Deposition Process for EUV Mask Blanks

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Junichi Kageyama[1], Vibhu Jindal[2], Patrick Kearney[2], Frank Goodwin[2]

[1] AGC Electronics America, Inc., [2] SEMATECH, Inc.

1. INTRODUCTION

1-1. Motivation

- The mask blank defectivity is one of the most crucial issues hindering adoption of Extreme Ultraviolet (EUV) lithography.
- In order to minimize defects from the multilayer deposition process several potential particulate sources from within the tool (e.g. shield) are being investigated.
- In this paper the relationship between the average surface roughness of the shield and the counts of Si family (Si and Si/Mo) defects is discussed.

1-2. EUV mask blanks structure and defect breakdown

- The blank consists of Si/Mo multilayer which is deposited on a polished substrate by an ion beam sputtering. Si, Si/Mo, AlOx and AlOx + Stainless Steel are dominant defects related to deposition process.

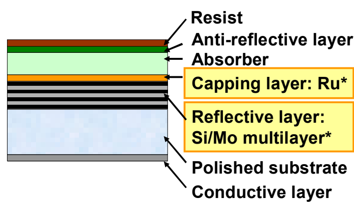

Fig.1 EUV mask blanks structure
* Discussed in this paper

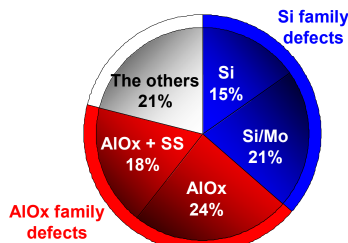

Fig.2 Defect pareto @ M1350 pixel10+/blank

2. EXPERIMENTAL

2-1. Deposition tool

- Si/Mo multilayer with Ru cap is produced in an ion beam sputtering tool, Veeco Instruments' Nexus LDD, at Sematech in Albany, NY.
- The inside wall of deposition chamber is covered by shields to prevent film deposition. The surface of the shields are critical to preventing particle from coming off and depositing onto the substrate.

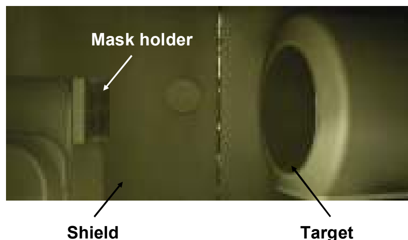

Fig.3 Deposition tool

2-2. Shield treatment

- Shields around the substrate and a part of shields around the target were defined as zone1. The rest of shields were defined as zone2.
- Various shield treatments and cleans were studied for the shields of each of the zones. To estimate average surface roughness Ra_{av}, the weighting factor of zone1 was assumed as 5%, that of zone2 was assumed as 95%. Then, the average surface roughness of the shield, Ra_{av}, is calculated as shown below.

$$Ra_{av} = Ra_1 \times 0.05 + Ra_2 \times 0.95$$

Tab.1 Average surface roughness of shield, Ra_{av}

Expt.	Zone1			Zone2			Ra_{av}
#	Treatment	Ra_1 (um)	Weight	Treatment	Ra_2 (um)	Weight	(um)
1	A	3.1	5%	A	3.1	95%	3.1
2	B	4.6		B	4.6		4.6
3	C	7.4		C	7.4		7.4
4	D	19.0		A	3.1		3.9
5	E	19.9		B	4.6		5.3
6	E	19.9		C	7.4		8.1

2-3. Failure analysis procedure

- A lot of mask blanks were deposited at the same deposition condition and the same shield treatment. All mask blanks were inspected by Lasertec's M1350.
- Many mask blanks were sampled for failure analysis from the above blanks.
- All defects of pixel 10 and above at M1350 (>100nm) were analyzed at FIB/SEM, FEI's Altula 835, and EDX, Oxford Instruments' INCA mics/x-stream//SEM Si(Li)).

3. RESULTS AND DISCUSSION

3-1. Counts of Si family defects vs Ra_{av}

- The relationship between the average surface roughness of the shield and the counts of Si family (Si and Si/Mo) defects was investigated.
- The empirical equation explaining these relationship well was obtained. It indicates that at least 8um Ra_{av} is required for 2 Si family defects/blank or less.
- Using the above knowledge, we continued the optimization of shield treatment.

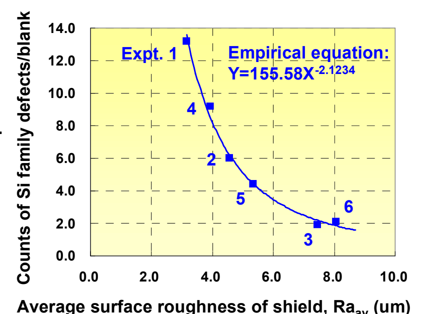

Fig.4 Counts of Si family defects vs Ra_{av}

3-2. Champion data

- As a result of the optimization of shield treatment, following champion data was updated (Inspection area: 142mm × 142mm, substrate material: quartz).

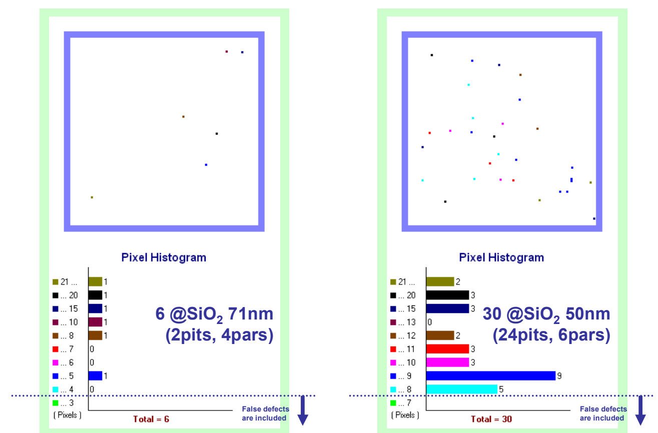

Fig. 5(a) Champion data @M1350

Fig. 5(b) Champion data @M7360

4. CONCLUSIONS

- The relationship between the average surface roughness of the shield and the counts of Si family (Si and Si/Mo) defects has been investigated.
  - Empirical equation has been obtained. It can expect the counts of Si family defects of mask blanks.
  - At least 8um Ra_{av} is required for 2 Si family defects/blank or less.
- After the shield treatment was optimized, the champion data have been updated as follows.
  - Total 6 defects @M1350 pixel 4+ (SiO_2 71nm)
  - Total 30 defects @M7360 pixel 8+ (SiO_2 50nm)