is shown below in Figure 3.

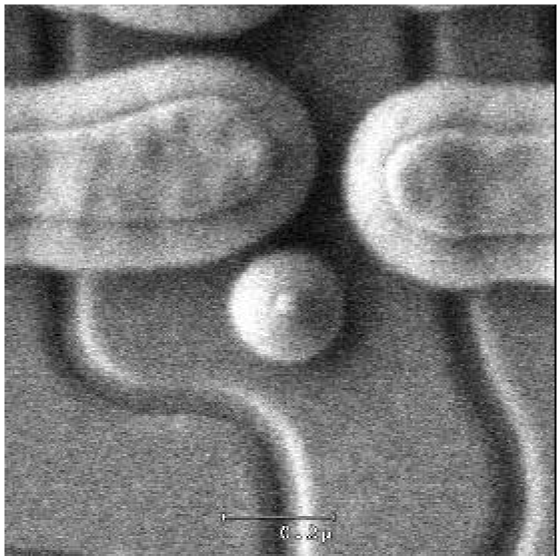

Figure 3: Typical cone defect.

Risk Assessment

As these filters were to be installed into a production tool, a risk assessment was performed to weight and understand the overall risks.   The risk associated with switching to the nylon 6,6 filtration material was assessed based upon the following criteria. Currently the nylon 6,6 filter material was used in other fabs for similar processes even though the hold up and filter area for the newer installation would be smaller. This risk was also considered low, as small hold up volume and lower filter area capsules were already in use in production.

Discussion of Results

After installation of the nylon 6,6 filter in the 193 nm resist dispense pump, the defect levels dramatically decreased. As can be seen in Figure 4, defects were variable utilizing the standard 0.05 µm filter. However, after installation of the nylon 6,6 filter, defect levels were not only reduced, but also were consistent (right side of data plot).

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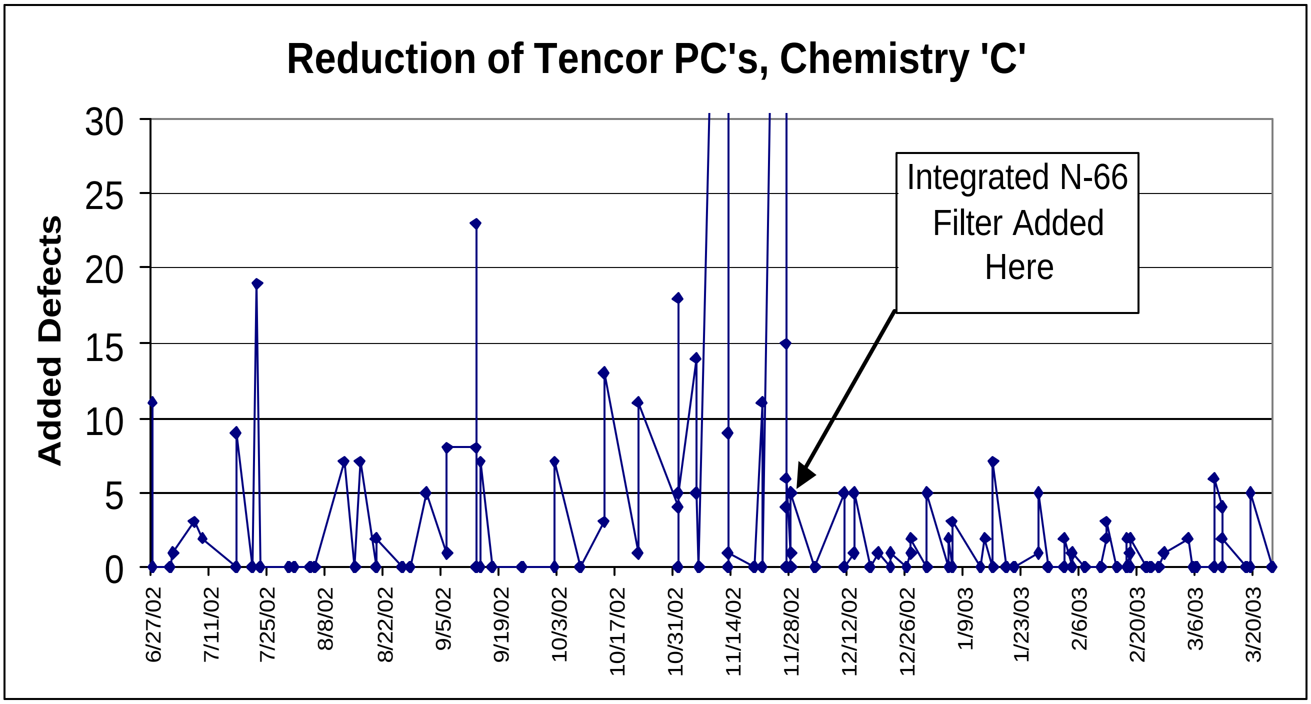

Figure 4: Defectivity pre and post 0.04 µm nylon 6,6 filter utilization in 193 nm resist

Figure 5 lists the mean PC's utilizing the nylon 6,6, filters in the 193 nm resist and BARC versus the standard 0.05 µm filters. The figure also includes data for DUV chemistry. In all cases, use of the nylon 6,6 filters greatly improves defectivity in the production environment.

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BARC					
STAT	DELTA	CHEMISTRY	N-66	PE	
MEAN PC'S	0.54	Z	1.99	2.53	
STD DEV	0.65	Z	2.81	3.46	
MEAN PC'S	0.29	S	0.00	0.29	
STD DEV	0.67	S	0.00	0.67	
MEAN PC'S	6.53	G	1.19	7.72	
STD DEV	11.48	G	2.27	13.75	
ARF Resist Chemistry					
STAT	DELTA	CHEMISTRY	N-66	PE	
MEAN PC'S	3.12	ALL	3.32	6.44	* OUTLIERS REMOVED
STD DEV	3.62	ALL	4.69	8.31	
MEAN PC'S	1.54	ALL	8.19	9.73	* OUTLIERS INCLUDED
STD DEV	3.48	ALL	22.63	26.11	
KRF Resist Chemistry					
STAT	DELTA	CHEMISTRY	N-66	PE	
MEAN PC'S	0.62	ALL	0.27	0.90	* OUTLIERS REMOVED
STD DEV	1.14	ALL	0.69	1.82	
MEAN PC'S	4.47	ALL	1.71	6.18	* OUTLIERS INCLUDED
STD DEV	48.34	ALL	6.27	54.61	

Figure 5: Defectivity reduction with filter change (>3000 Data Points)

Summary

This study concludes that the resist and BARC performance did not change with increasingly finer filter ratings utilized in 193 nm resist and BARC chemistries. This indicates that, using existing dispense systems, photoresists can be filtered below the 0.05 µm standard, without polymer shearing or the unintentional removal of requisite components in the resist. In addition, the reduction of micro bridge defects from 193 nm resists and cone defects from BARC chemistries can be achieved with the adoption of sub 0.05 µm filtration. Based on these data, appropriate protection in terms of particle removal is possible as line widths necessitate the use of fine filters in resist and BARC dispense pumps

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References

(1) B. Gotlinsky, J. Beach, M. Mesawich, “Measuring the Effects of Sub 0.1 µm Filtration on 248 nm Photoresist Performance”, SPIE Microlithography, 3999-138, March 2000.

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