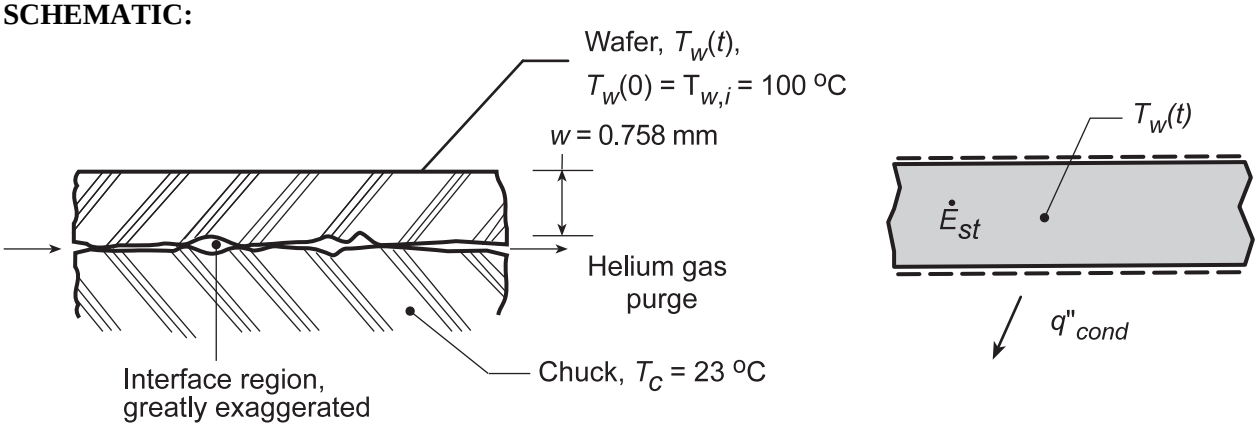
PROBLEM 5.13

KNOWN: Wafer, initially at 100°C, is suddenly placed on a chuck with uniform and constant temperature, 23°C. Wafer temperature after 15 seconds is observed as 33°C.

FIND: (a) Contact resistance, R''_{tc}, between interface of wafer and chuck through which helium slowly flows, and (b) Whether R''_{tc} will change if air, rather than helium, is the purge gas.

SCHEMATIC:



PROPERTIES: Wafer (silicon, typical values): $\rho = 2700$ kg/m^3, $c = 875$ J/kg·K, $k = 177$ W/m·K.

ASSUMPTIONS: (1) Wafer behaves as a space-wise isothermal object, (2) Negligible heat transfer from wafer top surface, (3) Chuck remains at uniform temperature, (4) Thermal resistance across the interface is due to conduction effects, not convective, (5) Constant properties.

ANALYSIS: (a) Perform an energy balance on the wafer as shown in the Schematic.

$$\dot{E}''_{in} - \dot{E}''_{out} + \dot{E}_g = \dot{E}_{st} \tag{1}$$

$$-q''_{cond} = \dot{E}''_{st} \tag{2}$$

$$-\frac{T_w(t) - T_c}{R''_{tc}} = \rho wc \frac{dT_w}{dt} \tag{3}$$

Separate and integrate Eq. (3)

$$-\int_0^t \frac{dt}{\rho wc R''_{tc}} = \int_{T_{wi}}^{T_w} \frac{dT_w}{T_w - T_c} \tag{4}$$

$$\frac{T_w(t) - T_c}{T_{wi} - T_c} = \exp\left[-\frac{t}{\rho wc R''_{tc}}\right] \tag{5}$$

Substituting numerical values for $T_w(15s) = 33$°C,

$$\frac{(33-23)^\circ C}{(100-23)^\circ C} = \exp\left[-\frac{15\,s}{2700\,kg/m^3 \times 0.758\times10^{-3} m \times 875\,J/kg\cdot K \times R''_{tc}}\right] \tag{6}$$

$$R''_{tc} = 0.0041\,m^2\cdot K/W \quad <$$

(b) R''_{tc} will increase since $k_{air} < k_{helium}$. See Table A.4.

COMMENTS: Note that $Bi = R_{int}/R_{ext} = (w/k)/R''_{tc} = 0.001$. Hence the spacewise isothermal assumption is reasonable.