Homework #1, ME/MSE 485, due on Jan. 18, 2011

1. A chip of 120 W is connected to a series of components vertically, see Fig. 1. The upper components are thermal interface material (TIM), heat sink and convective air(its temperature , Tair = 25C). The lower components are solder bumps(its total number is 10 units) surrounded by interface filler polymer (ifp), then to the bottom printed circuit board (PCB) whose temperature is set equal to T_{PCB} = 30C. Assume that the area of each component, i.e chip, TIM, heat sink, is 2 cm x 2 cm, i.e., A=4 cm^2. Answer to the following questions.

(1) Compute the thermal resistance of the convected air flow, R_{air}, by using Fig. 2 for a single module with air speed of 2m/sec where you have to estimate h from Fig. 2, first.

$$R_{air} = \frac{1}{hA} = \frac{1}{30\times 4\times 10^{-4}} = 83.333 \text{ (K/W)}$$

(2) Compute the thermal resistance of heat sink, R_{hs}, with thickness of aluminum heat sink being 3 mm, using the thermal conductivity value of aluminum ($K_{aluminum}$=230 W/(m.K).

$$R_{hs} = \frac{L}{kA} = \frac{3\times 10^{-3}}{230\times 4\times 10^{-4}} = 0.033 \text{ (K/W)}$$

(3) Compute the thermal resistance of TIM, R_{TIM} , where the thermal conductivity of the TIM is 1.5 W/(m.K) and its thickness is 0.1 mm.

$$R_{TIM} = \frac{L}{kA} = \frac{0.1\times 10^{-3}}{1.5\times 4\times 10^{-4}} = 0.167 \text{ (K/W)}$$

(4) Compute the thermal resistance of the combined solder bumps, R_{sb}, which are made of 63Sn/37Pb (its thermal conductivity=50 W(m K)). The diameter of each solder bump (spherical shape) is 1 mm. Assume that only 10 balls, each having cylindrical shape with diameter of 1 mm.

$$R_{SB} = \frac{L}{kA} = \frac{1\times 10^{-3}}{50\times [10\times (\pi\times 0.5^2)\times 10^{-6}]} = 2.546 \text{ (K/W)}$$

(5) Compute the thermal resistance of the inter filler polymer (ifp), R_{ifp} which is made of the molding compound (its thermal conductivity =0.7 W/(m K)), its thickness being the same as the height of the solder bumps, 1 mm.

$$R_{IFP} = \frac{L}{kA} = \frac{1\times 10^{-3}}{0.7\times [4\times 10^{-4} - 10\times (\pi\times 0.5^2)\times 10^{-6}]} = 3.643 \text{ (K/W)}$$

(6) Compute the equivalent thermal resistance for the entire upper route, R_{upper}, and the equivalent thermal resistance for the entire lower route, R_{lower},

$$R_{upper} = R_{TIM} + R_{air} + R_{hs} = 83.532 \text{ (K/W)}$$
$$R_{lower} = \frac{1}{\frac{1}{R_{sb}} + \frac{1}{R_{ifp}}} = 1.5 \text{ (K/W)}$$

(7) Compute the heat flow along the upper route, Q_{upper}, and the heat flow along the lower route, Q_{lower}, then , tempareture of the chip, T_{chip}. Assume that $Q_{upper} + Q_{lower} = Q_{chip}$.

$$Q_{upper} = \frac{\Delta T}{R_{upper}} = \frac{T_{chip} - 25}{83.532}$$
$$Q_{lower} = \frac{\Delta T}{R_{lower}} = \frac{T_{chip} - 30}{1.5}$$
$$Q_{upper} + Q_{lower} = Q_{chip} = 120 = \frac{T_{chip} - 25}{83.532} + \frac{T_{chip} - 30}{1.5}$$
$$T_{chip} = 206.736C$$

(8) If the coolant (air in Fig. 1) is replaced by water coolant with its heat transfer coefficient, h=10,000 W/(m^2 K), then , calculate R_{air}, R_{upper}, and T_{chip} provide all other components' properties being the same.

$$R_{air} = \frac{1}{hA} = \frac{1}{10000 \times 4 \times 10^{-4}} = 0.25 \text{ (K/W)}$$
$$R_{upper} = R_{TIM} + R_{air} + R_{hs} = 0.45 \text{ (K/W)}$$
$$R_{lower} = \frac{1}{\frac{1}{R_{sb}} + \frac{1}{R_{ifp}}} = 1.5 \text{ (K/W)}$$
$$Q_{upper} = \frac{\Delta T}{R_{upper}} = \frac{T_{chip} - 25}{0.45}$$
$$Q_{lower} = \frac{\Delta T}{R_{lower}} = \frac{T_{chip} - 30}{1.5}$$
$$Q_{upper} + Q_{lower} = Q_{chip} = 120 = \frac{T_{chip} - 25}{0.45} + \frac{T_{chip} - 30}{1.5}$$
$$T_{chip} = 67.692C$$

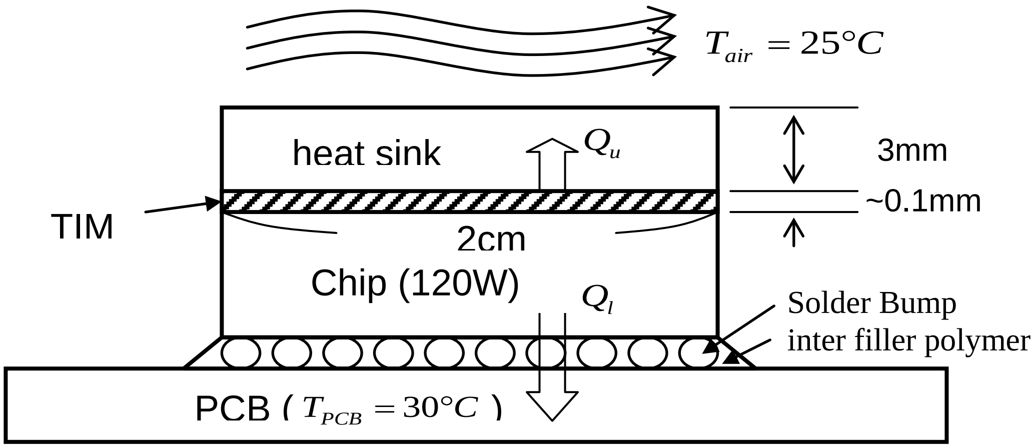

Fig. 1 Vertically integrated chip, TIM, heat sink, and solder bumps, etc.

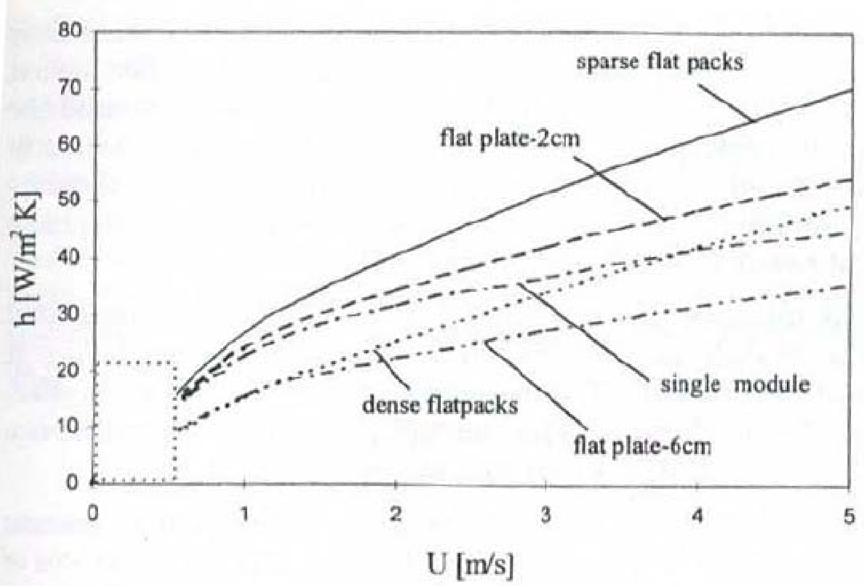

Figure 3.11 Typical heat transfer coefficients for forced convection air cooling of modules and flat plates.

Fig. 2 Heat transfer coefficient, h for air cooling