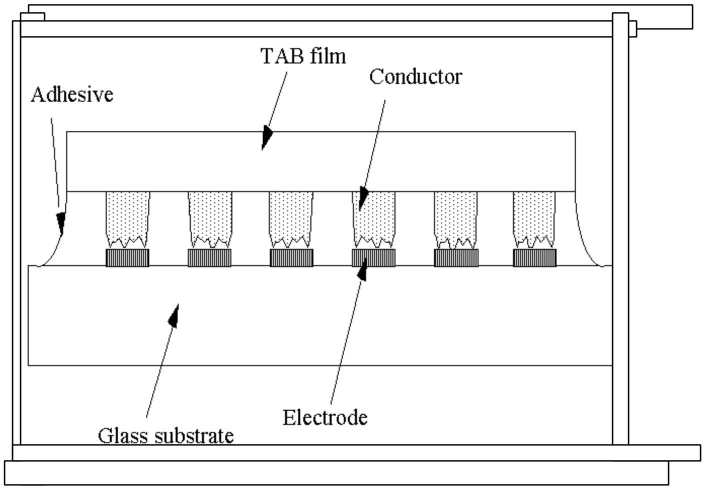
NCA: Non-Conductive Adhesive



A.2 Technology Drivers

- 2.1 Environment
  - Environmental:
    no-flux, no-Pb
  - No-Pb solders
    - -Melting temperatures
    - -Thermomechanical stress
  - Silver effects
- 2.2 Economics
  - Manufacturing
    - Fewer process steps
    - Available technologies (stencil/screen/dispense)
- 2.3 Technology drivers (c.f. solder)
  - Thermomechanical stress
    - Low process temperature
    - High compliance
  - Fine-pitch (area array) interconnect
    - Smaller particles than solder
    - No slumping
    - Inter-metallic diffusion in solders
    - Electromigration

A.3. ECA Applications

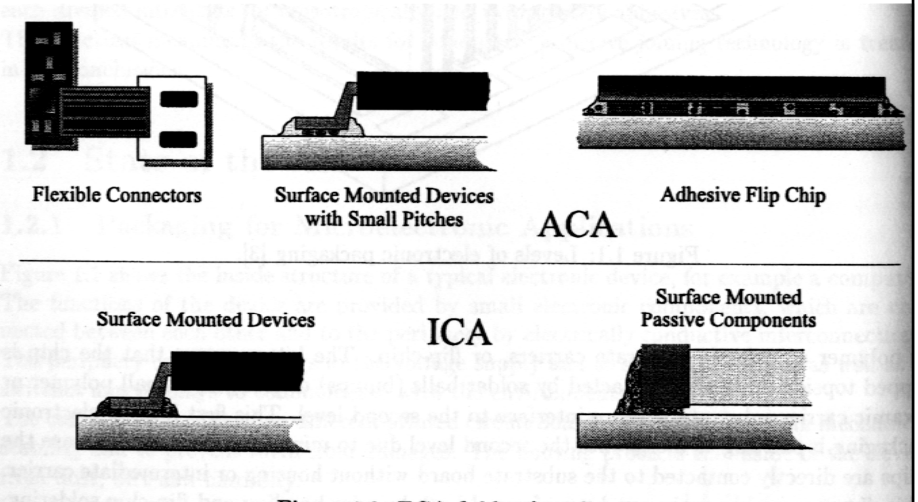
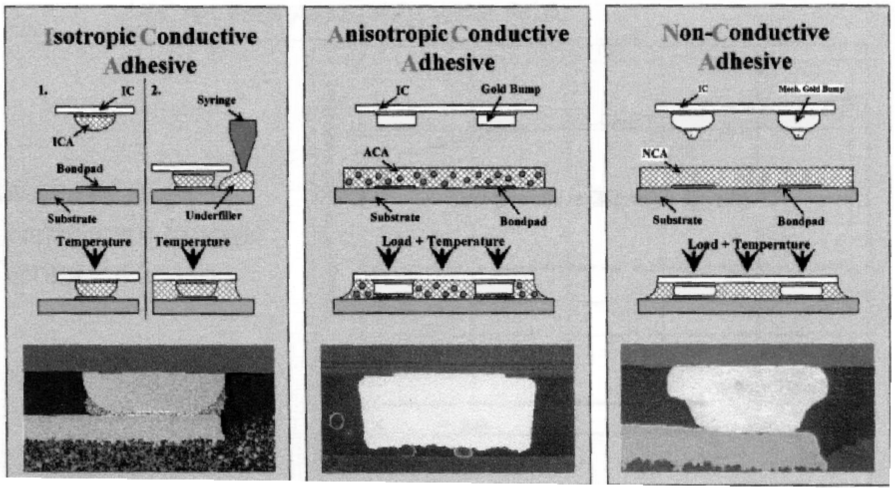


Figure 1.2: ECA fields of application.

A.4. Processing
e.g. Flip-Chip Assembly (IZM, Berlin)



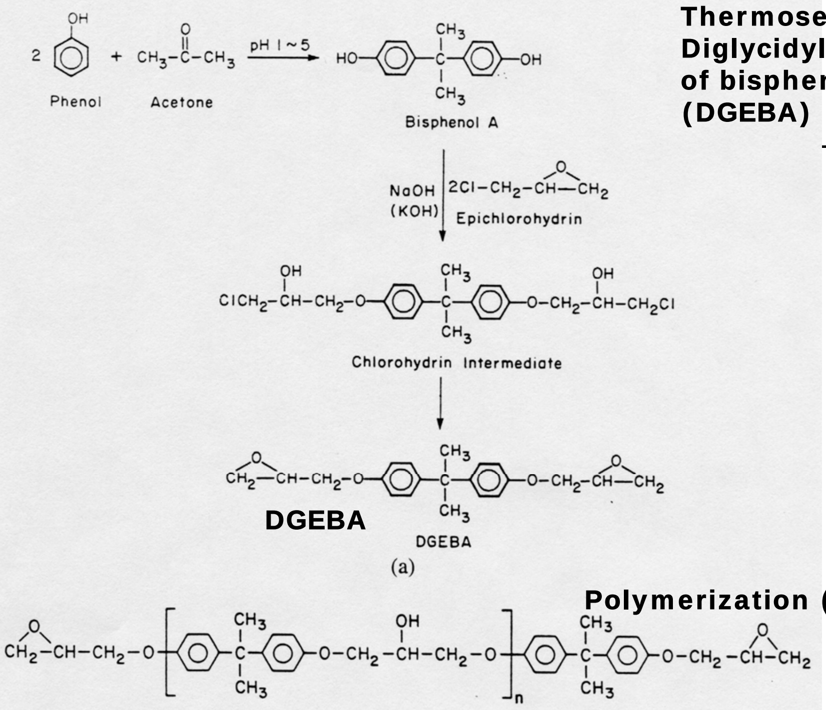
A.5. Materials

5.1 Metals
- Nickel/noble metals
- Silver
  - Silver Oxide

5.2 Polymers
- Thermoplastics - chains
- Thermoset epoxies -cross-link
- Thermoset/thermoplastic blends
- Additives
- Polyimide, silicones

5.3 Polymer Cure

Thermoset e.g. Diglycidyl ether of bisphenol-A (DGEBA)



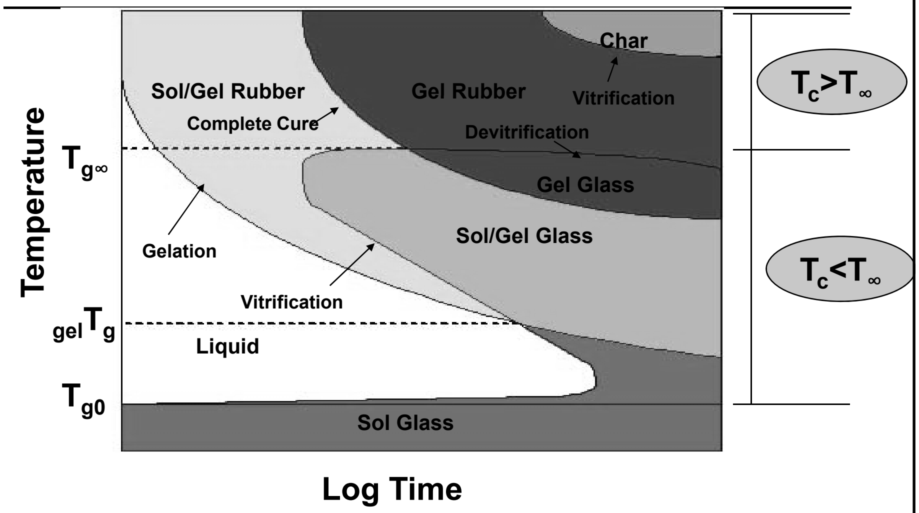
DGEBA

Polymerization (cure)

A.5.3 Curing

5.3.1 Cure process
5.3.2 Cure modeling
5.3.3 Glass transition temperature T_g
5.3.3 Cure optimization

A.5.3.1 Cure Process



Cure Effects

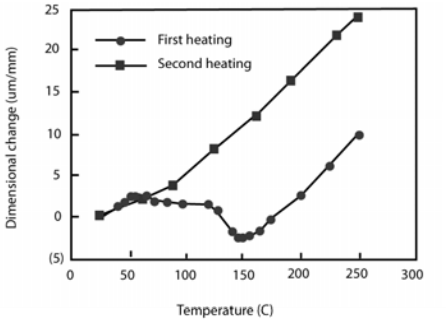


Figure 1. Dimensional change of conductive adhesive

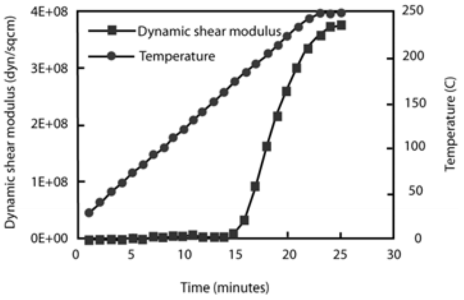


Figure 2. Dynamic shear modulus of conductive adhesive during cure

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A.5.3.2 Cure Models

- **Reaction rate $d\alpha/dt = k\, f(\alpha)$,**
  where $k = A \exp-(E/kT)$
  - **k = chemical rate constant, f (α) reactant concn.**
  - **α = degree of cure**
- **N-th order model: $f(\alpha) = (1 - \alpha)^n$**
- **Calculate degree of cure:**
  - **1st order: $d\alpha/dt = k(1-\alpha)$, $\therefore\ \alpha = 1-\exp(-kt)$**
  - **2nd order: $d\alpha/dt = k(1-\alpha)^{2,}$ $\alpha = 1 - (1 + kt)^{-1}$**
- **Auto-catalyzed model:**
  - **$f(\alpha) = \alpha^m (1-\alpha)^n$**
  - **Linear combination: $d\alpha/dt = k\, f(\alpha) = (k_1 + k_2\, \alpha^m)(1-\alpha)^n$**

DSC: Directly determine degree of cure α and rate of cure dα/dt

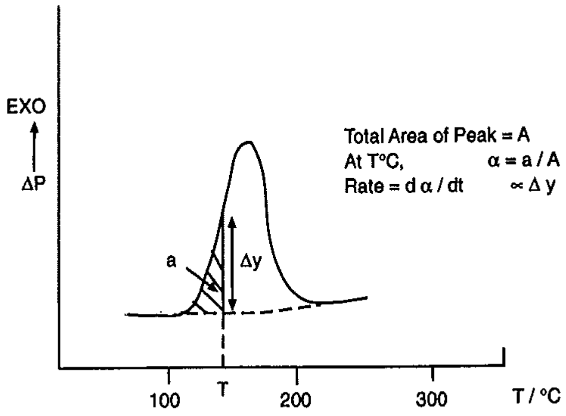
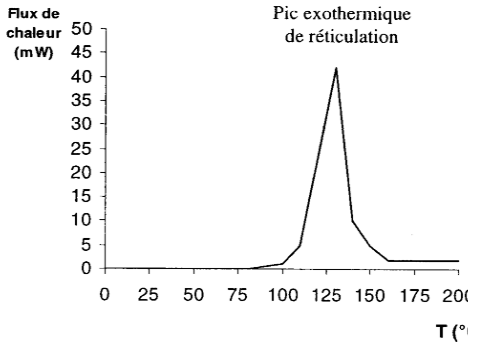
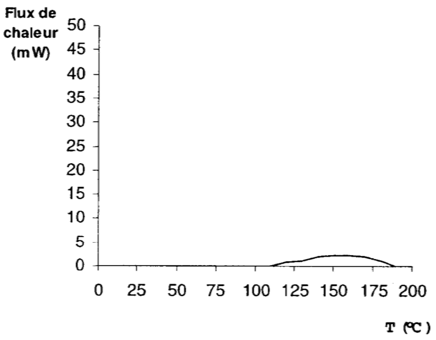


Figure 3.33 DSC curve for exothermic reaction showing measurement of partial and total areas.

Complete Cure: DSC before & after cure
More accurate cure assessment

(Perichaud/Fremont)





Use second DSC as measure of degree of cure - $\int_1 HdT/(\int_1 HdT+\int_2 HdT)$

Cure Calculations:

Differential Scanning Calorimetry (DSC) Heat flow vs time

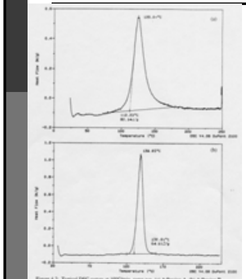


Figure 4.2: Typical DSC curves at 10°C/min. ramp run. (a) Adhesive A. (b) Adhesive B.

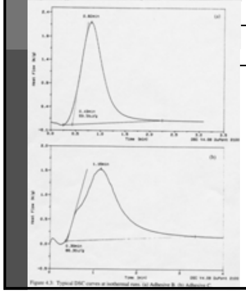


Figure 4.3: Typical DSC curves at isothermal runs. (a) Adhesive B. (b) Adhesive C.

$$\frac{d\alpha}{dt} = f(\alpha)\cdot A\cdot e^{-E/kT}, \quad \text{so}$$

$$\int_0^{\alpha p}\frac{1}{f(a)}d(\alpha) = A\int_{t0}^{tp}e^{-E/RT}dt$$

$$= \left(\frac{A}{\phi}\right)\cdot\int_{T0}^{Tp}e^{-E/RT}dT, \quad if \quad T(t) = \phi t$$

$$\approx \left(\frac{A}{\phi}\right)\cdot\int_{0}^{Tp}e^{-E/RT}dT, \quad if \quad T_0 << T_p$$

$$\approx \left(\frac{AE}{\phi R}\right)\cdot p\left(\frac{E}{RT_p}\right) \quad where$$

$$\log p(E/RT_p) \approx -2.315 - 0.4567E/RT_p$$

$$for \quad 20 < \frac{E}{RT_p} < 60$$

Find:

$$E \approx -\left(\frac{R}{0.4567}\right)\cdot\left(\frac{\Delta\log\phi}{\Delta\left(1/T_p\right)}\right)$$

ie var’n of peak exothermic temp with heat rate, and

$$A = \left(\frac{\phi E}{RT_p^{\ 2}}\right)e^{E/RT_p}$$

- k found for each T from E, A (experimental)
- E, A found from DSC, 13 heating rates

A.5.3.3 Glass Transition Temperature

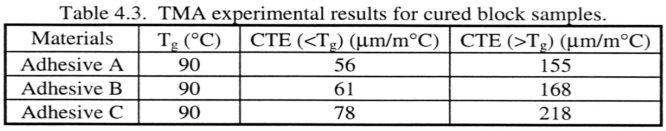
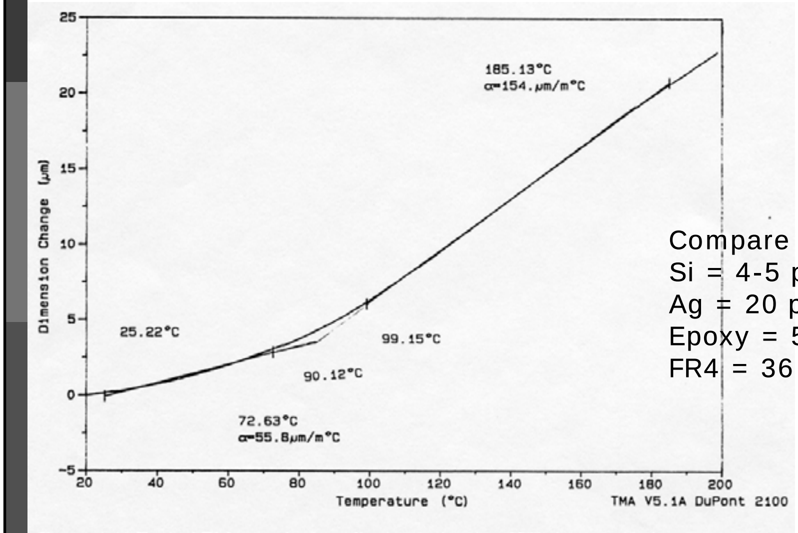


Table 4.3. TMA experimental results for cured block samples.

Materials	T_g (°C)	CTE (<T_g) (μm/m°C)	CTE (>T_g) (μm/m°C)
Adhesive A	90	56	155
Adhesive B	90	61	168
Adhesive C	90	78	218

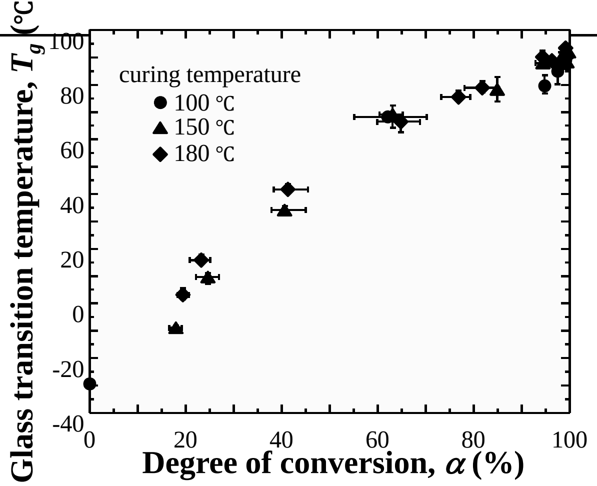


Compare CTEs:
Si = 4-5 ppm/°C
Ag = 20 ppm/°C
Epoxy = 54 ppm/°C
FR4 = 36 ppm/°C

Figure 4.4: Typical TMA graphs for Adhesive A showing CTE above and below T_g.

Relationship between degree of conversion and T_g

(Inoue et al)



One-to-one relationship between T_g and degree of conversion