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Modeling Wafer Temperatures Using the MSC Marc Welding Capability

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Abstract---Ion implantation into silicon wafers results in heat buildup in the wafers during the manufacture of integrated circuits. The wafers are subjected to an ion beam that rasters over the surface of the wafer. A two-dimensional scan is necessary to uniformly implant the surface of the wafer. The ion beam is scanned across the wafer at frequencies of 1-1000 Hz. The vertical scan is typically much slower, with frequencies that are <1 Hz. The MSC Marc welding capability was successfully used to model the motion of the ion beam heat source over the surface of the wafer. The model itself was built using the MSC Patran interface, and then exported to MSC Marc for analysis. After the text file was written out, it could be simply edited to change the parameters of the problem, including wafer diameter, beam diameter, beam power, beam velocity, and wafer backside cooling.

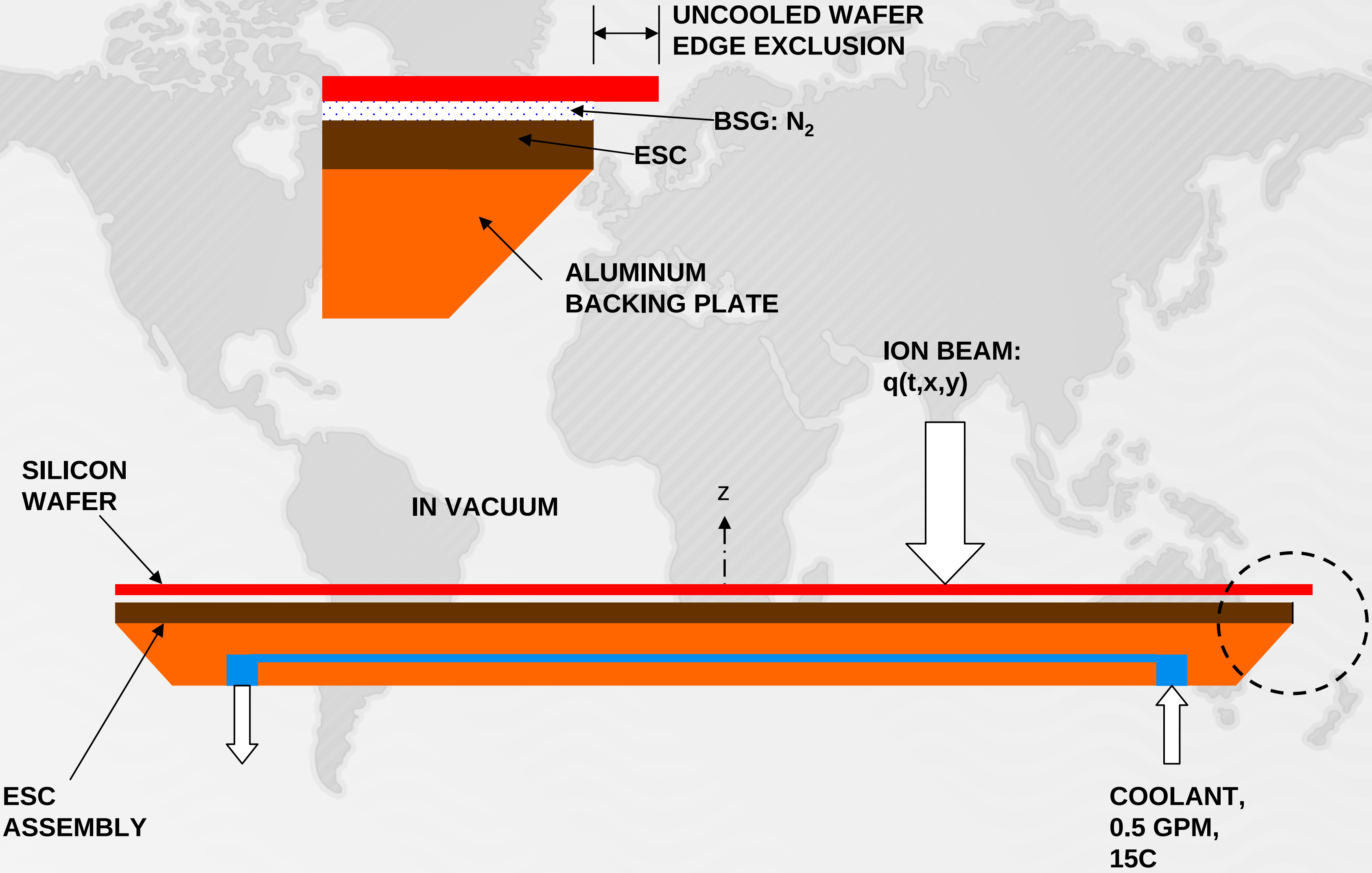
INTRODUCTION

- Wafer temperatures cannot exceed 80C in typical implanting recipes
- Ion beam power can be as high as 4kW on a 6mm diameter
- Wafer temperatures are very difficult to measure, usually by the "dot" method
- Analytical method is required to determine wafer temperatures *before* the implanter is designed

PROBLEM DEFINITION: GEOMETRY (see figure 1)

- Ion implant takes place in vacuum
- Wafer held in place by electrostatic clamp (ESC)
- Heat input is from ion beam, which rasters across wafer
- Heat is removed from back of wafer, via backside gas, into ESC
- Backside gas (BSG) is usually nitrogen, at pressures around 20 torr, producing heat transfer coefficient of ~80 mW/cm^2-C
- ESC consists of aluminum nitride, bonded to aluminum plate
- Aluminum backing plate is water cooled.

FIGURE 1. DEFINITION OF PROBLEM: GEOMETRY



UNCOOLED WAFER
EDGE EXCLUSION

BSG: N_2

ESC

ALUMINUM
BACKING PLATE

ION BEAM:
q(t,x,y)

SILICON
WAFER

IN VACUUM

Z

ESC
ASSEMBLY

COOLANT,
0.5 GPM,
15C

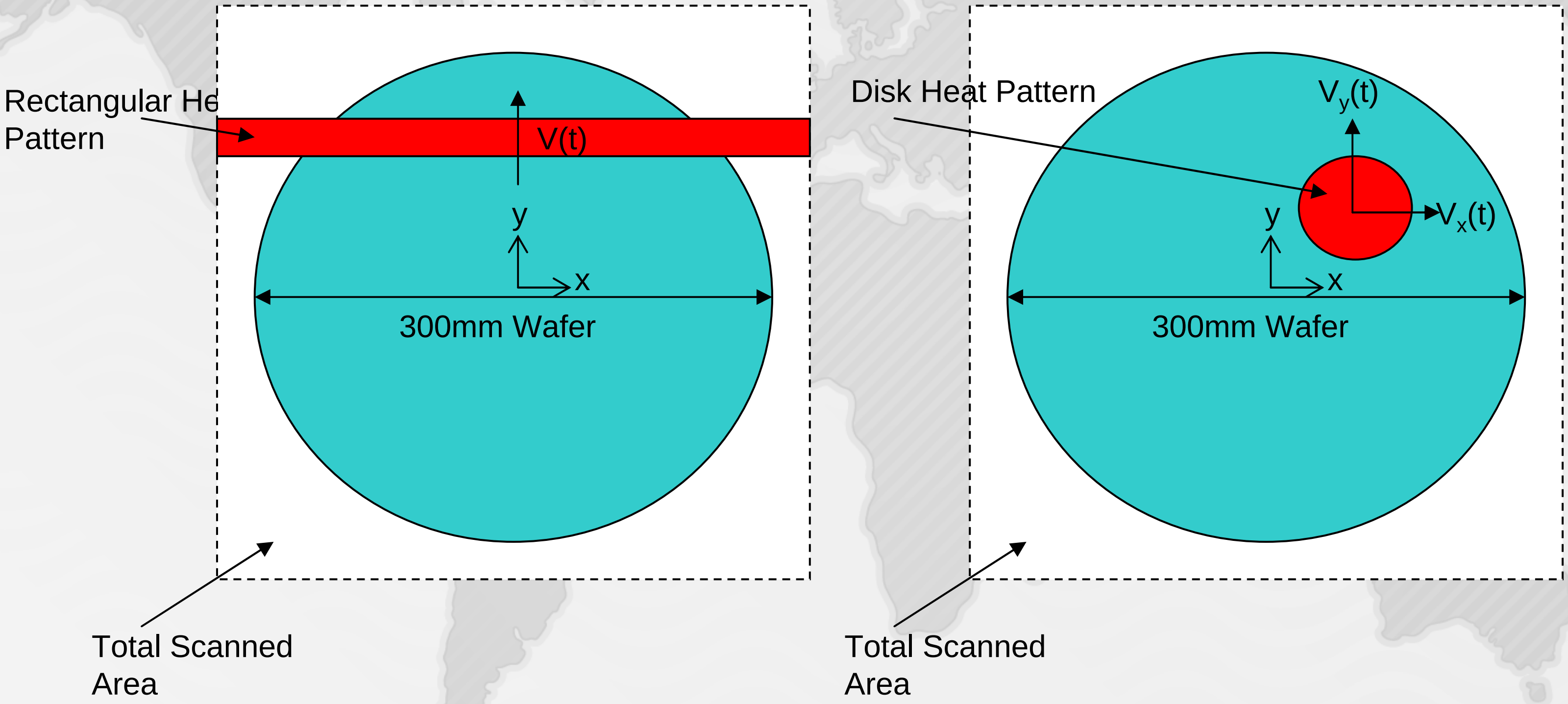
PROBLEM DEFINITION: MOVING HEAT SOURCE (see figure 2)

- For high speed x velocity, can model ion beam as rectangle (1D scan)
- For lower speed x velocity, must use disk (2D scan)

	x-direction scan speed	y-direction scan speed	Ion beam size
low/medium dose implants	~∞	~10 cm	~1 cm high rectangle
high dose implants	~1 m/s	~1 cm/s	~8 cm diameter disk

FIGURE 2. DEFINITION OF PROBLEM: MOVING HEAT SOURCE

Case: Low/Medium Dose **Case: High Dose**



ANALYSIS

- **Use MSC Marc to model transient temperatures.**
- **Use welding capability to model moving ion beam.**
  - Pavelik’s disk for modeling disk shaped ion beam.
  - User subroutine for modeling rectangular shaped ion beam.

Figure 3. Transient temperatures for rectangular ion beam

- **Q=1.5kW, V=19cm/s, H=2.5cm, Edge Exclusion=7.5mm**

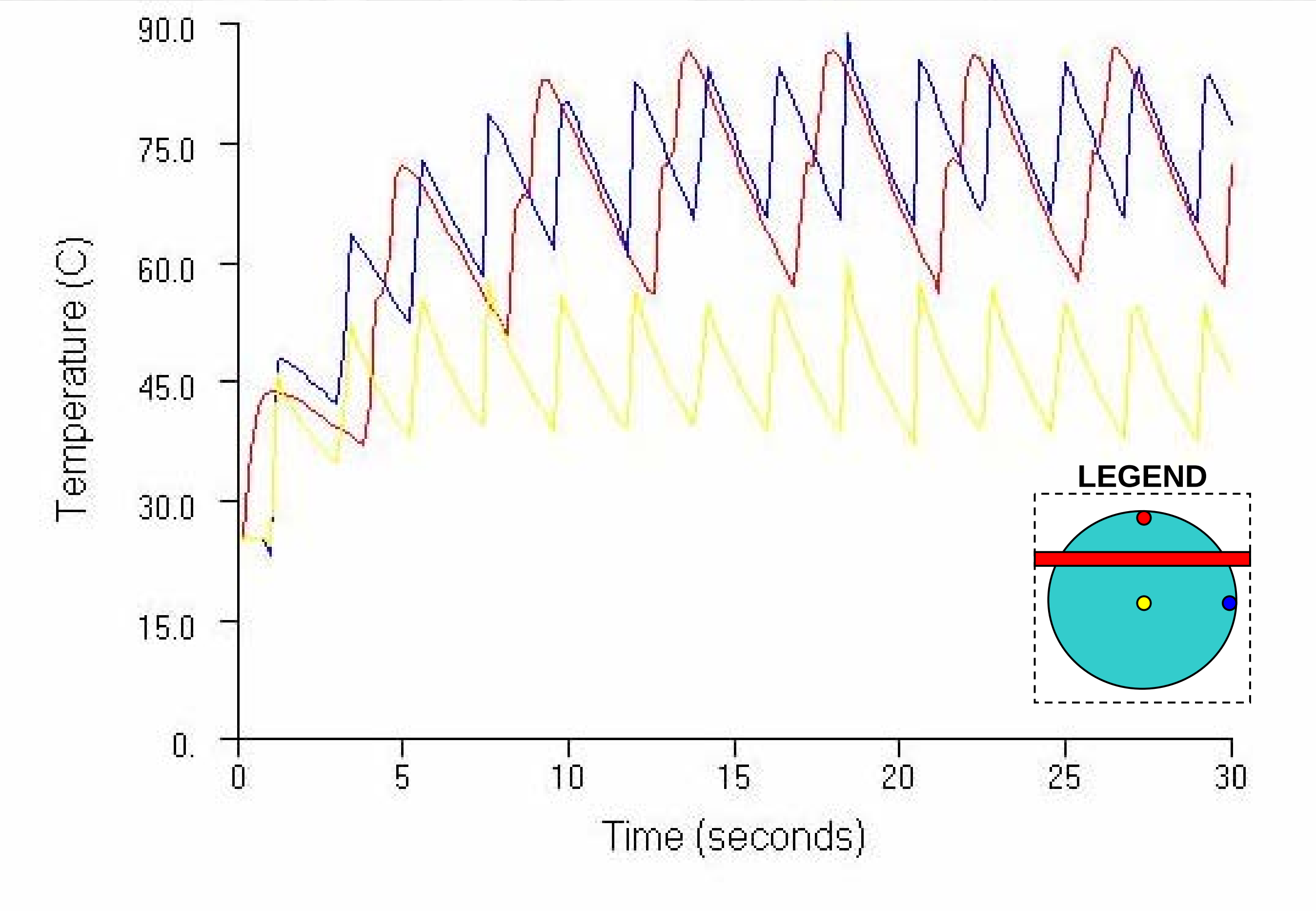
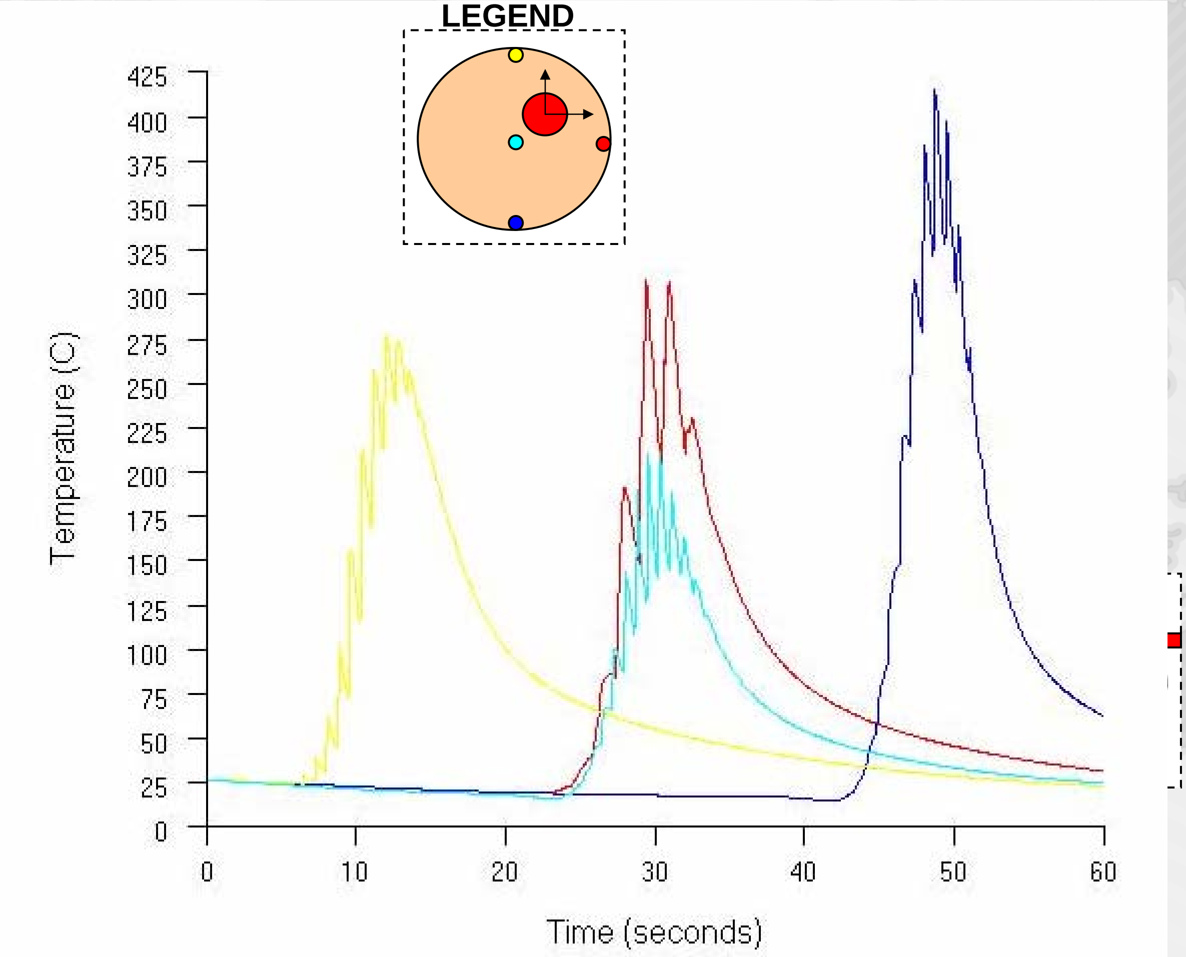


Figure 4. Transient temperatures for disk-shaped ion beam

- Q=1.5kW, V_x=60 cm/s, V_y=8 mm/s, D= 6 cm, Edge Exclusion=3.5mm



DISCUSSIONS

- **For rectangular beam, edge temperatures are highest.**
- **Reverse scanning causes a double-peak at the top and bottom edges.**
- **Peak temperatures can be reduced by adjusting scan speeds, beam diameter, overscan time, and by reducing edge-exclusion.**

DISCUSSIONS

- **For disk-shaped beam, edge temperatures are highest.**
- **Reverse scanning causes a double-peak at the top and bottom edges for multiple-scan recipes.**
- **Peak temperatures can be reduced by adjusting scan speeds, beam diameter, overscan time, and by reducing edge-exclusion.**

CONCLUSIONS

- **The welding capability in MSC Marc is well suited for modeling the moving ion beam and determining the transient wafer temperatures produced under implant conditions.**
- **Using these results, we can predict wafer temperatures in advance of actually building the mechanical scan systems.**
- **The model can be used to reduce wafer process temperatures by optimizing implant parameters such as:**
  - Beam power
  - Beam size
  - X and Y scan velocities
  - Over-scan distances and times

ACKNOWLEDGEMENTS

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