Acceptance test results for Temescal FC-2000

Vacuum parameters

Measurement	Requirement	Test result
Ultimate Pressure	≤ 9.9x10-8 Torr within 24-36 hours (datalogged)	20/03-2018: ≤ 9.9x10-8 Torr within 17 hours after 100 nm Ti deposition 20/04-2018: ≤ 9.9x10-8 Torr within 28 hours
Product Chamber (load lock) Pumpdown from atmosphere (3 sec exposure) and ready to start evaporation	≤ 5x10-6 Torr within 10 - 15 minutes	15/03-2018: ≈ 1*10-6 Torr within 15 minutes
Complete system pump down from atmosphere (3 sec exposure). Simulated a service (e.g. filling metals up)	≤5x10-7 Torr within 60 min. (Should be OK with 3 second atmosphere exposure. Longer exposures will likely not meet this time limit.)	13/03-2018: ≈ 2*10-7 Torr in 2 hours 16/03-2018: ≈ 9*10-7 Torr 103 minutes Both after longer than 3 sec exposure
Rate of Rise	≤8.0x10-6 Torr L/s after pumping to near ultimate pressure	20/03-2018: ≈ 3*10-7 Torr L/s over 12 minutes after 100 nm Ti dep, starting ≤ 9.9x10-8 Torr

Notes: The pumpdown time from loading the chamber until being ready for deposition has deteriorated since the acceptance test. Initially it took 15 min to reach 1*10-6 Torr for deposition as shown above, but by May 2018 the pumpdown time was typically 20 min until the machine was ready for deposition. This pumpdown time has been more or less stable until the time of writing (September 2018).

Ion beam gun process parameters

Ion-gun etch	Requirement		Test result	
Material	Etch rate	Uniformity specification	Etch rate	Uniformity specification
1. Native SiO_2 on Si wafer	SiO_2 removed in 5 minutes	Total removed, with minimum damage to Si substrate	Etched for 5 minutes	Tested by dipping in water. Difference in water affinity between etched and non-etched wafer, so probably native oxide was removed.
2. 100 nm (1000 Ång.) thermal grown SiO_2 on Si wafer, etching 4 nm (40 Ång.).	Min. 8 Å/min	+/- 15.0% WIW, +/- 10.0% WTW, +/- 10.0% BTB	Up to 12 Å/min in 5 min etch for a total of 5-6 nm etched	+/- 10 % WIW (10 wafers) +/- 3 % WTW (2 runs w 4 wafers each) +/- 10 % BTB (2 runs)

NOTES:

The WIW inhomogeneity mostly derives from a higher etch rate in the center point than at the 4 edge points measured: Approx. 15 % faster etching in the center than the edges over the 5 minutes at approx. 1-1.2 nm/min etching.

The BTB uniformity is difficult to evaluate due to only 2 identical test runs.

The wafers were mounted on the HULA fixture as usual.

At Danchip measured by Woollam ellipsometer 5 points over the 150 mm wafer using a simple model that only fits the thickness.

SiO_2 layer measured before and wafer etch.

Wafer In Wafer (WIW) uniformity = % = 100* (Max-Min) /(2 x X1)
Where: Max = the maximum measurement within a wafer
Min = the minimum measurement within a wafer
X1= the average of the points measured within a wafer
Wafer To Wafer (WTW) uniformity = % = 100* (Max-Min) /(2 x X2)
Where: Max = the maximum average of the wafers within a batch
Min = the minimum average of the wafers within a batch
X2= the average of the X1 of the wafers measured within a batch
Batch To Batch (BTB) uniformity = % = 100* (Max-Min) /(2 x X3)
Where: Max = the maximum average of the batch (average of the wafers)
Min = the minimum average of the batch (average of the wafers

X3 = the average of the X2 of the wafers measured within all batches

E-beam parameters

Test run	Uniformity requirement	Test results
4 processes of 10 nm Ti and 100 nm Au. With 4 x 150 mm Si wafers on the HULA fixture. 2 runs were with two nLOF resist wafers and two blank shadow-masked wafers. 1 run was with four nLOF resist wafers. 1 run was with four blank shadow-masked wafers.	**Thickness:** ±5% 1-sigma WIW ±5% 1-sigma WTW ±5% 1-sigma BTB *See definition of thickness uniformity below.*	**Thickness:** Measured on shadow masked wafers:±3.1 % 1-sigma WIW ±0.2 % 1-sigma WTW ±0.9 % 1-sigma BTB reproducibility Measured on nLOF masked wafers: ±2.3 % 1-sigma WIW WTW not remeasured ±3.4 % 1-sigma BTB comparing runs with different tooling factors (see below)
2 processes of 10 nm Ti and 100 nm Ni. With 4 x 150 mm Si/SiO_2 wafers on the HULA fixture. SiO2 thickness approx. 110-114 nm. 1 run was with two nLOF resist wafers and two blank wafers. 1 run was with two blank shadow-masked wafers and two blank wafers.	**Sheet resistance:** 2% 1-sigma WIW 2% 1-sigma WTW (2% 1-sigma BTB not tested) *See definition of sheet resistance uniformity below* **Thickness:** ±5% 1-sigma WIW (±5% 1-sigma WTW and ±5% 1-sigma BTB not tested) *See definition of thickness uniformity below.*	**Sheet resistance:** 1.3 % 1-sigma WIW 1% 1-sigma WTW **Thickness:** ±1.9 % 1-sigma WIW
Test of side wall deposition. 2 processes of 10 nm Ti and 100 nm Au. With 4 x 150 mm Si wafers on the HULA fixture, all with nLOF resist. Additional tests with tilted sample holder	We need to see how well the side walls are free of metal film: Look at the profile in a SEM. (Cleave the wafer)	Passed test with flying colors. See images of SEM cross sections below.

Notes: Since the two final side wall deposition process runs and the four initial Ti/Au runs were identical, wafers from the side wall deposition runs could be used to evaluate thickness uniformity along with the four initial runs. However, the two side wall runs were done with a different tooling factor because of a problem with shading of the quartz crystal thickness monitor for the initial four runs. This may have increased the BTB variation compared to runs where the crystal is not shaded. The average thicknesses measured for the two side wall deposition runs were within 0.5 % of each other.

The individual thickness measurements made by the Dektak XT have a rather large standard deviation (up to 3 % 1-sigma), which may explain why the WIW uniformity is worse than the WTW uniformity: The WIW measurement compares the averages of 5 spots with 5 measurements in most spots and 10 measurements in one spot, while the WTW uniformity compares the averages of these 30 measurements for 4 wafers.

How measurements and calculations were made:

The sheet resistance measurement at Danchip was measured by Capres, a produce of micro four point probe machines for semiconductor industry. 49 points over the 150 mm wafer, 5 mm edge exclusion.

Thickness was measured on films deposited with a shadow mask or with an nLOF mask. The Measured with the DektakXT at 5 points (center and 4 point at 5 cm from center with 5 measurements averaged for each spot, except in one spot per shadow masked wafer with 10 measurements).

The SEM was a Zeiss Supra 40 VP (Supra 1).

Sheet resistance uniformity evaluation:

Wafer In Wafer (WIW) uniformity = % = 100* (StdDev1) /(X1)

Where: StdDev1 = the standard deviation of all measurements within a wafer

X1 = the average of the absolute value of the points measured within a wafer

Wafer To Wafer (WTW) uniformity = % = 100* (StdDev2) /(X2)

Where: StdDev2 = the standard deviation of all X1 (both batches)

X2 = the average of the X1 of the wafers (both batches)

Thickness uniformity evaluation:

Wafer In Wafer (WIW) uniformity = % = 100* (StdDev1) /(X1)

Where: StdDev1 = the standard deviation of all measurements within a wafer

X1 = the average of the points measured within a wafer

Wafer To Wafer (WTW) uniformity = % = 100* (StdDev2) /(X2)

Where: StdDev2 = the standard deviation of all X1 within a batch

X2 = the average of the X1 of the wafers measured within a batch

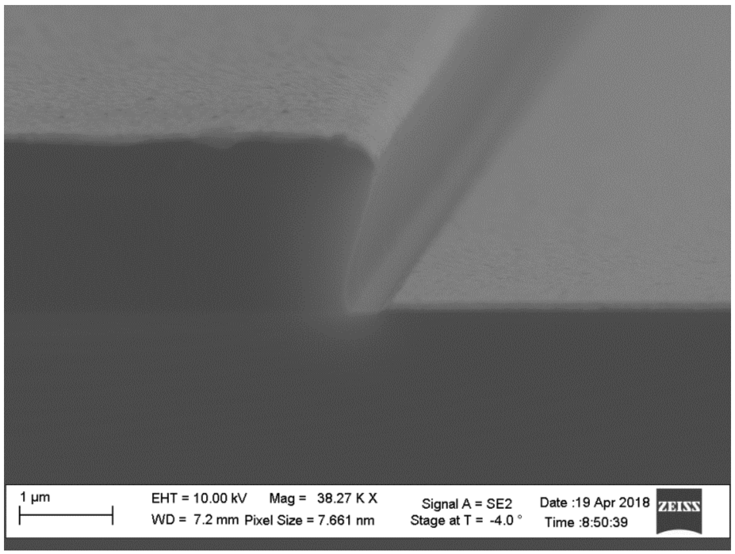
Batch To Batch (BTB or RTR) uniformity = % = 100* (StdDev3) /(X3)

Where: StdDev3 = the standard deviation of all X2 within all batches
X3 = the average of the X2 of the wafers measured within all batches

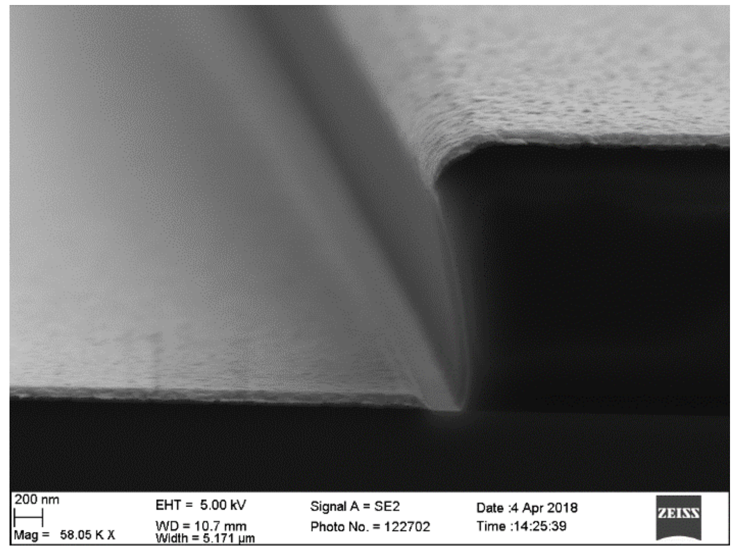
SEM cross sections: side wall deposition test

Wafers from side wall deposition test. There should be no deposition on the nLOF side walls, and this corresponds to what we see. Note the lack of deposition under the nLOF “overhang”, which gives a trough next to the wall before the deposited surface begins.

W 14



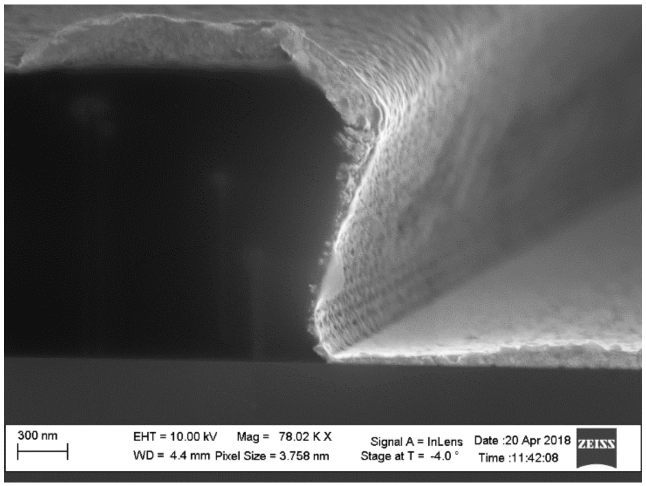
W26



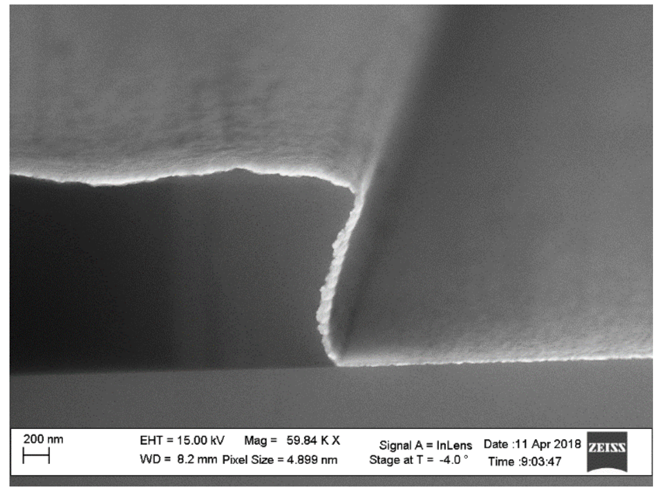
SEM cross sections: side wall deposition on tilted samples

Tilted samples were made with 27˚, 45 ˚ and 53 ˚ tilt compared to a surface that is normal to the deposition direction. We did not have a wide range of movement due to the large sample holder at the time. It is clear that there is side wall deposition on the tilted samples, as the trough next to the side wall is absent and there is Ti/Au visible on the side wall. As expected, it appears that there is more deposition on the side wall for the higher angles.

Tilt 27˚:



Tilt 45˚:



Tilt 53˚: