Acceptance test for Temescal FC-2000

At the acceptance test a general functional test of tool specifications and depositions tests as described below are conducted. The test is divided in two parts:

Part 1: A Factory Acceptance Test (FAT), where functional tests and a selection of process tests (to be agreed between buyer (DTU) and seller) are conducted prior to the shipment of the tool. DTU will attend the FAT.

Part 2: A Site Acceptance Test (SAT), including all functional tests and deposition tests as described below.

A. Vacuum parameters

	Measurement	Specification	Results
A1	Ultimate Pressure	≤ 9.9×10^{-8} Torr within 24-36 hours (datalogged)	***Passed within 20 hours***
A2	Product Chamber (load lock) Pumpdown from atmosphere (3 sec exposure) and ready to start evaporation	≤ 5×10^{-6} Torr within 10 - 15 minutes	***Passed***
A3	Complete system pump down from atmosphere (3 sec exposure). Simulated a service (e.g. filling metals up)	≤ 5×10^{-7} Torr within 60 min. (Should be OK with 3 second atmosphere exposure. Longer exposures will likely not meet this time limit.)	***Passed. After metal refill pump 65 min to 6 E-7 Torr***
A4	Rate of Rise	≤ 8.0×10^{-6} Torr L/s after pumping to near ultimate pressure	***Passed.***

B. E-beam parameters

B1: We need to have tooling factors in place for Ti, Ni, and Au:

E-beam deposition	Specification	Result
Material	Deposition rate	Tooling factor in place?
1. Titanium (Ti) 2. Nickel (Ni) 3. Gold (Au)	Up to 10 Å/s	Yes for Ti (2 Å/s), Ni, Au. Note Au deposited from liner.

B2: In addition, for the Site Acceptance Test at DTU Nanolab we planned to test that the deposition works from all pockets by manual deposition of ten different materials, which apart from Ti, Ni, and Au will include some of the following: Al, Cr, Ge, Pd, Pt, Ru, SiO2, Ag, and /or Ta. For these materials we consider the test passed when we reach a measurable deposition rate (since the tooling factor will not yet be determined).

> ***Result: PASSED.*** *In practice we tested pockets 1-5 (Ti, Ni, Au, Cr, Al) and pocket 10 (SiO2 from liner) before the tool was accepted. All went fine so we expected no issues with the others and indeed there were none.*

The e-beam test was similar to the one made for the 6-pocket Temescal FC-2000 purchased by Nanolab (then Danchip) in 2017/2018.

B3:

1. **5 processes of 10 nm Ti and 100 nm Au**. With 4 x 150 mm Si wafers on the HULA fixture. One run with 4 blank wafers, one run with wafers with shadow masks, and three runs with 1 shadow masked wafer, 1 blank wafer, and 2 nLOF wafers. This is to make it possible to evaluate WTW and BTB thickness and sheet resistance uniformity and to verify the thickness and lack of side wall deposition.

1.1. **Uniformity**:

2% 1-sigma WIW, 2% 1-sigma WTW and 2% 1-sigma BTB.
Relative standard deviation (st. dev. / |mean|)*100 of measured sheet resistance with 4pp technique on the blank wafers.

RESULT: PASSED
WIW 1-sigma variation 1.4-1.7 % on 7 wafers.
WTW 1-sigma variation 0.29 % for 7 wafers.
BTB 1-sigma variation 0.9 % for 4 batches.

1.2

Thickness: 110 nm
±5% 1-sigma WIW, ±5% 1-sigma WTW and ±5% 1-sigma BTB
measured with 5 points (center and 4 point at 5 cm from center)
The thickness is measured with a stylus profiler on shadow masked films and (as a check) after a lift-off process of at least one of the wafers with nLOF resist.

RESULT: PASSED with flying colors.
WIW 1-sigma deviation ranged from 0.9-1.9 % for 4 wafers with nlof + liftoff; 0.6-2.05 % for 8 wafers with shadow masks. The one with the largest standard deviation had some scratches from the shadow mask, so the expected thickness deviation is <2 % based on this measurement.

WTW 1-sigma deviation 0.9 % for 4 shadow-masked wafers from the same run.
BTB 1-sigma deviation 0.1 % for 4 batches nlof + liftoff; 1.3 % for 4 batches shadow masked.

1.3

Test of side wall deposition: Look at profile of nLOF wafers in SEM after cleaving. The aim is to verify that there is no sidewall deposition.

Passed, see images at end of this report.

2. **1 process of 10 nm Ti and 100 nm Ni.** With 4 x 150 mm wafers on the HULA fixture: two blank wafers and two with shadow masks. The wafers should be Si coated with 100 nm SiO2.

2.1. **Uniformity**:

2% 1-sigma WIW and 2% 1-sigma WTW (2% 1-sigma BTB not to be tested).
Relative standard deviation (st. dev. / |mean|)*100 of measured sheet resistance with 4pp technique on the blank wafers.

RESULT: PASSED
WIW 1-sigma variation 2.16 % on 1 wafer, 1.2 % for another three wafers..
WTW 1-sigma variation 0.34 % for 4 wafers from the same batch.

Accepted despite the outlier of one wafer with higher WIW variation, which was double checked and was due to a region where the sheet resistance was a little higher than on the rest of the wafer. It was near the edge and could be due to handling but we do not know.

2.2. **Thickness**: 110 nm
±5% 1-sigma WIW, ±5% 1-sigma WTW and (±5% 1-sigma BTB not to be tested)
measured with 5 points (center and 4 point at 5 cm from center)
The thickness of the layers is confirmed with a stylus profiler.

Not measured fully. The thickness of Ni was ~104.5 nm for one run and ~102 nm for the second run while Ti was approx. 9.5 nm in both runs; two wafers measured per run.

The sheet resistance measurements will be measured for Nanolab by KLA-Capres, a producer of micro four point probe machines. 49 points over the 150 mm wafer, 5 mm edge exclusion.

The thickness is measured at Nanolab with a Dektak XTA stylus profiler or KLA-Tencor P17 profiler – the Dektak was used.

The SEM to be used is a Zeiss Supra VP model – in fact a Zeiss Gemini SEM was used for some imaging.

C. Heater test

This test is performed with the 8” wafer holder with 3x8” wafers. The test constitutes the following:

	Heating to:	**Max time to reach temperature:**	**Result**
C1	150 °C	10 min (15 °C/min)	***PASSED 5 min***
C2	200 °C	20 min	***PASSED 6 min***
C3	250 °C	40 min	***PASSED 10 min. Overshoot to 259 °C with 46 % power***

After reaching 250 °C we will turn off the heating.

C4: In a subsequent test we will keep the system at 200 °C for 30 min without deposition

RESULT: Passed. *Was kept at 259 °C for 30 min, power dropped to 40 % over the first 25 min but temp stayed stable. PID integral changed from 0.002 to 0.001. Then power went to 0 and temp dropped to 253 °C. Eventually stabilizes at 251 °C with power at 27 %.*

C5: After the heater tests we will perform the Rate of Rise test again. The result should again be ≤ 8.0×10^{-6} Torr L/s after pumping to near ultimate pressure.

RESULT: Passed with flying colors. Result 6.4 E-7 Torr*L/s

D. Reactive deposition test

This test is performed with the same wafers and holder as the heater test.

D1: Test that O_2 pressure can reach $2*10^{-4}$ Torr.

RESULT: Passed. 30 % O_2 flow results in desired pressure.

D2: Test that we can run a process with Ti-deposition at 2 Å/s with O_2 pressure starting at $2*10^{-4}$ Torr and heating of the substrate to 200 °C to a thickness of 200 nm.

RESULT: Passed. 50 nm deposited nominally using Ti tooling factor.
< 9 min to 200 °C with max power set to 75 % (set to protect heaters from going straight to 100 % power). 20 % O_2 *flow for p = 1.5 - 2 E-5 Torr, power on heater around 29 % for 200 °C.*

TiO_2 *film was 170 nm thick as measured by XRR on the day of deposition with a density of 4.3-4.4 g/cm*^{3} *indicating O-poor Ti. The XPS results indicated the same – TiOx with x~1.4 inside the film compared to TiOx with x~2 at the surface.*

Images for test B3, 1.3: