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High Overlay Tolerance for Half-Micron Photolithography Using Heterodyne Holographic Wafer Alignment

K.Yamashita, and N.Nomura

Semiconductor Research Center, Matsushita Electric Industrial Co., Ltd.
3-15,Yagumo-Nakamachi, Moriguchi, Osaka 570, Japan

A new method to evaluate the non-uniform resist coating was proposed using Heterodyne Holographic Wafer Alignment. In this method, the resist coating non-uniformity is measured as the displacement of the alignment position after resist coating on DUV hardened resist alignment gratings. It has been confirmed that overlay accuracy was improved to 59nm/3σ after optimizing the resist coating. The overlay tolerance was investigated by analyzing overlay error budgets and overlay accuracy for processed wafers has been confirmed to be within 80nm/3σ.

Introduction

The requirement to achieve high overlay tolerance in half-micron photolithography is to overcome three problems such as non-uniform resist coating, mark deformation and surface roughness. By these problems, the overlay accuracy in conventional alignment methods was degraded below 0.25μm/3σ for processed wafers[1].

Interferometric alignment such as Heterodyne Holographic Wafer Alignment (HHWA) is considered to be one of the breakthroughs for 0.5μm photolithography because of its high response repeatability and the reliability[2]. It has the advantage of the surface roughness averaging that the overlay accuracy does not depend on the surface roughness[3]. On the other hand, the effects of non-uniform resist coating on overlay accuracy has not been studied in detail.

In this report, a new method to evaluate the non-uniformity of resist coating using HHWA was proposed to optimize the resist coating method (ENRICH), and the effects of non-uniform resist coating on overlay accuracy has been studied. It has been confirmed that HHWA can detect and correct wafer scaling due to non-uniform Al deposition. Also, high overlay tolerance for half-micron photolithography was obtained using ENRICH in HHWA.

Nonuniformity measurement of resist coating

The resist coating non-uniformity is measured as the displacement of the alignment position after resist coating on DUV hardened resist using HHWA. HHWA employs two interfering light rays and can detect the non-uniformity of resist coating as phase shift of wave-front.

Figure 1 shows the principle of ENRICH for two cases: the substrate reflection is much larger than the surface reflection and the opposite case. In the former case, two laser beams with different frequencies are incident onto the resist coated DUV hardened alignment gratings. The incident light penetrates the resist and is reflected by the substrate because DUV hardened resist has almost the same refractive index and does not mix with the upper resist. Optical path difference between ±1st order beams occurs during transmission through the non-uniform resist. The reflected light beams normal to the wafer interfere with each other and generate a beat signal. The resultant alignment position is displaced to the position where the optical path of ±1st order beams become equal. Resist coating non-uniformity is measured as the phase shift (Δ) of the beat signal when compared with the phase of beat signal without upper resist.

In the latter case, the detected light beam is diffracted from the resist surface and the same amount of the phase shift occurs due to the displacement of the diffraction center. For general case, the detected light beam is composed of the former and the latter case, and the same amount of phase shift is obtained.

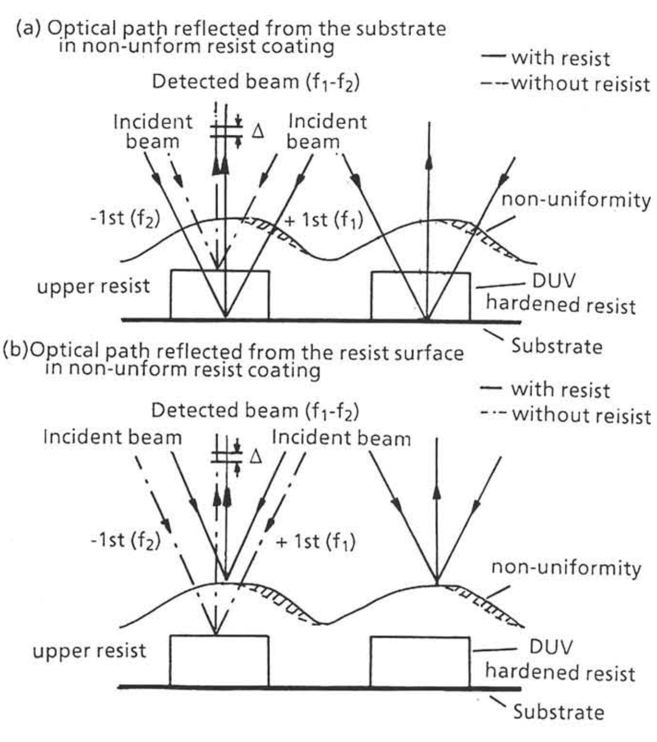

Figure 1 The principle of ENRICH

Experimental procedure and result

Figure 2 shows the process flow for ENRICH which comprises of sample preparation, resist coating, overlay and exposure ,and overlay

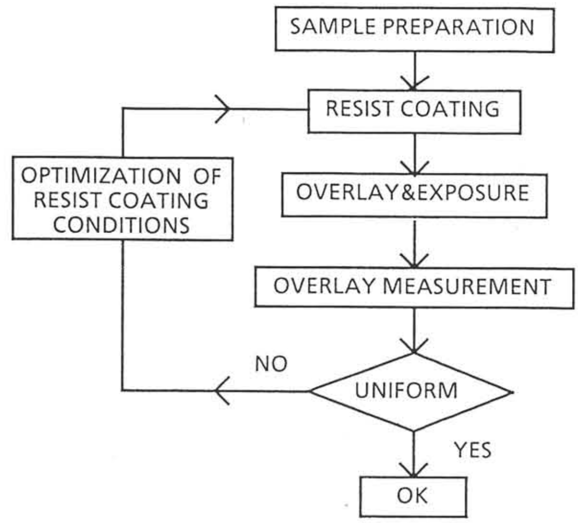

Figure 2 Process flow for ENRICH

measurement to achieve uniform resist coating. If uniform resist coating has not been achieved after overlay measurement, resist coating conditions such as coating speed, resist dispense volume, viscosity are optimized until uniform resist coating has been achieved .

Samples to examine the non-uniformity of resist coating were prepared with 4μm line and space DUV hardened resist alignment gratings with step height of 0.8μm and 1.5μm. 1.5μm thick resist was spin-coated on this alignment alignment gratings. After 2nd pattern was overlaid to the 1st wafer pattern by die to die alignment sequence using this alignment gratings, the sample was subject to exposure. Overlay accuracy of the 2nd pattern was measured referenced to the DUV hardened 1st resist pattern.

Figure 3 shows the SEM photograph of the resist coated DUV hardened resist alignment gratings with step height of 1.5μm. It was very difficult to measure the resist coating non-uniformity by SEM. Figure 4 shows the interference pattern of this resist coated DUV hardened alignment gratings which was observed by a laser microscope. Non-uniform fringe pattern was observed in the case of non-uniform resist coating, while no interference fringe was seen.

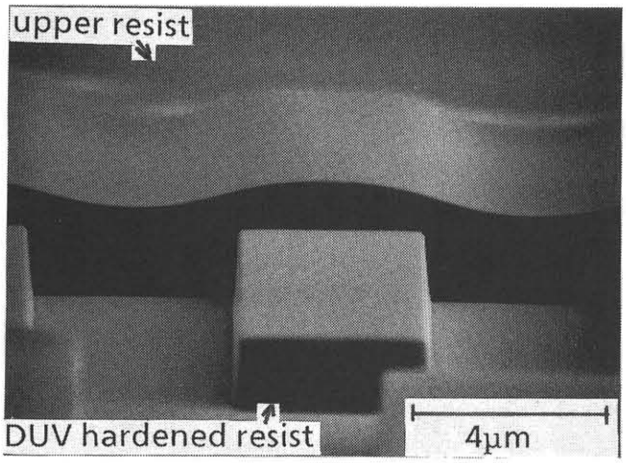

Figure 3 SEM photograph of the resist coated DUV hardened resist alignment gratings with step height of 1.5μm

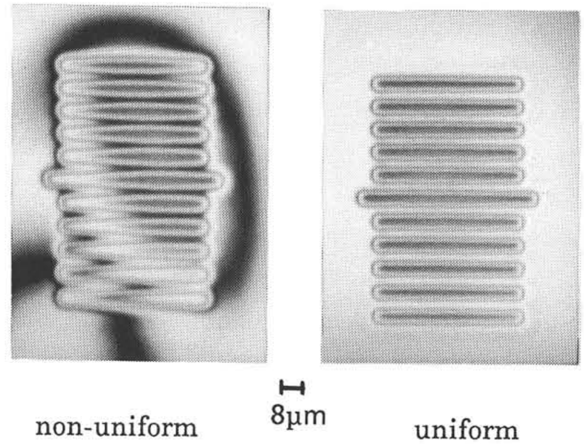

Figure 4 Interference pattern of the resist coated DUV hardened alignment gratings which was observed by a laser microscope

Figure 5 shows the resultant overlay error vector maps for non-uniform and uniform resist coating on DUV hardened resist alignment gratings. The alignment error became larger toward the edge of a wafer because the non-uniformity was enlarged due to the centrifugal force in poor non-uniform resist coating. It means that the non-uniform resist coating is one of the origin for wafer scaling error and that the non-uniformity can be evaluated quantitatively using ENRICH. Also, overlay accuracy was improved within 59nm/3σ using ENRICH, which is the same as that for ideal alignment mark. Figure 6 shows the comparison of overlay results with and without the optimized resist coating for polysilicon deposited LOCOS alignment gratings. Overlay accuracy was improved to be 80nm/3σ by using ENRICH. ENRICH is applicable for all alignment marks in a wafer process.

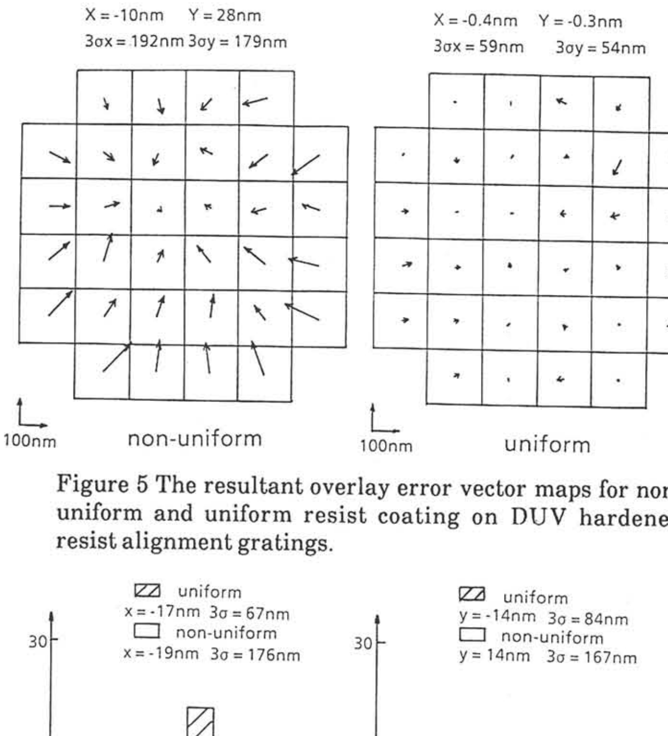

Figure 5 The resultant overlay error vector maps for non-uniform and uniform resist coating on DUV hardened resist alignment gratings.

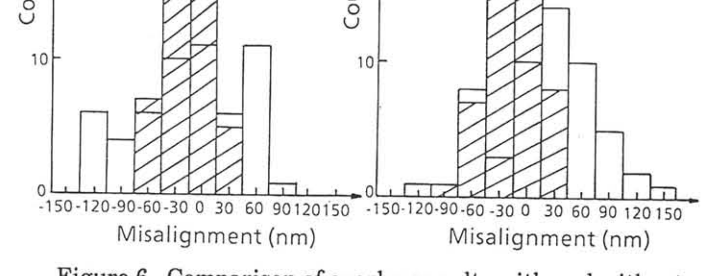

Figure 6 Comparison of overlay results with and without the optimized resist coating for polysilicon deposited LOCOS alignment gratings

Overlay analysis

The alignment error budget was estimated as described in Table.1. In this analysis, resist coating was optimized through evaluating the resist coating uniformity by ENRICH. Mark uniformity error is caused by the shape deformation of the alignment mark due to the wafer process such as non-uniform resist coating, surface roughness, and mark deformation. Other alignment error factors are related to the total alignment system accuracy of its individual stage precision, repeatability, alignment sequence and 1st shot positioning. In HHWA system, it was estimated to be 74nm/3σ for multi-global alignment sequence and 55nm/3σ for die to die alignment sequence. The mark uniformity of these processed alignment gratings was estimated to 30nm which was the same as an ideal alignment mark uniformity.

Figure 7 shows the wafer scaling dependency on overlay accuracy for Al deposited alignment gratings measured by HHWA. A wafer scaling problem caused by the non-uniform Al deposition was solved by 1ppm wafer scaling correction. Overlay accuracy was improved to 80nm/3σ because HHWA has a high response sensitivity of 5nm and can correctly detect the alignment mark positioning with the averaging effect of surface roughness. Mark uniformity of 30nm was achieved for every Al wafer, resulting in high overlay tolerances. The overlay accuracy within 80nm/3σ was obtained for every wafer process using HHWA.

Conclusion

A new method to optimize the non-uniformity of resist coating (ENRICH) was proposed using HHWA. Overlay accuracy of HHWA was improved to 59nm/3σ after optimizing the resist coating. Also, high overlay tolerance for every wafer process was obtained using the optimized resist coating. It has been confirmed that HHWA is a promising alignment method for production of half-micron semiconductor devices such as 16MB DRAMs and future sub-half micron devices.

References

(1) N.Magome and N.Shiraishi et al. ,Optical/Laser microlithography IV Proc. SPIE 1088,P238-247(1989)

(2) N.Nomura et al. ,Microelectronic Engineering 11 p.133-136 (1990)

(3) K.Yamashita et al. ,Tech. Digest of IEDM 1987, p749-752 (1987)

	Resist	LOCOS& SiO2	AL	AL (corrected)
Wafer Process Dependent Alignment Error				
Mark uniformity	30	30	58	30
System Dependent Alignment Error				
Repeatability	5	5	5	5
Stage precision	35	35	35	35
1st shot positioning	50	50	50	50
Alignment sequence	35	35	35	35
Reticle rotation	10	10	10	10
Measurement accuracy	20	20	20	20
Total Overlay Accuracy				
3σ Total	80	80	99	80
|mean|	15	25	20	20
|mean| + 3σ	95	105	119	100

UNIT (nm/3σ)

Table.1 Alignment error budget

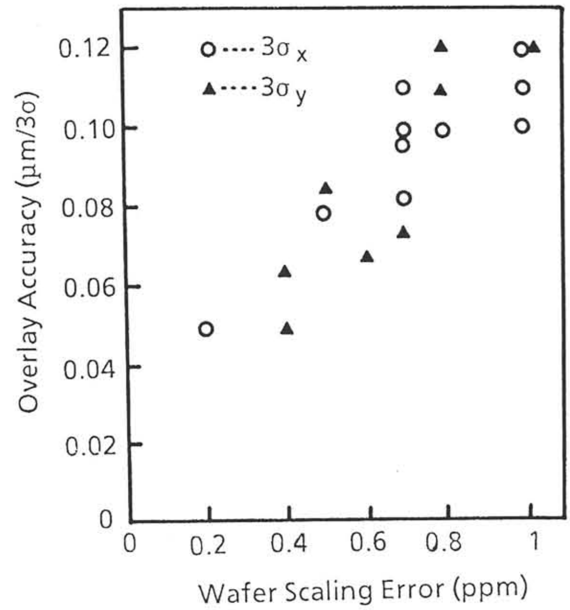

Figure 7 Wafer scaling dependency on overlay accuracy for Al deposited alignment gratings.