Set up and Characterization of an Optical Wide Stepper Process For DR15 Technology as a replacement for E-Beam Lithography

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ABSTRACT

An optical process has been introduced into the GaAs manufacturing line for the Dual Recess 0.15µm technology (DR15) to replace the e-beam lithography process. The goal of the project was to reduce the cycle time for the patterning operation. This paper reviews the initial characterization of the resist process; including the approach used to optimize the resist thickness and the resist clean process through feed-back from the electrical characteristic-pulse I-V data. This paper also shows side by side comparison of reliability data between the optical and e-beam lithography splits.

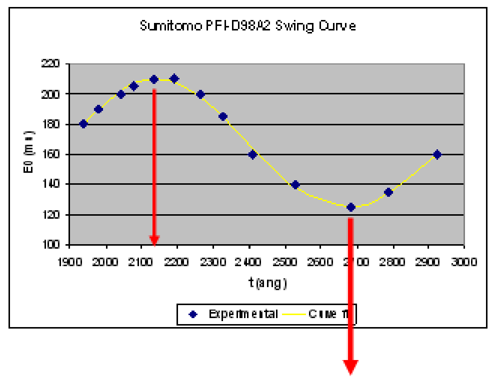
INTRODUCTION

The e-beam lithography (EBWPMMA) portion of the DR15 process was initially set up with an e-beam exposure process and had been running for many years for the .DR15 technology at TriQuint Semiconductor. Due to the limited capacity of e-beam exposure tools and the cycle time impact, work was conducted to qualify an equivalent optical exposure process for the EBWPMMA process. The goal was to move the EBWPMMA process onto an I-line stepper exposure tool in order to improve the throughput in the litho area. It was determined that the estimated improvement by switching to optical exposure process would allow for up to 20% additional wafer starts on the DR15 technology .

PROCESS CHARACTERIZATION

Sumitomo PFI98DA2 resist was selected for the optical process. After exposure, MF26 developer was used in a 1 minute puddle develop. The swing curve was collected for this resist (see Figure 1). Based on these experiments, the initial process was setup using a 2670A resist thickness.

Figure 1. The swing curve collected on PFI98DA2 resist for the optical process.



Next, a Bossung curve was collected showing that this resist is capable to print the 0.6µm CD with a DOF greater than 1.4µm. See Figure 2.

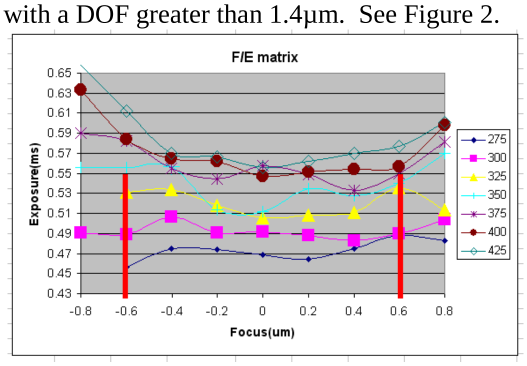


Figure 2. The Bossung curve collected on PFI98DA2 resist for the optical process

The CD size of the optical process was adjusted and matched to the established e-beam process. Downstream testing showed zero CD bias between the photo and etched CDs for the optically patterned devices.

Resist loss data was collected with the PFI98DA2 resist at every step of the process including after coat, after develop and after nitride etch and after dry recess, the data is comparable between the baseline e-beam and optical processes. See Figure 3 below.

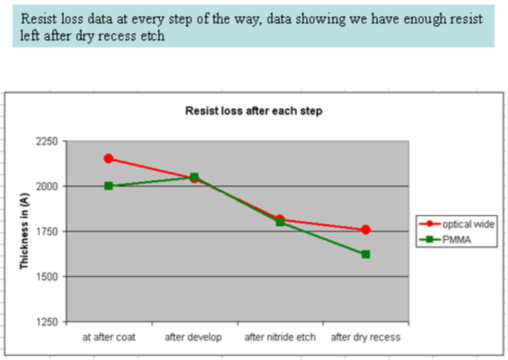


Figure 3. The resist loss curve comparison between optical exposure and e-beam write processes.

The next validation test looked for shifts in electrical performance. These tests showed that the electrical characteristics are very comparable between optical and the e-beam write baseline. The only exception was a slight deterioration of the pulse I-V characteristics for the optically patterned devices when compared to the e-beam baseline split (see Figure 4). This was determined to be a result of resist residues remaining on the surface of the WR channel after develop. In an attempt to eliminate the residues, resist thickness was reduced from 2670A to 2150A. The thought was to see if thinner resist could be more easily cleaned during the standard 25 min ash. In conjunction with the thinner resist, an NMP step was added as a clean step prior to the barrel ash to ensure no resist remained before the subsequent NH_4OH etch step.

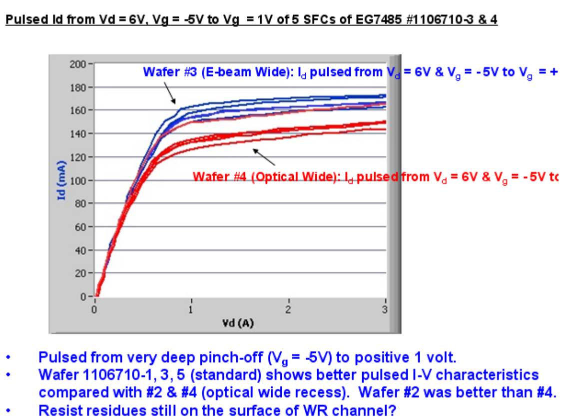


Figure 4. Pulsed I-V curve for optical exposure and e-beam write splits.

The SEM images in Figure 5-section 1 show that the NMP clean is very effective in eliminating the resist residues before the NH_4OH etch step. In contrast, the split without NMP pre-clean still exhibits some resist residues. Therefore, it was decided the NMP clean step is essential for a reliable optical process.

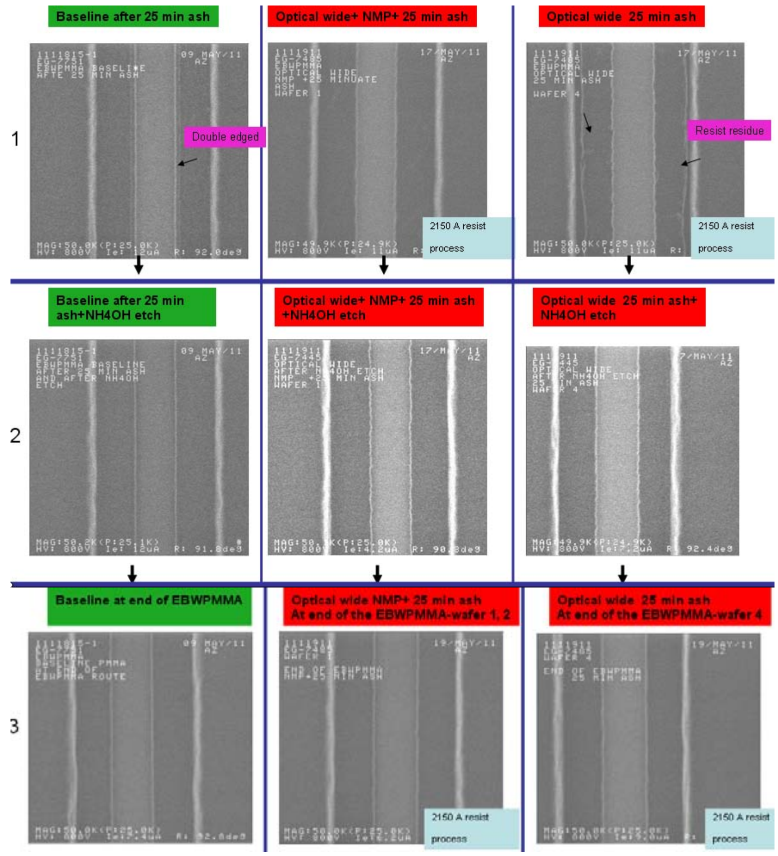


Figure 5. Showing the side by side comparison for resist residue status at 1. right after asher step. 2. right after NH4OH clean step and 3. at the end of the EBWPMMA route for vary splits (including baseline EBEAM split, optical split with NMP pre-clean before the 25 min barrel ash step, and optical split without NMP pre-clean step)

In order to check for profile differences, SEM cross sections were prepared and compared between the optical exposure and the e-beam write. As shown in Figure 6, no differences were observed between the two cross sections.

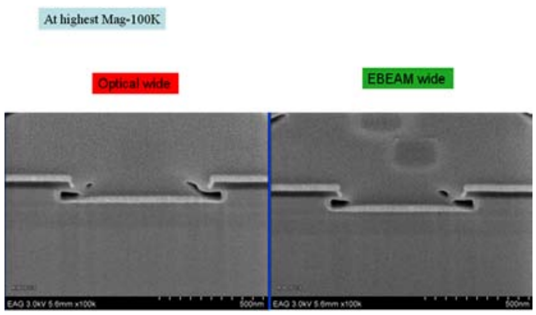


Figure 6. FIB cross section comparison between optical wide and Ebeam wide processes.

RESULTS

Split-lot electrical test showed that the adoption of a thinner resist with the addition of an NMP clean ,achieved similar pulsed I-Vcharacteristics compared with the e-beam patterned control wafers. See Figure 7.

Furthermore, the wafers using the optimized optical process delivered the best pulsed I-V performance in terms of highest pulsed drain currents and pulsed I-V ratios.

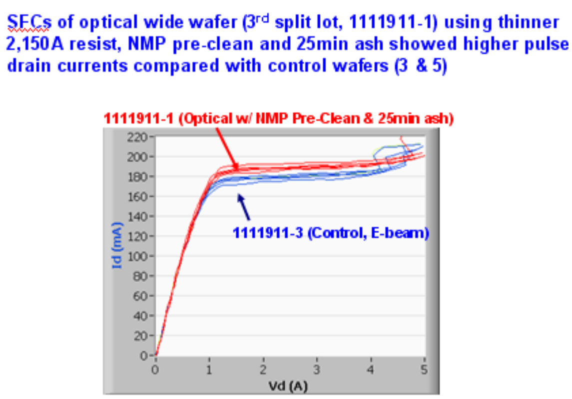


Figure 7. Pulsed I-V curve for optical and E-Beam write splits.

Once the initial electrical performance tests were completed, it was necessary to verify the long term performance of devices sent through the new process flow. Figure 8 shows the reliability comparison data between the e-beam write and the optical process. The optical split exhibited better reliability results as compared to the e-beam baseline split.

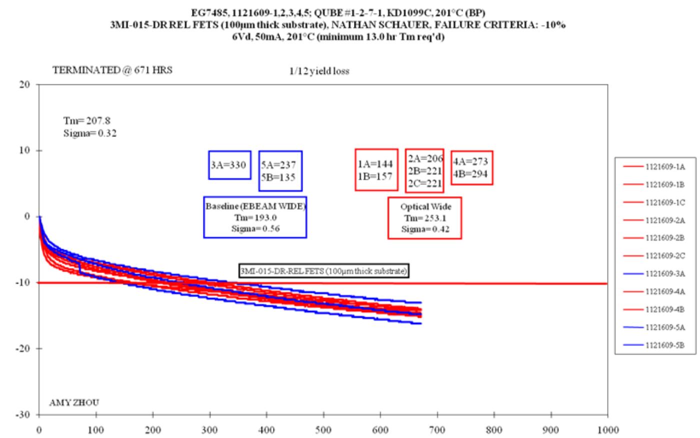


Figure 8 shows the reliability comparison data between the baseline Ebeam write and optical process.

Two DR15 pHEMT products were submitted for HAST testing. The performance between the splits is comparable from a visual standpoint with an equal number of visual failures between the splits.

CONCLUSION

An optical stepper process has been successfully added to the GaAs manufacturing line at TriQuint Semiconductor for the DR15 technology. The optimized resist thickness has been determined to ensure comparable pulsed I-V characteristics between the optical and e-beam splits. The process integration has been improved by eliminating the resist residues inside the channel. Lastly, the process margins were stabilized by adding a NMP pre-clean for the resist clean process. Reliability and HAST data demonstrated no difference between the optical exposure and e-beam write processes. By releasing the optical process a dramatic improvement in cycle time and wafers starts has been realized.

ACRONYMS

pHEMT: *pseudomorphic* high electron mobility transistor
EBWPMMA: Electron beam wide Poly Methyl Meth Acrylate)
EBEAM: Electron Beam exposure
GaAs: Gallium Arsenide
MMIC: Monolithic Microwave Integrated Circuit
HAST: Highly Accelerated Temperature/Humidity Stress Test
NMP: *N*-Methyl-2-pyrrolidone