APEX EXPO IPC
NEW IDEAS ... FOR NEW HORIZONS
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Current and Emerging Gaps in Standards for Semiconductor Assembly Materials in the Era of 2.5D and 3D Dimensional Devices

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Overview

- Flux usage
  - Standard flip-chip, 2.5D and 3D assembly
- CTF parameters for fluxes
  - "Critical to functionality"
- Review of standards
  - Relevant to semiconductor-grade fluxes
- Conclusions
  - Path forward

- **Flux usage**
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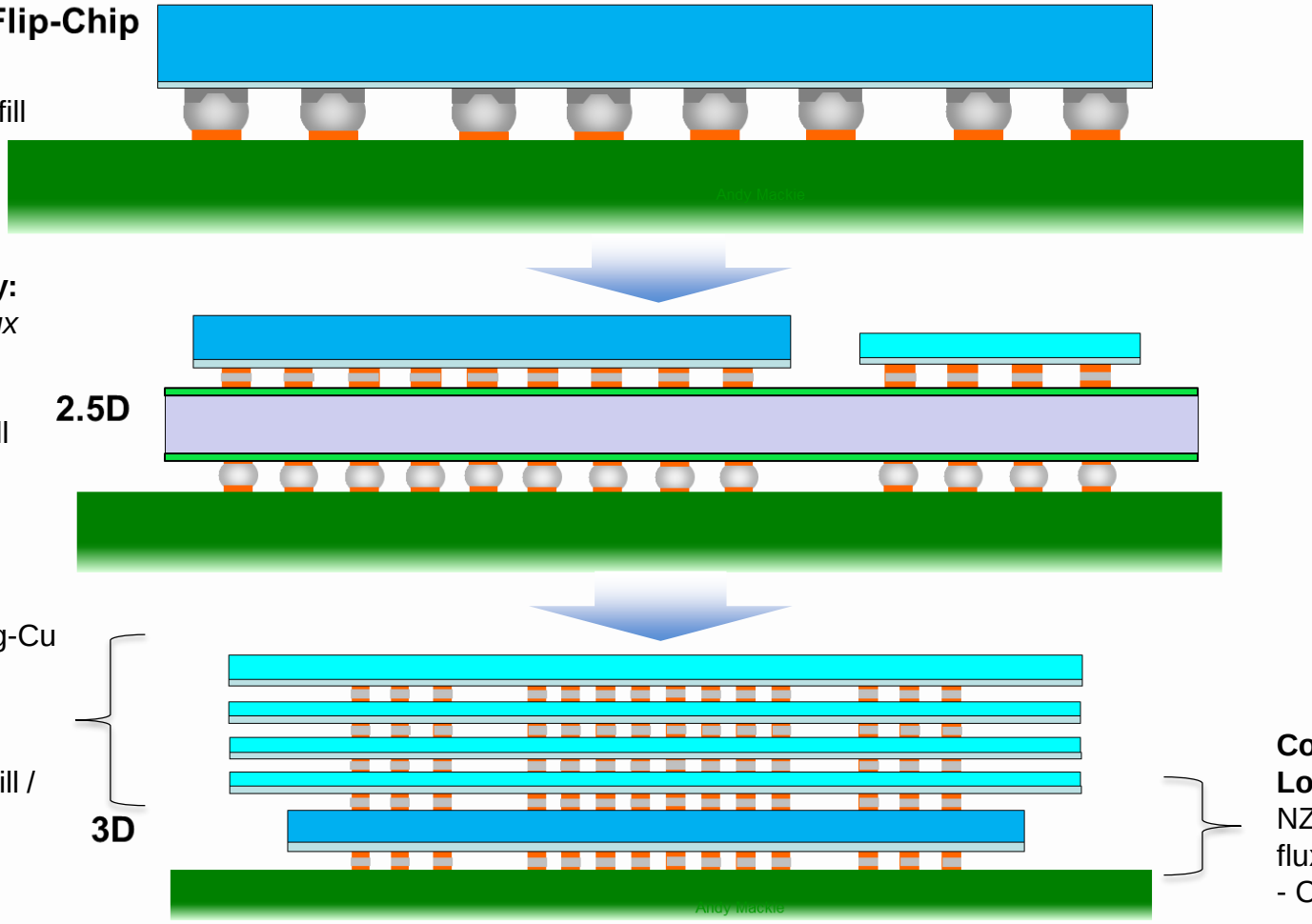
Flip-Chip Fluxes in Semiconductor Assembly

Logic Chip:
WS or NC flux
- Capillary underfill

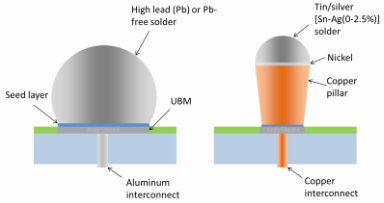
Logic and memory:
WS or ULR/NZR flux
- Capillary underfill
- Molded underfill

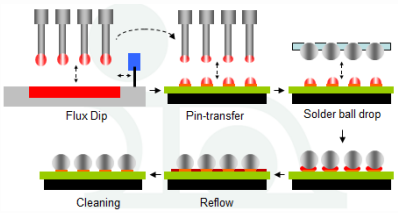
Memory cube:
- *NZR fluxes*:
  - Cu-SnAg-Cu
- *Fluxless*
  - CuOCu
  - CuCu
- Thermal underfill / NCF



Semiconductor-Grade Fluxes

Material Type	Flux Deposition Method	Final Device type	Observables for "Good" Process	Residue Compatibility (NC flux only)
Waferbumping fluxes	Spin-on after dispense	Bumped die	Shiny, smooth hemispherical, co-planar solder bumps. No solder on die or substrate surface.	No failures related to electrical conductivity between solder joints. Compatibility with underfill materials, with no delam during stress testing. No voiding.
Flip-Chip fluxes	Spray / jet of flux onto substrate Dipping flip-chip (bumped die) into open tray of flux	Assembled FC device	Reliable, void-free solder joint	
WLCSP fluxes	Printing of flux onto wafer surface (UBM pads / RDL)	WLCSP	Shiny, hemispherical solder spheres. High shear strength solder joints.	
Ball-Attach fluxes	Pin transfer from reservoir (tray) onto substrate	BGA or micro-BGA	Shiny, hemispherical solder spheres. No staining on substrate surface. High shear strength solder joints.	
NOTES:	*Sometimes both processes are used*			





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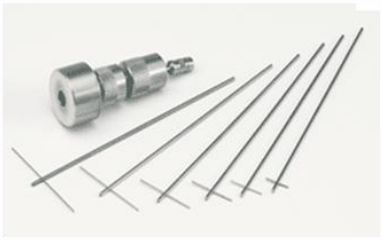
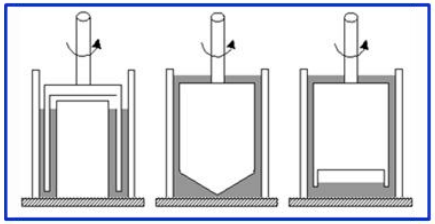
CTF Parameters for Flip-Chip Flux

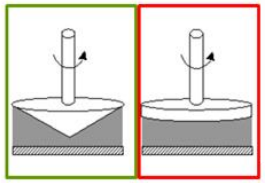
- Rheology
  - Application
    - Dipping or spraying/jetting
  - Tack
    - Hold die during reflow
- Electrical reliability
  - SIR / ECM
- Physical reliability
  - No delam / voiding
  - Good adhesion
- Halogen-levels
  - Driven by “environmental” or failure modes?
- Solderability
  - SnAg wetting onto RDL/PI metallizations

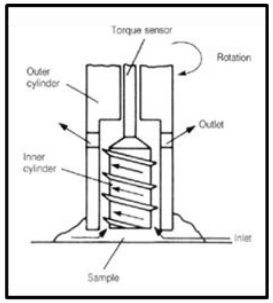
Rheology: Measurement

- Geometries:
  - "Uncontrolled" geometries
    - T-bar
    - Stand-alone spindles
  - Somewhat-controlled geometries
    - Parallel plate
    - Archimedes screw
  - Controlled geometries
    - Cone and plate
    - Concentric cylinder

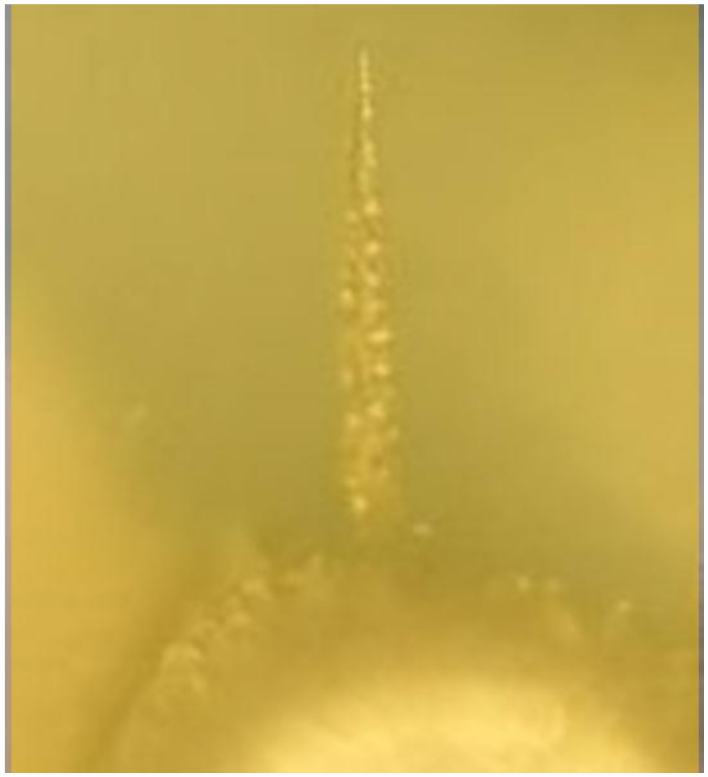






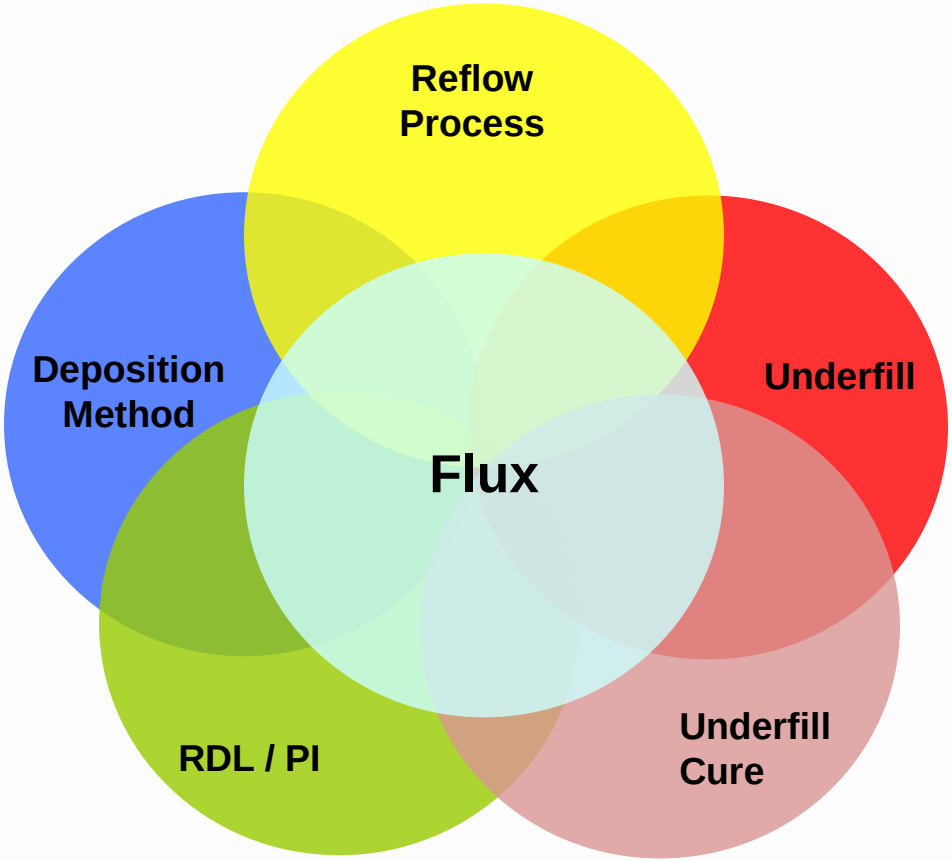


Electrical Reliability: No-Clean HF Fluxes



"There is no such thing as a no-clean material; there are only no-clean processes." - **Dave Hillman (Rockwell Collins), 1999**

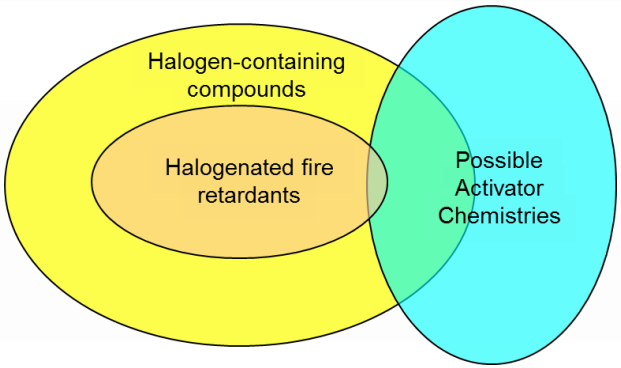
Electrical and Physical Reliability: Flux Compatibility

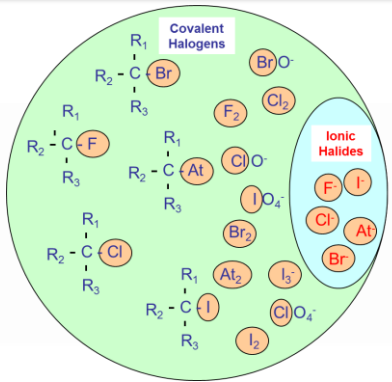


HFR* / Halogens / Halide Standards

Standard	Pass/Fail Criteria	Materials Concerned	Comments
JPCA-ES-01-1999	Br < 0.09wt% (900 ppm) and Cl < 0.09wt% (900 ppm)	Printed circuit boards (PCB/PWB)	Not Fluxes
IEC 61249-2-21	900 ppm maximum Cl and 900 ppm maximum Br 1500 ppm	Printed circuit boards (PCB/PWB)	Not Fluxes
IPC-4101B	900 ppm maximum Cl and 900 ppm maximum BR 1500 ppm	Printed circuit boards (PCB/PWB)	Not Fluxes
J-STD-004B	<500 ppm total halide	Fluxes and solder pastes	Cl- and Br- ions only: not covalent halogens
JEDEC J-STD-709A	<1000 ppm Cl and < 1000 ppm Br	Materials in the final electronics assembly only	Materials not appearing in the final assembly (volatile or washed off) don't count
JEITA ET-7304A	<1000 ppm Cl and < 1000 ppm Br	Solder Fluxes and Solder Pastes	"Halogen-free" is not truly halogen-free

[Note: 100ppm = 0.01% by weight]





**HFR = Halogenated fire - retardants*

- Flux usage
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Relevant Global Standards Organizations

Semiconductor-Grade Fluxes:

- SEMI:
  - Molding compounds
  - Leadframes
  - Chemicals
- JEDEC:
  - Reliability test methods
  - Shear strength
- IPC:
  - J-STD-004B

Nothing of relevance

ANSI/IPC J-STD-004B

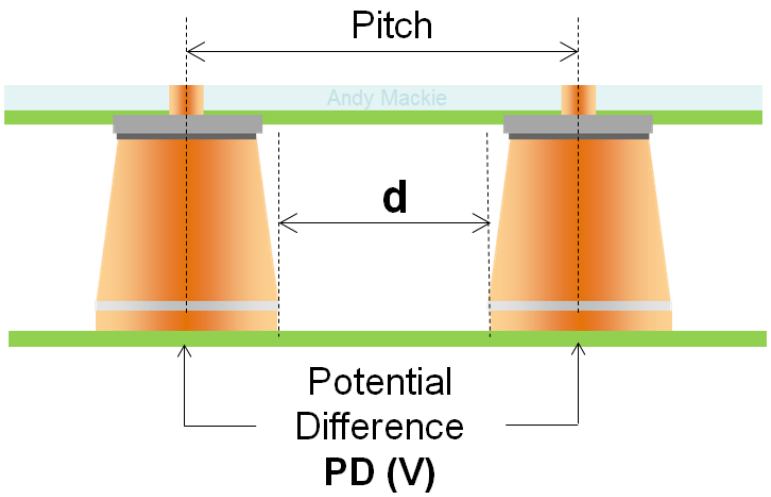
"1.2 **Purpose:** The purpose of this standard is to classify... **flux materials**... for use in... interconnections for **printed circuit board assembly.**"

Appendix A: Example Qualification Test Report			
Classification Tests	***Status***	**SMT Flux Types****	**Relevance to Semiconductor Grade (SG) NC Fluxes**
Copper mirror	***Required***	Liquid and pasty fluxes	Probably relevant, but what is allowable level?
Quantitative Halides	***Required***	Liquid and pasty fluxes	Relevant to various failure mechanisms. What level is allowable?
Corrosion	***Required***	Liquid and pasty fluxes	Probably relevant, but what is allowable level?
SIR	***Required***	Liquid and pasty fluxes	Highly relevant, but dependent on many factors: profile, underfill type
ECM	***Required***	Liquid and pasty fluxes	Highly relevant, but CTF is dependent on many factors: pitch, voltage, profile, underfill type
Characterization Tests			
Acid value	***Required***	Liquid and pasty fluxes	Proxy for "activity" level, but not specific
Specific gravity	***Required***	Liquid fluxes only	Feel-good but not relevant
Viscosity	***Required***	Pasty fluxes only	CTF for most SG fluxes. Tack is also often critical.
Visual	***Required***	Liquid and pasty fluxes	Probably relevant as a gross check of process/variations, but how to quantify?
Solids content	***Required***	Liquid and pasty fluxes	Varies with reflow profile and many other factors. Important for NC fluxes
Other Tests			
Qualitative halide (silver chromate)	*Optional: SMT Flux*	Liquid and pasty fluxes	Irrelevant and insensitive
Qualitative halide (fluoride spot)	*Optional: SMT Flux*	Liquid and pasty fluxes	Irrelevant and insensitive
SIR (IEC 61189-5)	*Optional: SMT Flux*	Liquid and pasty fluxes	Choose one standard for electrical reliability
SIR (Bellcore GR-78-CORE)	*Optional: SMT Flux*	Liquid and pasty fluxes	Choose one standard for electrical reliability
SIR (ISO9455-17)	*Optional: SMT Flux*	Liquid and pasty fluxes	Choose one standard for electrical reliability
Fungus	*Optional: SMT Flux*	Liquid and pasty fluxes	Questionable relevance
Halogen (EN 14582)	***Required***	Liquid and pasty fluxes	Relevant for NC fluxes
Wetting balance	*Optional: SMT Flux*	Liquid and pasty fluxes	Proxy for "solderability" level, but direct correlation to CTF in doubt
Spread test	*Optional: SMT Flux*	Liquid and pasty fluxes	Highly relevant proxy for many SG flux usages, but will vary with metallization, profile etc.
Tack (extensional viscosity)	**NONE**	**NONE**	Critical for many fluxes (WS and NC). J-STD-005 test is insensitive and of questionable reference
Adhesion	**NONE**	**NONE**	Shear and pull strength against all adjacent polymers
Particulate levels	**NONE**	**NONE**	Increasingly important for <100micron pitch devices

***"Liquid" (wavesoldering) and "Pasty (tacky)" fluxes (rework) are closest to semiconductor grade fluxes*

Field Strength in SIR/ECM

		ANSI/IPC J-STD-004B	
		SIR	EM
Field Strength (V/micron)	Bias	0.010	0.031
	Measurement	0.010	0.157
	T/%RH	40C / 90%RH	65C / 85%RH



Field strength = PD/d

Distance between adjacent conductors (d) /microns	PD(V) = 5	2	1	0.5
200	0.025	0.010	0.005	0.003
175	0.029	0.011	0.006	0.003
150	0.033	0.013	0.007	0.003
125	0.040	0.016	0.008	0.004
100	0.050	0.020	0.010	0.005
80	0.063	0.025	0.013	0.006
60	0.083	0.033	0.017	0.008
50	0.100	0.040	0.020	0.010
20	0.250	0.100	0.050	0.025
10	0.500	0.200	0.100	0.050

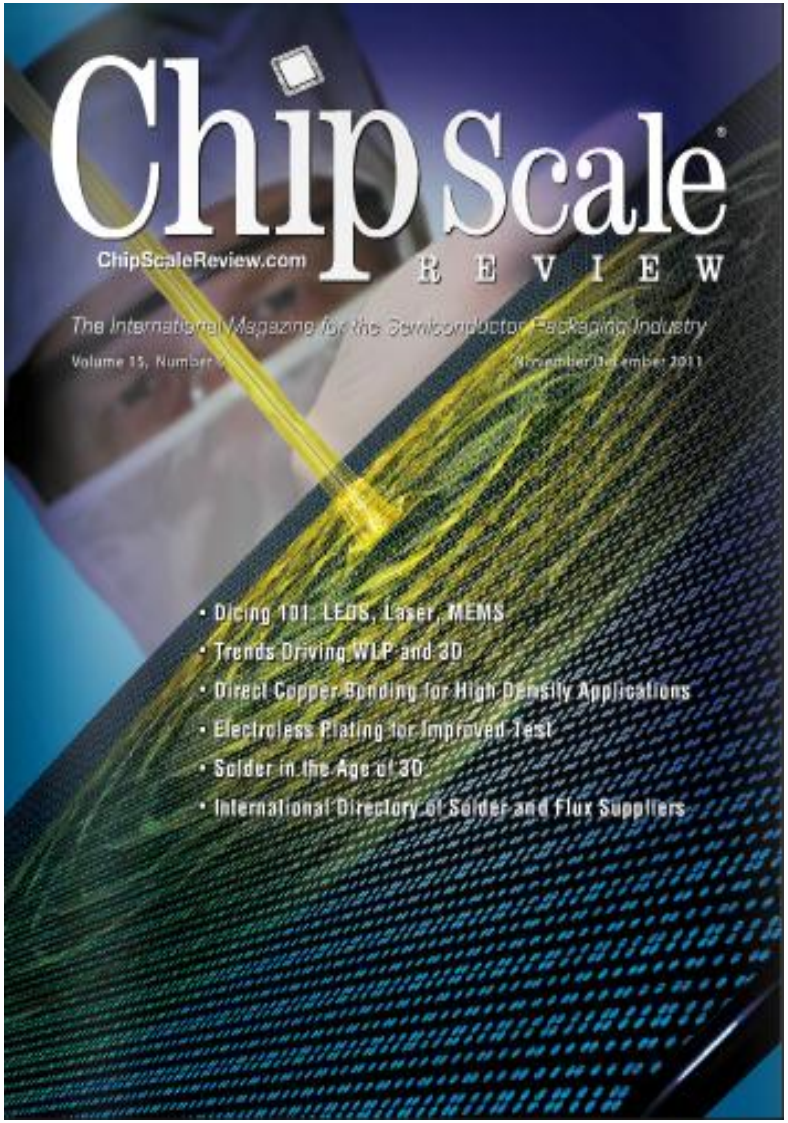
KEY:	
	Lower than IPC SIR and EM (Test)
	Lower than IPC EM (Test)
	Higher than IPC SIR and EM (Test)

Conclusions

- Fluxes are showing excellent extensibility of usage, even in the age of 2.5D/3D “dimensional devices”
- Semiconductor-grade fluxes are beyond the scope of the ANSI/IPC J-STD-004B
  - Current flux testing methods are inadequate and show poor correlation to CTF parameters (and their proxies) for such fluxes
- Drivers for “halogen-free” in semiconductor assembly are very different from “green” concerns
- SIR/EM and physical adhesion testing must be relevant to flux and underfill compatibility
  - Large, low clearance, ultrafine pitch (high I/O count) die: forcing condition for reliability

Thank you

Acknowledgements:
- Eric Bastow
- Mike McNamara
- Steve Foster



APPENDIX

What is "Zero"?

"Below the …."

- Limit of detection (LOD)
  - Function of noise in instrumentation
- Method detection limit (MDL)
  - Function of:
    - Noise in instrumentation
    - Errors in sample preparation methodology
- Limit of quantitation (LOQ)
  - Function of all above
- Practical limit of quantitation (PQL)
  - 5x MDL
    - May be as high as 250ppm

Why Have Standards for Assembly Materials?

- Materials testing and standards:
  - Level playing field for business
  - Provide assurance to customers
  - Cover CTF (or CTF proxies) for properties of materials

A "Good Standard"**

- Can be included in a contract
- Is clearly written
- Sets out requirements as metrics (quantifiable)
- Addresses quality and reliability

**Dieter Bergman: MEPTEC Roadmap Meeting - Nov 2013

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