REDUCING DEFECTS USING A 5X STEPPER IN PATTERNING 80µ SU8 on MEMS DEVICES

Jean-François Bédard[1], Jan Campbell, Martin Ivie
Elda Clarke and Gary Head,
TriQuint Semiconductor
500 W. Renner Rd Richardson, Texas 75080
[1)] Phone: 972-994-8356 Email: jbedard@tqs.com

Abstract:

This paper presents the benefits of patterning thick 80µ SU8 using a 5X stepper instead of a 1X proximity printer. To date there has been little success in patterning 80µ SU8 using a stepper. This paper discusses how the associated defects and yield loss using a 1X proximity printer were improved by changing to patterning with a 5X stepper and how this patterning of a thick 80µ film was accomplished.

INTRODUCTION

SU8 is negative acting photo-definable epoxy used for a variety of applications such as Micro electro mechanical systems (MEMS) and nano electro mechanical systems (NEMS) and nanotechnologies. These devices often used to modulate radio frequencies in microelectronic telecommunication devices.

The original SU8 lithography process at TriQuint Semiconductor used a 1X proximity printer to define the structures. Coating thick films is problematic and often has small bubbles in coating. These can then contact the mask, creating defects in the SU8 walls and transfer to the next wafer causing more defects. This results in significant yield loss, since the SU8 cannot be reworked after exposure. Further, if the mask is not perpendicular to the light beam or the light beam is not coherent, light can be deflected or scattered during exposure. This deflected or scattered light can cause the SU8 to cross link in areas that are not supposed to be exposed, resulting in patterning defects. Many things including the mask contacting bubbles in the surface of the resist causing non-perpendicularity or resist on the mask causing non-coherence of the light can cause the light to scatter. A typical defect signature on a wafer caused by this type of light scattering can be seen in Figure 1: Horn Defect

Figure 1: Horn Defect

The alignment in proximity printing is subject to rotation and translation error inherent to the distance between the wafer and mask. Distance is needed to avoid direct contact of the resist while performing the alignment (Figure 2: Alignment shift from Mask Touching)

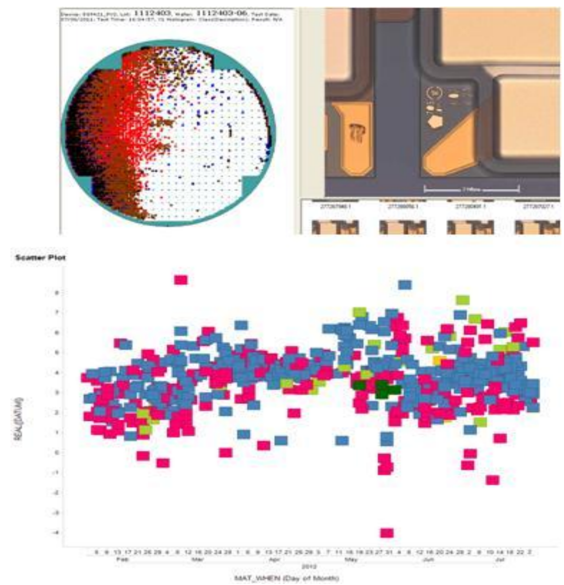


Figure 2: Alignment shift from Mask Touching

In addition the auto-alignment performance for the 1X proximity printer being used is in the range of ≥5µ for thick resists. That variation has to be accounted for in the design rules defining the minimum distance from the SU8 structure edge to the edges of other structures. The push to reduce die size and therefore improved overlay has made it necessary to evaluate a more accurate and consistent process to produce the SU8 structures. That new process also has to address the high cost of ownership for the 1X proximity printer that results from yield loss and scrap inherent to this type process. It was decided that the best approach was to try to use the 5X steppers that currently are used to pattern all the previous layers for the same devices.

METHODOLOGY

A 5X Reticle was obtained for the SU8 pattern of a device currently being printed using a 1X proximity print process. Initial tests were processed by splitting bare Si wafers between proximity printer exposure and stepper exposure at the patterning step. The coat and develop processes were held constant for both splits for the initial tests.

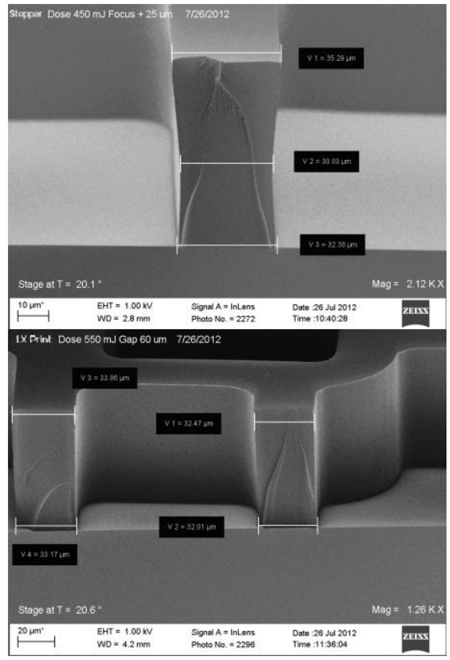
Wafers were processed at various exposures on the stepper and compared to those processed on the proximity printer using the standard exposure. The exposure for the stepper for further tests was selected to produce CD results close to those from the proximity printer.

Further tests were processed using production wafers. The coat process was still held constant, however, the develop process for the stepper portion of the splits was changed to a batch develop process, which was also being qualified.

Cross-section photos of the SU8 structures were taken using a scanning electron microscope (SEM) on the bare Si wafers. Defect data and overlay measurements were taken on production wafers as well as shear test data for the SU8 walls. In addition electrical parameter data, final visual inspection data, and build data for the production devices were checked.

RESULTS

Figure 3: SU8 Structure Cross Section Profiles shows the comparison between the profiles achieved with the 5X stepper (top) and that achieved with the proximity printer (bottom). The profiles are not significantly different.



FigurFigure.3: SU8 Structure Cross Section Profiles

Figure 4: SEM CD Comparison on Pilot Wafers shows the CD comparison for the 5X stepper (top) and the 1X proximity printer (bottom). The CD's for both are well within the normal distribution seen for the proximity print process.

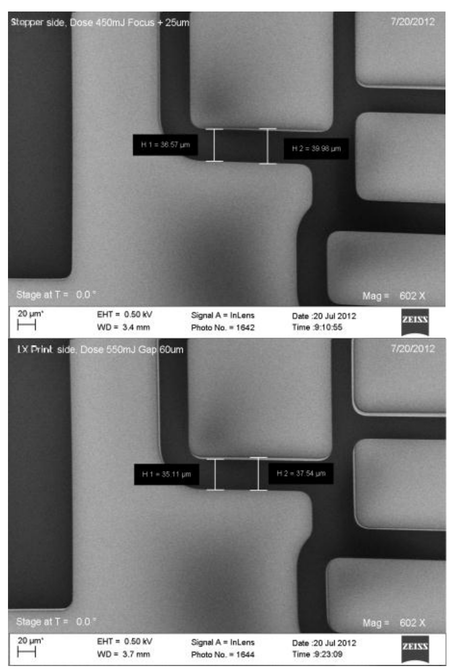


Figure 4: SEM CD Comparison on Pilot Wafers

From the graph in Figure 4: Shear Test Data, it can be seen that there is no significant difference in the data for the wafers printed with the 5X stepper as compared to those printed with the 1X proximity printer. The data for the wafers processed on the 5X stepper falls clearly within the distribution of the data for wafers processed on the 1X proximity printer.

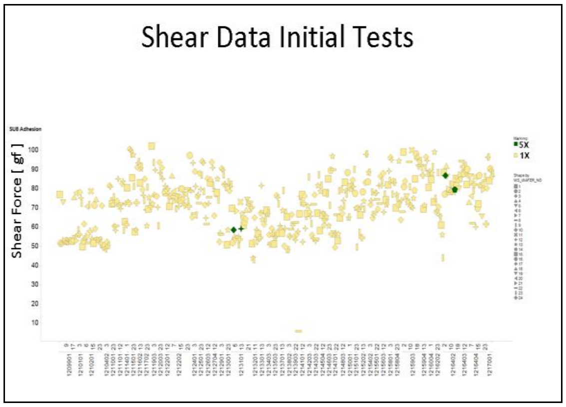


Figure 4: Shear Test Data

Figures 5 and 6 show the results of the overlay comparisons between wafers exposed using the 5X stepper and wafers exposed using the 1X proximity printer. For both Translation, shown in Figure 5 and Expansion, shown in Figure 6, the values are centered closer to 0 offset for the 5X stepper than for the 1X proximity printer. Also, the distribution of the Translation data from wafer to wafer within a lot is much tighter for the 5X stepper.

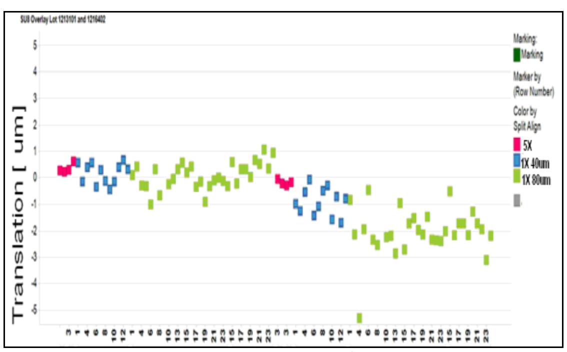


Figure 5: Alignment Translation Error of SU8 Structures Exposed on a 5X Stepper vs. a 1X Proximity Printer

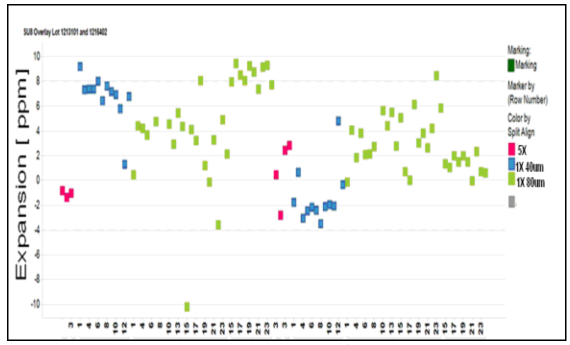


Figure 6: Alignment Expansion Error of SU8 Structures Exposed on a 5X Stepper vs. a 1X Proximity Printer

An example of the data from one of the electrical parameters tested is shown in Figure: 7. It can be clearly seen that the data for the two wafers,3 and 14, exposed using the 5X stepper falls within the data for the other wafers exposed with the 1X proximity printer.

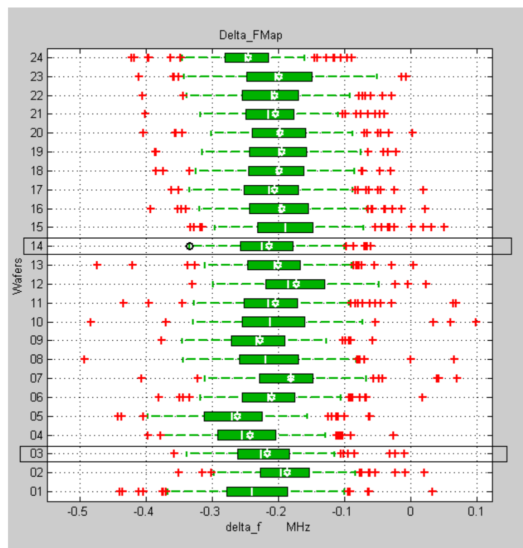


Figure 7: Example of One Electrical Parameter Tested

Figure 8: Yield Data for 5X Stepper vs. 1X Proximity Printer shows that the yield for the wafers, 3 and 14, processed on the 5X stepper falls clearly within the range for those wafers processed on the 1X proximity printer.

Yield Summary

WAFER#	Nsamples	Ngood	Yield
01	15115	14039	92.9%
02	15115	13917	92.1%
03	15115	13947	92.3%
04	15115	13893	91.9%
05	15115	13861	91.7%
06	15115	13562	89.7%
07	15115	14004	92.6%
08	15115	13575	89.8%
09	15115	14030	92.8%
10	15115	14207	94.0%
11	15115	14074	93.1%
12	15115	13513	89.4%
13	15115	13825	91.5%
14	15115	13659	90.4%
15	15115	14146	93.6%
16	15115	14228	94.1%
17	15115	13979	92.5%
18	15115	13852	91.6%
19	15115	14264	94.4%
20	15115	13902	92.0%
21	15115	13770	91.1%
22	15115	13098	86.7%
23	15115	13234	87.6%
24	15115	12988	85.9%
25	NO DATA	NO DATA	NO DAT

Figure 8: Yield Data for 5X Stepper vs. 1X Proximity Printer

CONCLUSIONS:

The CD and profile data produced using the 5X stepper matches that produced using the 1X proximity printer. The shear test data, the electrical test data, and the within wafer yield using the 5X Stepper are all comparable to those produced with 1X proximity printing. Using a 5X stepper to expose the SU8 structures produces improved overlay results including reduced wafer to wafer variation for translational misalignment.

Also, by switching to the 5X stepper process, there are reductions in expenses for mask cleaning, the need to have multiple masks to accommodate the cleaning cycles is eliminated, and there is a reduction in labor requirements, specifically in the need of the operator to confirm the alignment prior to exposing the wafer. These all translate to a significant annual cost savings.

Finally, this process will open the way to reduce die size and will improve the quality of the devices while maintaining a competitive process cost.

ACKNOLEDGEMENTS

The authors would like to acknowledge and thank for their support the following: the TriQuint Photo Equipment Engineering Techs and Engineers; and the manufacturing staff at TriQuint Semiconductor TX

ACRONYMS

AOI: Automatic Optical Inspection an inspection done with a machine and not relying on a human for defect detection.
MEMS: Micro electro mechanical systems
NEMS: Nano electro mechanical systems
CD: Critical Dimension.
SEM: Scanning Electron Microscope.