SNF RRAM Standard Process Flow and Characterization of Lesker-2 TiN

ENGR241 Week 3 End-week Updates

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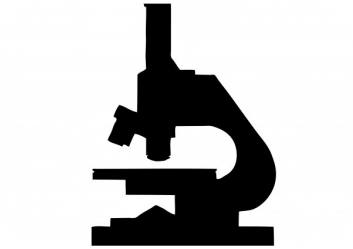
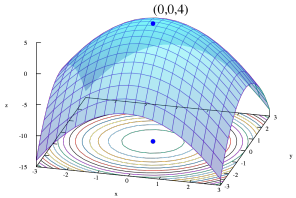
Aim & Goals

- Test and characterize ALD RRAM devices
- Develop TiN recipe on new Lesker with low oxygen contamination
- Compare TiN properties (composition, resistivity, topography)
- Make electrical/imaging data and test structure layouts available to SNF
- Make SOPs for RRAM stacks and report TiN findings



Process Flow Development



Parameter Optimization

Comprehensive Documentation

SNF Database

Tool Training Update

- ✓ XPS qualification
- ✓ Refresher on PT-Ox/PT-MTL
- ✓ Wet bench: wbflexcorr
  - ➢ For sidewall/oxide/resist cleaning process

Need a bit more characterization:

- ❑ Prometrix
- ❑ Nanospec
- ❑ P2

TiN Sample Preparation & Characterization

(Not drawn to scale)

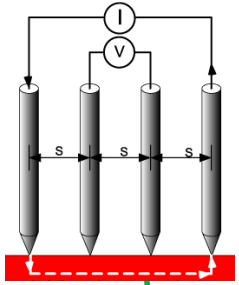
Start with Si wafer
Standard RCA Clean

Dry grow 100nm SiO_2 (thermco)

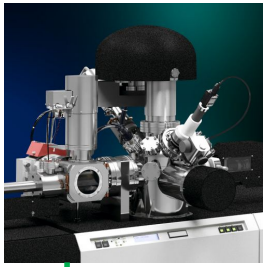
Sputter 30nm TiN

Compare 3 sputtering tools: Lesker-1 (SNF), Lesker-2 (SNF), AJA (non-SNF)

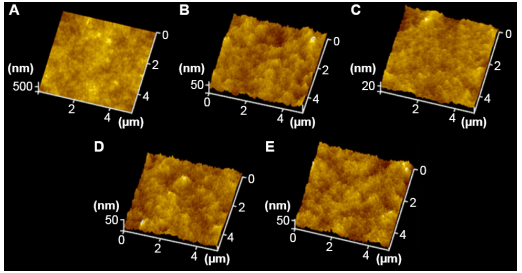
Prometrix Resistivity



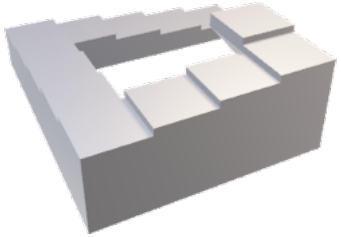
XPS/Auger Composition



AFM Surface Roughness



AFM Step Height



Measure 3-4x throughout quarter to quantify oxidation over time

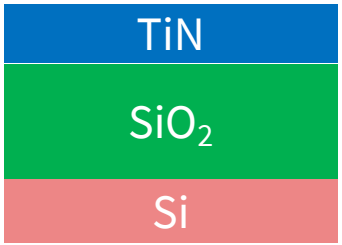
Stanford University

Progress Updates: Fabrication

Update: Lesker-2 expected to go live in early Feb.

- ✓ RCA clean wafer
- ✓ Woollam to measure native oxide thickness (11.2Å)
- ✓ Dry oxide growth for 1hr in thermco4 @ 1100℃ (~100nm)
- ✓ Woollam to confirm final oxide thickness (~1062.54Å, ~1052.91Å)
  - › Exact thickness is not important, just there to insulate TiN from Si
  - › Good quality oxide is important to get accurate TiN surface roughness
- ❑ Sputter 30nm TiN (Kapton tape for step)
  - ✓ AJA (non-SNF)
  - ❑ Lesker-1 (SNF)
  - ❑ Lesker-2 (SNF)
- ❑ AJA Characterization
  - ✓ XPS
  - ❑ Prometrix
  - ❑ AFM
- ❑ Lesker-1 Characterization
- ❑ Lesker-2 Characterization

Underlined is planned to be done by Tuesday



Lesker TiN target

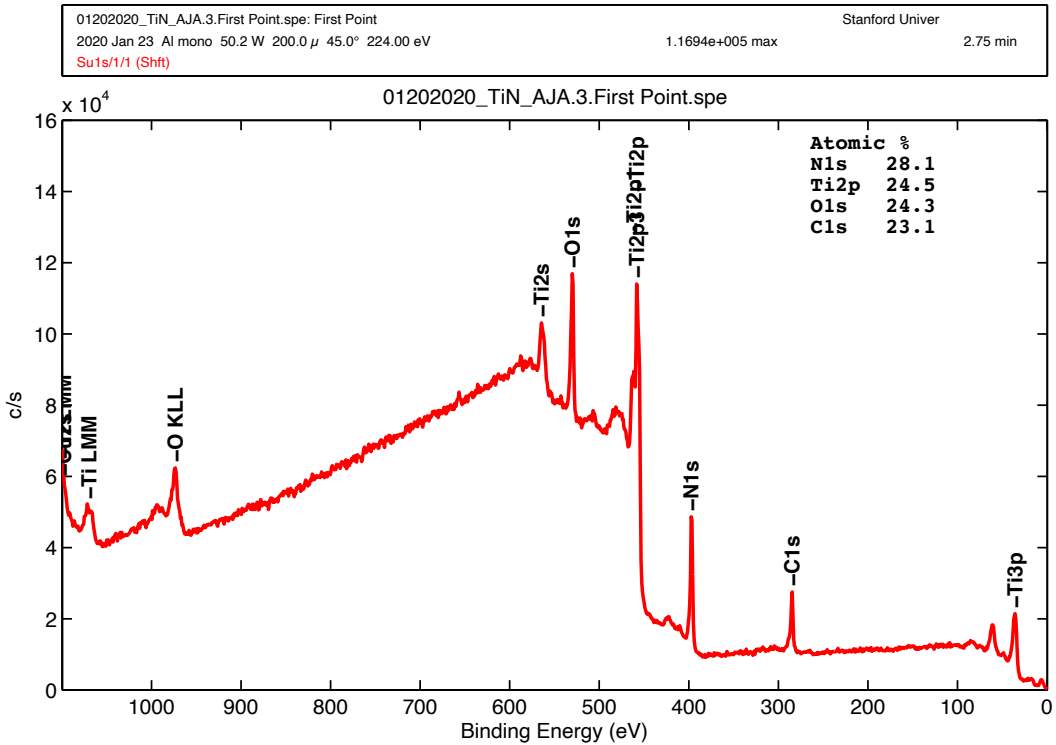
AJA TiN Sputter Recipe: Reactive Sputtering

- **Target:** Ti
- **RF Power:** 200W
  - 150W also ok; different dep rates
- **Wafer Bias:** 100V
  - DC bias 92-94V on AJA in practice
- **Ar Flow:** 30 sccm
- **N Flow:** 3 sccm
  - Unit conversion means that this is written as 30 on AJA somehow
- **Set Pressure:** 2.15 mTorr
  - 1.8-1.9 mTorr on AJA in practice

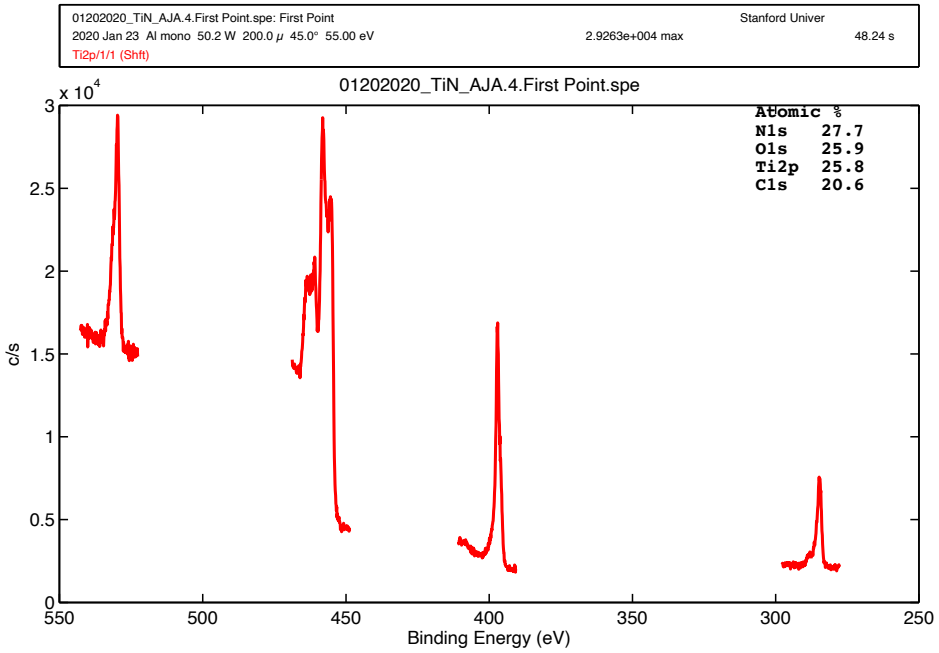
Recipe:

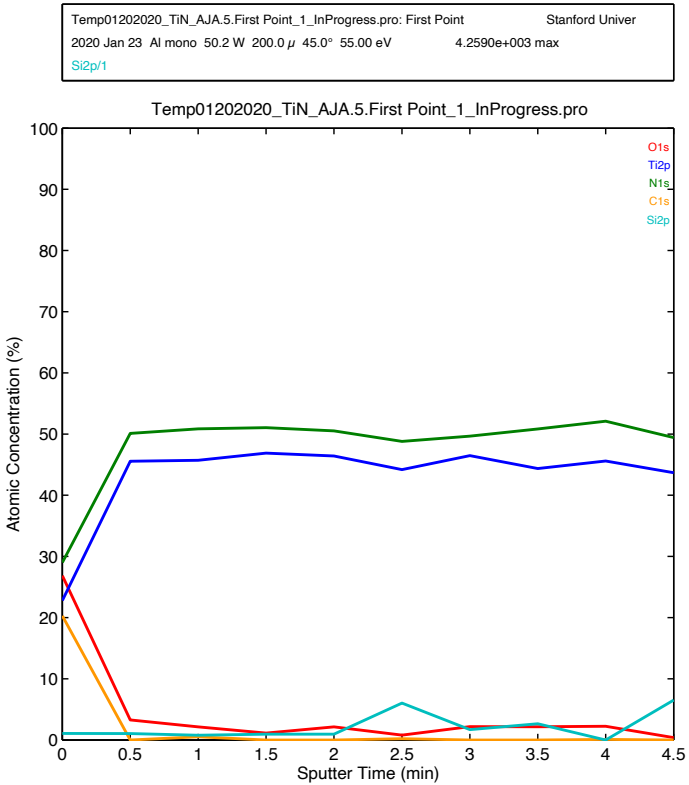
- Load sample and wait for 1e-7 base chamber pressure
- Plasma on another target (conductive) e.g. Al, GeTe
  - Eases plasma ignition for TiN target
- Plasma on Ti target
  - Bias on other target off
- 20s ramp-up of Ti target RF power
- 2 minutes pre-sputtering of Ti target (shutter closed, no wafer bias)
- 20s ramp-up of wafer bias
- Open shutter and deposit for X seconds
- Close shutter
- 20s ramp-down of Ti target RF power

AJA XPS Results: Surface Survey Scan



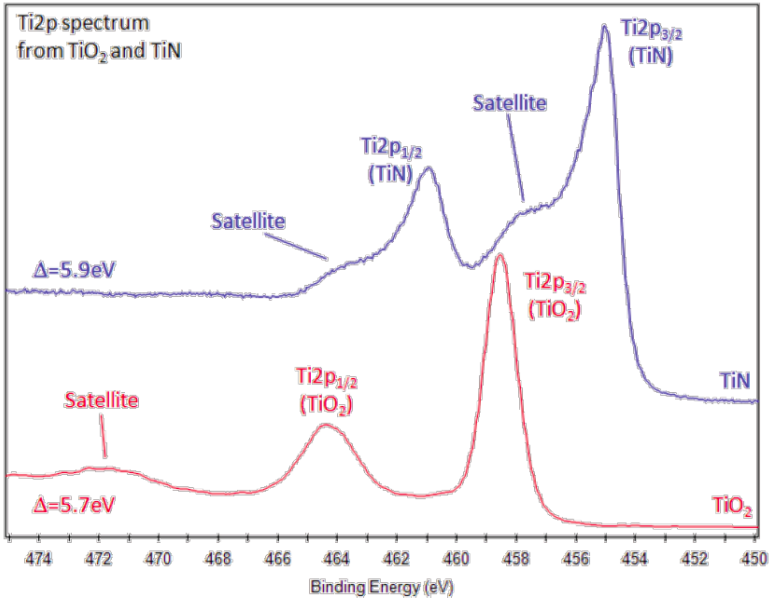
AJA XPS Results: Hi-Res + Depth Profile



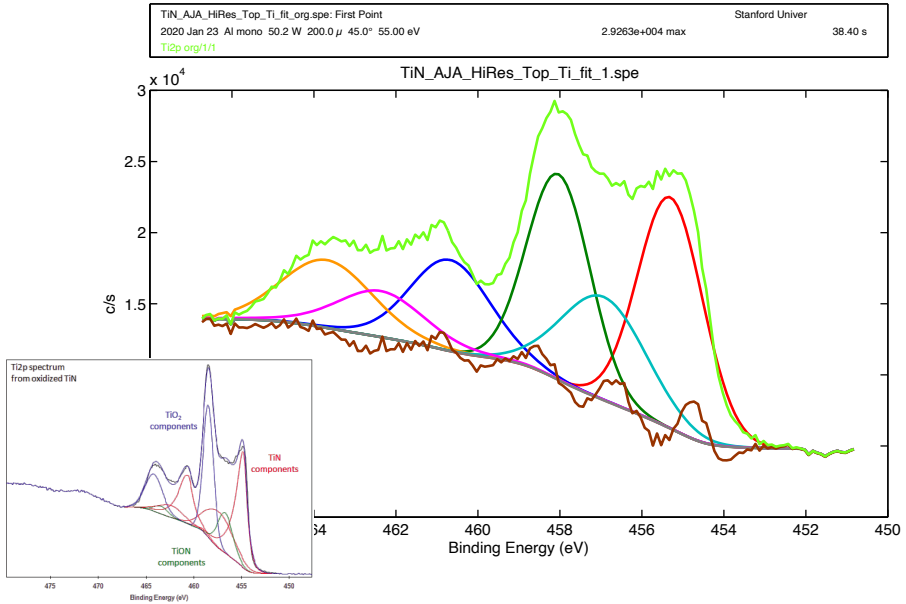


AJA XPS Results: Fitting

Chemical state	Binding energy $Tip_{3/2}$ / eV
Ti metal	454.1
TiN	454.9
TiO_2	458.5



Ti fit has spin-orbit splitting that causes doublet peaks



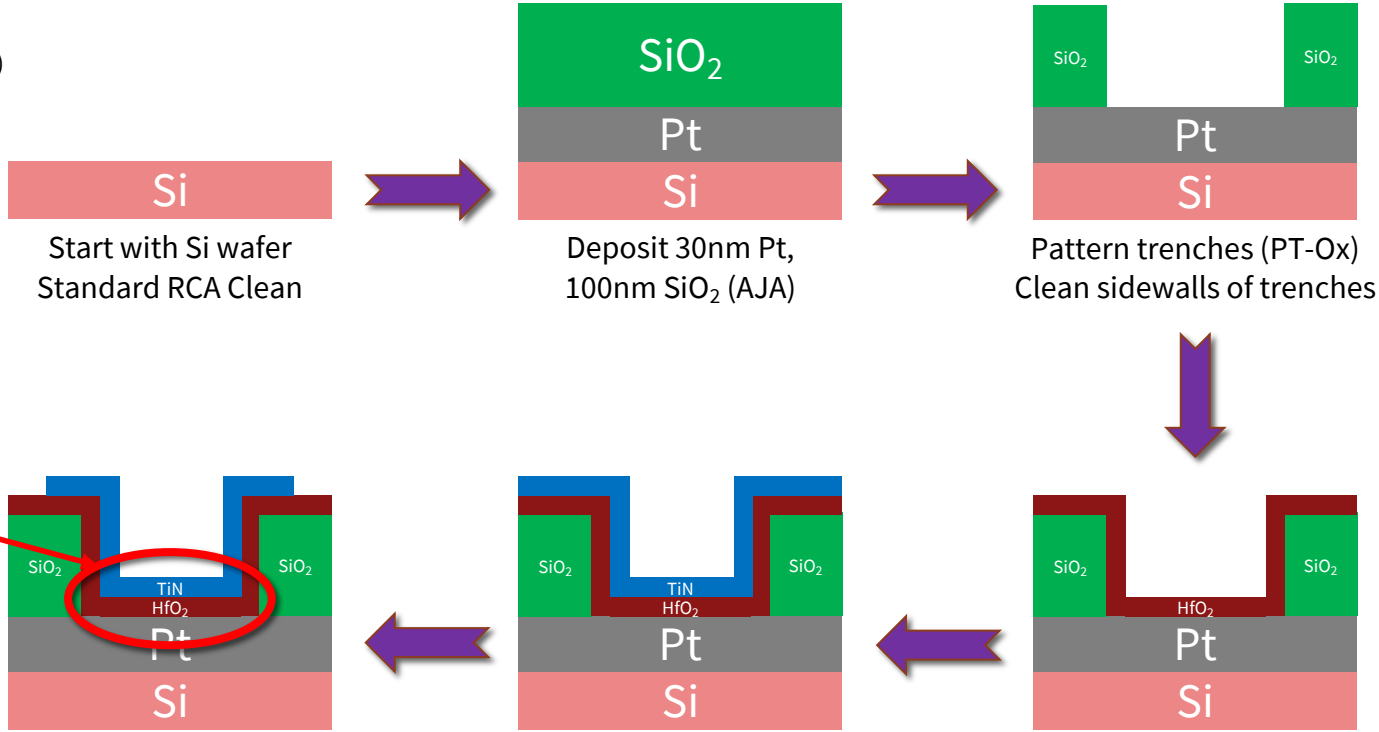
- Ti2p peak has significantly split spin-orbit components (Δ_{metal}=6.1eV).Splitting -value varies with chemical state ($\Delta_{nitride}$=6.0eV, Δ_{oxide}=5.7eV).
- Typically FWHM for each spin-orbit component is the same, but for Ti2p the $Ti2p_{1/2}$ component is much broader than the $Ti2p_{3/2}$ peak. Consequently, $Ti2p_{1/2}$ peak is much shorter than expected.
- Caused by Coster-Kronig effect. (Post-ionization, $Ti2p_{1/2}$ state is very short lived compared to $Ti2p_{3/2}$ state.)
- Causes difficulty in accurately peak fitting Ti2p region with multiple chemical states

Lesker: Which Recipe? Discussion

- TiN isn't used that often in Lesker
- My original plan:
  - Master Recipe on Src 2 (TiN source) with downstream control
    - 35 -> 5 sccm Ar to allow plasma to ignite
    - No other sputtering gases
  - Didn't have enough time to run recipe ☹
- Paul Comita recipe: Ti/TiN co-sputter for higher Ti concentration
- Other recipes call for 3 to 5 sccm Ar with TiN target
- Should I try to work with Maurice to replicate the AJA recipe on Lesker-1?
  - XPS shows that it works super well in producing low-oxygen TiN
  - May not even need Lesker-2 to do good-quality TiN

RRAM Process Flow Outline

(Not drawn to scale)



Process Flow Parameters

- **Resistive switching material (metal oxide):** hafnia
- **Seed layer:** none
- **Dimensions:**
  - **TiN electrode thickness:** 30nm
  - **Resistive switching layer thickness:** 10nm
  - **Device size:** {1, 2, 3, 4, 5, 8, 10, 20, 40, 50} um
- **RS oxide growth temperature:** 250C
- **Annealing:** none
- **Metal oxide ALD method:** thermal
- **TiN deposition method:** sputtering
- **Top contact:** TiN only

Progress Updates

Underlined is planned to be done by Tuesday

- ✓ RCA clean wafer
- ❖ Deposit 10nm Ti with AJA (skipped)
- ✓ Deposit 30nm Pt with AJA
- ✓ Deposit 100nm SiO2 with AJA
- ✓ Woollam to check oxide thickness (834Å)
- ❑ Photolithography
  - ❑ YES Oven for 30 mins
  - ❑ SVG Coat 2 with 1µm Shipley 3612 resist, 2mm EBR, skip prime step
  - ❑ Expose with Heidelberg: look at previous runs, logbook, exposure charts by tool (dose: 80, defoc: ±2)
  - ❑ SVG Develop (1µm 3612 dev) w/post-exposure bake and inspect
- ❑ PT-Ox: Oxide_ER_Test, 1 min
- ❑ Nanospec to check etching
- ❑ Matrix for resist ashing: use defaults (Strip.rcp 120s) and inspect to see if resist is removed
- ❑ Metal cleaning on wbflexcorr
  - ❑ SRS-100 for stripping photoresist from metal wafers, 60C
  - ❑ PRS-1000 for final metal clean before deposition or furnace step, 40C
- ❑ Fiji1 thermal HfO_2: 100 cycles standard recipe
- ❑ Woollam to check oxide thickness
- ❑ TiN deposition 30nm
- ❑ Photolithography (see previous)
- ❑ PT-MTL: still need details
- ❑ Microscope to check etching
- ❑ Matrix for resist ashing (see previous)
- ❑ Metal cleaning on wbflexcorr (see previous)

Layout Generator

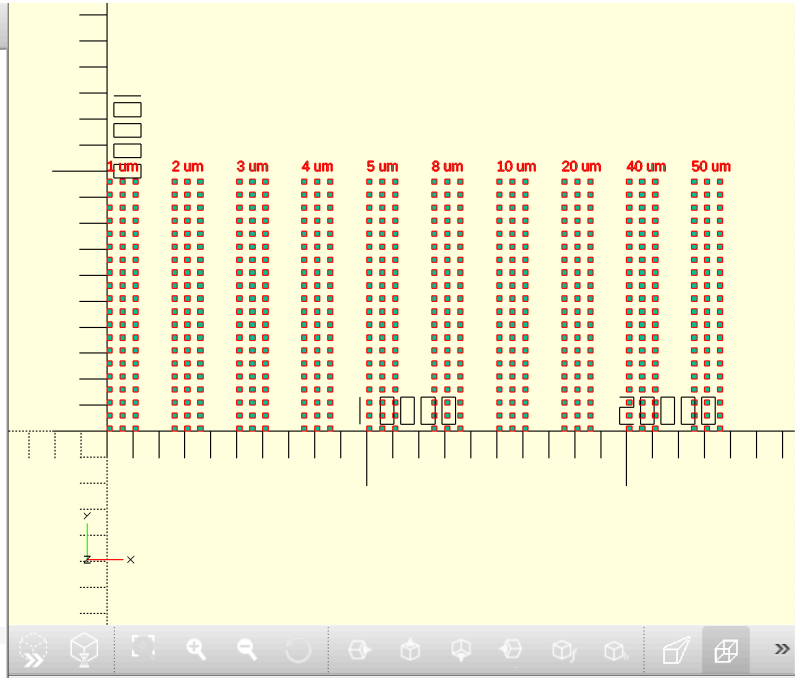
```
// All units in microns

// Design parameters
n_groups = 10;
n_rows = 20;
n_cols = 3;
pad_size = 200;
pad_spacing = 500;
group_spacing = 1000;
rram_size = [1, 2, 3, 4, 5, 8, 10, 20, 40, 50];
font_size = 400;

// Select when exporting: layer 0 is via trench, layer 1 is TE pad
layer = 1;

// Create pads/trenches in groups
translate([pad_size/2, pad_size/2, 0])
for (i = [0 : n_groups - 1]) {
    translate([i * (pad_spacing * n_cols + group_spacing), 0, 0])
    for (row = [0 : n_rows - 1]) {
        translate([0, row * pad_spacing, 0])
        for (col = [0 : n_cols - 1]) {
            translate([col * pad_spacing, 0, 0])
            if (layer == 1) square(pad_size, center=true);
            else square(rram_size[i], center=true);
        }
    }
}

// Pad group labels
if (layer == 1)
for (i = [0 : n_groups - 1]) {
    translate([i * (pad_spacing * n_cols + group_spacing), n_rows * pad_spacing, 0])
    text(str(rram_size[i]," um"), size = font_size);
}
```



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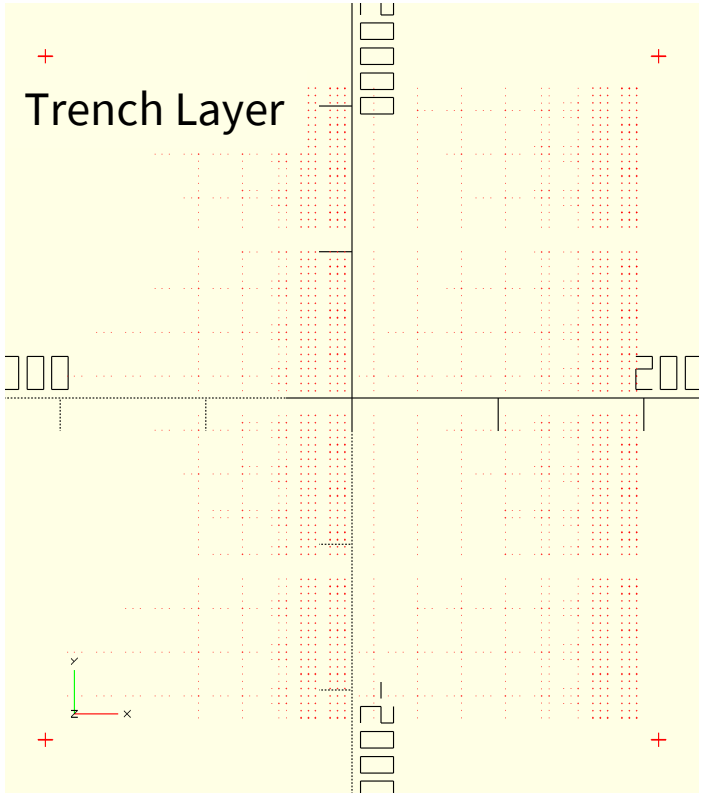

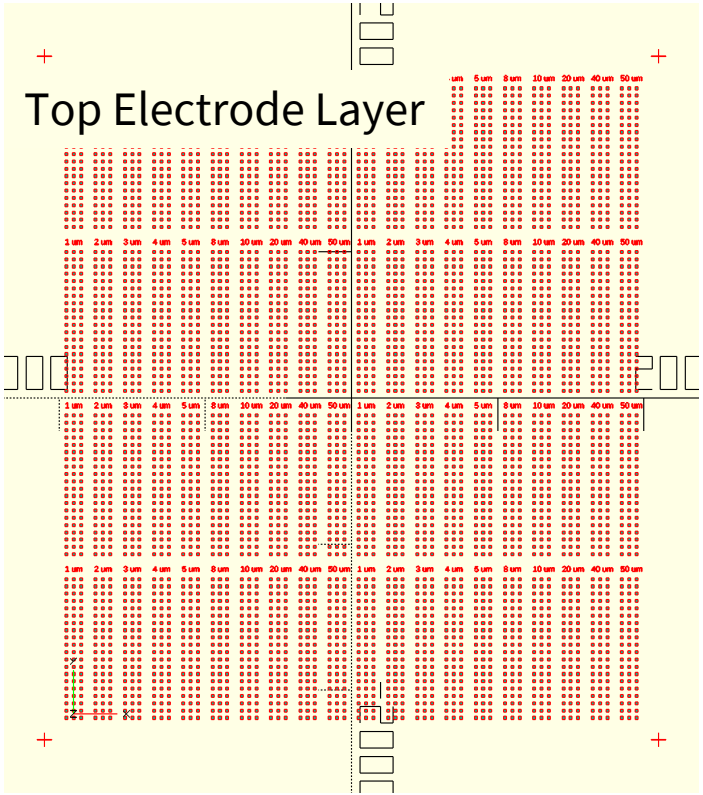

Finalized layout: alignment marks, tiling, centering about origin to make Heidelberg usage easier
Design dimensions: about 4cm x 4cm, (20x3 array) x (4x2 grid) devices per size with 10 device sizes

Thank you!

QUESTIONS?