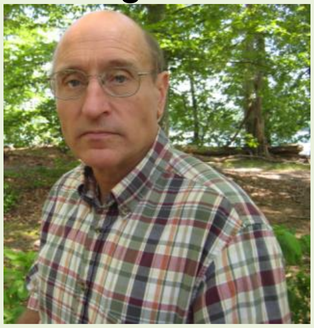
IPC Electronics Midwest 2010

Analytical Procedures for Portable Lead-Free Alloy Test Data

Greg Munie



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Biography:

Gregory C. Munie is currently IPC's Technical Conference Director for IPC APEX, EXPO conferences. Prior to joining IPC he worked for Kester Solder, Lucent Technologies and AT&T Bell Labs. He has an M.S. and a Ph.D. in Physical Chemistry from the University of Illinois at Urbana-Champaign.

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ANALYTICAL PROCEDURES FOR PORTABLE LEAD-FREE ALLOY TEST DATA

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Why a new “Alloy Test Method?”

- Describes material tests that generate portable data
- Allowing for
  - direct comparison of different alloys
  - aiding in alloy acceptability determination for various applications,
  - development of reliability models

Outline

- Genesis in December 2008
- Follow-up discussions APEX 2009
- Input received from SMEs
- Conference Call July 22, 2009
- Discussions IPC Midwest 2009
- First white paper issued by IPC SPVC June 2010

Summary of December 2008 Meeting

Excerpts from Meeting Minutes

- Called in Response to OEM Difficulties with Alloy Proliferation
- Joint meeting between the IPC Solder Products Value Council and various OEMs and EMS
- If the proliferation of lead free alloys is a test issue for OEMs and EMS does every alloy need to be tested completely?
- OEM proposals for a standard test procedure were reviewed.
- Greg Munie asked to condense current test procedures into a “test standard” format for further review.
  - Three levels of testing: physical properties, manufacturing, reliability.
- Group to reconvene at APEX 2009 to review test procedures
- Intent: IPC to create a committee on alloy material properties.

APEX 2009 Meeting

Excerpts from Meeting Minutes

- Status of the current draft of the alloy test method was reviewed.
- Additional comments from HP on a standard test procedure were reviewed.
- Flextronics presented a review of its lead free test vehicle.
- Industry SMEs to be canvassed for their views on the proposal.

SME Input on Draft

Summary : Agreed on Items

- Thermal cycling : Alloy characterization tests should cover the range of interest
- Creep characteristics (stress exponents and creep activation energies) are essential parameters
- Measurements need to made on realistic sized samples, i.e. solder joint size
- Standard material properties are necessary but not sufficient for complete alloy characterization.

Summary: Open Items

- The type of testing required for qualification should depend on the solder form/application.
- The current draft lacks sufficient assembly-level testing.
- Test methods need to be much more prescriptive, allowing much less variability in testing methodology.
- The current proposal does not address vibration.
- Test the various solder forms in ways relevant to their end use.
- The thermal cycling and manufacturing test vehicles/procedures are undefined

Conference Call July 22, 2009

Electronics IPC Midwest

Excerpts from Meeting Minutes

- The draft was reviewed and major changes made:
  - Scope
  - Copper dissolution
  - All original “levels” of testing references were removed: the document becomes a stand alone test document.
  - Tensile and creep sample size: Auburn sample size procedure will be used
  - Speed and duration of testing changed
- A new committee co-chaired by Greg Henshall of HP and Joe Smetana of Alcatel-Lucent will address the issues of manufacturability and reliability testing
- Meeting set for IPC Midwest to review progress

IPC Midwest 2009 Meeting

Excerpts from Presentations and Discussions

- The draft was reviewed and the major changes made since APEX summarized:
  - Scope
  - Copper dissolution: NIST or NPL? TBD
  - Tensile and creep sample size are standardized on the recommendations of Auburn: The samples now reflect typical solder joint size.
  - Speed and duration of testing changed to reflect the need for constitutive model data.
- The committee co-chaired by Greg Henshall of HP and Joe Smetana of Alcatel-Lucent will continue to work the issues of manufacturability and reliability testing.
- A small working team will begin re-write of present document.

SPVC Working Group Discussion: APEX 2010

- The physical test are well defined in the current draft
- The issues of manufacturability and reliability testing are still in progress.
- What options are available to get the information collected to the industry now?
  - New standard committee
  - Incorporate test methods in an existing standard
  - Issue test methods a s a guideline
  - Issue test methods as a white paper with a follow up round robin test of "portability"
- The white paper route was chosen by the SPVC

Review of Test Methods in White Paper

Overview: Sections 1 and 2

- Section 1: Scope and Purpose changed to reflect new direction:
  - Direct comparison of different alloys
  - Aiding in alloy acceptability determination for various applications
  - Development of reliability models
  - Other uses.
- Section 2: Applicable documents, e.g. ISO, J-STDs, etc.

Overview: Section 3 General Test Requirements

- 3.2.1 Composition: all elements to be reported via AES/ICP (No XRF)
- 3.3 Differential Scanning Calorimetry
  - ASTM E794-01, Standard Test Method for Melting and Crystallization Temperatures by Thermal Analysis at ramp rates of 2 ºC and 10 ºC
  - Sample pre-conditioned by one run from ambient to 50 ºC above liquidus

Overview: Section 3

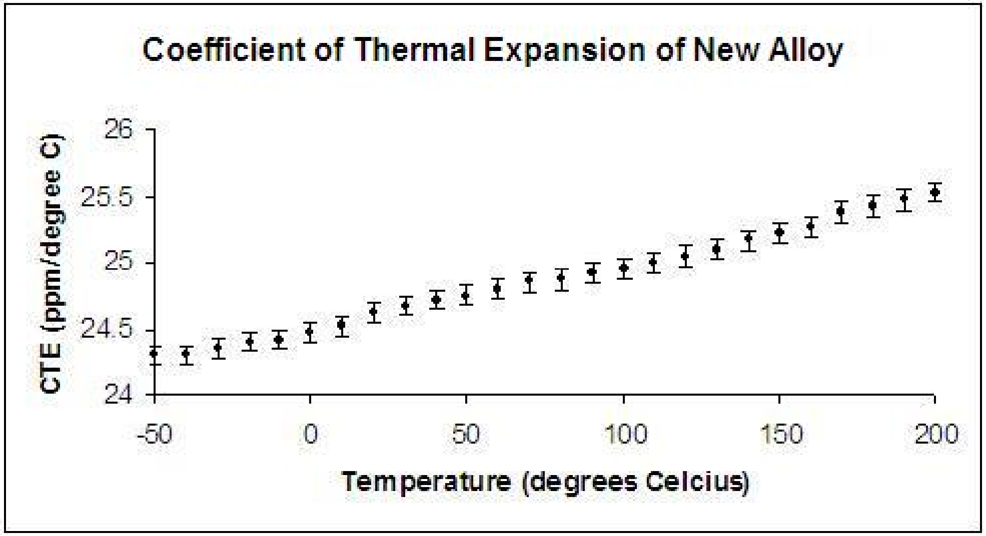
- 3.4 Wetting Balance: J-STD-002B Solderability Tests for Component Leads, Terminations, Lugs, Terminals and Wires
  - Bare copper test coupons per Figures 4-8 of J-STD-003 activated rosin flux #2
  - SAC 305 control for ten runs at 255° C
  - Precondition:
    - 8 hours at 72° C/85% humidity
    - Followed by 1 hour bake at 105° C
  - Test conditions: Parts immersed at 45° incident to solder pot to a depth of 0.4 mm at 2 mm/sec
  - Individual curves (not averages) are reported
  - Options, e.g. finish, as agreed on by user and vendor.

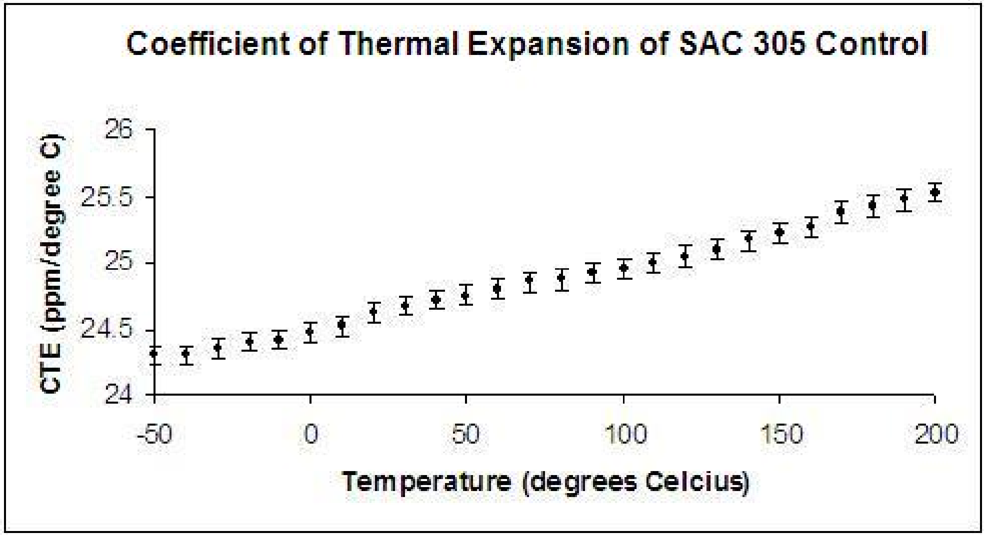
Overview: Section 3

- 3.5 Copper Dissolution per NIST 960-8, Section 13, “Liquid Solder Dissolution.”
- 3.6. Thermal Expansion, Tensile and Creep Testing
- Material Coefficient of Thermal Expansion (CTE): CTE shall be measured using either the IPC-TM-650 2.4.24 test method or ASTM E831-06
  - Automotive/Aerospace: -50 to 165 ° C
  - Server/Telecom/Consumer products: 0 to 100 ° C
  - Finite Element Analysis data collection: -50 to 200 ° C

Overview: Section 3 CTE (continued)

- Three samples of both the new alloy and a SAC 305 control shall be tested.
- The sample geometry shall be the same for all six samples and shall be as specified in 3.6.21 (Auburn sample preparation).
- The test report shall provide a graph of thermal expansion (ppm/ºC) versus temperature (ºC), measurements taken every 25° C through range, e.g. from -50° C to 200° C, averaged for the three tests of each solder alloy. Ramp rate: 10° C/min.
- The standard deviation for each data point (as error bars), along with the averaged values at each temperature shall be provided for each sample and a SAC305 control.


Coefficient of Thermal Expansion of New Alloy
CTE (ppm/degree C)
26
25.5
25
24.5
24
-50
0
50
100
150
200
Temperature (degrees Celcius)


Coefficient of Thermal Expansion of SAC 305 Control
CTE (ppm/degree C)
26
25.5
25
24.5
24
-50
0
50
100
150
200
Temperature (degrees Celcius)

Overview: Section 3

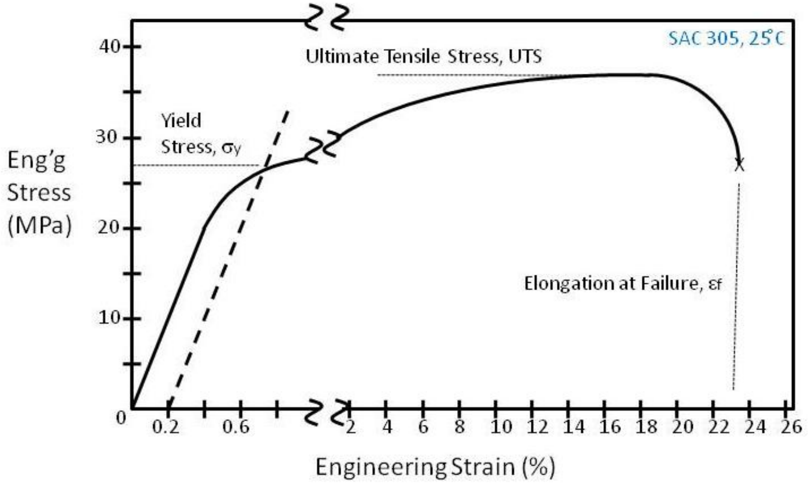
- 3.6.2 Tensile Testing per ASTM Procedure E8.
  - Sample preparation per Auburn University method (Insure realistic size and cross sectional uniformity.)
  - Samples shall be aged for 48 hours at 125° C and a minimum of 3 and up to 5 samples shall be tested for each set of conditions
  - X-ray analysis for voids required before testing

Overview: Section 3

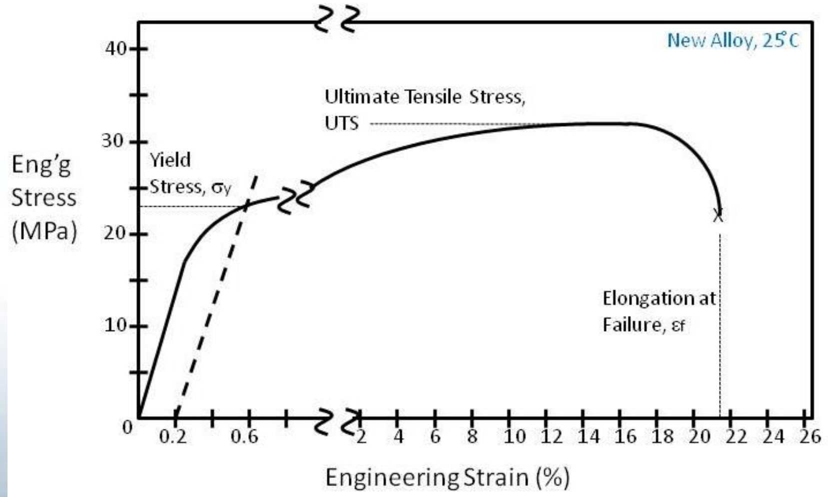
- 3.6.2.2 Test Conditions
  - SAC 305 control
  - 25ºC with optional -40ºC, 60ºC, 90 ºC, and 125ºC.
- Three samples of each alloy shall be tested at each temperature.
- The tensile test shall be conducted at a strain rate of 10-4 s-1.
- The geometry, testing and aging conditions must be identical for all samples.

Overview: Section 3

- 3.6.2.3 Data Reporting for both the new alloy and SAC 305 at each temperature shall be done by plotting the engineering stress against the engineering strain (to failure), measured by conventional tensile testing for both alloys at each temperature and for each sample.



SAC 305, 25°C
Ultimate Tensile Stress, UTS
Yield
Stress, σy
Eng'g
Stress
(MPa)
Elongation at Failure, εf
Engineering Strain (%)



New Alloy, 25°C
Ultimate Tensile Stress,
UTS
Yield
Stress, σy
Eng'g
Stress
(MPa)
Elongation at
Failure, εf
Engineering Strain (%)

Temperature (ºC)		-40	25ºC REQUIRED	60	90	125
New Alloy	0.2% offset σy (MPa)					
	UTS (MPa)					
	Elongation at failure (%)					
	Toughness (Area under the curve in units of MPa)					
SAC 305	0.2% offset σy (MPa)					
	UTS (MPa)					
	Elongation at failure (%)					
	Toughness (Area under the curve in units of MPa)					

Overview: Section 3

3.6.3 Creep Behavior: provide data for constitutive modeling and to estimate creep rupture time for a given set of loading conditions.

- Testing per National Physical Laboratory REPORT DEPC MPR 021 “The Measurement of Creep Rates and Stress Relaxation for Micro Sized Lead-free Solder Joints.”
- Sample geometry per 3.6.2.1 or NPL report
- 3 (minimum) to 5 samples tested for each set of conditions. SAC305 as a control.

Overview: Section 3

3.6.3 Creep Behavior:

- Test at 10 Mpa or
- Test at 25% of the UTS (Note: This requires doing a suitable stress-strain tensile test first as per section 3.6.2.)

Overview: Section 3

3.6.3 Creep Behavior: For each set of creep test conditions report (individual and average values per condition):

- A plot of creep strain versus time.
- The strain rate (differentiating strain versus time) to determine the minimum strain rate (also called secondary or steady state creep rate).
  - The minimum creep rate
  - The time to rupture and rupture strain
  - Both under given conditions: load and temperature

Overview: Section 3

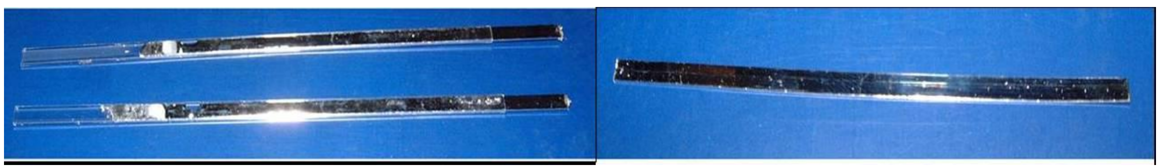
3.7 Dynamic Modulus: per ASTM-1875-00

- Published values may be used.
- Modulus data shall be at 25 ° C with 63/37 Sn-Pb solder as a control. (Optional at -40ºC, 0ºC, 50 ºC, 75ºC, and 100ºC.)
  - Use geometry of section 7.2 of ASTM-1875-00
  - Use equations (2), (4), (8) and (15) of ASTM-1875-00 to determine (respectively):
  - Elastic modulus (E)
  - Shear modulus (G)
  - Poisson's ratio (v).

Temperature (ºC)		-40	0	25ºC REQUIRED	50	75	100
New alloy	E (GPa)						
	G (GPa)						
	ν						
Sn-37Pb control	E (GPa)						
	G (GPa)						
	ν						

Sample Preparation

(Courtesy Auburn University)



(b) Specimen solidified in glass tube (c) Specimen after removal from glass tube

Figure 2.2 - Solder Melting System and Specimen Preparation

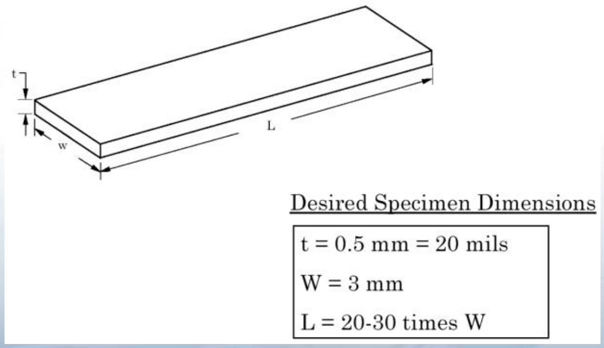


Figure 2.3 - Auburn Uniaxial Specimen

Action Items Open

- Test vehicle development (separate committee formed):
  - ATC
  - Shock/Vibration
  - Manufacturing
- Shock and Vibration test method (in development)
- Verification of validity of test methods:
  - Industry
  - Academia

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Questions?