Development of Consensus Standards to Support IGA Analysis of Microelectronic Packages

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Motivation

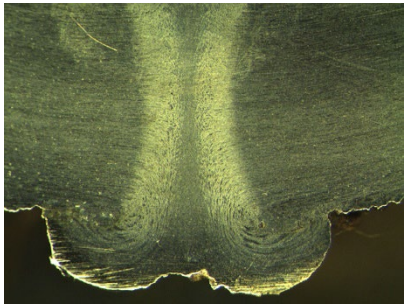
Moisture Trapped Inside Microelectronic Packages Can Cause Long-Term Problems and Lead to Device Failures

- Military standards mandate internal moisture levels of microelectronic packages not exceed 5000 ppmv.
  - Mil-Std-883 and Mil-Std-750, TM 1018
- An assortment of commercial products have similar requirements.
  - Energetic devices, MEM's technologies, implantable devices, etc.
- Internal Gas Analysis (IGA) methods using mass spectrometers are used to measure the moisture content of internal gases withdrawn from devices.
- Various moisture calibration systems for IGA are commercially available.
  - As a result, IGA methods are generally considered most accurate for relatively large packages - typically 0.1 cc or greater.
- The development of single-use moisture standards with internal volumes representative of typical microelectronic packages is an on-going need.
  - Target internal volumes ranging from 1 cc to 0.001 cc
  - Successful development would augment - <u>not replace</u> - existing systems

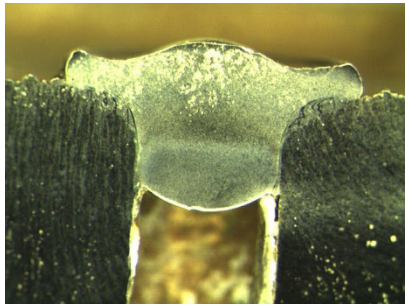
Phase I: Goals and Accomplishments

Fabrication and Testing of 1 cc Moisture Specimens Demonstrated:

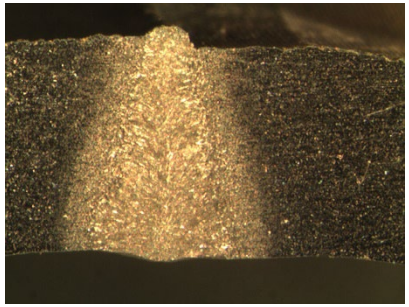
- Moisture concentrations were controlled to less than 5000 ppmv √
- The feasibility of four disparate moisture loading techniques: √
  - Volumetric, gravimetric and two proprietary techniques
- The feasibility of four welding techniques (for the body and fill port) √



Inertia Weld (Body)



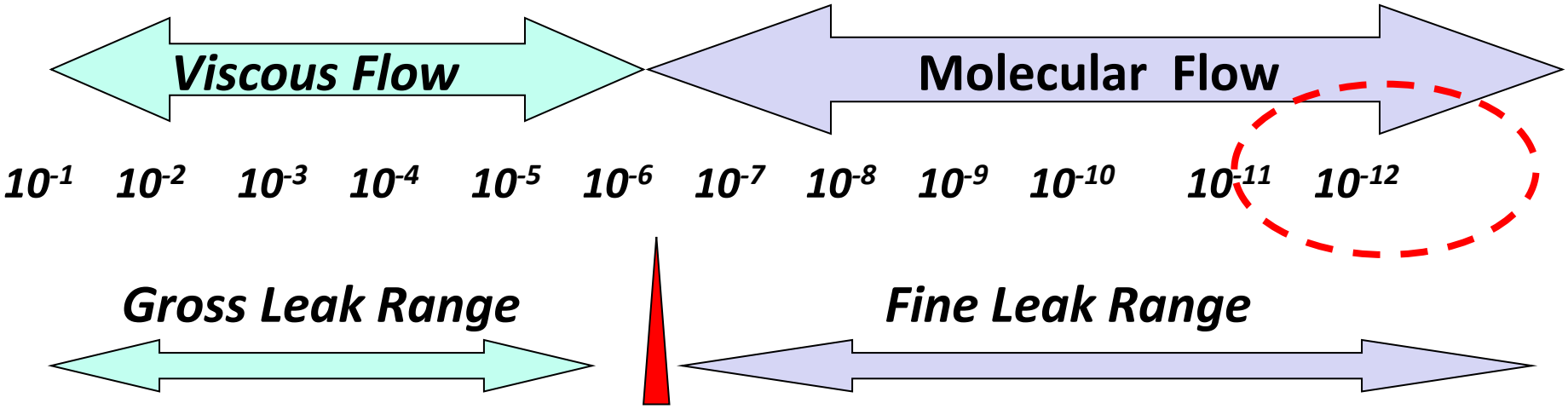
Resistance Weld (Fill Port)



Laser Weld (Body)

- Evaluation of six different alloys for weldability and hermeticity √
- Seal integrity to leak rates less than $1x10^{-11}$ atm cc/s √
  - Leak rate testing using ^{85}Kr (Radiflo®) gross and fine methodology

Phase I: High-Sensitivity Hermeticity Testing



Viscous Flow Equation:

$$Q = \frac{\pi\, r^4}{16(\mu)(L)}\left(P_i^2 - P_o^2\right)$$

⇨ P_i = total internal pressure

Molecular Flow Equation:

$$Q = K\sqrt{\frac{T}{M_w}}\left(p_i - p_e\right)$$

⇨ p_i = partial internal pressure

Phase II: Goals and Accomplishments

Fabrication and Testing of Moisture Specimens Demonstrated:

- Fabrication, moisture filling and hermetic sealing of specimens with internal volumes of 1 cc, 0.1 cc, 0.01 cc and 0.001 cc. √
- Development of nitrogen "control" specimens with moisture concentrations less than 500 ppmv. √
  - Repeatable concentrations of 200 +/- 50 ppmv deemed feasible
- Magnitude of moisture concentrations controlled to 1200 ppm. √
  - Tolerance / variability work to be addressed in future project phases
- Oxygen concentrations reduced to non-detectable levels. √
- Hydrogen concentrations greatly reduced using bake-out pre-treatment. √
- Seal integrity to leak rates less than $1x10^{-11}$ atm cc/s. √

Phase III: Goals and Accomplishments

A Large Population of Specimens Was Fabricated for Testing:

- 40 specimens in each volume size: 1 cc, 0.1 cc, 0.01 cc and 0.001 cc.
- A single 1500 ppmv target was set for all moisture concentrations.
- All specimens passed $1x10^{-11}$ atm cc/s leak testing. √
- Results for the 1 cc specimens: average of 1250 ppmv. √
- Unfortunately, a manufacturing error prevented many of the 0.1 cc specimens, and nearly all of the 0.01 cc and 0.001 cc specimens, from being tested.
  - A post-fabrication modification was attempted, but with only marginal success.
    - The modification itself often introduced microscopic flaws in many of the specimens.
    - Metallurgical analysis of these parts is currently underway.
- Replacement specimens are currently being fabricated and will be tested once completed.

Research-in-Progress

Mass Balance Analysis Technique

- The mass balance technique currently under development is intended to enable moisture concentration analysis independent of IGA.
  - The ultimate goal in development of this technique is to help eliminate doubts in IGA measurements.
    - May prove particularly useful in resolving lab-to-lab discrepancies.
  - Given the limitations of existing laboratory instrumentation, initial mass balance work is being conducted using 10 cc vessels.

Mass Balance Closure and Process

- Three independent methods for closure of the mass balance are under investigation.
- The details of the closure process are beyond the scope of this discussion and will be disclosed at a later date.

Phase IV / Future Work

Continued Refinement of the Mass Balance Technique

- Upon successful completion of the current work-in-progress proving feasibility, a larger population of 10 cc specimens will be fabricated.
  - The goal of this work will be to provide a means to ensure the accuracy of additional constituent concentrations in addition to moisture.
  - An additional goal will be to extend the mass balance technique to specimens with internal volumes of 1 cc and less.

Reproducibility and Repeatability Testing

- Larger populations of 1cc, 0.1 cc, 0.01 cc and 0.001 cc specimens will be fabricated in order to statistically assess loading tolerances and moisture concentration variability.

Shelf-Life and Aging

- Specimens will be fabricated in order to assess the effects of extended aging on moisture concentrations and to determine expected shelf-life.

Summary

- Prototype consensus standards to support IGA testing of microelectronic packages have been successfully fabricated and tested.
- Internal volumes ranged from 1.0 cc to 0.001 cc.
- Welding processes have been studied and selected.
- Specimens have been shown to pass extremely high-sensitivity leak tests.
- Four different moisture loading techniques have been demonstrated.
- Moisture concentrations were controlled to levels as low as 1000 ppmv.
- The presence of residual oxygen was eliminated from samples.
- A “mass balance approach” is under development as a possible means to provide verification of moisture concentrations independent of IGA.
- Future work will focus on quantification of moisture tolerances, specimen variabilities and aging and expected shelf life.