MSE/ME 485 Final Exam, open notes and book, March 17,2011

Problem 1. A chip is bonded to a substrate by solder layer as shown in Fig. 1. The maximum shear stress and strain take place at free end. For a given temperature change, ΔT, the maximum shear stress reaches at free end, 50 MPa, which is the yield stress in shear of the solder material. If the chip-solder-substrate system is subjected to repeated thermal cycles, N, between Tmax = 150 C and Tmin=20 C, let us estimate the critical number of cycles, N_c, at and above which the solder at free end opens up a crack. The shear modulus of the solder material is 5GPa. For chip, E_c=70GPa, ν_c=0.34, α_c=16 x 10^{-6}/C and for substrate, E_s = 290GPa, ν_s = 0.2, α_s = 6 x 10^{-6}/C, L=1 cm. The thickness of the solder layer t_0 = 1 mm, thickness of the chip and substrate are 3mm and 4mm respectively.
Answer to the following questions:

(1) Calculate the maximum shear strain (γ_{max}) at free end, assuming the elasto-plastic layer boundary, x_c= 0.8 L, where L is one half of the chip length.

(2) Coffin –Mason Law is given by
$\Delta \gamma = a N^{b}$ --(1)
where $\Delta \gamma$ is amplitude of shear strain cycle, a is constant , equal to 10^3, power b is a constant , equal to -1, and N is number of fatigue cycles. Using Eq.(1) predict the failure number of cycles (Nf).

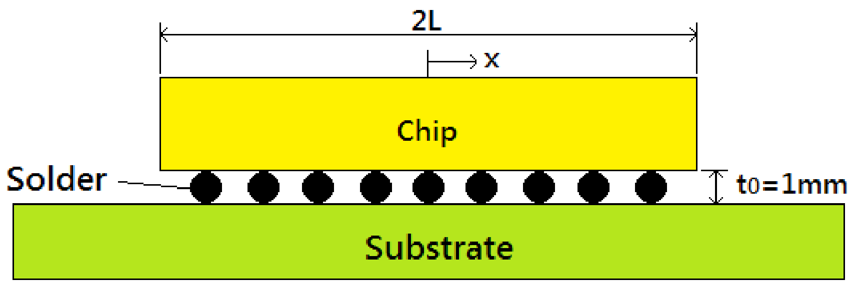


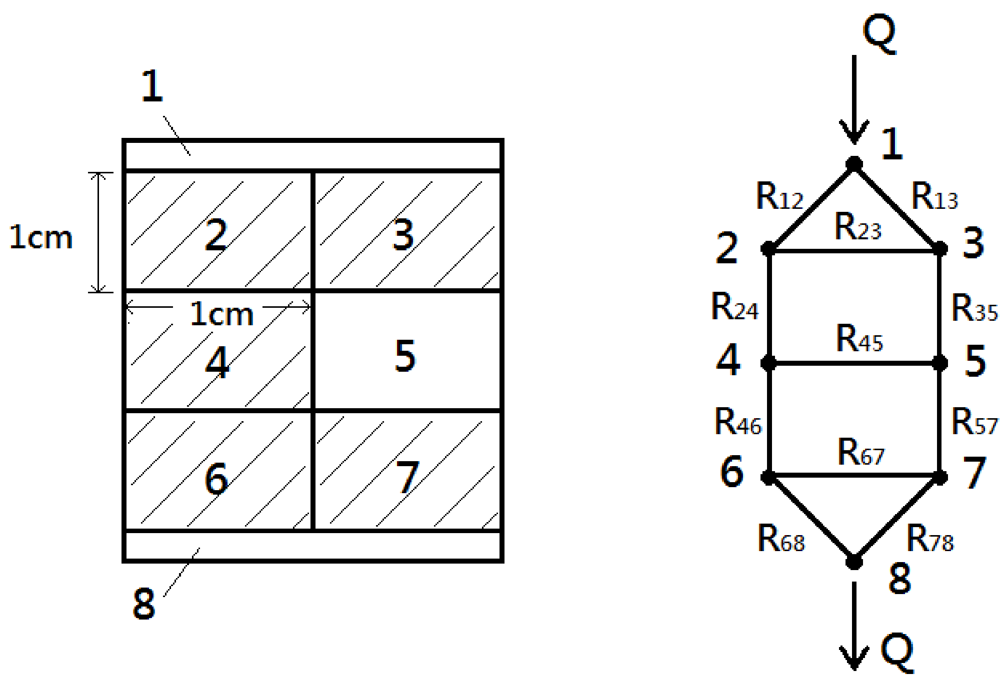
Fig. 1 A chip is bonded to substrate with metal solder

Problem 2. Consider the thermal composite composed of conductor (shaded), K_{f1}=100W/(Km), and one insulator, K_m=0.2W/(Km), see figure 2. Under applied heat at the top, Q=100W, we would like to calculate the temperature at top, T_1, and the temperature at mid-points, T_2-T_7, where the temperature at the bottom, T_8 is set to 0 C. Answer the following questions.

(1) Calculate all thermal resistances, R_{ij} defined in the figure, assuming the thickness perpendicular to this paper sheet is 1cm.

(2) Set the algebraic equations at nodal points (1-8) by using Kirchoff Current Law: all currents (or thermal flow in this problem) coming to i-th nodal point if they are summed up, it is equal to zero.

(3) Solve for temperatures, T_1-T_7.



(a) Composite made of conductor (shaded) and insulator (non-shaded). Each unit is 1cm by 1cm

(b) Equivalent thermal resistor model

Fig. 2 Thermal flow from the top to the bottom, while no heat flow horizontally.

Problem 3. Discuss various electronic composite models for a composite made of conductive fillers and insulator matrix (polymer).

Fillers: E = 100 GPa, k = 250 W/(m K), $\sigma = 10^5$ S/cm, $\mu = 200\mu_0$, $\varepsilon = 1\varepsilon_0$

Polymer matrix: E= 2GPa, k=0.1 W/(m K), $\sigma = 10^{-10}$ S/cm, $\mu = \mu_0$, $\varepsilon = 3\varepsilon_0$

μ_0 and ε_0 are the magnetic permeability and dielectric constant of vacuum, which are $4\pi\times10^{-7}$ H/m and 8.854×10^{-12} F/m respectively. Volume fraction of fillers, f = 0.5. Assume that the shape of fillers is spherical

(1) Law of mixtures(two formulae, one is based on series connection, the other based on parallel connection) for mechanical (Young's modulus, E), thermal conductivity (k), electrical conductivity (σ) , dielectric constant (ε) and magnetic permeability (μ)

(2) If you use the Maxwell model or Eshelby model (Eq.(4.93) of the text book), what are the values of thermal and electrical conductivities of the composite, then compare these with the data predicted by the law of mixture models

(3) Discuss the limitations of the above two models (Law of mixtures and Maxwell) when there exists a large gap between the filler and matrix properties. For such a case, what model is the best to be used?