EFFECT OF ADVANCED 5 NM IMPACT DUO FILTRATION ON 32 NM ELECTRICAL YIELD

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Introduction

The continuing reduction of critical dimensions in advanced lithographic processing puts greater importance on the reduction of defectivity. The use of complex, multiple imaging layers, anti-reflective coatings, photoresists, topcoats, etc. in state-of-the-art ArF immersion lithography dramatically increases not only the probability, but the degree to which defects can affect the final product yield.

Of major concern are microbridging and cone defects, which are particularly damaging, as they do not generally become apparent until after successive processing steps have been performed. The removal of the contaminants which cause microbridging defects often requires advanced filtration beyond simple size exclusion, sieving mechanisms.

To meet the increasing demands for continuous defect reduction, filtration options include reducing pore size or introducing alternative media types. Entegris has developed a single point-of-use (POU) filter that addresses both of these requirements, the Impact® Duo.

Filter Membrane for POU Filters

The POU filter is the last opportunity in the lithographic process to remove potentially damaging contaminants from the photochemical stream. The POU filter should have the following characteristics:

- Spontaneous wetting by the photochemical
- Excellent priming and venting properties
- Good particle retention capability
- High liquid flow rate with low pressure drop
- Chemical compatibility between the membrane and photochemical
- Low extractables and good cleanliness

Two membrane materials are generally used for POU filtration with photochemical materials: ultra-high molecular weight polyethylene (UPE) and polyamide (nylon). These filter media exhibit dramatically different retention methods. Particle removal with UPE is generally achieved via a sieving mechanism, that is, through size exclusion within the membrane. Polyamide is a much more polar media and exhibits a higher degree of non-sieving or adsorptive removal than comparable UPE membrane.

Each of these materials has advantages and disadvantages associated with it. While the UPE generally has a tighter pore structure capable of removing very small particles, UPE is not universally capable of removing the polar components of photoresists thought to cause microbridging. In these cases, polyamide, which is generally a more open structure, has greater nonsieving capability, enabling it to often capture polar species thought to lead to the microbridging defect. The Impact Duo filter system uses both of these media in order to take advantage of the specific retention capabilities of each.

Electrical Yield Performance

The performance of the Impact Duo filter was evaluated at a North American semiconductor manufacturer under production conditions. The customer compared an Impact V2 20 nm UPE and an Impact Duo 5 nm filter on parallel dispense points on a single integrated TEL® Lithius coat track and ASML® 1900i scanner system. Over a six-week time frame, 100 wafers were processed across four thin wire metal levels through both filtration paths.

Successful yield monitoring was performed utilizing the PDF Solutions Characterization Vehicle® (CV®) electrical test chip[1] to accurately measure specific test sites that are designed to monitor defects of interest. In this case, the customer was interested in all failures measured in the back-end-of-line (BEOL) stack, as well as single line opens (SLO) and multiple line opens (MLO). This approach is different from the standard optical inspection approach, whereby defects of interest are detected by a metrology tool and are classified by a user.

While the routine metrology technique is of use to determine the appearance of a defect, the defects in current 32 nm processing and below have become too small for abundant detection. By instead utilizing a focused test site, engineers can accurately determine the electrical yield effect of process changes instead of relying on a sample of defects that have been detected and imaged.

In this study statistical analyses of yield data showed an overall reduction in defectivity of 27% with the Impact Duo filter. This is shown below in Figure 1.

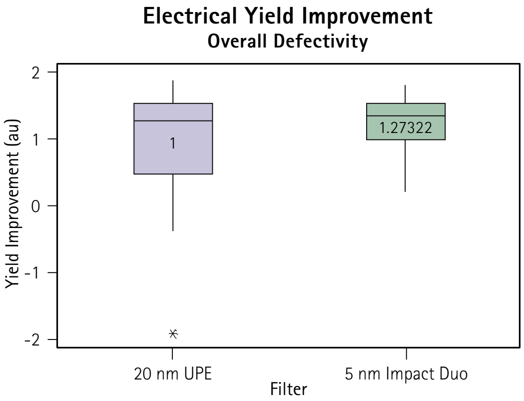

Figure 1: Overall electrical yield improvement of 27% when switching from 20 nm UPE to 5 nm Impact Duo POU filtration.

Figure 2 shows a 15% improvement in single line opens, which are attributed to the microbridging defect.

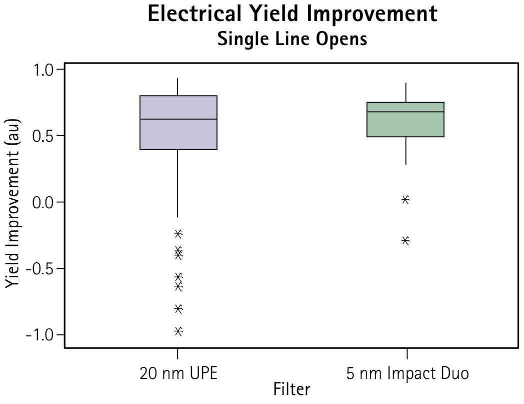

Figure 2: Single line open electrical yield improvement of 15% and reduction in outliers when switching from 20 nm UPE to 5 nm Impact Duo POU filtration.

In order to better quantify the effect of a 27% electrical yield improvement, consider the following example. Assume a 200 mm² die on 300 mm wafers running at 150 wafers per hour. Using the equation:

$$DPW = d\pi\,(d/4S - 1/2^{1/2}S)$$

where: d = wafer diameter (mm)
S = die size (mm²)

a value of 350 die per wafer (DPW) is obtained, resulting in a total production of 52500 die per hour for this process. If an overall yield of 90% is assumed, then a 27% improvement would yield 1417 additional die per hour for an overall yield of 92.7%.

Conclusion

The Impact Duo filter, which contains both nonsieving and sieving layers, showed significant reduction of microbridging defects, shown as single line opens during electrical yield testing. Future testing will investigate the effects of various properties of the Impact Duo filter, including pore size, membrane thickness and membrane morphology.

References

1. Yang, Tanya; Lee, Hun Chow; Lim, Victor; Fang, Hong Gn; Mardiyono, Tri; Wang, Qionghan; Li, Fei; Sa, Zhao; Anand, Inani,; Nguyen, Phan, "A System to Optimize Inline Defect Detection Using Short Loop Test Chips Leading to Faster Yield Learning," *Advanced Semiconductor Manufacturing Conference,* 2011.

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