DESIGN OF EXPERIMENTS TO ASSESS THE SOLDERABILITY OF VARIOUS PRINTED WIRING BOARD FINISHES

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Driving Forces for HASL Replacement

- Shrinking pitches, particularly in array packages (e.g. 20mil spacing, 12mil ball diameter)
- Global push towards Pb-free electronics materials (esp. Europe and Japan)

PWB Finishes Selected For Experiment

- HASL (control)
- Immersion Sn (2 vendors, 1 chemistry)
- Immersion Ag (2 vendors, 2 chemistries)
- Electroplated Au / electroplated Ni

Note: OSP and ENIG not selected based on shelf life concerns, cost, and supplier capabilities

Method / Materials

- “Spread Test”, with the response variable being a ratio of diameters (D_{avg} / D_0)
- Sn63Pb37 solder spheres (d = 0.012”)
- Tacky flux (no-clean; same chemistry as in paste flux used in production)
- Flux was placed using automated and programmable dispensing machine

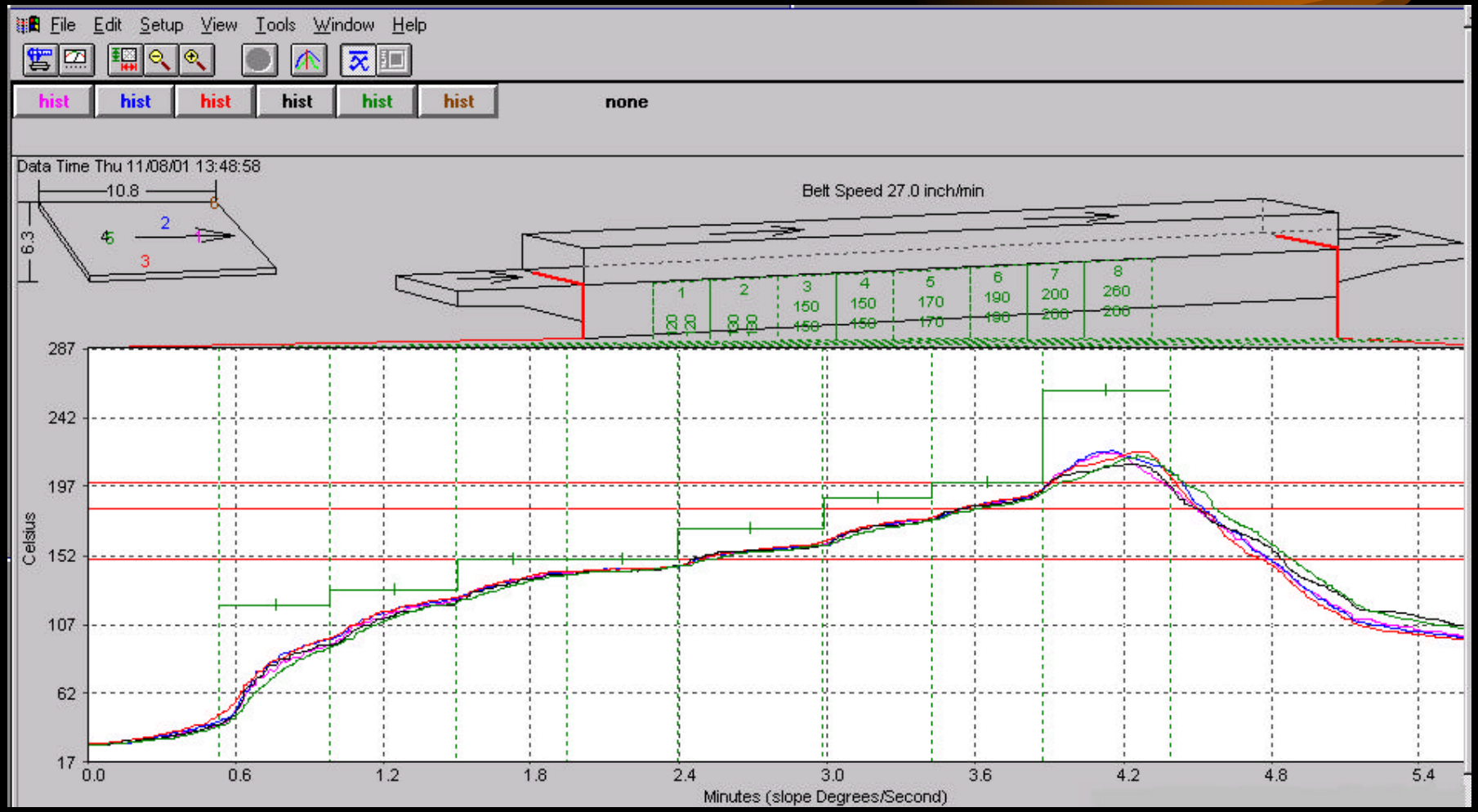
Method / Materials (continued)

- Pneumatic vacuum pencil used to place solder spheres
- 8 zone reflow oven used; profile set up to comply with flux/paste vendor recommendation
- Profile verified using travelling profile recorder

Method / Materials (continued)

- Microscope / digital micrometer used to measure solder after reflow (±0.0001”)
- X,Y dimensions averaged to give a “diameter”

Reflow Profile



PWB Finishes / Thickness Data

Finish	Vendor	Chemistry	Thickness (10^{-6} inches)
HASL	A	N/A	52 – 724
ImSn1	A	1	37 – 51
ImSn2	B	1	44 – 55
ImAg1	B	2	18 – 27
ImAg2	A	2	12 – 21
ImAg3	A	3	5.3 – 8.1
Au / Ni	C	N/A	Ni: 142 – 389 Au: 0.64 – 1.6

Experiment Design

- Number of finishes = 7
- Preconditions = 2 (“out of the package” and twice exposed to reflow profile)
- 3 replicate PWBs for each of the 14 conditions above, with 10 solder spheres per PWB (420 spheres total)
- Response variable = D_{avg} / D_0

Experiment Design (continued)

- D_{avg} : average "diameter" of the 10 reflowed solder deposits per PWB
- D_0 : 0.012" ± 0.0005" (initial sphere diameter)
- Solderability increases as D_{avg}/D_0 increases

ANOVA (Analysis of Variance)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F_0
Finishes	2.457	6	0.410	35.921*
Reflow Passes	1.837	1	1.837	161.140*
Interaction	2.103	6	0.351	30.746*
Error	0.319	28	0.0114	
Total	6.716	41		

ANOVA (continued)

- Finishes, reflow passes, and interaction all statistically significant at the 95% confidence interval
- Strong contribution to variation by ‘Reflow Passes’

Statistical Analysis

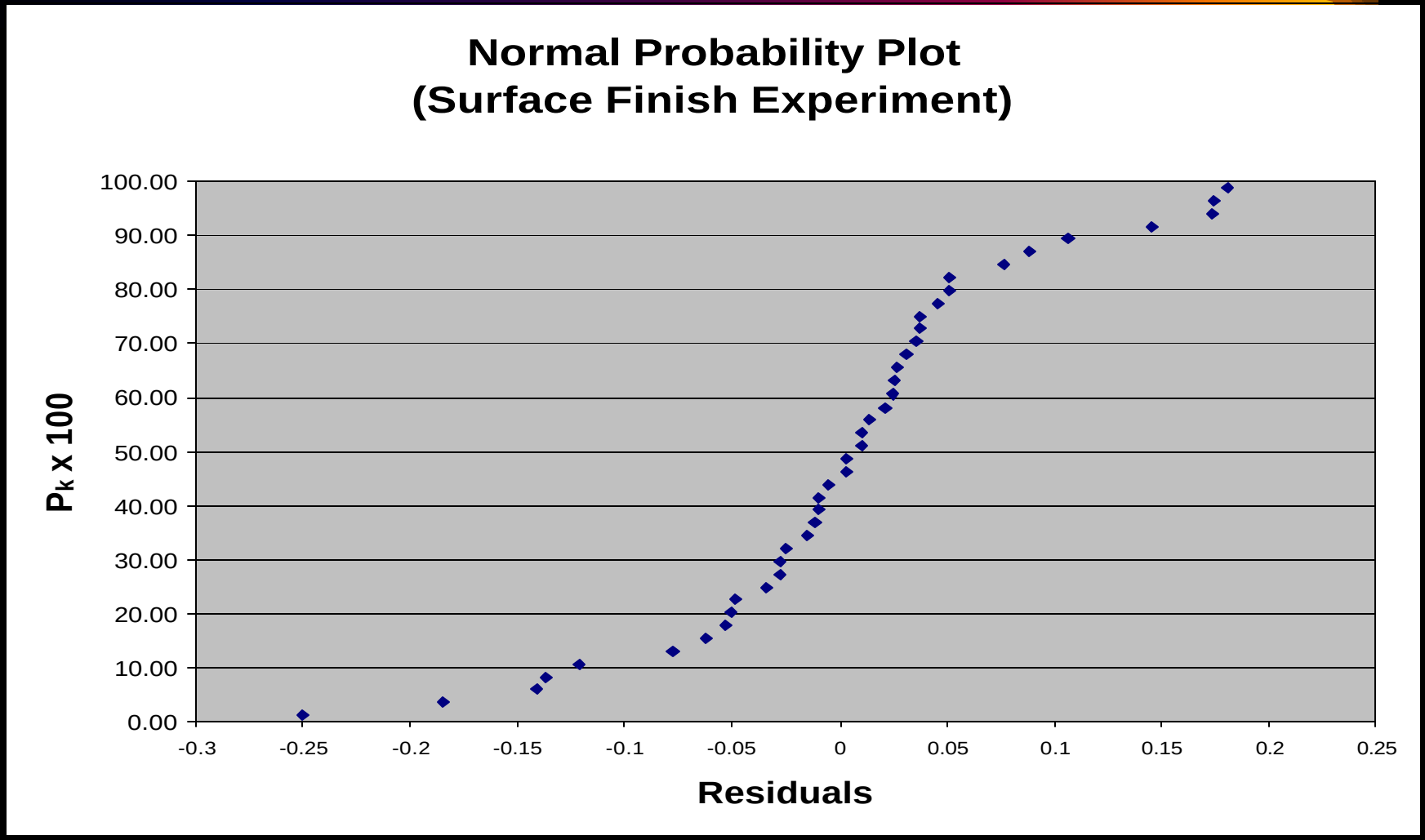
- Duncan Multiple Range Test - used to verify which (if any) cell means were better than others
- Normal Probability Plot - used to validate assumptions of normally distributed data
- Residual Plot - shows the variation of individual data points within a cell from their respective cell means

Duncan Multiple Range Test

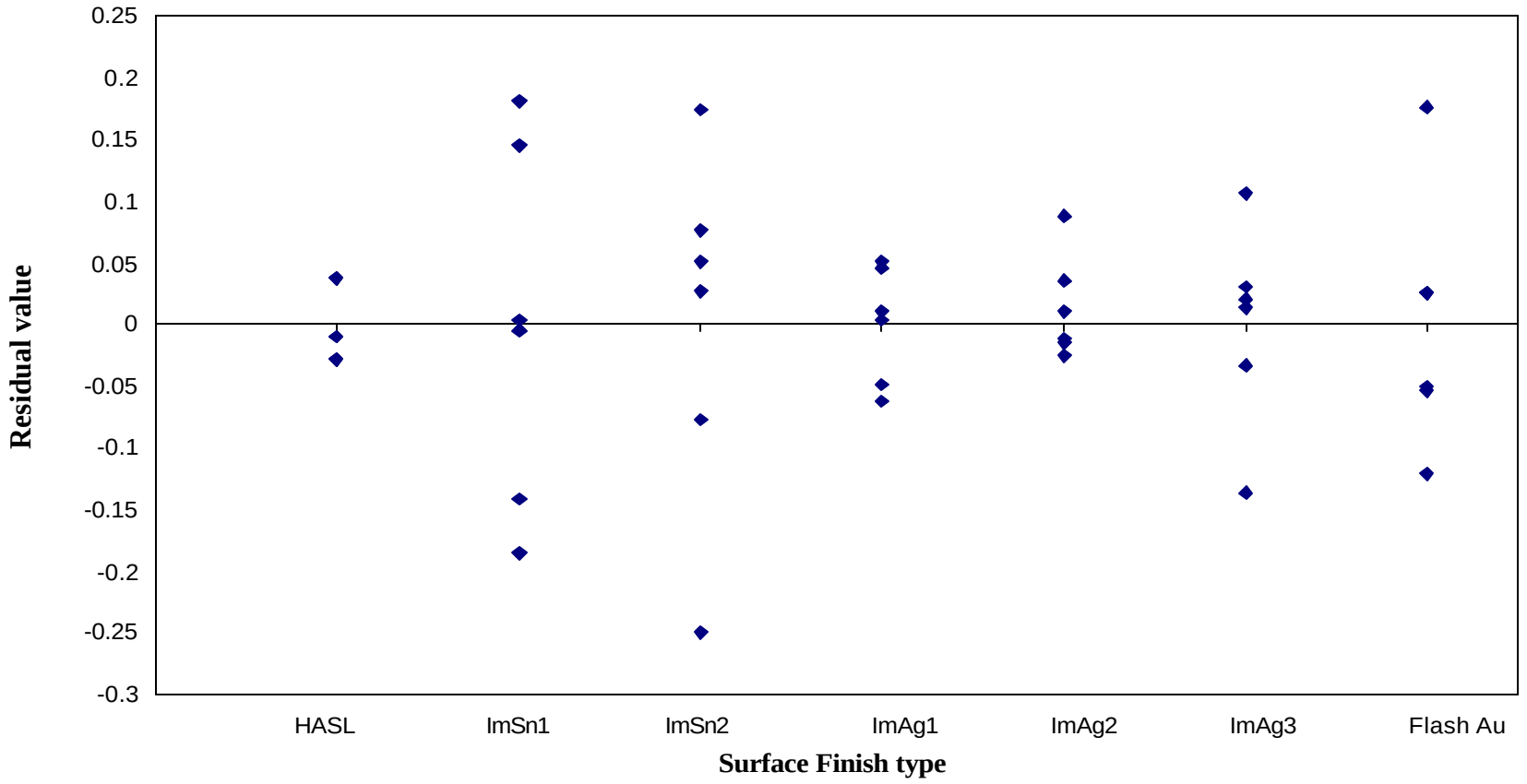
- Performed with means from the second precondition (3 total reflow passes)
- 95% confidence level
- Revealed 3 significantly different solderability levels as follows (highest to lowest):

ImAg3 > HASL, Au/Ni, ImAg1,2 > ImSn1,2

Normal Probability Plot



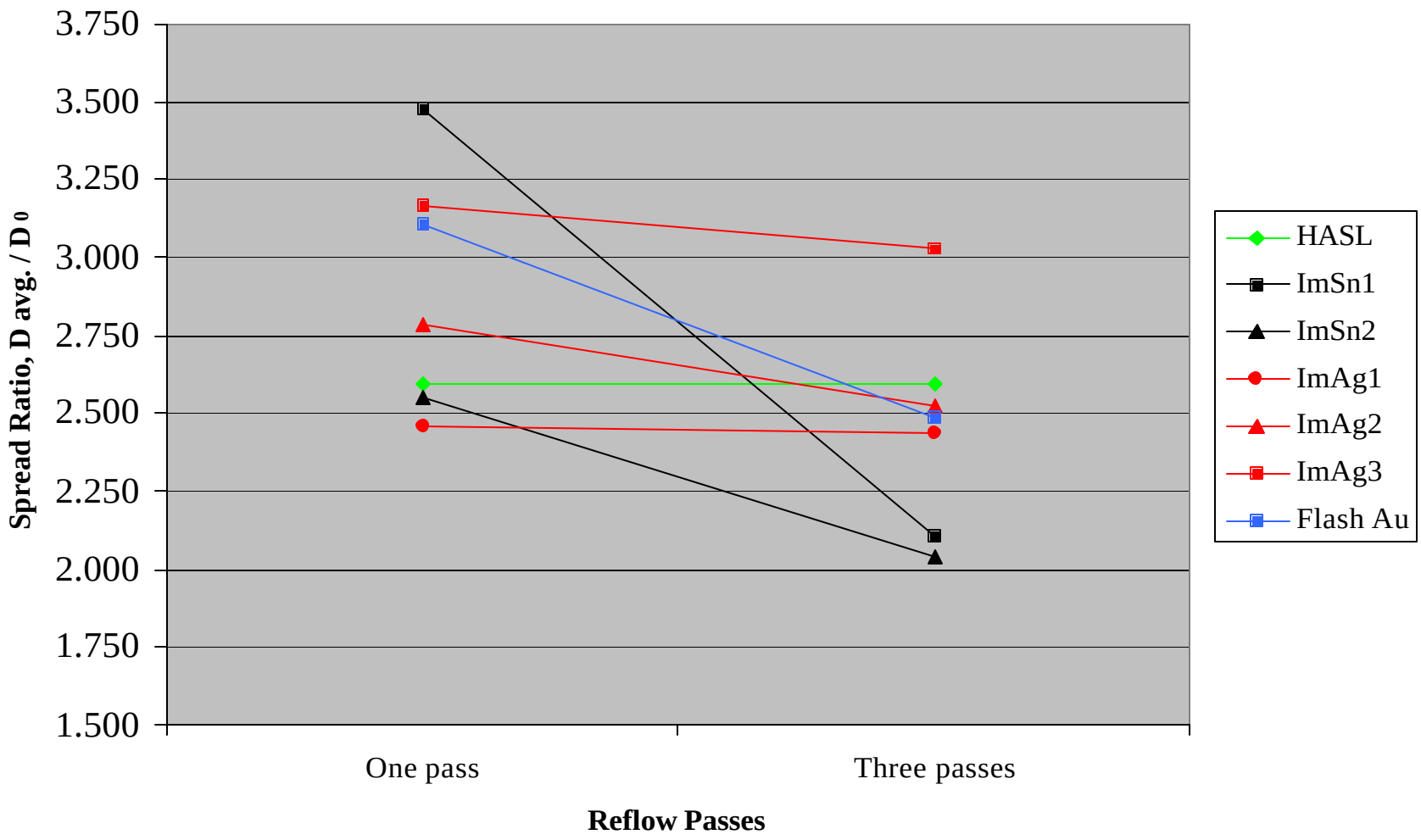
Residual Analysis



Residual Analysis (continued)

- Low variation in HASL, ImAg
- Higher variation in ImSn
- Data for HASL after 3 reflow passes not available

Spread Ratio Comparison



Conclusions

- The finish **ImAg3** was the best performer; 17% better spread ratio than HASL after 3 reflow cycles
- For ImAg in general, the spread ratio and silver thickness did not appear to be correlated; more related to vendor/chemistry

Conclusions (continued)

- ImAg had superior repeatability over ImSn and Au/Ni (more tightly spaced residuals)
- ImAg affected least by multiple reflow passes (approx. 5% spread ratio decrease vs. 20% for Au/Ni and 30% for ImSn) -- Ag and Cu do not form an intermetallic
- SEM/EDX revealed no sign of Ag_3Sn intermetallic “needles” in the solder joints

Conclusions (continued)

- Decrease in ImSn spread ratios believed to be a result of Cu-Sn intermetallic reaching the pad surface after multiple reflow cycles
- Cross sections were not conclusive of this due to damage, but Arrhenius calculations support the hypothesis (~57 µin. “growth” after 3 reflow passes may be possible)
- Other possibilities: oxides, sulfides? Must explain why 1 pass - OK, 3 passes - NG

Final Comments

- Pricing index (averages based on current suppliers' feedback): HASL = 1.0, ImAg = 1.10-1.15, Au/Ni = 1.10-1.20, ImSn = 1.10-1.15
- Long-term reliability experiment in progress to compare Au/Ni and ImAg to HASL for leaded, array, and QFN packages - results by 12/2002 or 01/2003

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