PROBLEM SET #3

Issued: Thursday, February 21, 2019.

Due: Thursday, March 7, 2019 at 9:00 a.m. on Gradescope.

1. You have a 6" 675μm-thick bare silicon wafer and deposit a 1μm thick layer of silicon dioxide at 400°C with zero initial stress.

(a) Find the stress of the silicon dioxide when the wafer is cooled down to 25°C. Is the stress compressive or tensile? Table PS3.1 contains helpful material properties for silicon and silicon dioxide.

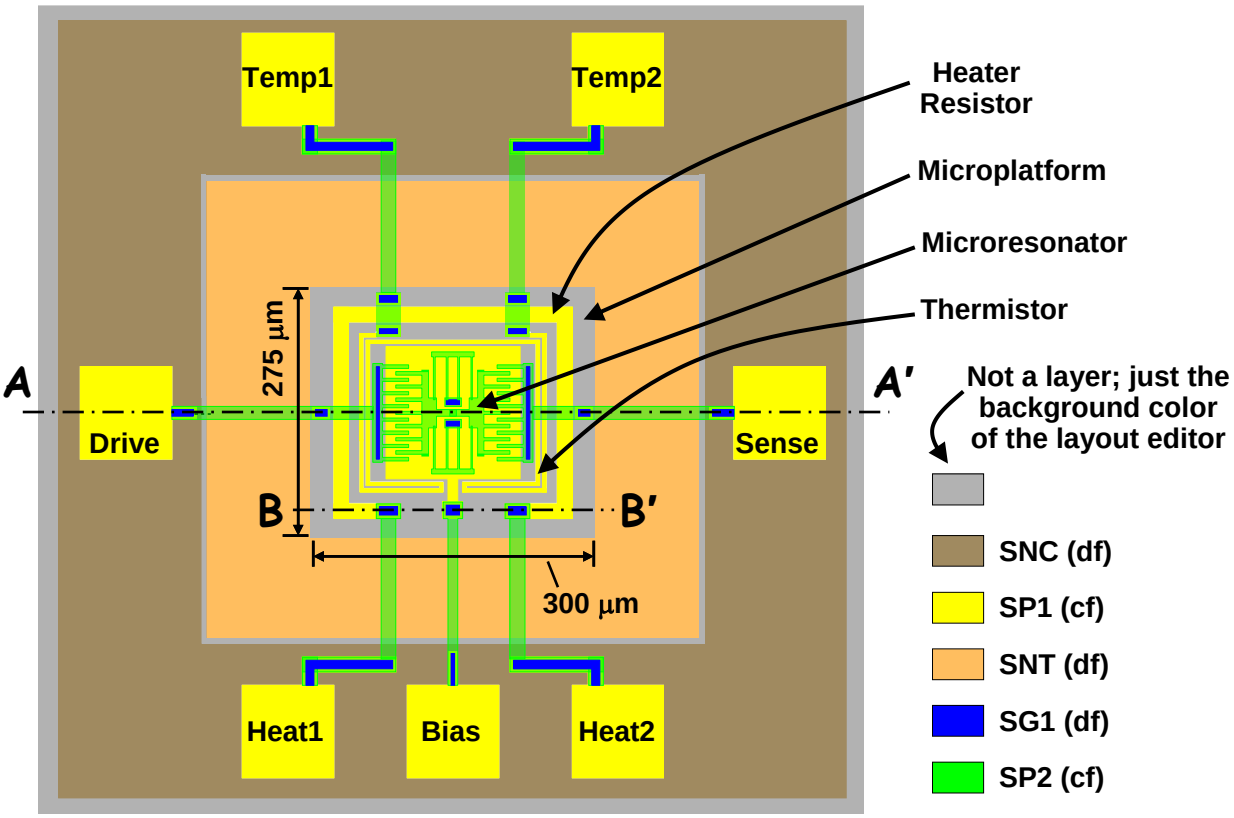
(b) Due to the thin-film stress of the silicon dioxide, does the wafer bend upwards or downwards? Determine the radius of curvature of the wafer.

	Silicon	Silicon Dioxide
Density, ρ (kg/m^3)	2300	2200
Young's Modulus, E (GPa)	150	69
Poisson's Ratio, ν	0.22	0.17
Thermal Expansion Coefficient, α_T (K^{-1})	2.8×10^{-6}	0.7×10^{-6}

Table PS3.1

2. The following pages comprise a (possibly flawed) surface micromachining process flow for a platform supported folded-beam comb-driven micromechanical resonator with layout shown below. This platform-mounted device actually comprises a micro-oven-controlled micromechanical resonator, for which the resonance frequency is stabilized against temperature fluctuations by heating the platform and stabilizing its temperature via feedback electronics. No details are spared in this flow; even equipment names are given, as are diagnostic steps used to verify select process steps. LPCVD furnace program names (for equipment in the UC Berkeley Microlab) are also given. These details are included to present a more realistic situation. In doing this problem, you must sift through the extraneous information and concentrate on the recipe information (i.e., temperatures, times, doses, etc. ...).

For etch steps, if the etch uses a plasma or RIE process, assume that the etch is largely anisotropic. Also, assume that any etch is done by first calculating the amount of time needed to etch based on the etch rate, then doing a 30% overetch afterwards to remove any small remaining spots of material. Individual mask layouts can be found at the end of the problem.



(a) Draw the cross-section of the structures along the A-A′ line in the layout (i) before step 12.0 of the process; and (ii) at the end of the process. Here, you should get the thickness dimensions correct, but the length dimensions can just be estimated (since they're not all given in the layout). Also, use a compressed horizontal (i.e., length) scale in your drawing.

(b) Draw the cross-section of the structures along the B-B′ line in the layout (i) before step 15.0 of the process; and (ii) at the end of the process. Again, get the thickness dimensions correct and just estimate length dimensions, using a compressed horizontal (i.e., length) scale.

(c) After fabrication via this process, you find that the resonator device and heating/temperature sensing elements do not function as designed. In particular, all bond pads seems to be shorted to one another. What is wrong? Where did the process go wrong? How would you change the process to correct the problem?

(d) If the springs supporting the platform provide a total restoring stiffness of 2 N/m, and the contact angle of water underneath the platform during drying is 30^{o}, will the platform be stuck down after drying in air? [Assume the room temperature surface tension of a water-air interface is 72.75×10^{-3} N/m.]

Micro-Oven uResonator Process

0.0 Starting Wafers: 8-12 ohm-cm, n-type, (100) prime or just n-type test wafers.
Control Wafers: PSGlF, PSGlB (Si)
NITlF, NITlB (Si)
POLYlF, POLYlB (tylanll ctrl.)
PSG2F, PSG2B (Si)
POLY2F, POLY2B (Si)
PSG3F, PSG33 (81)

1.0 Substrate Ground Plane Poly Deposition: target = 3000 A

1.1 Standard clean wafers.

1.2 Phosphorous-doped polysilicon deposition:
tylanll, SDOPOLYG
time = 1 hour 40 minutes, temp.= 650 C
(Dep. Rate - 1800 A per hour)

2.0 Sacrificial PSGl Deposition: target = 2 um
(immediately after n+ diffusion)
tylanl2, VDOLTOC
Flows (sccm): SiH4 = 60, pH3 = 10.3 (entered), 02 = 90
time (2um) = 1 hour 40 minutes (-1000 A per 5 min.)
tox =
Include etching controls: PSGlF and PSGlB

3.0 uPlatform Anchor Photo Mask: SNC (chrome-df)

3.1 Spin (double thickness for 2 um oxide),
expose, develop, descum, hard bake.

3.2 Etch in lam2:
For 2 um oxide: [press = 2.8 Torr, power = 350 W, gap = 0.38 cm, CHF3 = 30 sccm, CF4 = 90 sccm, He = 120 sccm, time = 1 min. I , [power = 0, same gases, time = 1 min.] 3X
Overetch with 700 W recipe.

3.3 Inspect under IV probe station: check contact

3.4 Wet dip in 5:l BHF for 10 secs.

3.5 Remove resist, piranha clean wafers.

4.0 Nitride Support Deposition: target = 3 um
Deposit silicon-rich low-stress nitride:
tylan9, SNITC.V
temp. = 835 C, Flows (sccm): SiH2C12 = 64, NH3 = 16
time = 14 hrs., (-2200 A per hour)
tnit =
Include etching controls: NITlF and NITlB

4.0 uStructure Polyl Deposition: target = 3000 A
(immediately after nitride support deposition)
Phosphorous-doped polysilicon deposition: tylanll, SDOPOLYG
time = 1 hour 40 minutes, temp.= 650 C (~1800 A per hour)
Include etching controls: POLYlF, POLYlB

5.0 uStructure Polyl Definition Mask: SP1 (emulsion-cf)

5.1 Spin, expose, develop, inspect, descum, hard bake.

5.2 Plasma etch poly-Si in Lam1 etcher, inspect
(CC14/He/02 at 300 Watts, 280 mTorr)

5.3 Remove PR, piranha clean wafers along with PSG2F and PSG2B.

6.0 Al Etch Mask Deposition: target = ~5000 A
CPA: pressure = 6 mTorr, power = 4.5 kW, track speed = 16 cm/s

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7.0 Microplatform Definition Mask: SNT (chrome-df)

7.1 Spin, expose, develop, inspect, descum, hard bake.

7.2 Plasma etch Al in lam3.

7.3 Inspect: use IV probe station: make sure field is nonconductive

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7.4 Plasma etch nitride in Teagal etcher, inspect.

7.5 Remove PR, pirahna clean wafers

7.6 Strip A1 in sink8 A1 etch.

8.0 Sacrificial PSG Deposition: target = 2 um
tylanl2, VDOLTOC
Flows (sccm) : SiH4 = 60, pH3 = 10.3 (entered) , 02 = 90
time (2um) = 1 hour 40 minutes (~1000 A per 5 min.)
Include etching controls: PSG2F and PSG2B

9.0 Sacrificial PSG Densification
RTA in Heatpulsel: 30 secs @ 950 C
(also do PSG2 ctrls)

10.0 (optional) Dimple Photo Mask: CD1 (chrome-df)

10.1 spin, expose, develop, descum, hard bake.

10.2 timed wet etch in 5:l BHF. (E.R. ~ 3000 A per min.)

10.3 Remove resist, piranha clean wafers.

11.0 uStructure Anchor Photo Mask: SG1 (chrome-df)

11.1 Spin (double thickness for 2 um oxide), expose, develop, descum, hard bake.

11.2 Etch in lam2:
For 1 um oxide: etch as usual.
For 2 um oxide: [press = 2.8 Torr, power = 350 W, gap = 0.38 cm, CHF3 = 30 sccrn, CF4 = 90 sccrn, He = 120 sccrn, time = 1 min.],[power = 0, same gases, time = 1 min.] 3X
For both cases, overetch with 700 W recipe.

11.3 Check contact using IV probe station.

11.4 Wet dip in 5:l BHF for 10 secs.

11.5 Remove resist, piranha clean wafers.

12.0 uStructure Poly2 Depostion: target = 2 um
Phosphorous-doped polysilicon deposition: tylanll, SDOPOLYG
time = 11 hours, temp.=650 C
Include etching controls POLY2F and POLY2B (tylanll cntrls).

13.0 Oxide Mask Deposition
tylanl2, VDOLTOC
Flows (sccrn): SiH4 = 60, PH3 = 10.3 (entered), 02 = 90
time = 25 minutes (~1000 A per 5 rnin.)
Include etching controls: PSG3F and PSG3B

14.0 RTA Anneal
Heatpulsel: 1 min. @ 1100 C in 50 l/sec N2

15.0 uStructure Poly2 Definition Mask: SP2 (emulsion-cf)
Align to ustructure polyl.

15.1 Spin, expose, develop, inspect, descum, hard bake.

15.2 Etch in oxide mask in lam2.

15.3 (optional) Remove resist:
technics-c, 10 min. 02 plasma B 300 W

15.4 Etch 2nd poly in laml: [press = 280 mTorr, power = 300 W, gap = 1.5 cm, CC14 = 130 sccrn, 02 = 15 sccm, He = 130 sccm, time = 1 rnin.] then [power = 0, same gases, time = 1 rnin.] 5 or 6X, depending upon etch rate (E.R. usually - 4000 A per min.)

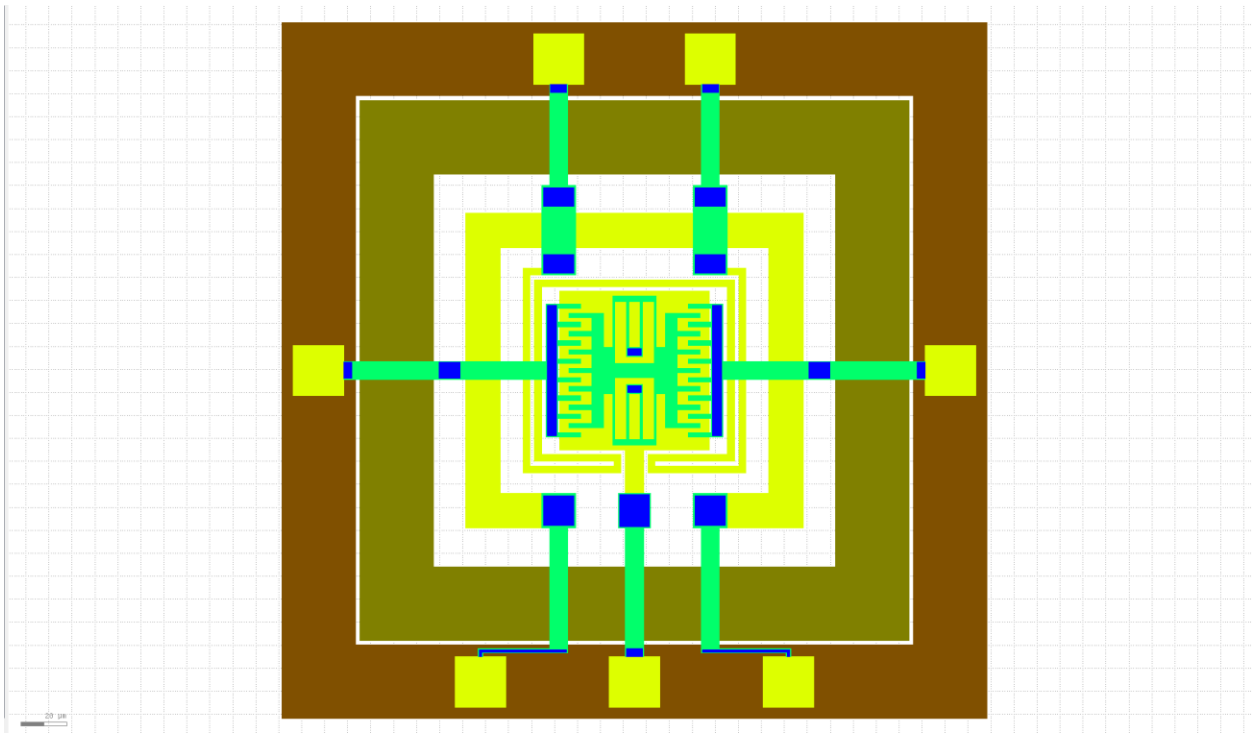
15.5 If haven't already removed resist, remove resist.
technics-c, 10 min. 02 plasma B 300 W

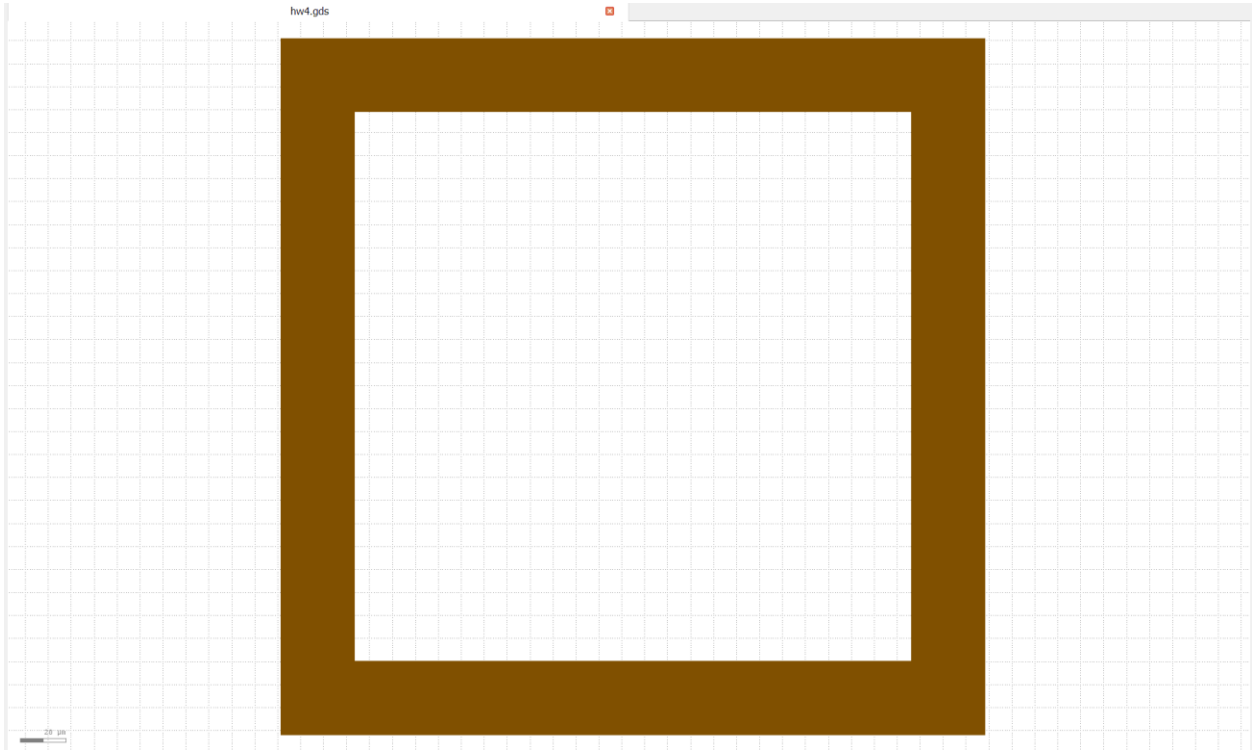
16.0 uStructure and uPlatform Release

16.1 Piranha clean in sink8.

16.2 Wet etch in 5:l BHF (~6000 A per rnin.) in sink8.
(Etch for whatever time is needed to remove all exposed oxide, including oxide underneath structures)
Slowly agitate, rinse.
Spin dry or N2 gun dry.

16.3 Piranha clean in sink8 for 10 min. Follow with standard DI rinses. No HF dip. Spin dry or N2 gun dry.

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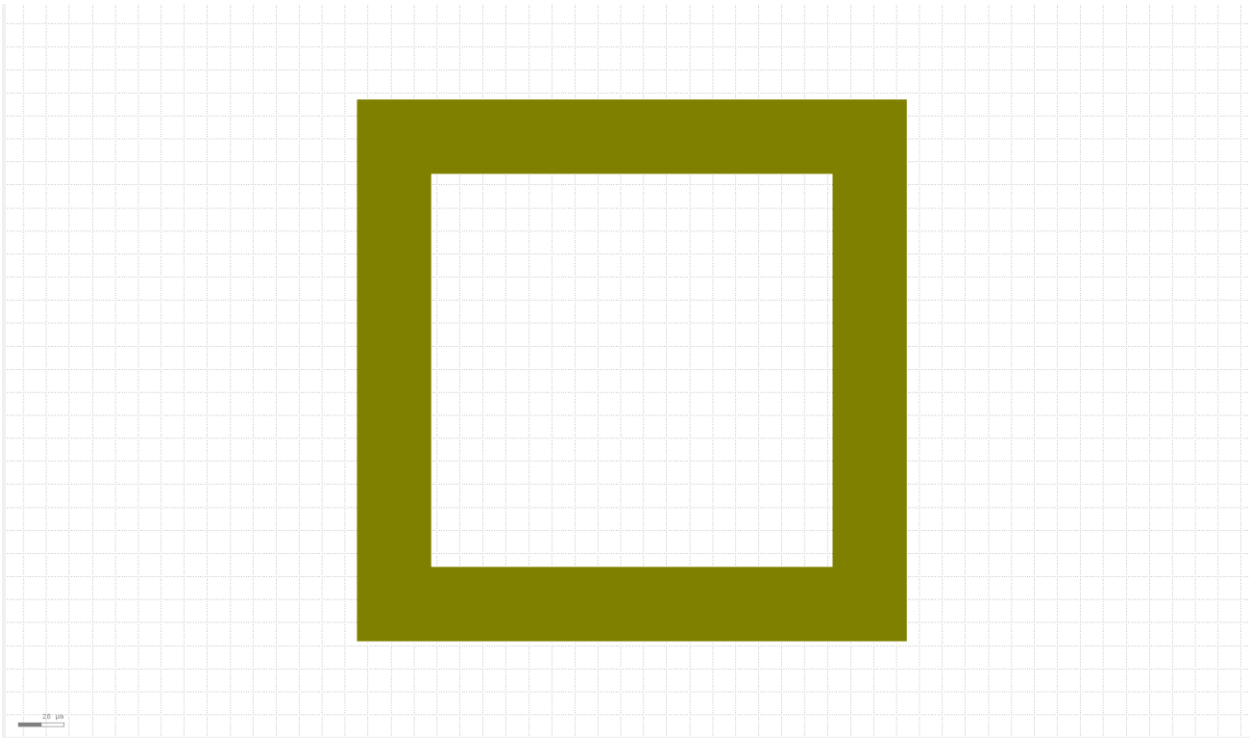

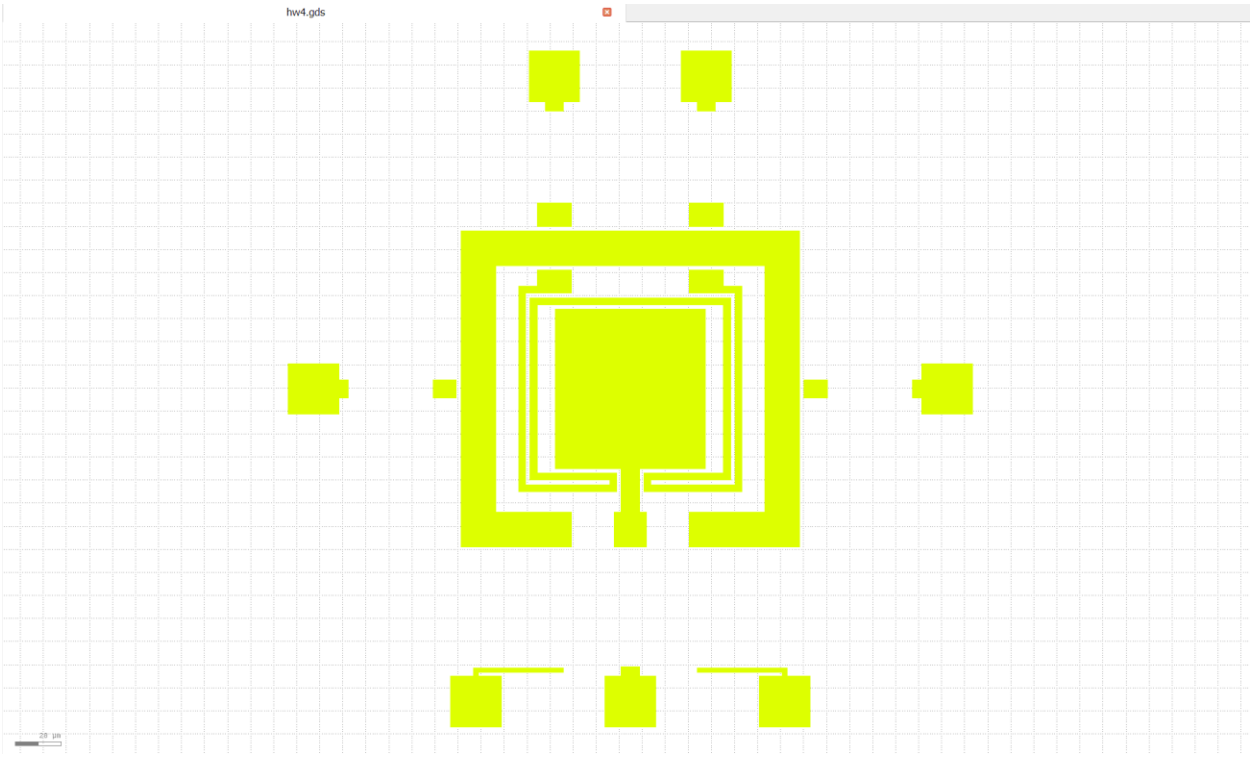
hw4.gds