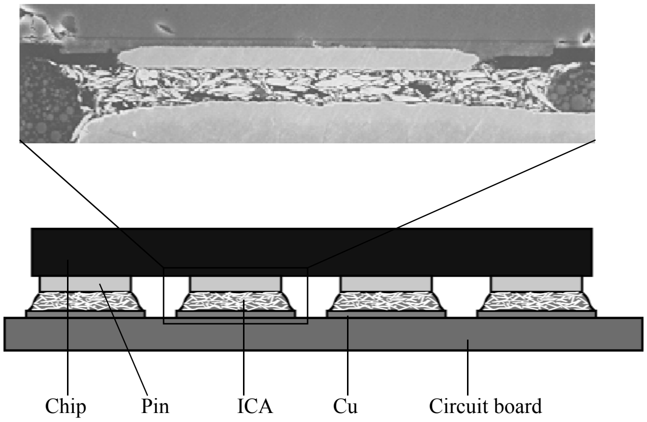
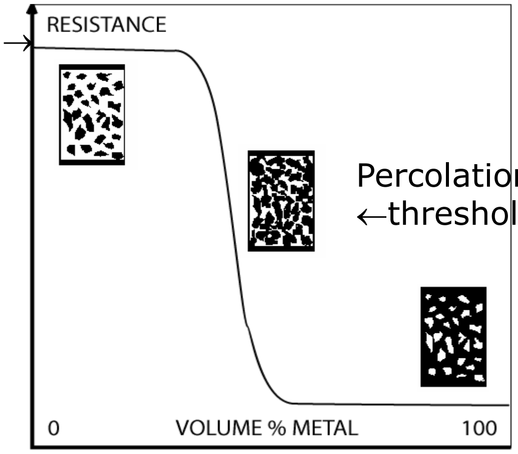
1.2. Assembly

1. **Print & Cure**
2. **Stud Bump applications**
3. **Polymer bumps**

1.3 ICA Structure & Percolation



ICA Percolation



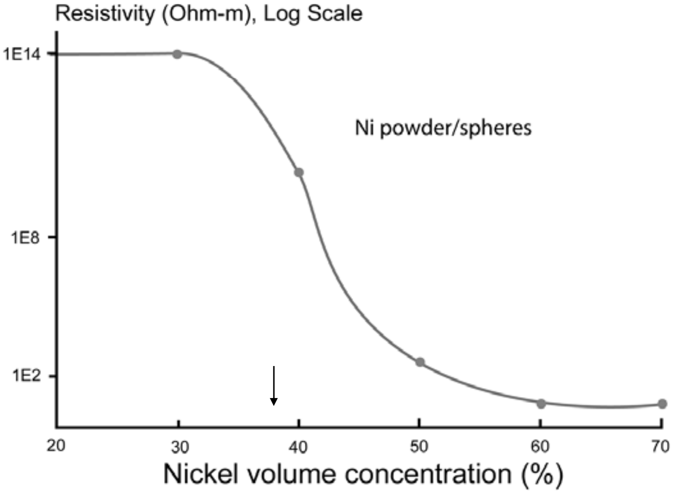
Insulating→

Percolation
←threshold

←conducting

Polymer Metal

Experimental Percolation



1.4 Properties

Commonly used isotropic conductive adhesives

(Jagt, Chapter 11, Conductive adhesives for Electronics Packaging)

Adhesive & Type	Viscosity (Pa.s)	Potlife	Glass transition	Volume Resistivity Ωcm	Shear strength (MPa)	Curing time (min.)	Curing Temp. (°C)
ICA 1 (1 comp.)	65	3 days	80	2.10^{-4}	11	10-15	130-150
ICA 2 (2 comp.)	25-35	3-4 days	85	$1\text{-}4.10^{-4}$	10	30	130-140
ICA 3 (2 comp.)	50	2 days	50	$2\text{-}4.10^{-5}$	8	90	130-140
ICA 4 (1 comp.)	160-200	4 days	80	5.10^{-3}	5	20-30	120-130
ICA 5 (1 comp.)	310-350	4 days	80	1.10^{-3}	4	20-30	120-130
ICA 6 (2 comp.)	150-200	8-12 hr	75	$2\text{-}5.10^{-4}$	14	10-15	170-180

Compare intrinsically conducting polymers,

e.g. Polyaniline: $\rho = 10^{5}$ (intrinsic) to 10^{-2} Ω.cm (doped)

Compare Ag: $\rho_{Ag} = 1.6 \times 10^{-6}$ Ω.cm; $\rho_{ICA} = 12.5$ to $312.5 \times \rho_{Ag}$

Properties of a typical ICA

Property	Values
Viscosity @ 25°C	55,000 cps
Work Life @ 25°C	2 weeks
Cure Condition	1 hour @ 150°C
Cure Option	1/2 hour @ 175°C
Volume Resistivity	5×10^{-4} ohm-cm
Glass Transition Temperature (T_g)	90°C
Coefficient of Thermal Expansion	Below T_g 55ppm/°C
	Above T_g 200ppm/°C
Thermal Conductivity	3.20W/mK@ 121°C

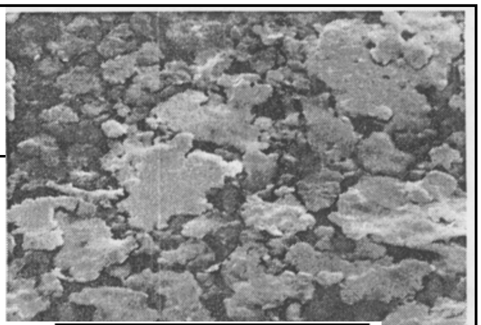
1.5 ICA Problem History

- **Silver migration → polymer**
- **Electrical conductivity → silver**
- **Electrical stability → pad metallurgy**
- **Adhesive strength/shear strength**
- **Rework → thermoset/thermoplastic blend**
- **Impact resistance → Liu/Tong**
  - **Via fill → high density substrates**
- **Electrical conduction mechanism**
- **Self-alignment**

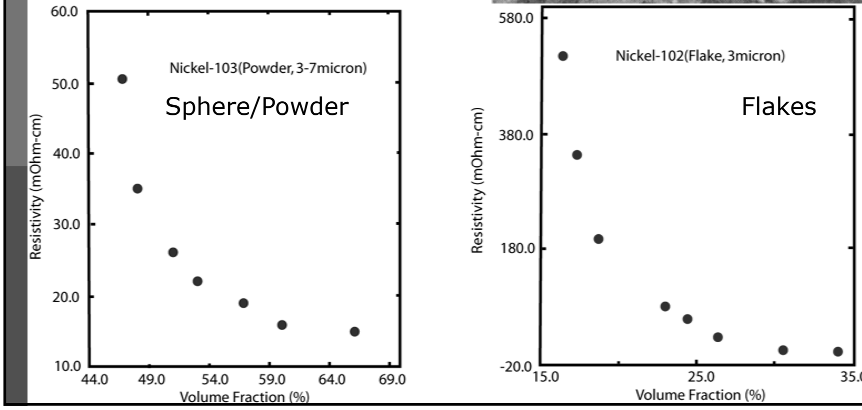
2. Filler Structure

2.1 Flakes
2.2 Bi-modal
2.3 Layering
2.4 Nanoparticles
2.5 Low Melting Point (LMP) Alloys
2.6 Self-alignment

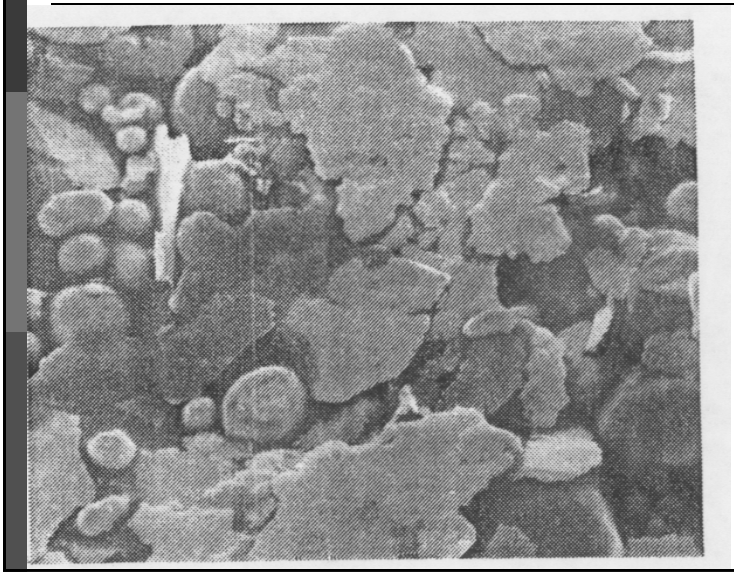
2.1 Flakes: surface/vol ratio



Percolation Threshold Comparison



2.2 Bi-modal: Flakes + powder



e.g.

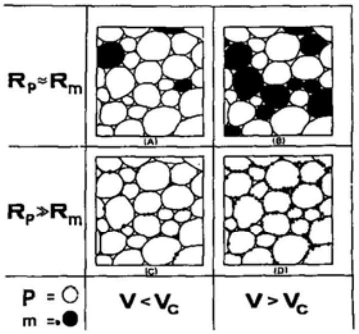
10μm diameter flakes

(<1μm thick)

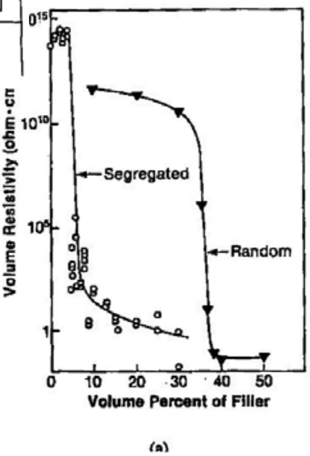
plus

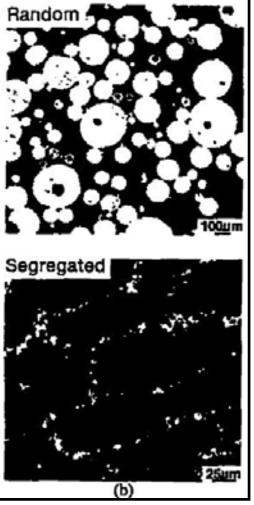
1-3μm diameter powder

(spheres)

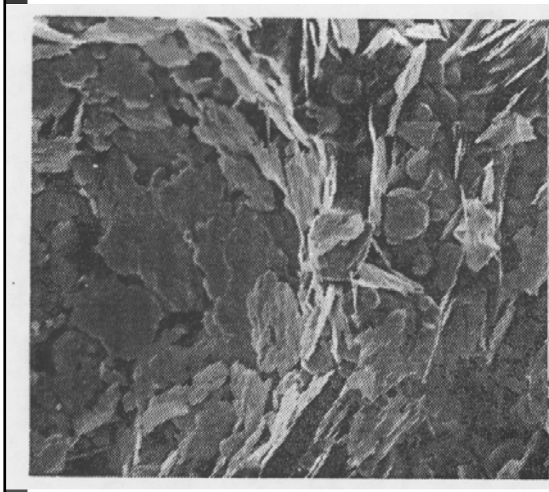


Bi-modal Model





2.3 Layering



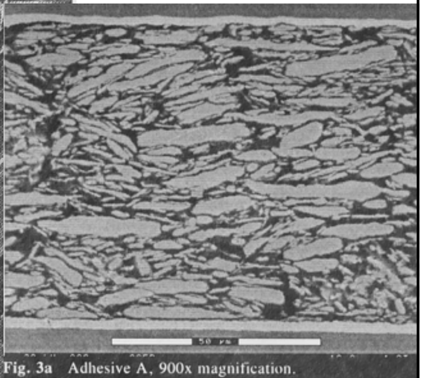
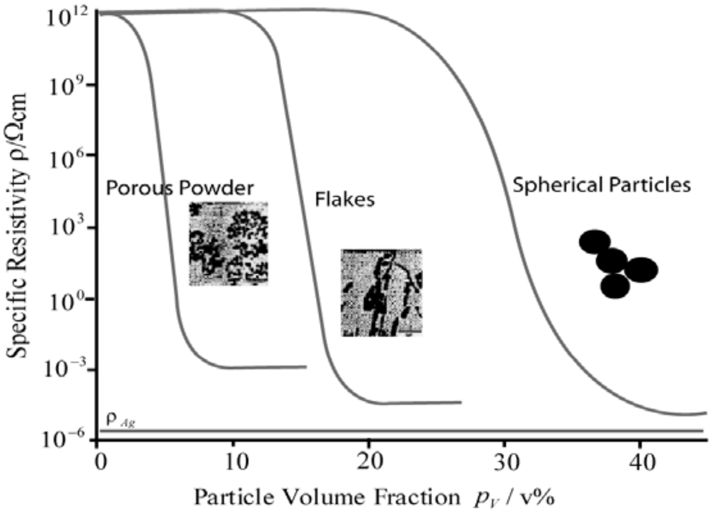


Fig. 3a Adhesive A, 900x magnification.

Constable et al (Adhesives'98)

2.4 Nanoparticles



Percolation limits of different ICA filler particles

Nanoparticle Sintering

[Wong et al, ECTC'06]

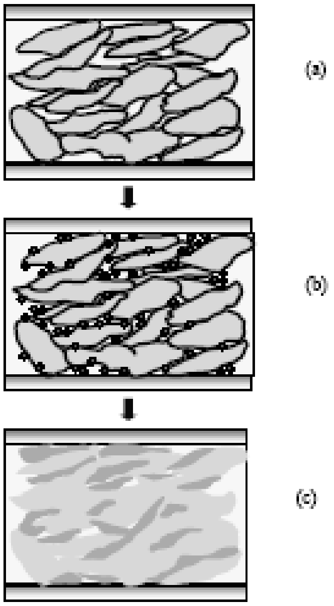


Figure 1. Schematic of particles and flakes between the metal and pads. (a) is conductive adhesives with silver flakes as fillers; (b) is conductive adhesives with both flakes and nanoparticles as fillers; (c) is conductive adhesives with sintered particles among flakes as fillers.

2.6 Self-alignment

(CP Wong)

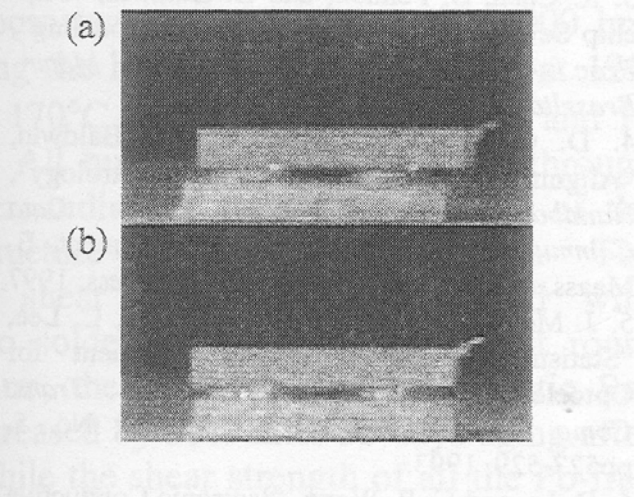
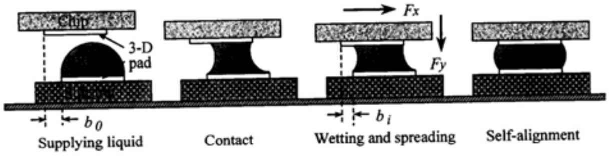
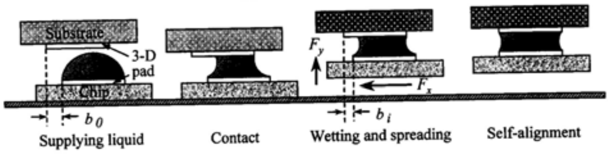


Figure 8 (a) Self-alignment test for ECAs filled with the LMA filler before the reflow and (b) after the reflow.

Self-Alignment [Kim et al, Polytronic 2003] (Model)



(a) Put-down model

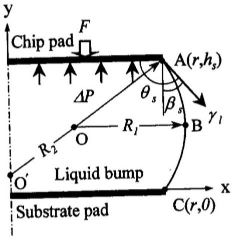


(b) Pull-up model

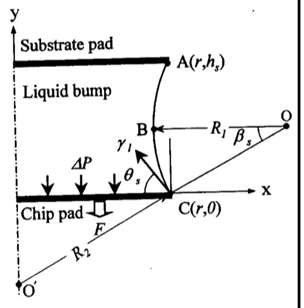
Figure 1. Principles of self-alignment processes using surface tension of resin material.

Table 1 Material properties of epoxy adhesive

Properties	Epoxy adhesive
Viscosity (Pa·s)	6.0
Surface tension (N/m)	0.035
Specific gravity	1.73
T_g (°C)	149
C.T.E (10^{-6}/°C)	19



(a) Put-down model

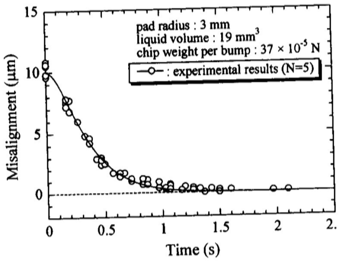


(b) Pull-up model

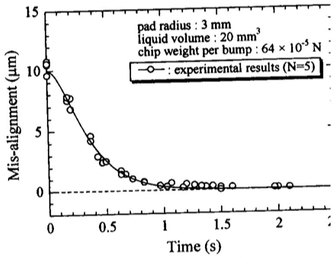
Figure 2. A single joint model.

Self-Alignment (Expt)

[Kim et al, Polytronic 2003]

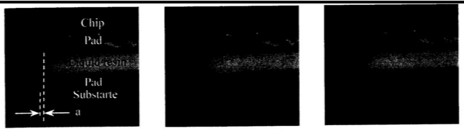


(a) Put-down model



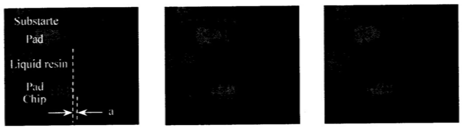
(b) Pull-up model

Figure 5. Self-alignment behavior.



(a-1) t : 0 s, a : 100 µm (a-2) t : 0.5 s, a : 40 µm (a-3) t : 2.6 s, a : 0.2 µm

(a) Put-down model



(b-1) t : 0 s, a : 100 µm (b-2) t : 0.5 s, a : 43.3 µm (b-3) t : 2.8 s, a : 0.14 µm

(b) Pull-up model

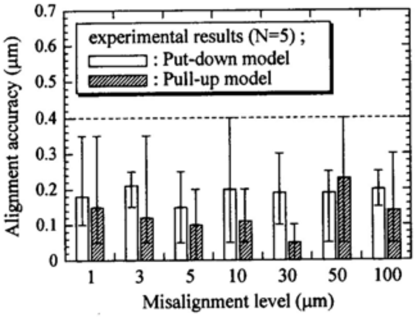


Figure 7. Alignment accuracy at different levels of misalignments.

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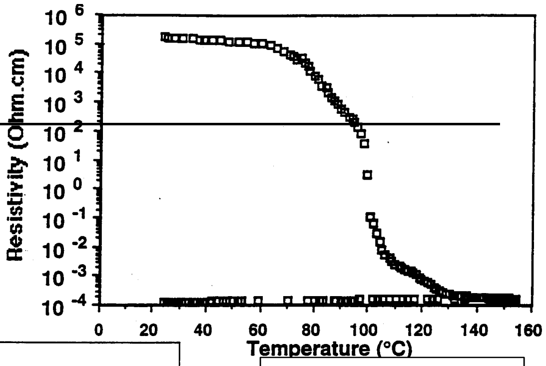
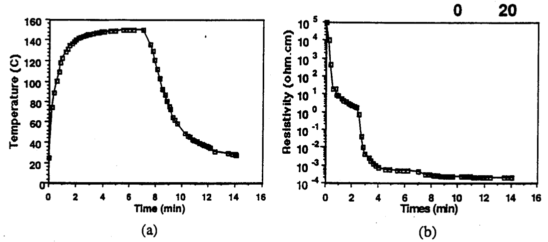
3. ICA Cure

3.1 Resistance change with cure
3.2 Cure model
3.3. Shrink vs. cure
3.4 Cure optimization
3.5 Microwave cure

3.1 Resistance Change





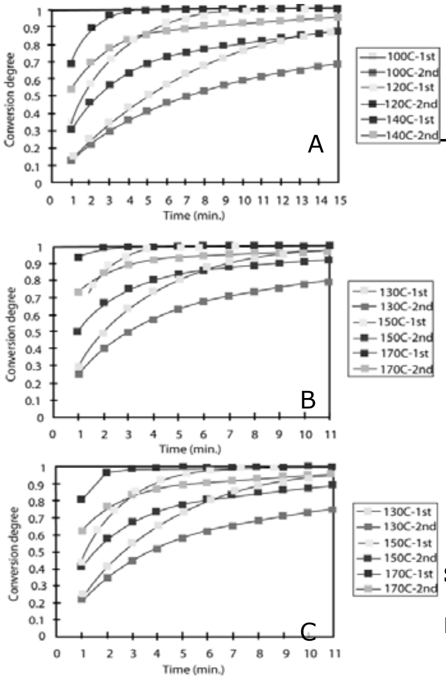
(a) (b)

Figure 4.20: (a) Temperature profile for 3 minutes isothermal cure at 150°C. (b) Resistivity change during isothermal cure at 150°C for Adhesive C.

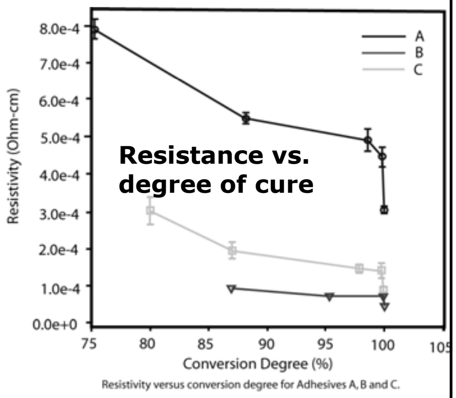
Figure 4.20: (a) Temperature profile for 3 minutes isothermal cure at 150ºC. (b) Resistivity change during isothermal cure at 150ºC for Adhesive C.

3.2 Cure Modeling:

3 Adhesives



Degree of Cure vs. Time



Resistance vs. degree of cure

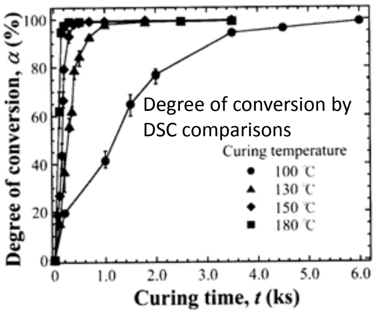
Resistivity versus conversion degree for Adhesives A, B and C.

Simple 1st order cure models work well

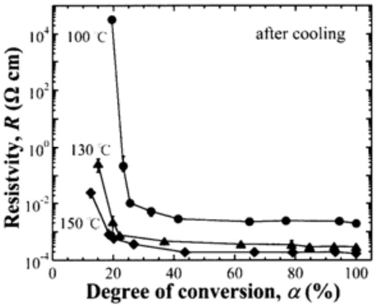
Manufacturer profiles → incomplete cure

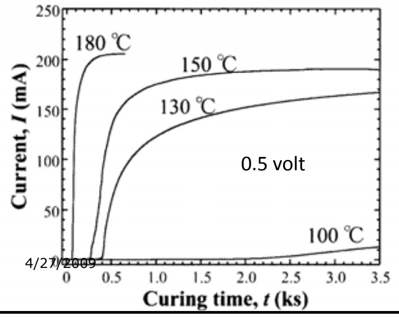
Inoue & Suganuma, Soldering & Surface Mount Technology, 18 (2) 2006, pp. 40-45

ICA cure: Manufacturer's specification 150°C

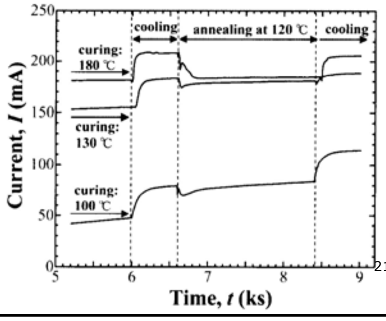


Degree of conversion by DSC comparisons

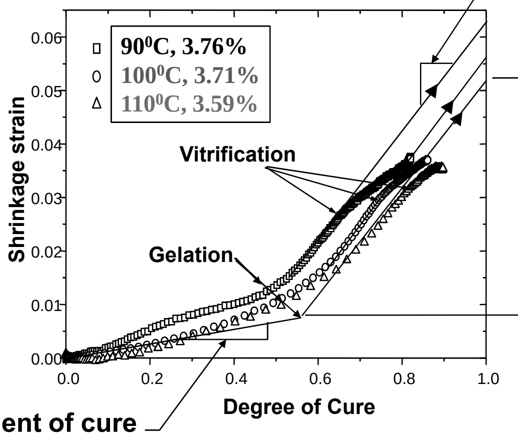




0.5 volt



3.3 Cure Shrinkage/Degree of Cure Characteristics



Coefficient of cure shrinkage (CCS_2) – **almost independent of cure temperature**

≈4.2%
Almost independent of cure temperature

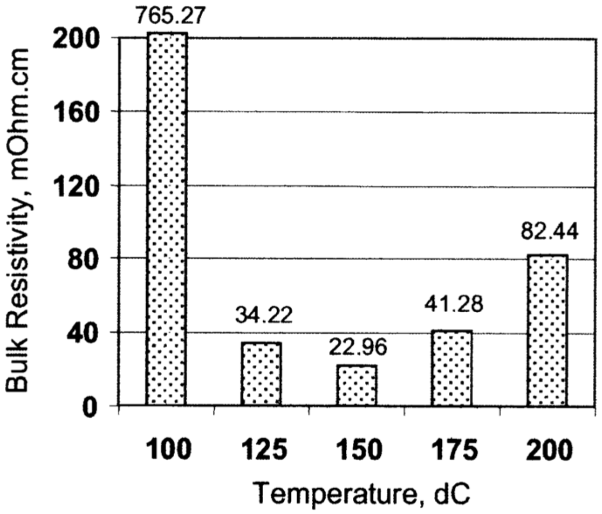
Coefficient of cure shrinkage (CCS_1)

Slide courtesy of E. H. Wong

3.4 Cure Optimization

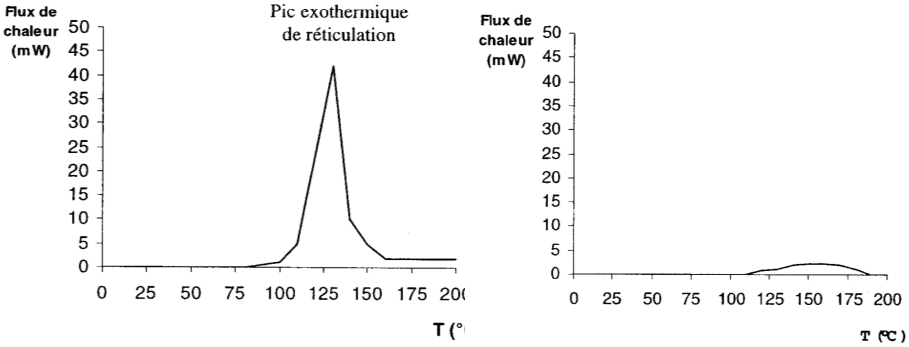
- ☐ **Removal of volatile organics**
  - **Organic liquids/solvents added**
  - **Viscosity control for printing**
- ☐ **Complete cure**
- ☐ **Polymer degradation**
- ☐ **Problems:**
  - **Bubbles**
  - **Ag particle/polymer delamination**

Importance of optimized cure temperature
Fan/Tison/Wong [ECTC 2002]



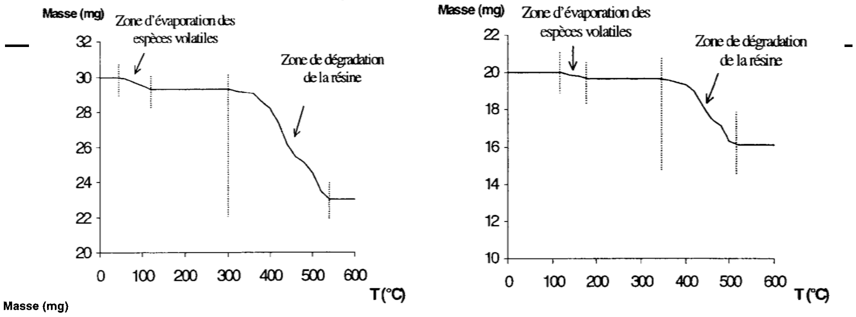
Complete Cure (Th'set 1): DSC before & after cure

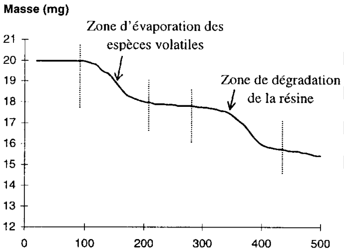
(Perichaud/Fremont)



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

Thermogravimetric during cure: volatiles & degradation → composition





Type	Mass% Volatiles	Mass% Ag
Th'set 1	2.0%	75%
Th'set 2	1.2%	80%
Th'plastic	10%	80%

(Perichaud/Fremont)

Cure Profile & Bubbles : 8175A

(Perichaud/Fremont)