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Gold-Tin Solder Wetting Behavior for Package Lid Seals: *A Case Study*

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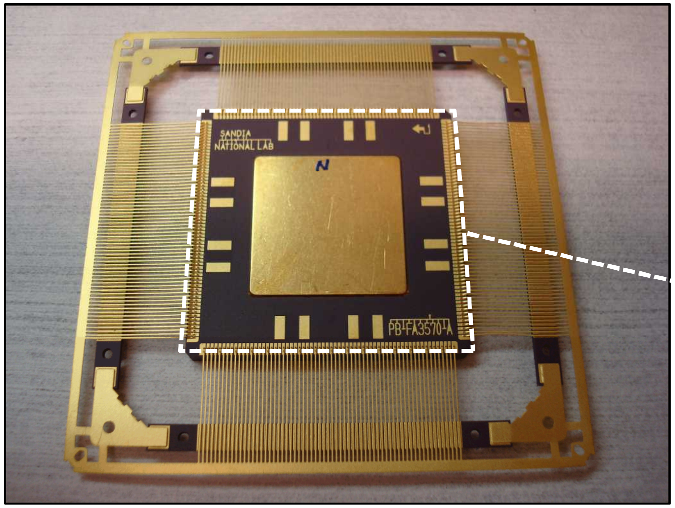
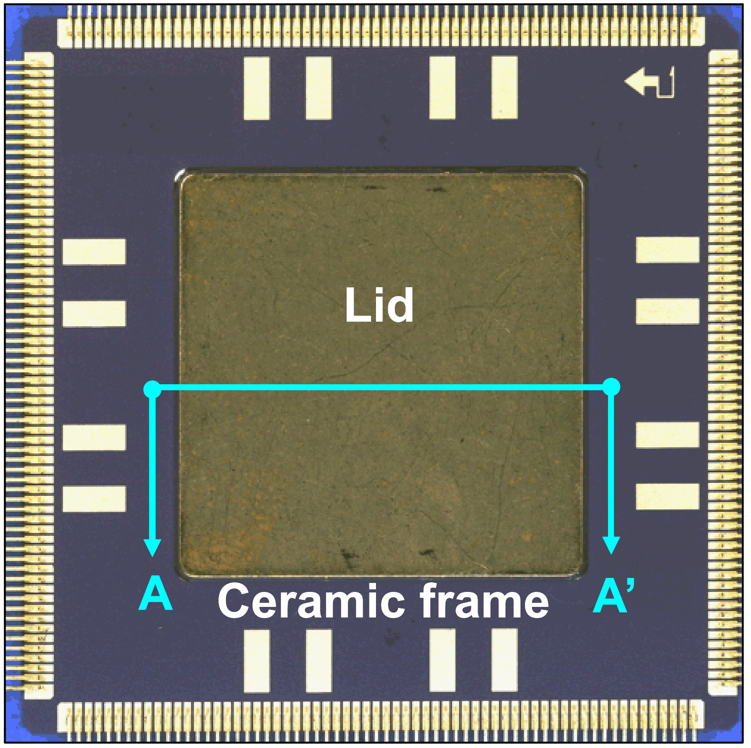
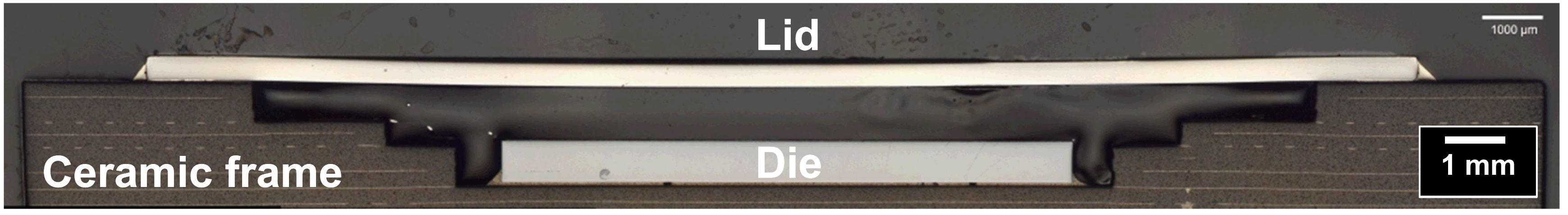
Introduction

- The 80Au-20Sn (wt.%) solder alloy it suitable for the hermetic sealing of ceramic electronic packages.



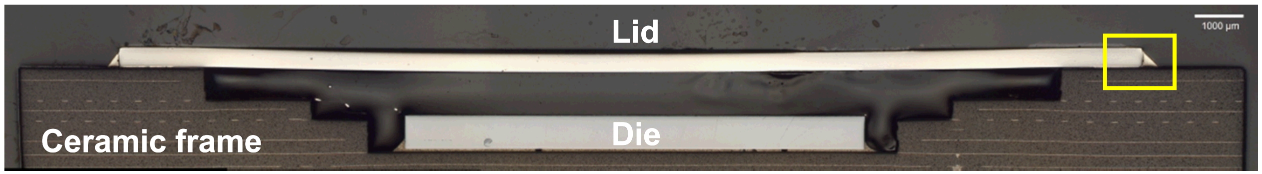


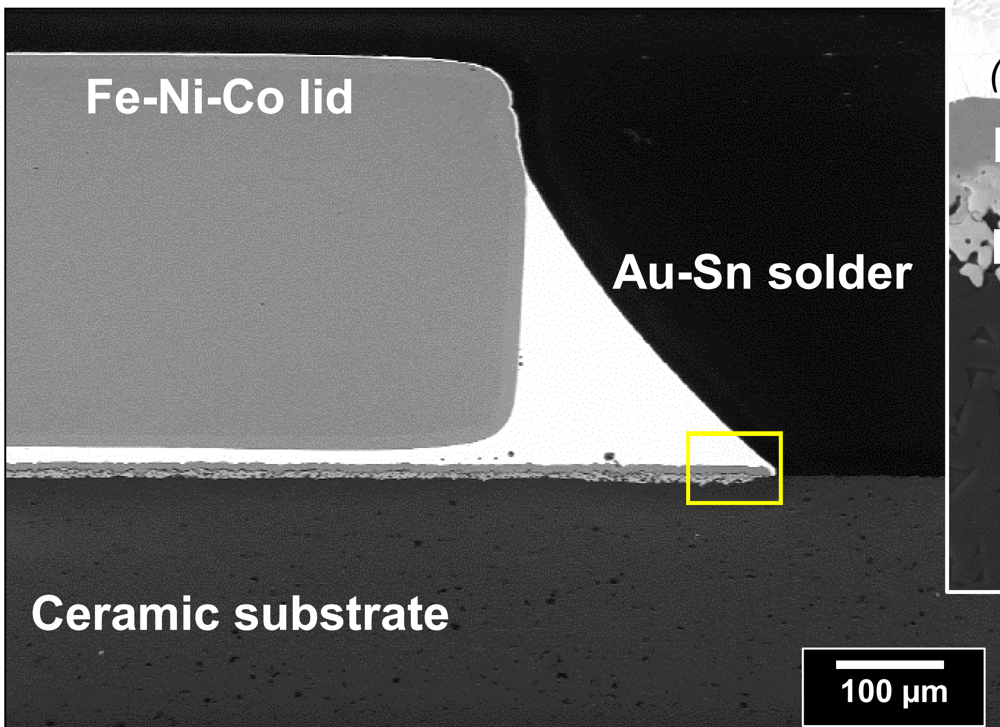
A – A'

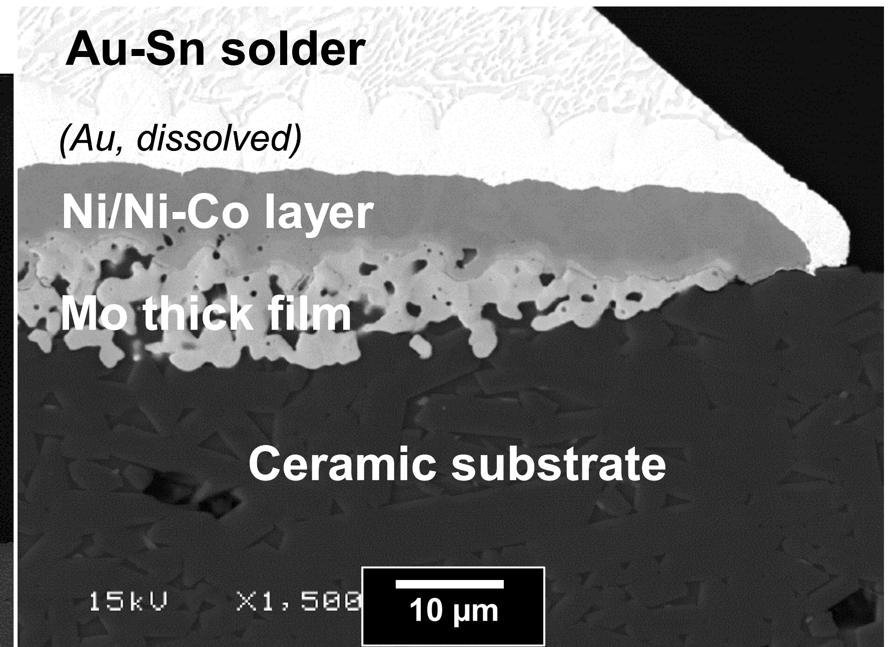


Introduction

- A Mo thick film and electroplated Ni/Co and Au layers support Au-Sn wetting and spreading on the ceramic substrate (frame).



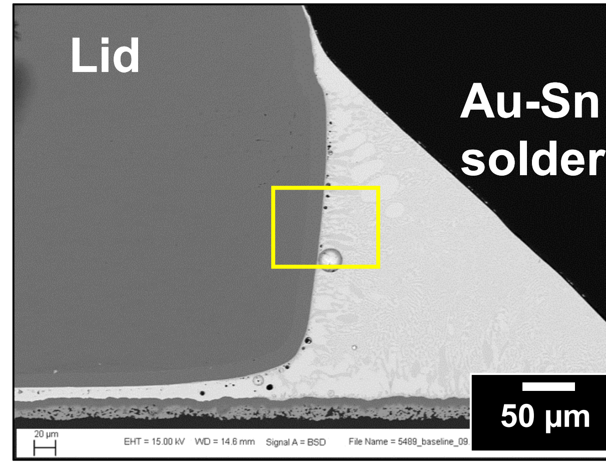


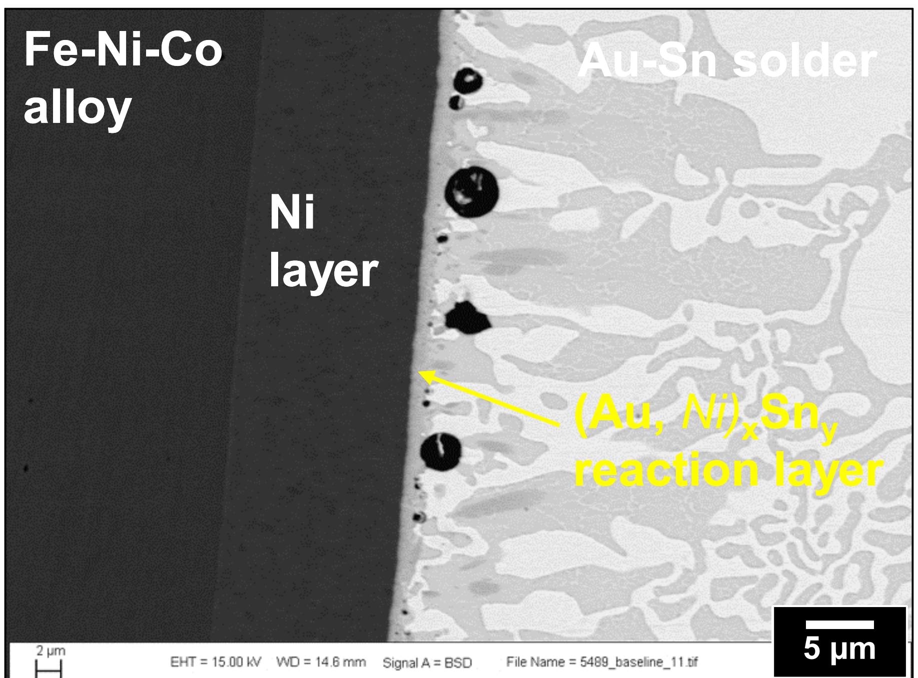


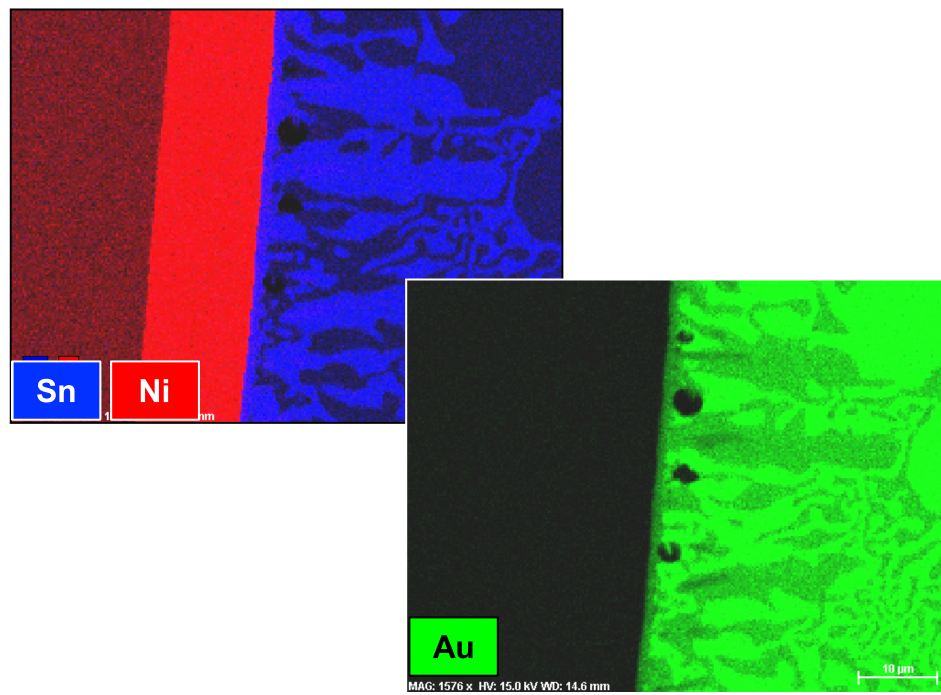
The Au-Sn solder wets the Ni/Co solderable layer.

Introduction

- The Au-Sn solder wets and spreads on the Ni solderable finish of the lid.
  - A Au protective finished dissolved into the molten Au-Sn solder.
- The reaction layer is (Au, *Ni*)$_x$Sn$_y$ intermetallic compound (IMC) having (unexpectedly) only a trace of Ni.







Introduction

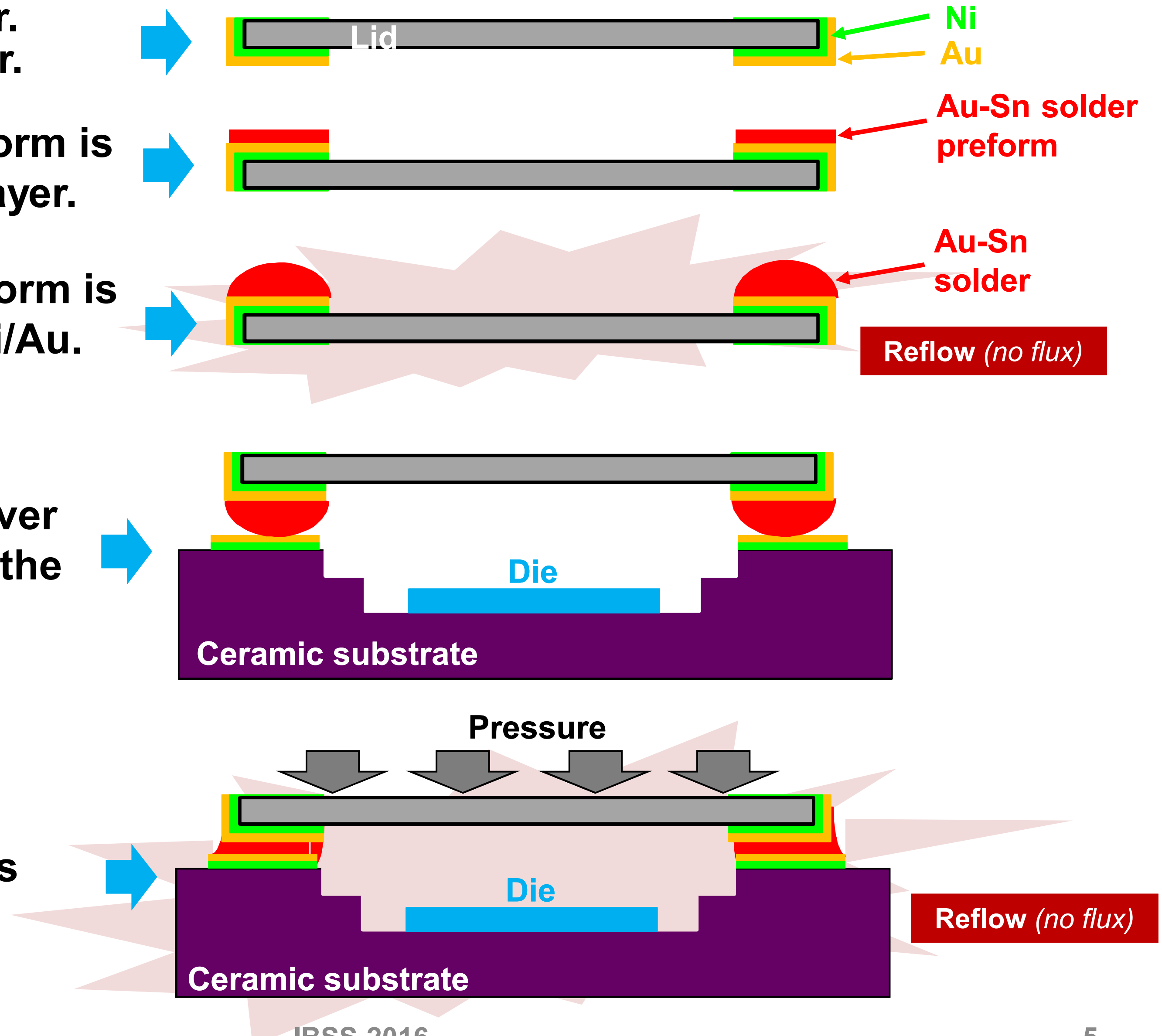
Ni solderable layer.
Au protective layer.

Au-Sn solder preform is tacked to the Au layer.

Au-Sn solder preform is reflowed on the Ni/Au.

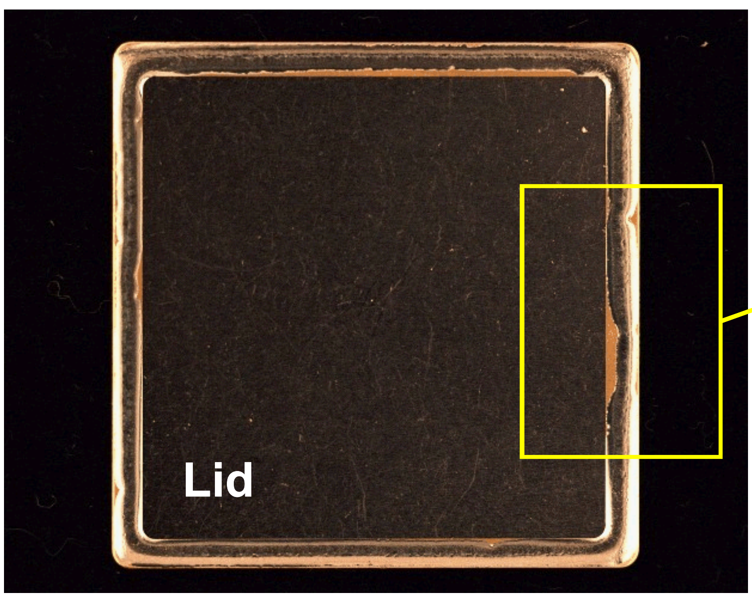
The lid is placed over the Ni/Au layer on the ceramic substrate.

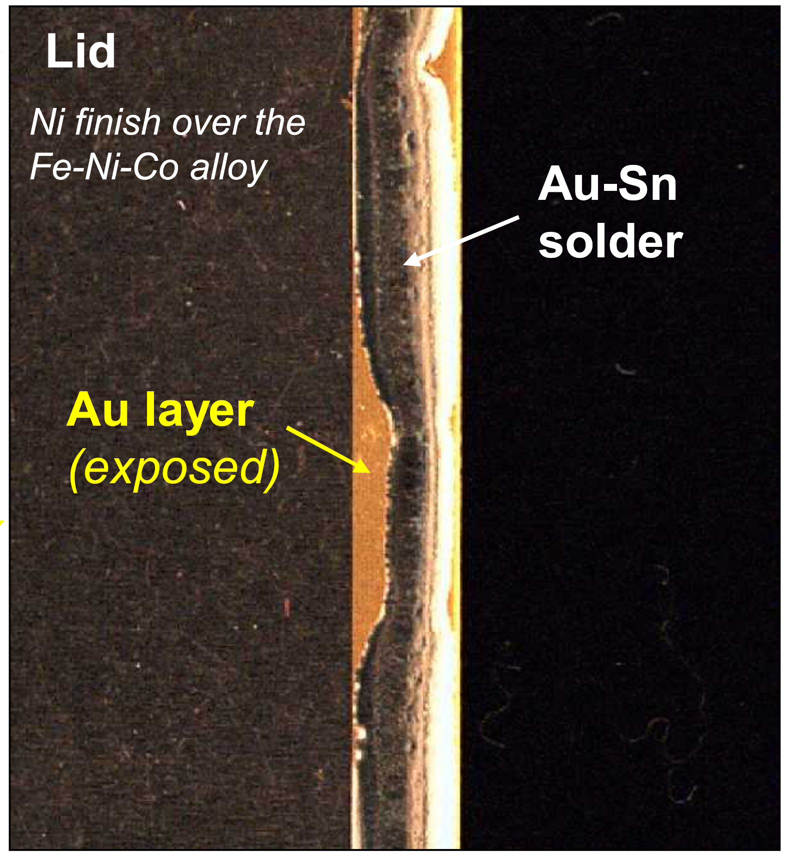
A second reflow process completes the lid seal joint ***without a flux.***



Problem

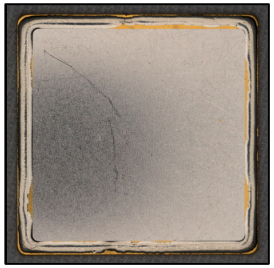
- The 80Au-20Sn solder preform was reflowed on the lid in preparation for the sealing of the electronic package.
- Areas of non-wetting appeared that were indicated by exposure of the Au-Ni finish around the lid perimeter.



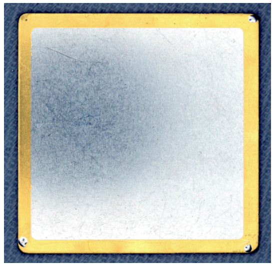


Approach

- **Question #1**: *Are non-wetted areas due to poor solderability or simply the wetting-and-spreading "dynamics" of Au-Sn solder?*
- **Question #2**: *If poor solderability, what is (are) the root-cause(s)?*
  - **Organic contamination on the Au surface?**
  - **Ni-O formation on the surface due to Ni diffusion?**
- **Methodology #1: Perform surface and depth profile analyses of the Au finish on existing lids using Auger Electron Spectroscopy (AES).**



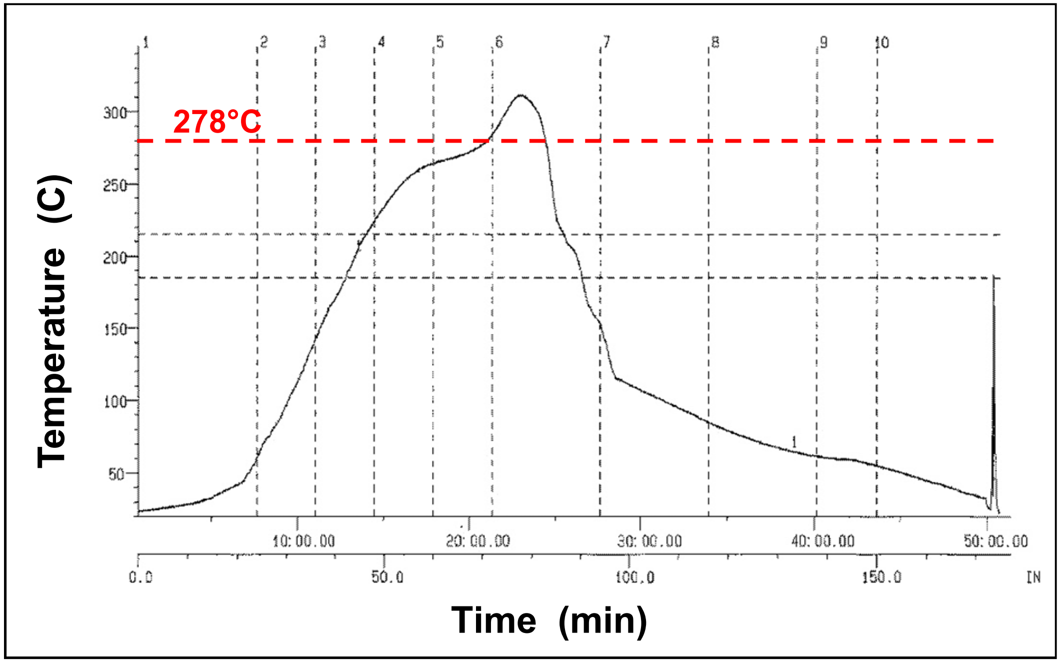
- **Methodology #2: Perform AES surface and depth profiles on pristine lids exposed to a thermal profile that simulates that used to reflow the Au-Sn solder.**



The AES analyses were performed at multiple sites to confirm reproducibility.

Approach

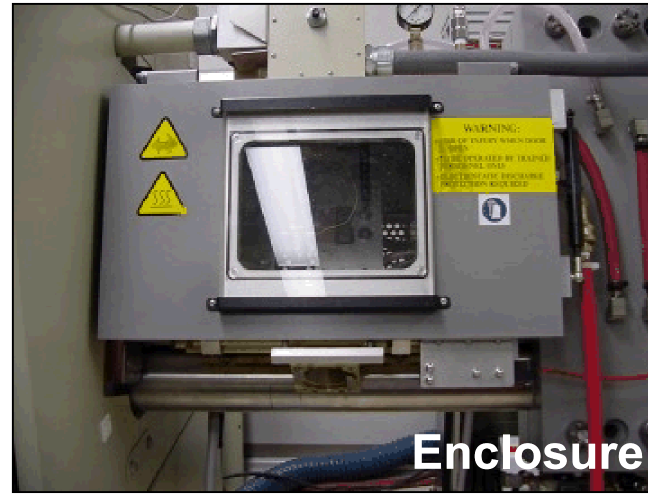
- **Methodology #2** *(con't)*: **A simulated Au-Sn reflow thermal profile was developed in the Gleeble™ 3500 system:**

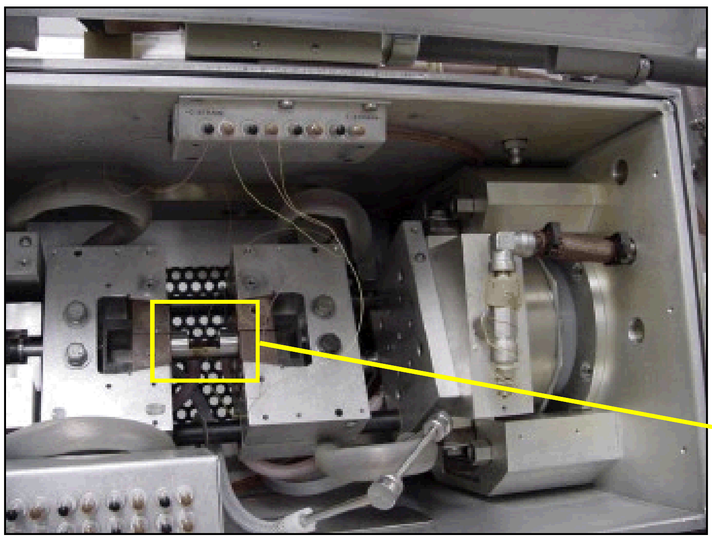


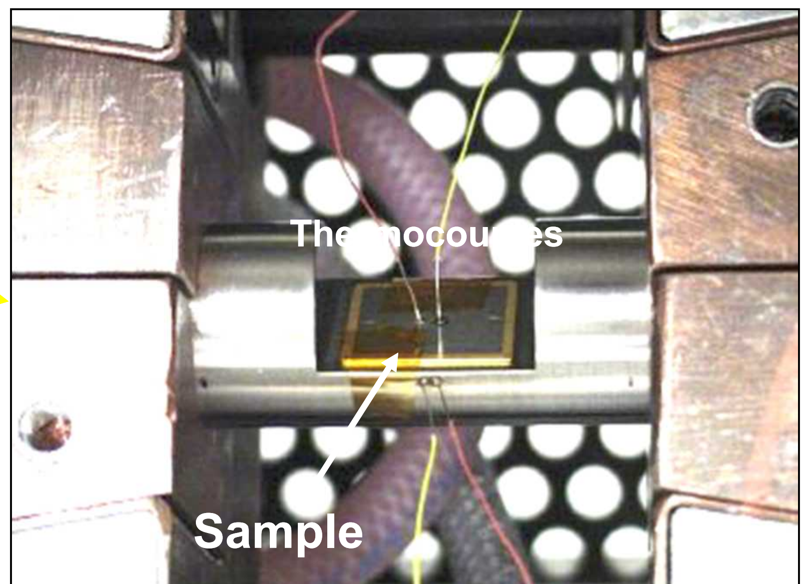
- **The simulate reflow was performed in either nitrogen or air atmospheres to account for the two extreme conditions.**
  - **Organic contamination and Ni diffusion are both sensitive to the atmosphere above the Au surface.**

Approach

- **Methodology #2** *(con't)*: **These photographs show the equipment and set-up of the test specimen in the Gleeble™ apparatus.**

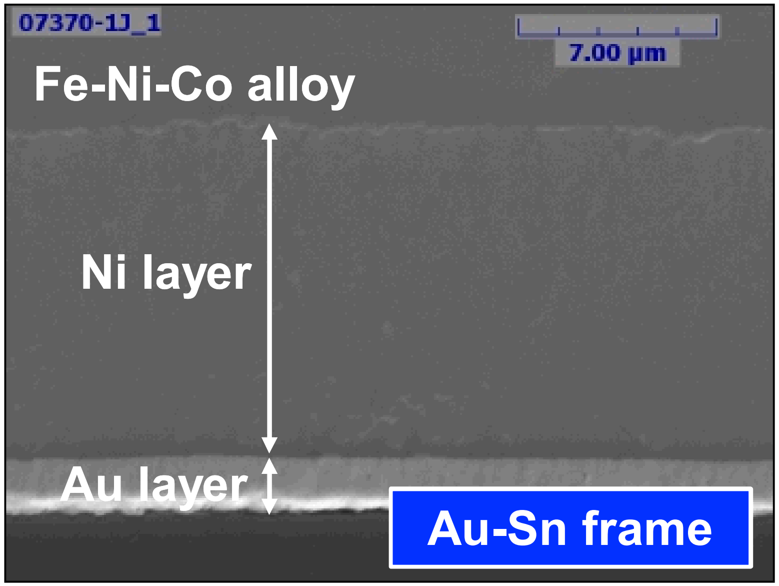




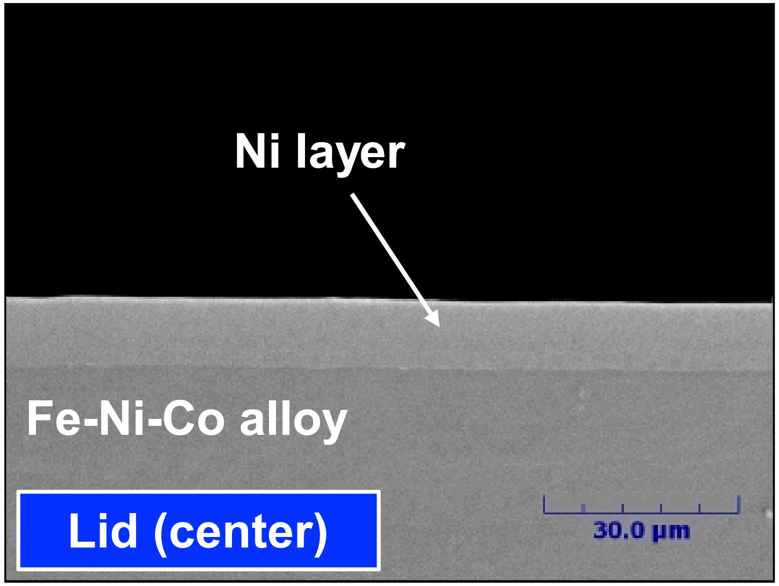


Results – Existing Lid with Au-Sn Solder

- The Ni and Au thicknesses were measured on the lid.
  - The Ni thickness was determined at the site of the Au-Sn solder bond as well as in the center of the lid.



Ni: 11.6 ± 0.1 µm.
Au: 1.68 ± 0.06 µm.

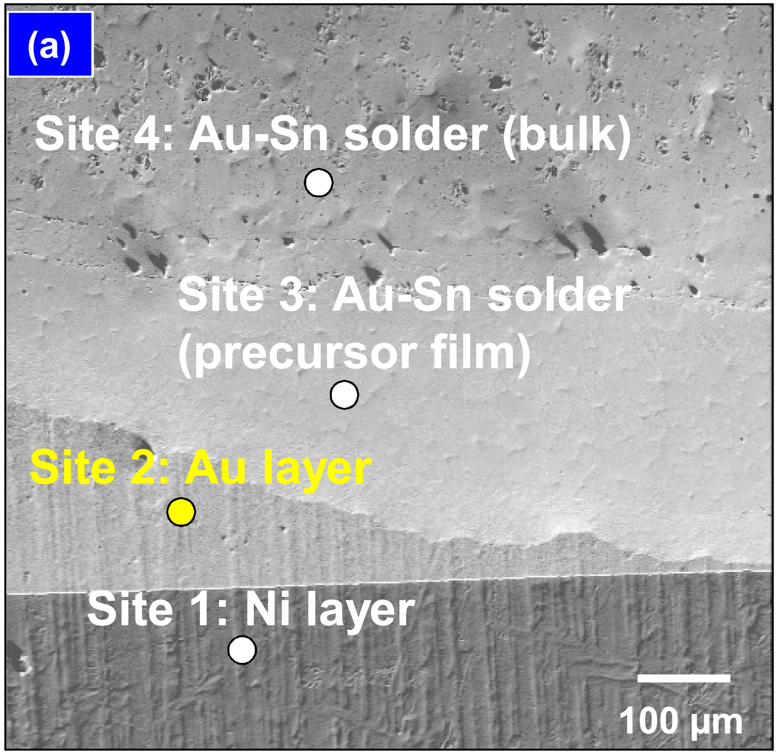


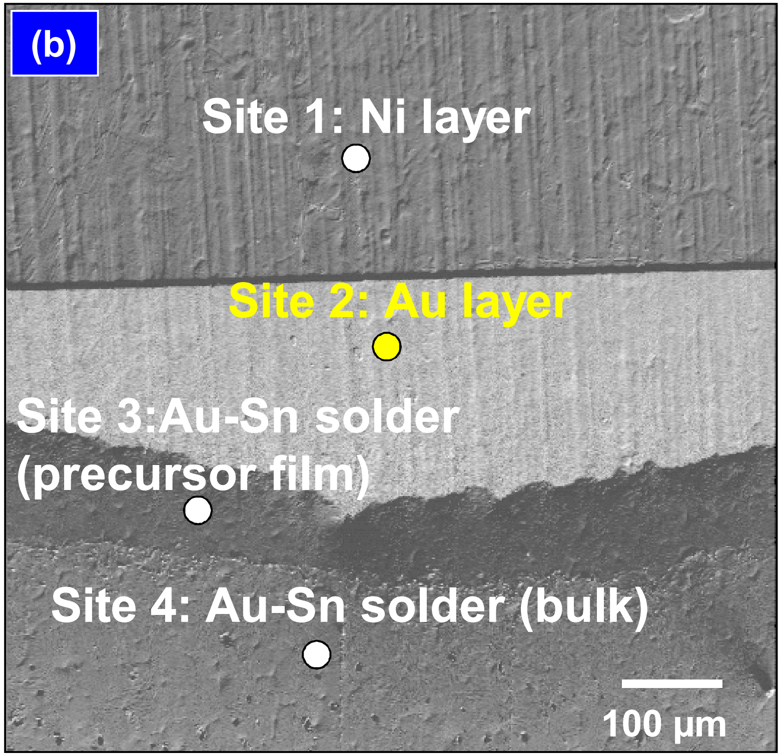
Ni: 10.3 ± 0.4 µm.

- The Au and Ni layers were sufficiently thick to serve their respective functions as protective and solderable finishes.

Results – Existing Lid with Au-Sn Solder

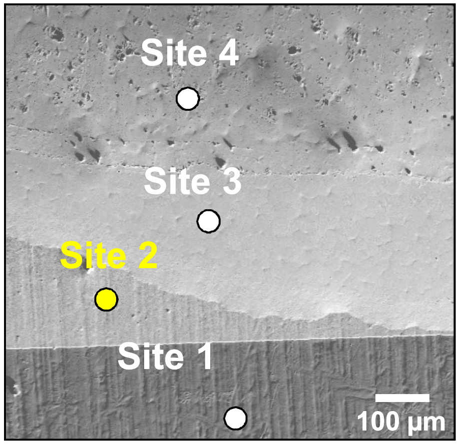
- Two locations were examined on an existing lid: (a) and (b).
- Four "sites" were analyzed per the two locations, each of which reflected a different structure.
  - Site 2 was of particular interest because it was the non-wetted Au layer surface.





Results – Existing Lid with Au-Sn Solder

- **The AES surface survey is shown for location (a).**
  - **The C contamination of site 1, bare Ni surface, was "typical" and served as a suitable baseline.**
  - **The C concentration is commensurate with the hydrocarbon "gettering" of Au surfaces.**
  - **A trace of Ni on the Au surface represents minor Ni diffusion through the Au layer.**



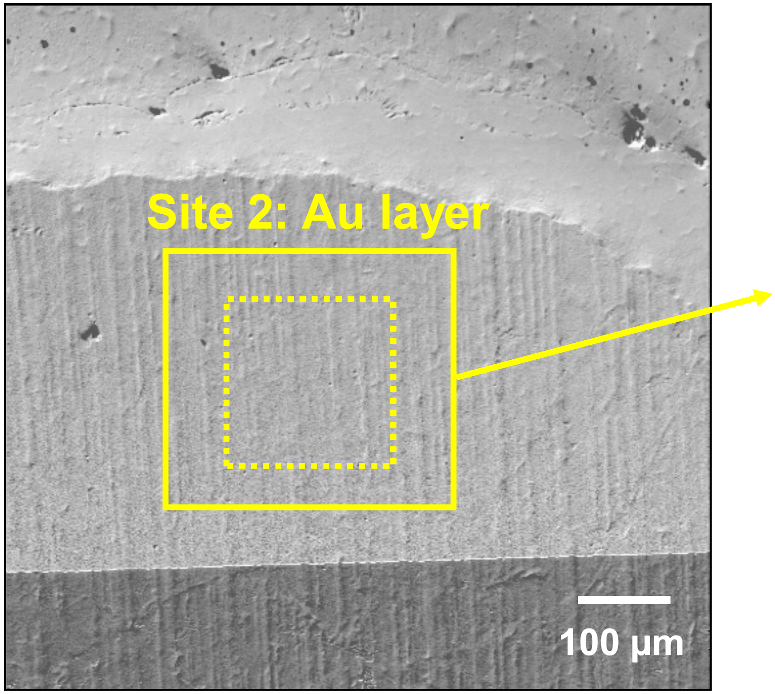
Site	Element Concentration (at.%) C	N	O	P	S	Cl	Ca	Cu	Fe	Co	Ni	Au	Sn
1, Ni layer	35	2	18	1	1	0.5	1	0.1	1	1	37	2	0.5
2, Au layer	45	1	5	0.5	1	0.5	2	0.5	1	2	3	38	1
3, Au-Sn, precursor	50	1	18	0.5	0.5	0.1	1	0.5	1	1	0.5	15	11
4, Au-Sn, bulk	45	1	26	0.5	0.5	ND	1	0.1	1	2	0.5	7	15

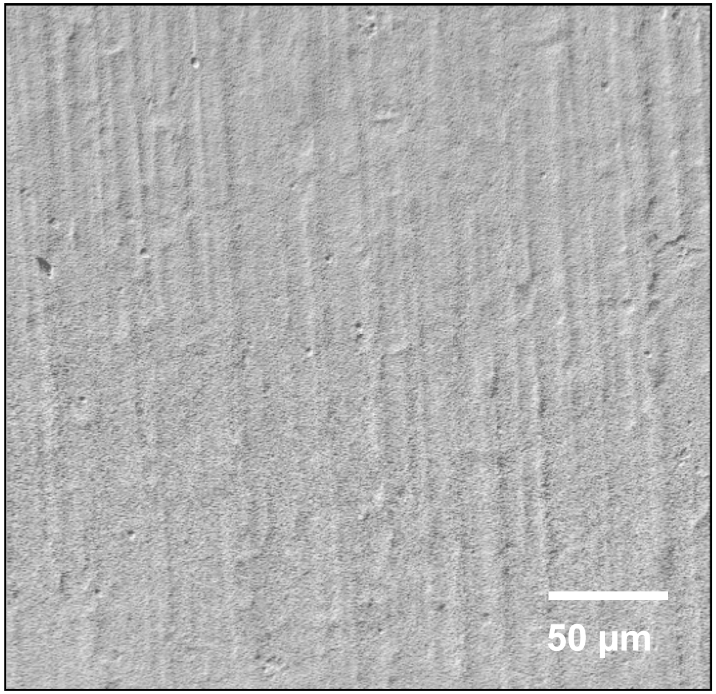
Experimental error: (± 1 – 2 at.%)

Ancillary organic contamination or undue Ni diffusion were not detected on the Au surface.

Results – Existing Lid with Au-Sn Solder

- **An AES depth profile was performed at a site 2 surface (Au layer).**
  - **An initial surface survey was conducted within the solid box.**
  - **The depth profile was performed in the dashed box area.**
  - **Surface features (roughness) ≪ sampling area.** *(Preferred …)*





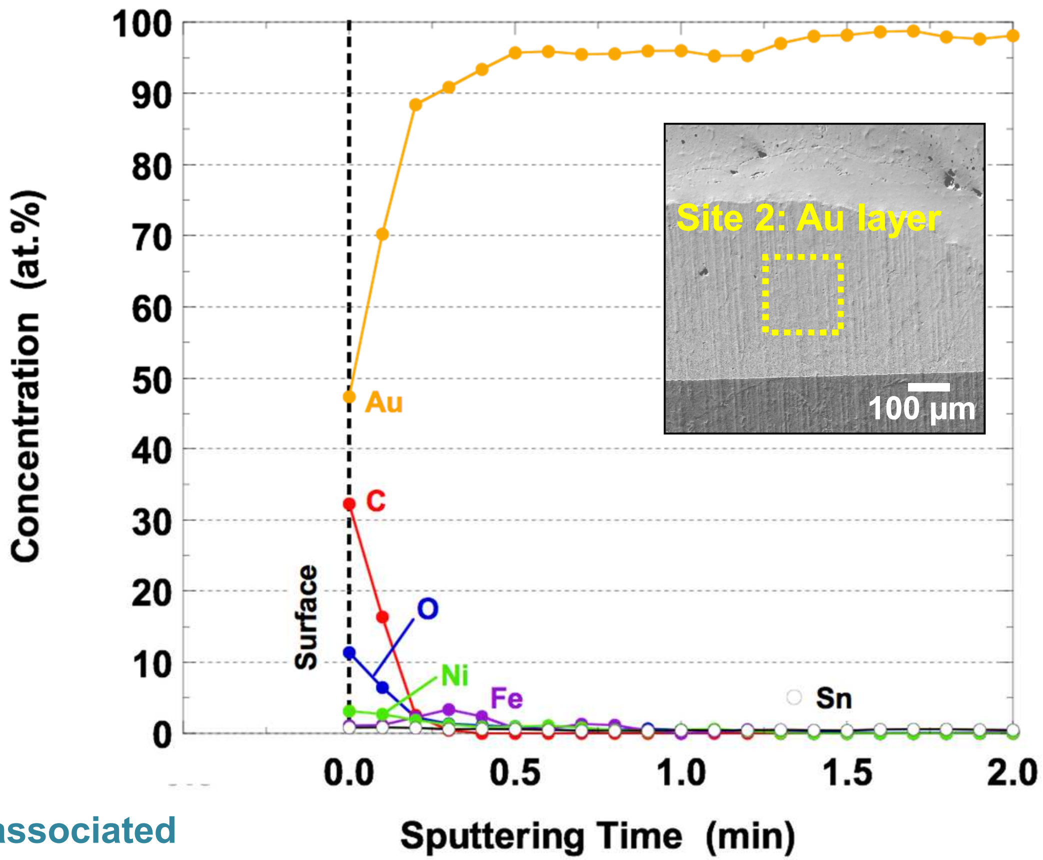
- **The AES surface survey reproduced the previous data to within the experimental error (± 1 – 2 at.%) of the technique.**

Results – Existing Lid with Au-Sn Solder

- The AES depth profile is shown for site 2 (Au layer).

- The C at.% level is typical; it quickly dropped off in the layer, which implies that its source is atmospheric and not contamination from the plating bath ("drag-out").

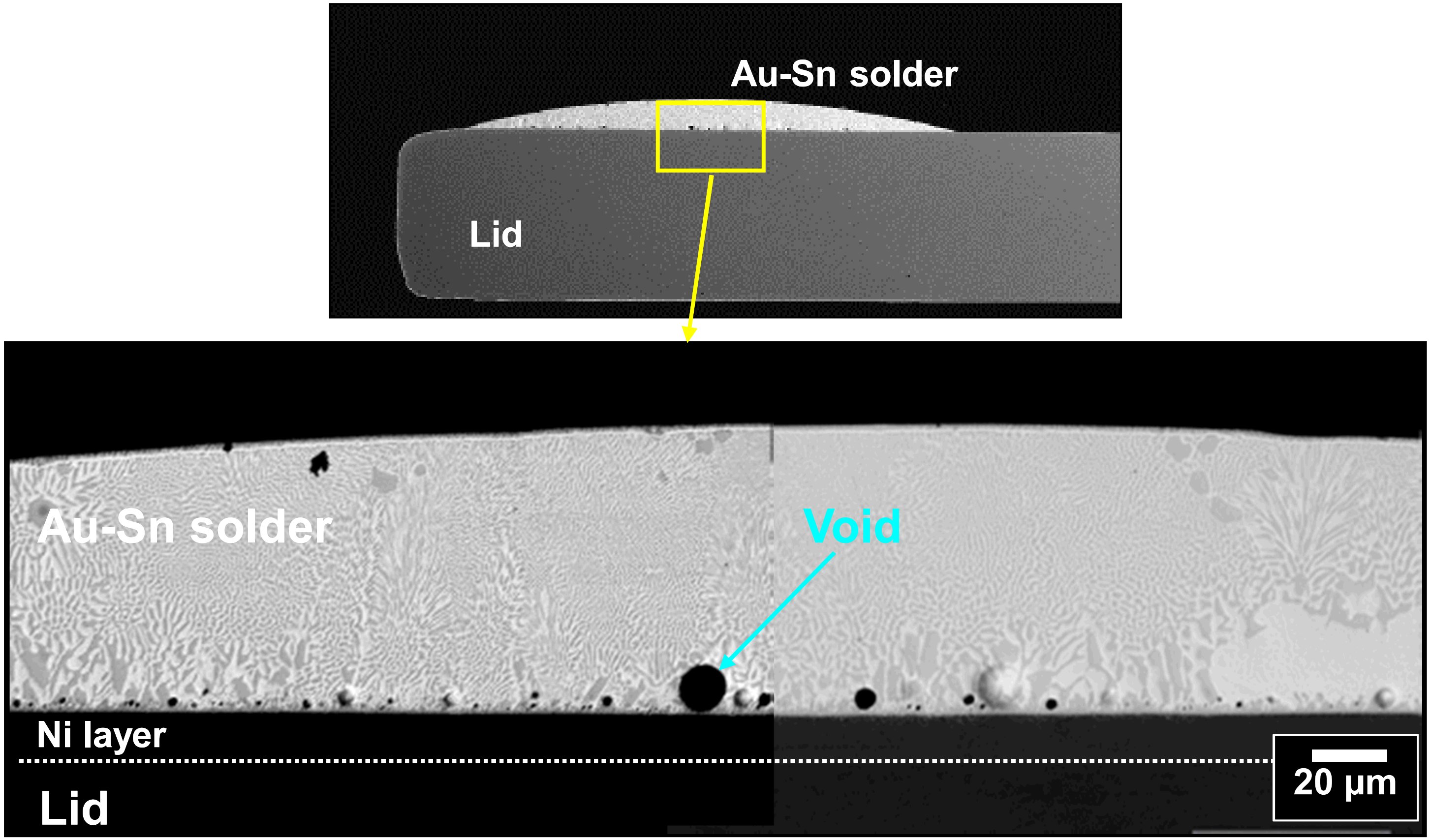
- The Ni at.% level persisted in the near-surface region of the Au layer.
  - The Ni diffused to the surface under the oxidation potential and accumulated there in the absence of a concentration gradient
  - A 3 at.% Ni concentration and its associated Ni-O formation is just below levels that degrade wetting and spreading activity.



- The Fe at. % level was most likely a plating bath contaminant.

Results – Existing Lid with Au-Sn Solder

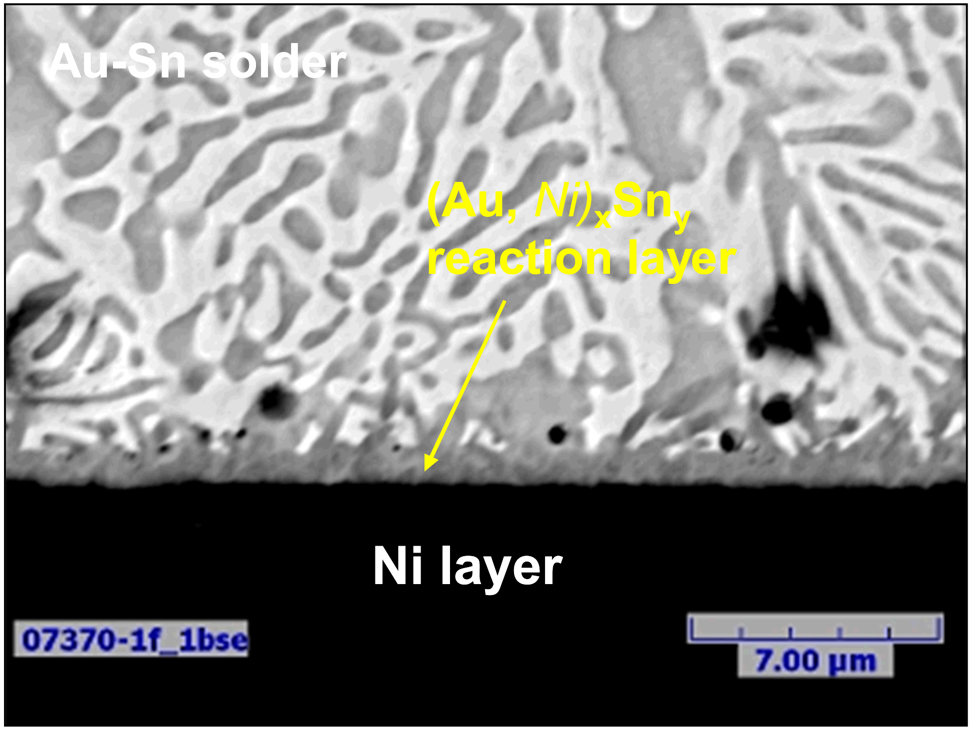
- Metallographic cross sections and scanning electron microscopy (SEM) were used to examine the Au-Sn solder on the lid.



- “Champagne voids” are typically caused by the volatilization of organic compounds in the Au layer.

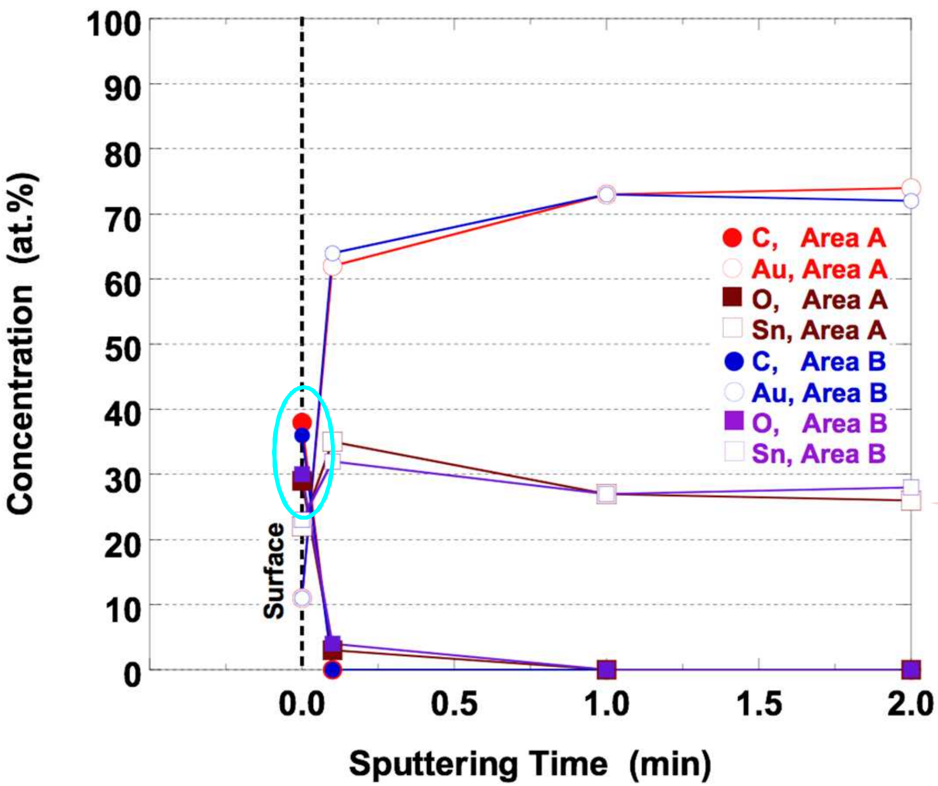
Results – Existing Lid with Au-Sn Solder

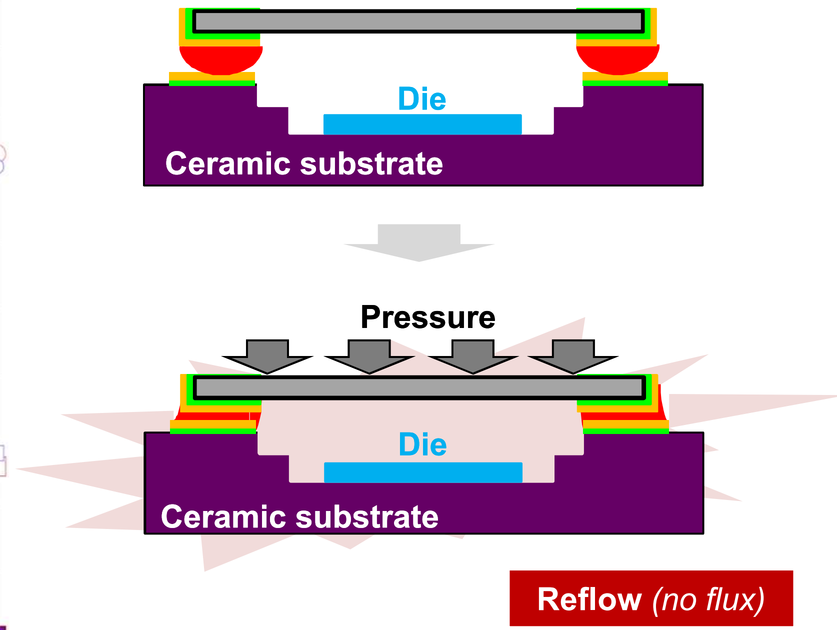
- **The (Au, *Ni*)$_x$Sn$_y$ reaction layer indicated proper wetting of the Ni layer surface.**



Results – Existing Lid with Au-Sn Solder

- The AES technique illustrated the C and O (oxide) species present on the surface of the Au-Sn preform (site 4).

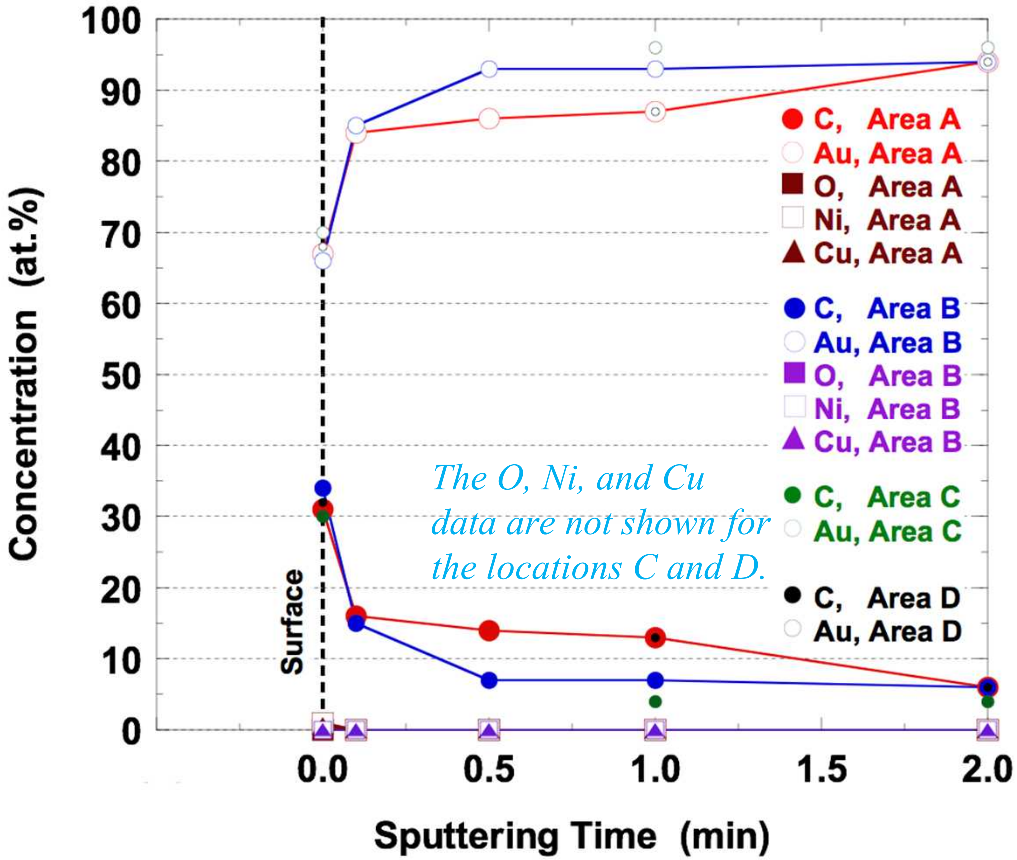


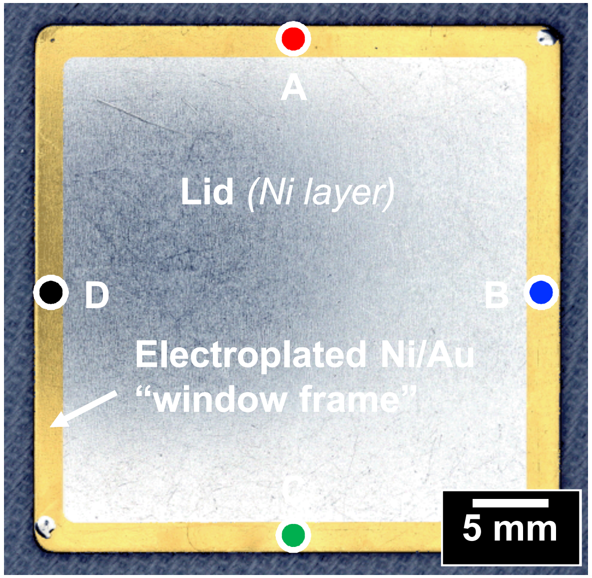


- The mechanical pressure is required to break up the carbon/oxide skin on the preform to initiate wetting.

Results – Pristine Lid *(without Au-Sn Solder)*

- Two (2) pristine lids were obtained without the Au-Sn preform.
  - The AES analyses were performed at four (4) locations labeled A, B, C, and D for the ***baseline condition*** *(no reflow)*.





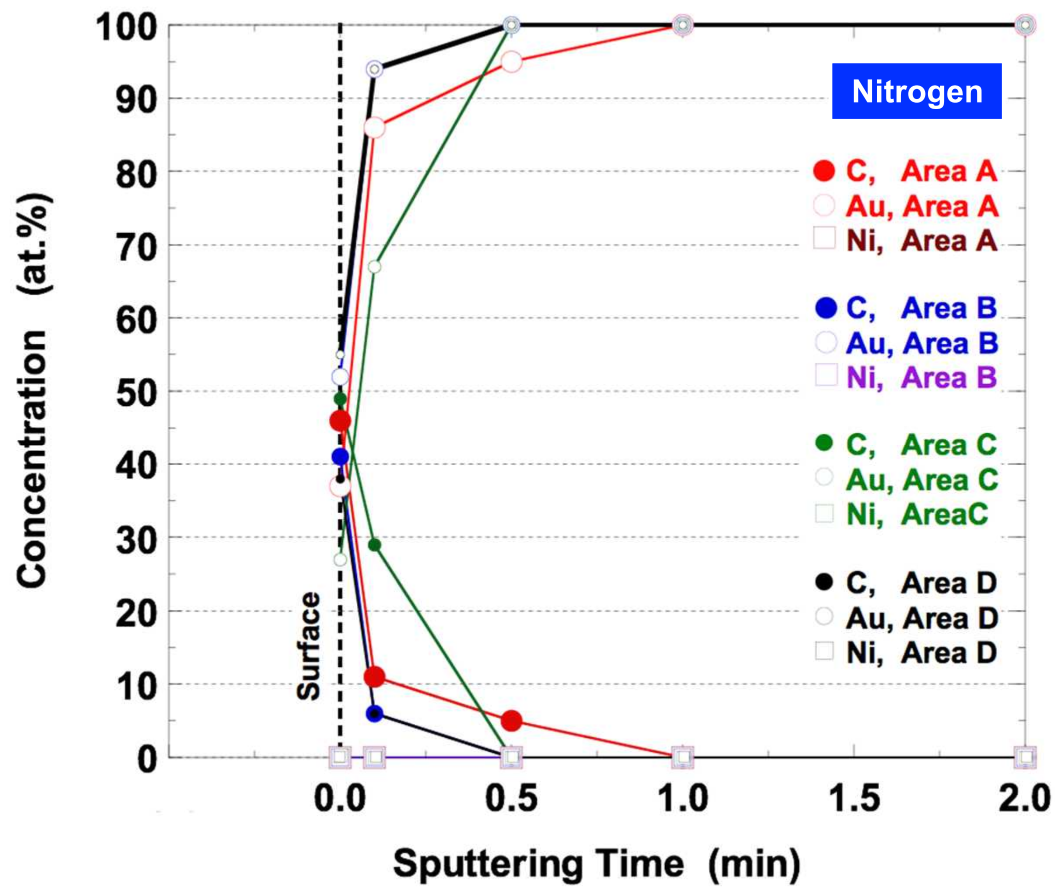
The C signal maintained a relatively high level of 5 – 15% through the Au thickness.

- The C signal was caused by incorporated plating bath species.

Results – Pristine Lid *(without Au-Sn Solder)*

- One (1) of each of the two (2) lids was exposed to the Au-Sn profile in nitrogen and the other, in air.
- The results of the Au-Sn profile performed in nitrogen are shown:

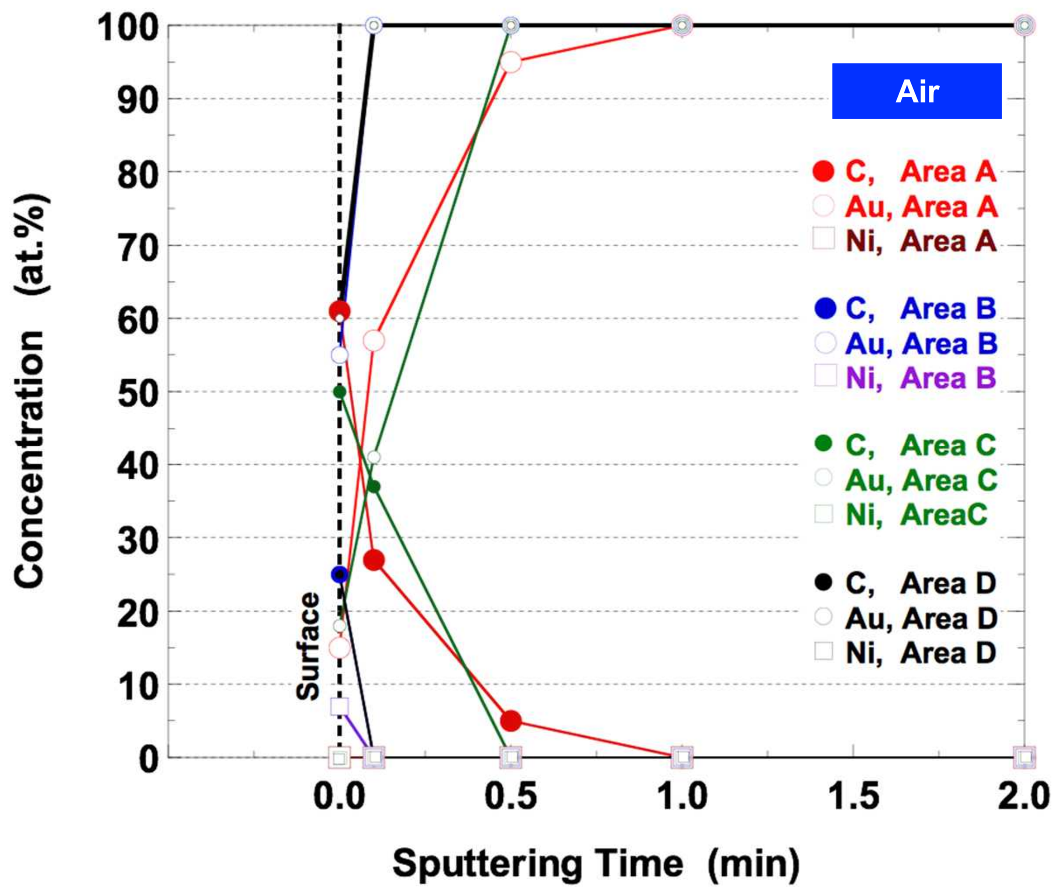
- The C at.% level was of a typical level at the surface.
- A loss of the C signal was observed with increasing depth into the Au layer.
  - The reflow process drives off the residual C entrapped in the Au layer from the plating step.
- The absence of a significant Ni signal indicates that the thermal profile (in nitrogen) did not drive Ni diffusion.



Results – Pristine Lid *(without Au-Sn Solder)*

- The results of the Au-Sn profile performed in air are shown:
- The surface and near-surface C signals were only slightly raised versus the nitrogen environment.

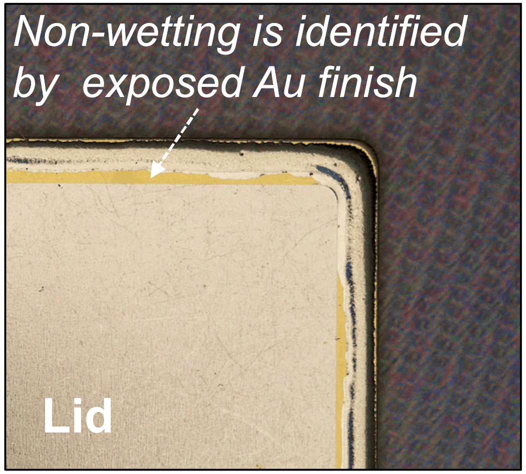
  - The small increase of C on the surface stemmed from hydrocarbons in the air or the exiting of C from the Au film.
  - A critical observation is that the air environment did not accelerate the diffusion of Ni in the Au.
    - Therefore, the relatively higher Ni contents of the lid already exposed to the Au-Sn reflow step, experienced an added exposure to high temperatures.



Summary

- The 80Au-20Sn (wt.%) solder forms the joint between a Fe-Ni-Co alloy lid and the ceramic frame to form the hermetic package.

- Non-wetting was frequently observed when the Au-Sn solder was initially reflowed to the lid Au/Ni frame (no flux).



- The likely scenarios were:
  - Organic contamination
  - Ni diffusion to the Au surface
  - Peculiarities of Au-Sn wetting behavior

- The reflow cycle drives organic compounds from the Au layer, but does not promote significant Ni diffusion to the Au surface.

Excessive organic contamination or Ni-O were not detected on the surface, implying that the non-wetting was caused by the intrinsic wetting-and-spreading ("peculiarities") of the molten Au-Sn alloy.