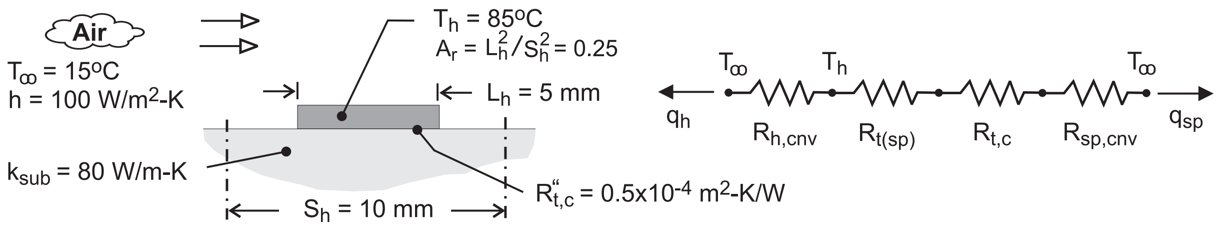
PROBLEM 4.37

KNOWN: Dimensions of chip array. Conductivity of substrate. Convection conditions. Contact resistance. Expression for resistance of spreader plate. Maximum chip temperature.

FIND: Maximum chip heat rate.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state, (2) Constant thermal conductivity, (3) Negligible radiation, (4) All heat transfer is by convection from the chip and the substrate surface (negligible heat transfer from bottom or sides of substrate).

ANALYSIS: From the thermal circuit,

$$q = q_h + q_{sp} = \frac{T_h - T_\infty}{R_{h,cnv}} + \frac{T_h - T_\infty}{R_{t(sp)} + R_{t,c} + R_{sp,cnv}}$$

$$R_{h,cnv} = \left(h\,A_{s,h}\right)^{-1} = \left(hL_h^2\right)^{-1} = \left[100\,\mathrm{W/m^2\cdot K}\left(0.005\mathrm{m}\right)^2\right]^{-1} = 400\,\mathrm{K/W}$$

$$R_{t(sp)} = \frac{1 - 1.410\,A_r + 0.344\,A_r^3 + 0.043\,A_r^5 + 0.034\,A_r^7}{4\,k_{sub}\,L_h} = \frac{1 - 0.353 + 0.005 + 0 + 0}{4\left(80\,\mathrm{W/m\cdot K}\right)\left(0.005\mathrm{m}\right)} = 0.408\,\mathrm{K/W}$$

$$R_{t,c} = \frac{R''_{t,c}}{L_h^2} = \frac{0.5\times10^{-4}\mathrm{m^2\cdot K/W}}{\left(0.005\mathrm{m}\right)^2} = 2.000\,\mathrm{K/W}$$

$$R_{sp,cnv} = \left[h\left(A_{sub} - A_{s,h}\right)\right]^{-1} = \left[100\,\mathrm{W/m^2\cdot K}\left((0.010\mathrm{m})^2 - (0.005\mathrm{m})^2\right)\right]^{-1} = 133.3\,\mathrm{K/W}$$

$$q = \frac{70^\circ\mathrm{C}}{400\,\mathrm{K/W}} + \frac{70^\circ\mathrm{C}}{\left(0.408 + 2 + 133.3\right)\mathrm{K/W}} = 0.18\,\mathrm{W} + 0.52\,\mathrm{W} = 0.70\,\mathrm{W} \qquad <$$

COMMENTS: (1) The thermal resistances of the substrate and the chip/substrate interface are much less than the substrate convection resistance. Hence, the heat rate is increased almost in proportion to the additional surface area afforded by the substrate. An increase in the spacing between chips (S_h) would increase q correspondingly.

(2) In the limit $A_r \to 0$, $R_{t(sp)}$ reduces to $2\pi^{1/2}k_{sub}D_h$ for a circular heat source and $4k_{sub}L_h$ for a square source.