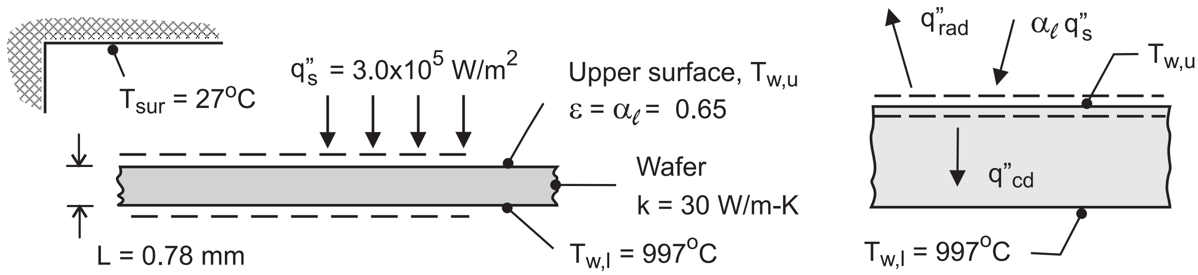
PROBLEM 1.56

KNOWN: Silicon wafer, radiantly heated by lamps, experiencing an annealing process with known backside temperature.

FIND: Whether temperature difference across the wafer thickness is less than 2°C in order to avoid damaging the wafer.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) One-dimensional conduction in wafer, (3) Radiation exchange between upper surface of wafer and surroundings is between a small object and a large enclosure, and (4) Vacuum condition in chamber, no convection.

PROPERTIES: Wafer: k = 30 W/m·K, $\varepsilon = \alpha_\ell = 0.65$.

ANALYSIS: Perform a surface energy balance on the upper surface of the wafer to determine $T_{w,u}$. The processes include the absorbed radiant flux from the lamps, radiation exchange with the chamber walls, and conduction through the wafer.

$$\dot{E}''_{in} - \dot{E}''_{out} = 0$$

$$\alpha_\ell q''_s - q''_{rad} - q''_{cd} = 0$$

$$\alpha_\ell q''_s - \varepsilon\sigma\left(T^4_{w,u} - T^4_{sur}\right) - k\frac{T_{w,u} - T_{w,\ell}}{L} = 0$$

$$0.65 \times 3.0 \times 10^5 W/m^2 - 0.65 \times 5.67 \times 10^{-8} W/m^2 \cdot K^4 \left(T^4_{w,u} - (27 + 273)^4\right) K^4$$

$$-30 W/m \cdot K\left[T_{w,u} - (997 + 273)\right] K/0.00078\ m = 0$$

$$T_{w,u} = 1273\,K = 1000°C$$ <

COMMENTS: (1) The temperature difference for this steady-state operating condition, $T_{w,u} - T_{w,l}$, is larger than 2°C. Warping of the wafer and inducing slip planes in the crystal structure could occur.

(2) The radiation exchange rate equation requires that temperature must be expressed in kelvin units. Why is it permissible to use kelvin or Celsius temperature units in the conduction rate equation?

(3) Note how the surface energy balance, Eq. 1.13, is represented schematically. It is essential to show the control surfaces, and then identify the rate processes associated with the surfaces. Make sure the directions (in or out) of the process are consistent with the energy balance equation.