Instructions for the Experiment

“Redox based Non-volatile Memory Devices”

Atomic Layer Deposition: FlexAL® ALD tool:

Loading/Unloading Wafer into transfer part:

1. Lower the z-shift.*
2. Turn out the turbo pump. *
3. Open N2-supply. *
4. Wait, until air pressure is reached. The door will open automatically. *
5. Unload all the wafers on z-Shift. *
6. Load up to 4 cleaned wafers to z-shift. *
7. Close the door, then the N2-supply, and start the turbo pump. *
8. Heat out the wafers (200 °C for at least 30 Minutes). *
9. Raise z-shift to safe position. *

Load Wafer into chamber:

1. Move z-shift down.*
2. Load wafer carefully onto transfer arm. Retract the arm.*
3. Move z-shift up to safe mode and make sure the arm cannot hit the z-shift.*
4. Make sure the wafer does not overlap and lies completely on the transfer arm.
5. On ALD-PC, go to System/Pumping.
6. Left click on the wafer at the transfer part, and then to the empty place within the chamber. This starts the loading assistant.
7. Simply follow the instructions at the screen.

Checking parameters:

1. Check the base pressure of the system (should be around 2×10^{-6} mbar).
2. Check the table temperature of the system (should be 250 °C).
3. Go to presets and check if all the temperatures are in range.
4. Go to recipes and check the right settings of the recipe.

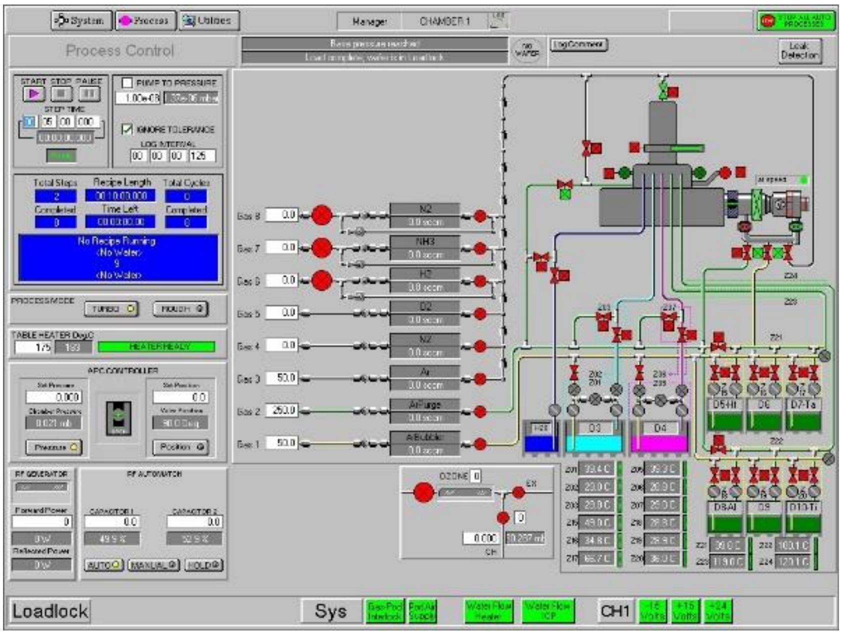
Starting the process:

1. In recipe menu, click start.
2. Control the screen and the right switching of the valves.
3. During plasma step, control if the plasma is ignited correctly (no dounle striking etc.)
4. Wait, until the process is finished (yellow alert).

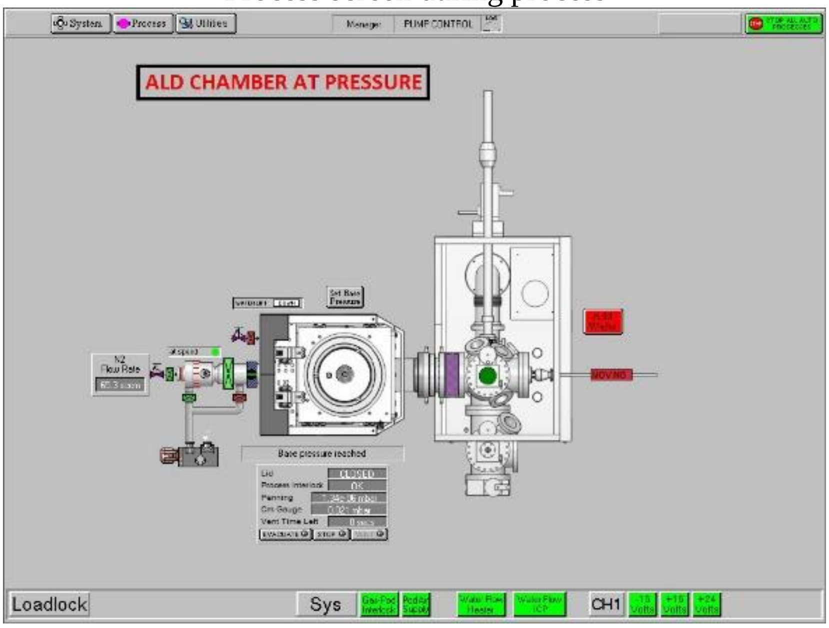
Unloading the wafer from the chamber:

1. Wait, until the chamber is pumped and the base pressure has reached 2×10^{-6} mbar.
2. Go to System/Pumping.
3. Leftclick on the wafer in the chamber, then leftclick on the free position in the transfer part.
4. Follow the instructions on the screen.
5. Move down z-shift.
6. Place on z-Shift.
7. Retract transfer arm and move up z-shift.

<u>** Already been done*</u>



Process screen during process



Pumping screen

Lithography process for top electrodes by image reversal at Suss MicroTec MA6 with Hg-lamp @ λ = 350 nm

1. Switch on N_2, lamp and mask aligner
2. Load mask
3. Switch on hotplates at 120 °C (left) and 90 °C (right)
4. Clean the substrates:
   Acetone, 2-Propanol + ultrasonic for 2 min
   Drying: 120 °C bake for 3 min
   Cool down for 3min
5. Spin coat samples with resist AZ 5214 E
   use recipe of the spin coater – C-RCP-4 (4000 rpm)
6. Prebake on the hotplate
   90°C for 5min
   Cool down for 3min
7. Load the sample to the mask aligner and align the TE pattern to the BE pattern
8. Exposure to UV light 10s, 350W, CP-Mode, HP-Mode
9. Reversal bake on the hot plate
   120°C for 60 s
   Cool down for 3min
10. Flood exposure 60 s (without mask). CP-Mode (350W), Lamp test Mode
11. Develop in AZ 326 MIF, 90s
12. Rinse cleaning and dry with N_2.
13. Check the sample under microscope and if it is not good,
    immerse the sample back by acetone and repeat the procedure from step 1.

DC sputtering of Ti (5 nm) / Pt (25 nm) film for top electrodes at Univex 450^{0}C / Leybold

1. Turn on DC generator and MFC´s
2. Open latch at load-lock door and vent the load-lock with “BEL” button (at SPS controller)
3. Put samples on adequate carrier plate and mount the carrier plate carefully onto load lock holder
4. Evacuate the load-lock with “VAC” button (at SPS controller)
5. Choose process #6 (at SPS controller) and
   Press “START” button
6. Check: the movement of robot arm,
   gas flows and pressure for chambers #6 (Ti) and #5 (Pt)
   voltage and DC-power for chambers #6 (Ti) and #5 (Pt)
   during deposition,
   transport of the carrier plate back into the load lock
   after deposition.
7. Press the “VAC” button to end process #6 (at SPS controller)
8. Vent the load-lock with “BEL” button (at SPS controller)
9. Dismount carrier plate out of the load-lock
10. Close load-lock, close the latch at the load-lock door

11. Evacuate load-lock with "VAC" button (at SPS controller)
12. Dismount the samples from the carrier plate and wrap the carrier plate into cover
13. Switch off DC generator and MFC´s.

Parameters:
5 nm Titanium
Gas inlet (Argon) 30% (~ 60sccm)
Pressure: 2.2E-2 mbar
Power: 20% DC (300W)
Time: 12s

25 nm Platinum:
Gas inlet: s.o.
Pressure: 1.4E-2 mbar
Power: 25% DC (345W)
Time: 14s

Lift-Off process - Acetone , Ultrasonic – 1 min, Power 1, Rinse with 2-propanol dry with Nitrogen

Electrical characterization of Pt/Ti/TiO_2/HfO_2 /Pt memory elements using the Agilent Semiconductor Analyzer B1500A
Sample: FC_2_m

1. Initial I(V) curve and forming:
   Voltage scan: 0 V .. **1 V** .. 0 V… **-1 V**… 0V
   Forming: 0 V.. **4 V** .. 0 V… **-1.8 V**… 0V
   Current Compliance: $I_{CC, SET}$ = 50 µA; $I_{CC, RESET}$ = -5 mA
   Derive: *I(V) an R(V) characteristic, $V_{Forming,,}$ 1st LRS*

2. Measure 5 I(V) cycles:
   Voltage scan: SET: 0 V .. **1.3V** .. 0 V
   RESET: 0 V .. **-1.3V** .. 0 V
   Current Compliance: SET: 100 µA
   RESET: -5 mA
   Derive (with errors): LRS, HRS, HRS/LRS (Ratio), V_{SET}, V_{RESET}

3. Test read voltage dependence:
   Switch the device to the ON-state (LRS)
   Read out with voltage ramps up to: 0.1 V, 0.2 V, 0.4 V (I_{CC} = 300 µA)
   Derive: *LRS(V_{Read})*

Test the ability of multi-level switching:

1. Multi-level RESET:
   Set voltage: 1.5 V
   Current compliance: $I_{CC} = 100\ \mu A$
   Increase the reset voltage stepwise:
   -1 V, -1.2 V, (-1.3 V), -1.5V, -1.7 V
   Derive: $HRS(V_{RESET})$

2. Multi-level SET:
   Set voltage: 1.5 V
   Increase current compliance stepwise:
   100 µA, 300 µA, 500 µA, 700 µA

   RESET: -1.5 V, $I_{CC} = -1$ mA (after each SET)
   Derive: $LRS(I_{CC})$

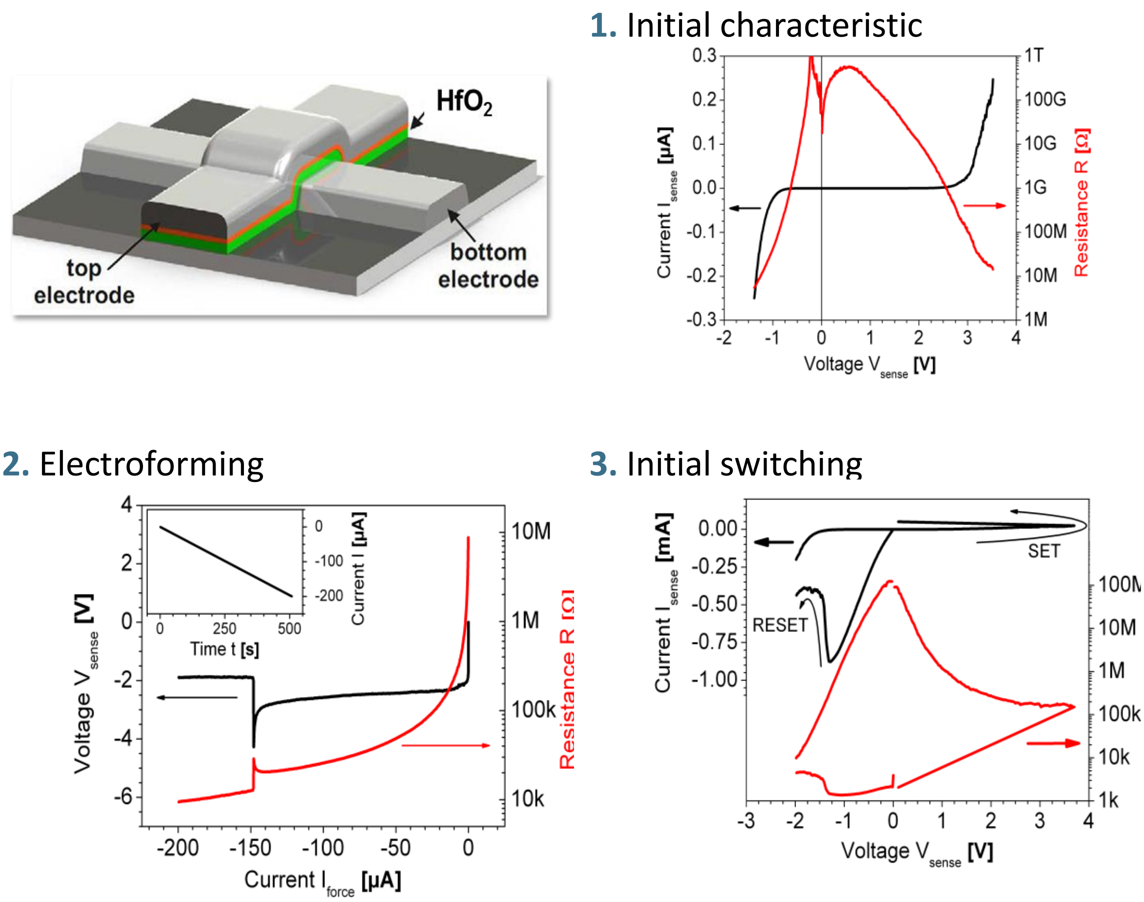


Fig. 1: Exemplary resistive switching of a HfO_2 based test device

a)

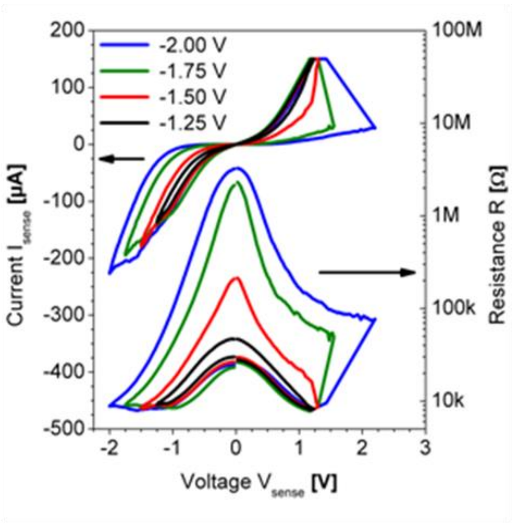


Fig. 2: Demonstration of multilevel switching of an exemplary HfO_2 based test device

b)