Heat and Cooling Channel Design Analysis for an Electrostatic chuck

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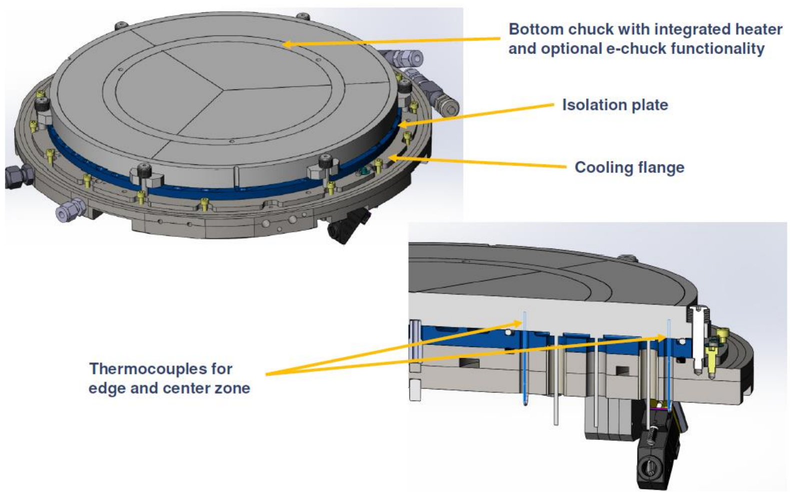
Objective:

- To design a heater, which will have a uniform heating of wafer with a Heater uniformity of 3% (measured with a TC wafer at 17 locations) of the maximum temperature to be reached which is 250 °C.
- To design an air cooling chamber so as to reduce the temperature to 50°C with cooling rate of 20°C.



Process Conditions:

- Combined vacuum and electrostatic chuck Integrated heater
- 2 Zone heater: center and edge zone
- Temperature ramp rate: 30°C/min heating, 20°C/min cooling
- Heater uniformity 3% (measured with a TC wafer at 17 locations)
- Process condition in chamber: 0.1mbar
- Electrostatic clamping force (vertical): ~10N
- Clamping voltage: +/- 1.5 kV
- Surface flatness wafer side: <5μm (goal: <2μm)
- Wafer size: 200mm and 300mm

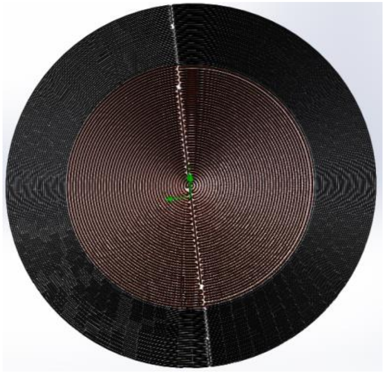
PARAMETERS FOR ITERATIONS

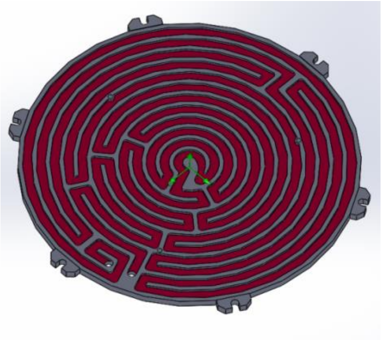
ITERATIONS	ADHESIVE THICKNESS(mm)	COOLING CHANNEL TYPE	COOLING CHANNEL WIDTH(mm)	COOLING CHANNEL HEIGHT(mm)	COOLING CHANNEL WALL THK(mm)	CURRENT INNER &OUTER ZONE(A)
ITERATION 1	0.25	NON-SPIRAL	4	3	1.33	11.5&11.5
ITERATION 2	0.3	NON-SPIRAL	8	3	4	4.252&5.556
ITERATION 3	0.3	NON-SPIRAL	8	3	4	4.342&5.963
ITERATION 4	0.3	SPIRAL	14	5	4	2.02&2.61

ITERATIONS	HEAT TRACE MATERIAL	CERAMIC MATERIAL	HEAT TRACE THICKNESS(mm)	HEAT TRACE WIDTH INNER ZONE(mm)	HEAT TRACE WIDTH OUTER ZONE (mm)	HEAT TRACE OTHER MODIFICATIONS
ITERATION 1	ES 161 MO-W-MN	Ceramic Al2O3	0.4	1	0.7	NIL
ITERATION 2	ES 161 MO-W-MN	Ceramic Al2O3	0.016	3	4	LOCAL THINNING NEAR MOUNTING HOLES
ITERATION 3	ES 161 MO-W-MN	Ceramic Al2O3	0.016	3	4	Traces locally thinned to 3.65 ,3.75,& 3.85 in local regions
ITERATION 4	AgPd 29115	Plasmapure AD-998 Al2O3	0.021	3	3.5	localized thinning is done in certain places

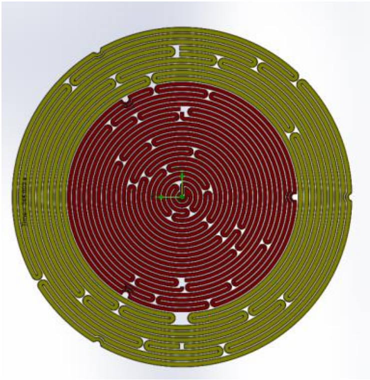
HEAT TRACE AND COOLING CHANNEL MODELS

ITERATION 1

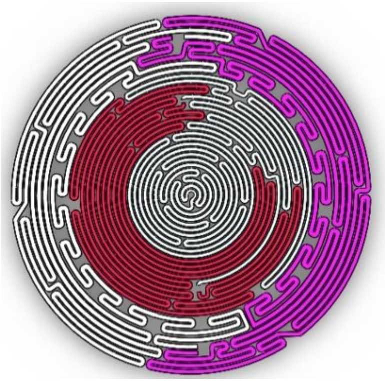




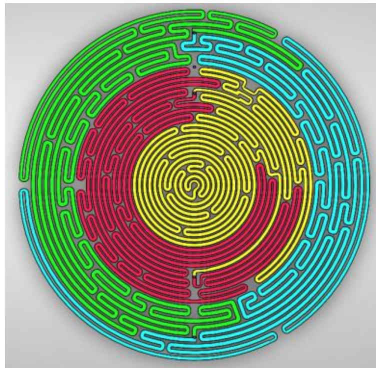
ITERATION 2



ITERATION 3



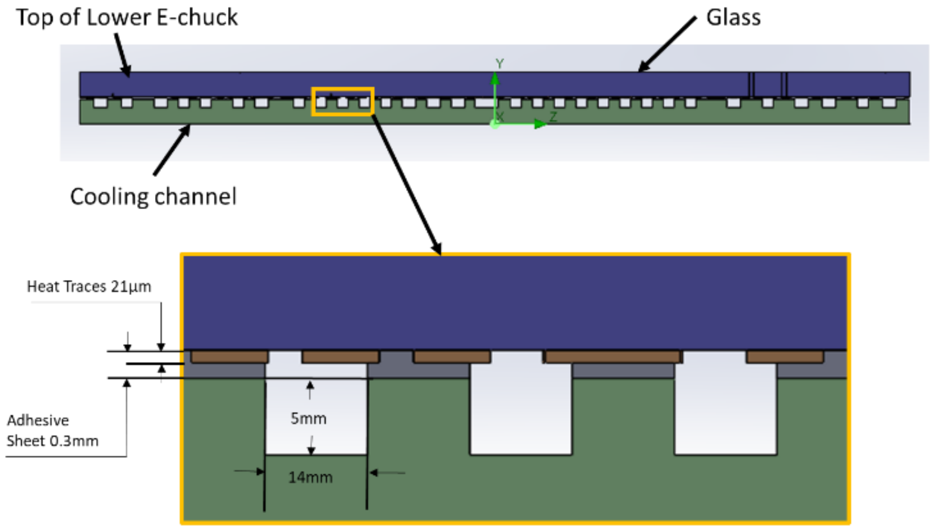
ITERATION 4



Note: Total iterations that were actually performed were about 50. Only important iterations are being reported in this presentation.

MODEL AND INPUTS

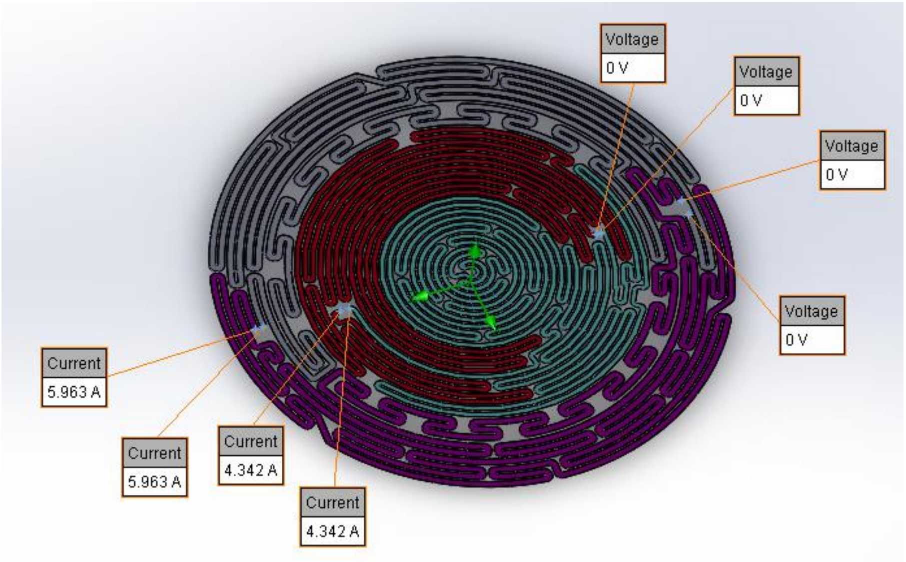
Model cross-section



Heat Trace thickness exagerated for clarity.

NOT TO SCALE

Electrical Inputs

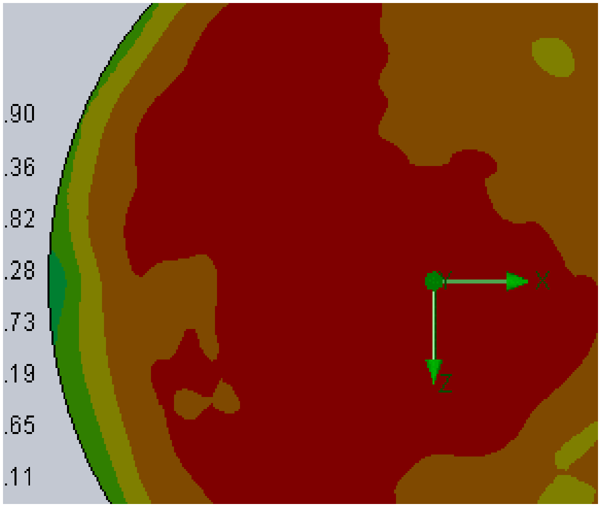


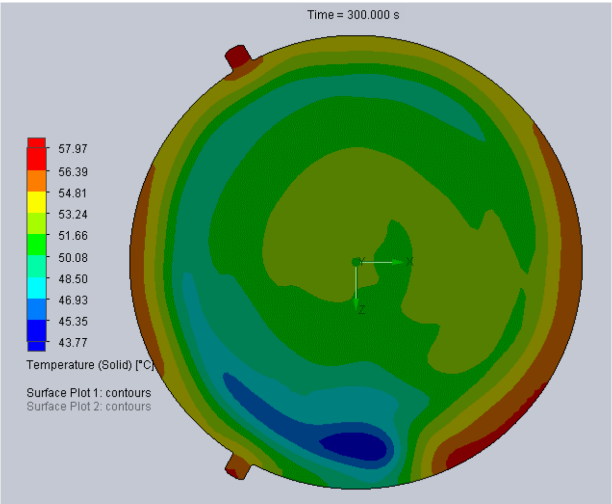
HEATING PHASE:

The localized thinning in certain trace length have been done to achieve uniform temperature rise. Apart from the localized area, temperature difference is around 6.5deg in the top of E-Chuck which is within the maximum allowable temperature range of 7.5°C.

COOLING PHASE:

The cooling phase with the given max pressure cools the top phase of chuck from 250 °C to 50 °C at around 5minutes. The cooling in the local region at inlet diameter of 15mm is having a high temperature reduction to 44 degrees at end of 5 minutes. The range of temperature on the top of E-Chuck is 12.1°C.



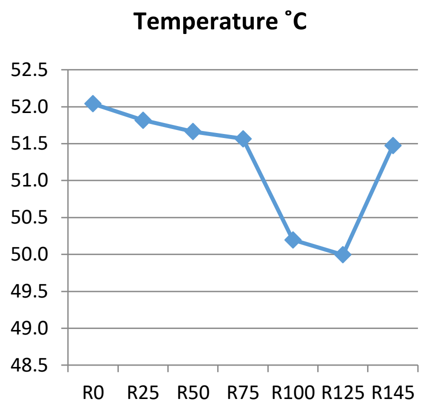


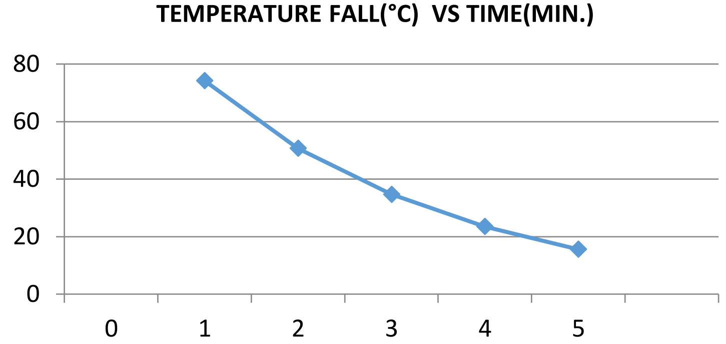
RESULTS: COOLING PHASE

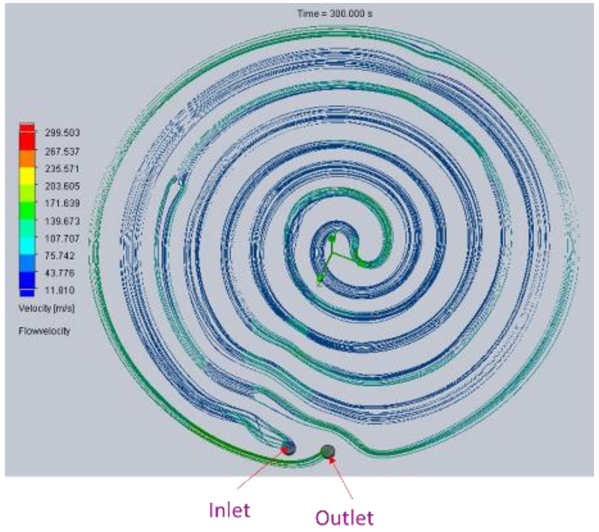
Max and Min Temperature at top of E-Chuck

Location	R0	R25	R50	R75	R100	R125	R145
Temperature ˚C	52.0	51.8	51.7	51.6	50.2	50.0	51.5

Maximum Temperature=	56.1
Minimum Temperature=	44.2







COOLING PHASE OUTPUT TEMPERATURE VS TIME

TIME (MINUTES)	AVERAGE TEMPERATURE(°C) /MIN	TEMPERATURE FALL (°C)/MIN	MAXIMUM TEMPERATURE(°C) /MIN	MINIMUM TEMPERATURE(°C) /MIN
0	250	-	252.3	245.9
1	175.8	74.2	190.8	147.0
2	125.1	50.7	139.3	102.5
3	90.4	34.7	139.3	102.5
4	66.9	23.5	74.2	56.2
5	51.3	15.6	56.1	44.2

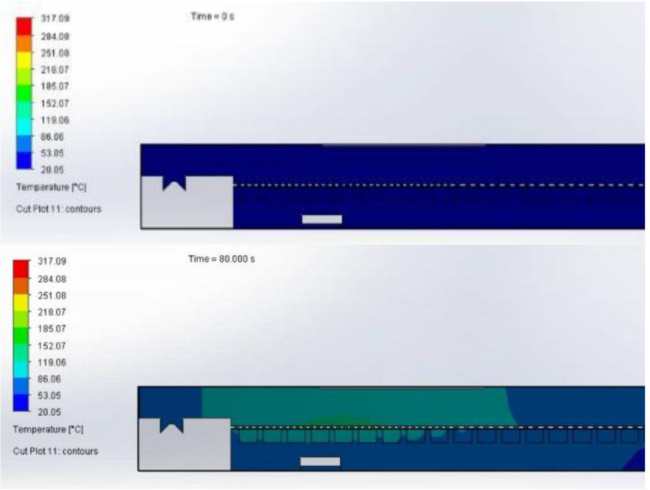
RESULT COMPARISON & BENEFITS

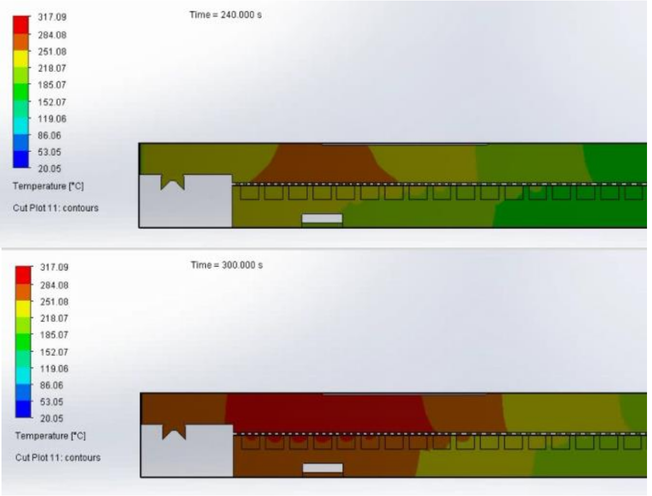
Benefits:

- Normal heating units are water cooled. In this study, we are able to use air cooling to achieve the desired cooling which saves lot of liquid handling cost. Also high tolerances and special gaskets will be required if water cooled.
- Prototyping cost saved by 50%. Only one final prototype was build to finalize the model.
- Total time saved in prototyping was by 6months.

HEATING PHASE OUTPUT RESULT COMPARISON

ITERATIONS	TOP FACE TEMP.VARIATION(°C)	TOP FACE MAXIMUM TEMP.(°C)	TOP FACE MINIMUM TEMP.(°C)	VOLTAGE OUT(INNER ZONE) VOLTS	VOLTAGE OUT(OUTER ZONE)VOLTS
ITERATIONS 1	147.2	317	169.8	432	487
ITERATIONS 2	21.1	259.3	238.2	256	327
ITERATIONS 3	7.2	253.3	246.1	254	248
ITERATIONS 4	6.4	252.3	245.9	238	253





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