BACK TO THE FUTURE: HOW IMPLEMENTING RETRO-STYLE PROCESSING CAN BE AN IMPROVEMENT

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Abstract:

Single wafer develop replaced batch-develop for most semiconductor process several years ago. For the photo-definable epoxy process used at TriQuint Texas, the develop process that was originally set up was a single wafer, multiple puddle solvent develop process. This paper will discuss how switching this process to a batch-develop process showed overall improvements in a variety of areas including throughput/cycle time and electrical yield.

INTRODUCTION

As loadings for the product line using the photo definable epoxy process have increased, methods to save the expense of buying new capital equipment have been sought. One of the longest cycle-time processes for this product line is the develop process for the photo-definable epoxy. This process was originally set up as a multi-puddle, single wafer develop process with a post exposure bake. On examining the process requirements for critical dimensions and resist thickness, it was determined that an older style, batch-develop system should be capable of doing this process.

This paper will discuss the equipment chosen to perform the “new” batch-develop process on and the current equipment used for the single wafer process, the methodology used for comparing the batch process to the single wafer process and the results found when this comparison was made.

EQUIPMENT

The equipment used for the single wafer develop process was an EVG150 coat/develop system. The PEB (Post Exposure Bake) was done using a single hotplate. The develop process was done using the standard stream develop nozzle to build the puddle.

For the batch-develop process, the PEB for the first three phases was done on the EVG150 and for phases four and 5 the PEB was done using a C&D produced multiple hotplate (MHPO) track system. The C&D system has three hotplates that are operated in parallel. The actual develop process was done in a four tank hood with a programmable robotic transfer arm. Three of the four tanks are filtered and recirculating solvent tanks, and the fourth tank is a quick dump rinse (QDR) DI water tank.

A Semitool spin rinse dryer (SRD) was used for final drying of the wafers after the batch-develop process. A Dage shear test measurement system was used for measuring the shear strength of the resulting epoxy structures. Automatic optical inspection tools were used for the inspections post cure, post develop and at final inspection. Various probe equipment was used for the electrical tests.

METHODOLOGY

For both processes PGMEA was used as the main develop chemistry and isopropyl alcohol (IPA) was used for the rinse. The batch-develop process utilized a first PGMEA tank immersion, followed by a second PGMEA tank immersion, and finally an IPA rinse tank immersion. In addition, for the batch-develop process, tests were run using the QDR DI water rinse after the IPA as well as without using it. After the final tank immersion, the wafers in the cassette were transferred to the SRD for final drying.

Agitation was used in each of the solvent tanks for the batch-develop process and the solvents were under continuous recirculation during the process.

Initial tests were processed using pilot wafers split between the single wafer and the batch-develop processes. Height and width of the patterned structures (see example in Figure 1.) after develop were compared, as well as overall general appearance. A scanning electron microscope (SEM) was used to take the width measurements and a profilometer was used to take the step height measurements. For these tests the QDR was not used.

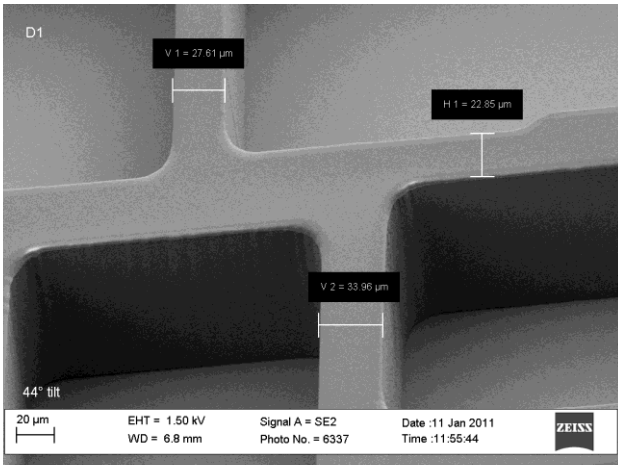

Figure 1 Examples of Patterned Structures Measured for Width

In the next phase of testing, sample wafers from three lots were processed using the batch-develop processes with the rest of the wafers in the lots receiving the standard develop process. Step Height, shear strength and automatic optical inspection (AOI) data after develop were compared. Again, the step height data was taken using a profilometer. The shear data was taken using a Dage shear test system utilizing a 20μ x 20μ block structure on several sites per wafer. For these tests the QDR was not used.

In the third phase of testing, four lots were split between batch-develop (even numbered wafers) and the standard develop (odd numbered wafers) process. Shear test data after cure of the photo-definable epoxy, frequency shift data after cure of the photo-definable epoxy, and final AOI and electrical yield data were compared between the splits. Again, for these tests the QDR was not used.

For phase four testing, ten full production lots were processed through batch-develop. Six lots of one device type were processed, three lots of a second device type were processed and one lot of a third device type was processed. Shear test data after cure of the photo-definable epoxy, frequency shift data after cure of the photo-definable epoxy, and final AOI and electrical yield data were compared to data from lots processed at the same time using the standard process. These lots were processed using a single cycle of the QDR.

In the fifth and final test phase, splits were run between the batch-develop process with (odd numbered wafers) and without (even numbered wafers) using the QDR DI water rinse. Again, shear test data after cure of the photo-definable epoxy, frequency shift data after cure of the photo-definable epoxy, and final AOI and electrical yield data were compared between the splits.

RESULTS

On pilot wafers the structure widths for the baseline process averaged 28.6μ and those for similar structures on the batch-develop process averaged 27.9μ. The step heights were 80.5μ and 81.1μ respectively. Basic visual microscopic showed that the patterns were produced equally well with either develop process.

For the first lot of Phase 2, there were no defects attributable to the batch-develop process seen at AOI. The shear data was slightly lower on the two batch-developed wafers, averaging 62g as compared to that for two randomly selected wafers from the standard develop process, which averaged 73g, but still well above the minimum acceptable level of 40g. The step height for the one batch-developed wafer measured was 78.6μ Five standard processed wafers were measured for step height with a range from 78.6μ to 79.6μ with an average of 79.1μ.

The second lot processed for Phase 2 only had step height and shear data taken. Again, 2 wafers were processed using batch-develop. The shear data for these two wafers averaged 70.1g and the step height data averaged 79.1μ. The respective data from two wafers processed using the standard develop process was 74.8g and 79.4μ.

The third and final lot for Phase 2 only had AOI data collected. For this lot, six of twenty-four wafers were processed using batch-develop. The defect density averaged 4.67% for the batch-developed wafers and ranged from 3.38% to 6.09%. For the standard process wafers, the average was 4.54% and ranged from 3.24% to 6.93%. The two populations were not significantly different.

For the third phase, the shear data for the standard splits averaged 45.9g and for the batch-develop splits it averaged 50.9g. The electrical yield for the batch-develop splits averaged approximately 0.6% higher than that for the standard splits. The final yield after OAI for the batch-develop splits averaged approximately 0.7% higher than that for the standard splits.

The data for the full lots processed in phase four was very similar for all three device types. The average shear data for the first device type was 54g compared to a baseline of 58g, for the second device type the average was 72g compared to a baseline of 78g and these values fro the third device type were 63g and 71g respectively. The frequency shift (ΔF) data was -0.44kHZ, -0.54kHz, and -0.59kHZ for the three device types all of which have a target range of -0.7 to -0.3kHZ. The electrical yield data was 2.7%, 3.2%, and 4.0% greater than baseline for the three devices respectively and the AOI Data was 2.2%, 2.5%, and 4.1% higher.

The first test lot split between batch-develop process with and without the QDR water rinse showed an average electrical yield increase of 4.1% for the split with rinse. At AOI this delta was reduced to 3.1%. This indicated that there was some AOI yield loss due to the QDR which correlated to what was seen with particle count tests. The QDR system was thou roughly cleaned and the three more lots were split between batch-develop process with and without the QDR water rinse. For the three lots the electrical yield was 1.41% and 3.02% better for the QDR split for two lots of one device and was no different for the third lot whish was another device. For the AOI yield, the QDR splits were 0.6% and 3.0% better for the first two lots and about 0.1% worse for the third lot. The shear data for the lots was all well within specification as was the ΔF data.

Raw throughput calculations for the batch-develop process show it is capable of up to 3360 wafer passes per week as compared to 671 wafer passes per week for the single wafer develop process. It is estimated that the same throughput using the batch-develop process can be achieved using equipment that is $1/6^{th}$ the cost of the equipment for the same throughput with the single wafer develop process.

CONCLUSIONS

The batch-develop process can produce equivalent results for shear test and frequency shift, plus potentially show a slight overall final yield increase as compared to the standard single wafer develop process. In addition, it will show a current 5X increase in throughput and, for future expansion and loadings increases, show a 6X cost reduction for capital equipment.

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ACRONYMS

AOI: Automatic Optical Inspection and inspection done with a machine and not relying on a human for defect detection.

MHPO: Multiple Hotplate Oven a bake system on a C&D coater track in which wafers can be processed on up to three different hotplates either in parallel or series.

PEB: Post Exposure Bake a bake done after exposure and before develop to complete the photoreaction in the exposed resist.

PGMEA: Propylene Glycol Mono Ether Acetate, a solvent.

QDR: Quick Dump Rinse, a tank which uses DI water to rinse product by filling then dumping the water out quickly.