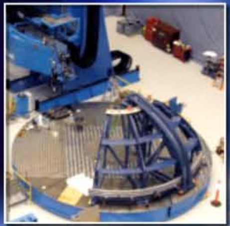
NASA Electronic Parts and Packaging (NEPP) Hermeticity Task Overview






NEPP Program Task 13-294: Hermeticity Correlation Study

NASA MSFC/GSFC

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AGENDA

I. **Introduction**

II. **Overview of Hermeticity**

III. **Hermeticity Correlation Study**

   A. Helium Desorption Issue

   B. Instrument Correlation Study

   C. Leak Standard Development

   D. Test Method Optimization

IV. **Future Work**

INTRODUCTION

Hermeticity task is a collaborative effort between GSFC/MSFC to address the following:

- Gain understanding of the influence of component part material on resultant leak rate data
- Determine CHLD test equipment capability between NASA centers as well as correlation of test results with other equipment used for hermeticity testing (OLT, Krypton-85, IGA)
- Design, fabricate, and test gross leak hermeticity standards
- Provide input to DLA Land & Maritime to optimize hermeticity specifications based on the knowledge gained during correlation study, part testing, and research efforts

OVERVIEW

"Why, When, How, and What" Of Hermeticity Testing

- Fine and gross leak testing is used to determine the effectiveness of package seals in microelectronic packages. Damaged or defective seals and feedthroughs allow ambient air/water vapor to enter the internal cavity of the device which can result in internal corrosion leading to device failures.

- Testing may be performed just after sealing process, but usually performed during screening/qualification. Sometimes performed as part of a DPA or failure analysis.
- Testing is performed in accordance with MIL-STD-883, Test Method 1014 for hybrids/microcircuits and MIL-STD-750 for 1071 for discrete semiconductor devices

- Three systems are used to non-destructively test: CHLD, KR-85, OLT
  - *CHLD, Kr-85 systems use back pressurization of a tracer gas to enter existing leak paths. A detector is used to determine the presence of gas.*
  - *OLT uses a pressurization technique which causes lid deflection if the device is non-hermetic*

OVERVIEW

What is a Failure? Two Failure Classifications

- Screening/Qualification Failures: Hermeticity and IGA Testing
  - *Helps manufacturers validate process is operating nominally*
  - *Prevents non-conforming product from entering the supply chain*
  - *Identifies lots that may have potential latent defects (IGA)*
- Test/Field Failures
  - *Hard electrical failures identified during system level testing or during the mission*
  - *Cost and scheduling impacts or in worst case scenario loss of mission*

Are the test methods in MIL Specs adequate?

- Recent evidence verified non-hermetic parts are being shipped
  - *A DoD analysis of program data identified Class K hybrid failures which had passed MIL-STD-883 hermeticity screening requirements yet failed IGA during investigation.*
    - *Example 1 - One hybrid lot was rescreened to tighter leak rates of MIL-STD-750 : 23 of the108 parts tested failed*
    - *Example 2 - Vehicle level electrical field failure: 3 yrs 1st functional failure at system level with 2 additional failures within 6 months.*

What are the leak rate limits?

- **MIL-STD-750E, Test Method 1071.9 “Hermetic Seal”**
  - *Equivalent standard leak rates (atm cc/s air) for volumes:*
    - ❑ $\leq$ 0.002 cc: 5 X 10^{-10}
    - ❑ > 0.002 and $\leq$ 0.05 cc: 1 X 10^{-9}
    - ❑ > 0.02 and $\leq$ 0.5 cc: 5 X 10^{-9}
    - ❑ > 0.5 cc: 1 X 10^{-8}
- **MIL-STD-883H, Test Method 1014.13 “Seal”**
  - *Equivalent standard leak rates (atm cc/s air) for volumes:*
    - ❑ $\leq$ 0.01 cc: 5 X 10^{-8}
    - ❑ > 0.01 and $\leq$ 0.5 cc: 1 X 10^{-7}
    - ❑ > 0.5 cc: 1 X 10^{-6}

OVERVIEW

How do we determine optimum leak rate requirements?

Leak Rates : Vol cc : Time to Exchange 50% atmoshphere

Volume	1.00E-06	5.00E-07	1.00E-07	5.00E-08	1.00E-08	5.00E-09	1.00E-09	5.00E-10
0.002 cc	0.4 Hrs	0.8 Hrs	3.9 Hrs	7.7 Hrs	1.6 Days	3.2 Days	16.0 Days	32 Days
0.01 cc	1.9 Hrs	3.9 Hrs	1 Days	2 Days	8.0 Days	16 Days	80 Days	160.5 Days
0.1 cc	19 Hrs	2 Days	8 Days	16 Days	80.2 Days	160 Days	2.2 Years	4.4 Years
0.4 cc	3 Days	6 Days	32 Days	64 Days	321 Years	2 Years	8.8 Years	17.6 Years
0.75 cc	6 Days	12 Days	60 Days	120.3 Days	2 Years	3 Years	16 Years	33.0 Years
1 cc	8 Days	16 Days	80 Days	160.5 Days	2 Years	4 Years	22 Years	44 Years
3 cc	24 Days	48 Days	240.7 Years	1.3 Years	7 Years	13 Years	66 Years	132 Years
5 cc	40 Days	80 Days	1.1 Years	2.2 Years	11 Years	22 Years	110 Years	220 Years
8 cc	64 Days	128.4 Days	1.8 Years	3.5 Years	18 Years	35 Years	176 Years	352 Years
10 cc	80 Days	160.5 Days	2.2 Years	4.4 Years	22 Years	44 Years	220 Years	440 Years
12 cc	96 Days	192.5 Days	2.6 Years	5.3 Years	26 Years	53 Years	264 Years	528 Years
15 cc	120.3 Days	240.7 Days	3.3 Years	6.6 Years	33 Years	66 Years	330 Years	659 Years

Volume	1.00E-10
0.002 cc	4.4 Years

Volume	5.00E-11
0.002 cc	320.9 Days

Volume	1.00E-11
0.01 cc	2.2 Years

$$P_t = P_0 e^{-(kt)}$$

$$k = \frac{\text{leak rate}}{\text{vol cc}}$$

t = time (sec)

This "Exchange Table" shows the number of 'hours,' 'days,' or 'years' required for a device to ingest 50% of the atmoshphere to which it is exposed, based on the volume of the part, (cc), and the leak rate of the part.

These exchange values have been studied and confirmed using Kr85 measured leak rates and IGA evaluation.

Yellow: MIL-STD-883 TM 1014 Leak Rate Limits

Green: MIL-STD-750 TM 1071 Leak Rate Limits

OVERVIEW

How do we determine optimum leak rate requirements?

Leak Rates : Vol cc : Time to Exchange 90% atmoshphere

Volume	1.00E-06	5.00E-07	1.00E-07	5.00E-08	1.00E-08	5.00E-09	1.00E-09	5.00E-10
0.002 cc	1.3 Hrs	2.6 Hrs	12.8 Hrs	1.1 Days	5.3 Days	10.7 Days	53.3 Days	107 Days
0.01 cc	6.4 Hrs	12.8 Hrs	3 Days	5 Days	26.7 Days	53 Days	267 Days	1.5 Years
0.1 cc	3 Days	5 Days	27 Days	53 Days	266.5 Days	1 Years	7.3 Years	14.6 Years
0.4 cc	11 Days	21 Days	107 Days	213 Days	3 Years	6 Years	29.2 Years	58.4 Years
0.75 cc	20 Days	40 Days	200 Days	1.1 Years	5 Years	11 Years	55 Years	109.5 Years
1 cc	27 Days	53 Days	267 Days	1.5 Years	7 Years	15 Years	73 Years	146 Years
3 cc	80 Days	160 Days	2.2 Years	4.4 Years	22 Years	44 Years	219 Years	438 Years
5 cc	133 Days	267 Days	3.7 Years	7.3 Years	37 Years	73 Years	365 Years	730 Years
8 cc	213 Days	1.2 Years	5.8 Years	11.7 Years	58 Years	117 Years	584 Years	1,168 Years
10 cc	267 Days	1.5 Years	7.3 Years	14.6 Years	73 Years	146 Years	730 Years	1,460 Years
12 cc	320 Days	1.8 Years	8.8 Years	17.5 Years	88 Years	175 Years	876 Years	1,752 Years
15 cc	1.1 Years	2.2 Years	10.95 Years	21.9 Years	109.5 Years	219 Years	1,095 Years	2,190 Years

Volume	1.00E-10
0.01 cc	7.3 Years

Volume	5.00E-11
0.002 cc	2.9 Years

Volume	1.00E-11
0.002 cc	14.6 Years

$$P_t = P_0 e^{-(kt)}$$

$$k = \frac{\text{leak rate}}{\text{vol cc}}$$

t = time (sec)

This "Exchange Table" shows the number of 'hours,' 'days,' or 'years' required for a device to ingest 90% of the atmoshphere to which it is exposed, based on the volume of the part, (cc), and the leak rate of the part.

These exchange values have been studied and confirmed using Kr85 measured leak rates and IGA evaluation.

Yellow: MIL-STD-883 TM 1014 Leak Rate Limits

Green: MIL-STD-750 TM 1071 Leak Rate Limits

What is the purpose of this study?

NEPP funded the Hermeticity Correlation Task to determine test equipment capability and focus on optimizing both MIL-STD-750 and MIL-STD-883 test methods based on findings from our research and testing.

CHLD
(Pernicka 700H System)

Krypton-85
(IsoVac Mark V Bomb Station)

OLT System
(NorCom 2020 Optical Leak Test System)

Helium Desorption Issue

Objective

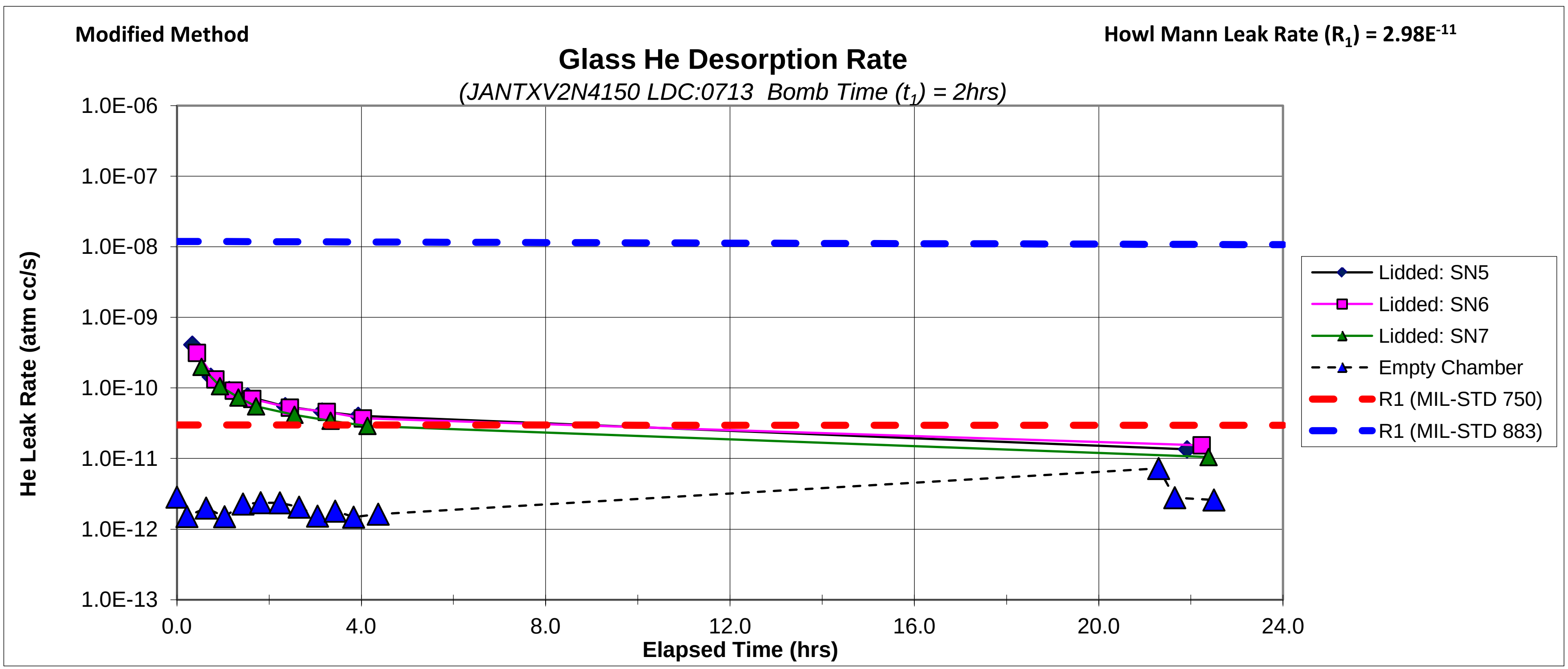
- Gain understanding of the influence of component part material on resultant leak rate data

Issue

- MSFC purchased a CHLD system in 2008 that has the sensitivity to test to the tightened fine leak rate requirements of MIL-STD-750.
- MSFC discovered that glass feedthroughs exhibit different levels of surface desorption after He bombing resulting in false failures not evident prior to tightening.
- Therefore MSFC developed a method to characterize devices for desorption which allows the establishment of optimum bombing conditions while taking into consideration CHLD instrument sensitivity.
- As written the test method is inadequate to address this issue. MSFC will propose this change in the next revision.

Helium Desorption Issue

- **Three JANTXV2N4150 LDC0713 transistors tested**
  - **L1 = 5 X 10^{-9} atm cc/s (air), Bomb pressure = 60 psig, Bomb time 2 hours, Volume = 0.22 cc**
  - **Howl Mann He leak rate limit for these conditions:**
    - **R1 = 2.98 X 10^{-11} atm cc/s for 0 hour dwell time**
    - **R1 = 2.97 X 10^{-11} atm cc/s for 24 hour dwell time**
- **Glass He desorption rates (atm cc/s He)**
  - **After ~4 hours: 2.90 X 10^{-11} to 4.03 X10^{-11} (*Empty chamber: 1.63 X10^{-12}*)**
  - **After ~24 hours: 1.05 X 10^{-11} to 1.54 X10^{-11} (*Empty chamber: 2.59 X10^{-12}*)**



MSFC Characterization Method

Suggested bomb times are 0.5, 4, and 12 hours. Test devices in smallest chamber (with insert if necessary). Use batch test T-times for devices being tested and for all empty chamber tests. Lidded devices must be known good hermetically sealed devices.

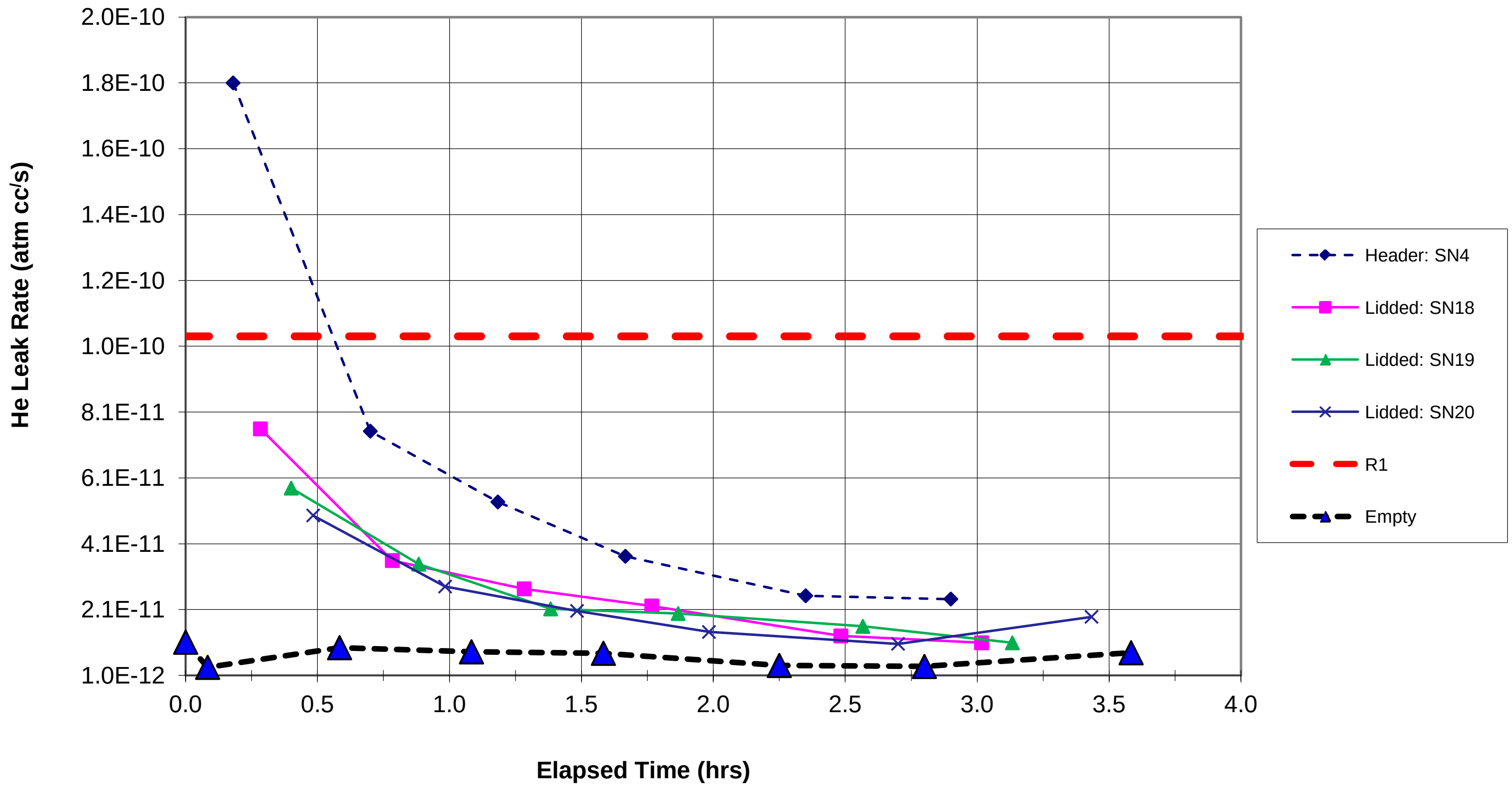
1. Bomb 3 serialized lidded devices and 1 delidded device for selected bomb time.
2. Prior to bomb end time, run calibration and a minimum of three empty chamber tests.
3. Remove parts from bomb chamber. Note exact time parts are removed from bomb chamber.
4. Perform following test runs:
   A. Empty chamber (1st empty chamber test should correspond with dwell time = 0)
   B. Delidded device
   C. Lidded device number 1
   D. Lidded device number 2
   E. Lidded device number 3
5. Repeat Step 4 continuously for four hours. Repeat Step 4 after 8 hours and 24 hours if the devices have not returned to empty chamber values. Calculate exact dwell time from the time stamp on the Excel leak table for each test run.
6. Plot measured helium leak rates of each device and empty chamber versus dwell time.
7. Plot R_1 over test time.
8. Use all three charts (0.5, 4, and 12 hours) to determine optimum bomb time and dwell time parameters.

Helium Desorption Issue

Method: 20/5/50/50/5
(Lidded Device)

Howl Mann Leak Rate (R_1) = 1.04E-10
(L=5.00E-9; P_e=74.7psia; V=0.126cc; t_1=4hr)

Glass He Desorption Rate
(IR TO-39: Bomb Time (t_1) = 4hrs)



Instrument Correlation Study

Objective

- Determine CHLD test equipment capability between NASA centers as well as correlation of test results with other equipment used for hermeticity testing (OLT, Krypton-85, IGA)

Status

- Confirmed GSFC/MSFC CHLD performance
  - *Used 2 calibrated helium leak standards to verify high/low leak range accuracy*
  - *Verified empty chamber values to confirm analyzer sensitivity to detect fine leaks*
- Performed GSFC/MSFC CHLD and OLT correlation study on 3 sets of MIL-STD-750 gross/fine leakers
- Started MSFC/IsoVac Kr85 correlation study on the same devices
- Will perform IGA testing on devices for final confirmation and comparison
- Planning a second instrument correlation study using MIL-STD-883 devices

Instrument Correlation Study

Part	System	Tester	Fine						Gross					
			a	b	c	d	e	Results	a	b	c	d	e	Results
Set 1	Kr85	IsoVac						**5/5**						**5/5**
(TO-18)		MSFC							**TBD**		**TBD**	**TBD**	**TBD**	**TBD**
	CHLD	MSFC	**P**	**P**	**G**	**P**	**G**	**2/5**	**P**		**P**	**P**	**P**	**1/5**
0.0345 cc		GSFC	**P**	**P**	**P**	**P**	**P**	**0/5**	**P**		**P**		**P**	**2/5**
	Kr85 (retest)	IsoVac												
	OLT	Norcom	**G**			**P**	**G**	**4/5**	**?**		**F**	**F**	**P**	**3/5**
	RGA	ORS												
Set 2	Kr85	IsoVac						**5/5**						**5/5**
(TO-5)		MSFC												
	CHLD	MSFC		**G**	**G**	**G**		**5/5**				**F**	**F**	**5/5**
0.2244 cc		GSFC		**G**				**5/5**	**F**	**F**		**F**	**F**	**5/5**
	Kr85 (retest)	IsoVac												
	OLT	Norcom	**P**		**P**		**P**	**2/5**	**P**	**P**		**P**	**P**	**1/5**
	RGA	ORS												
Set 3	Kr85	IsoVac						**5/5**						**5/5**
(ceramic)		MSFC												
	CHLD	MSFC	**P**	**P**	**P**	**P**	**P**	**0/5**						**5/5**
0.0026 cc		GSFC	**P**	**P**	**P**	**P**	**P**	**0/5**	**F**		**F**	**F**	**F**	**5/5**
	Kr85 (retest)	IsoVac												
	OLT	Norcom												
	RGA	ORS												

Notes:

Green:	*Parts Failed and correlate with baseline Kr85 rejection results*
Red:	*Part Failed but failed gross when Kr85 failed them as fine (G) or failed fine when Kr85 failed them as gross (F)*
	Instrument not capable to test parts
P:	Indicates parts passed and do not correlate with baseline Kr85 data
?:	NorCom marked "no result"

Leak Standard Development

Objective

- Design, fabricate, and test gross leak hermeticity standards

Issue

- Traceable standards are not available to verify that all three test systems have the capability to detect gross leaks

Status

- MSFC finalized a design configuration of three package sizes. Standards are being fabricated using typical manufacturing processes and are comprised of all metal components to minimize desorption.
- CHLD and Kr-85 testing will be performed on the as-received devices to ensure hermeticity.
- Collaborate with outside vendor to drill submicron size cylindrical holes to obtain standardized flow rates. Test using all three pieces of equipment.
- Patent research and obtain NIST certification

Test Method Optimization

Objective

- Provide input to DLA Land & Maritime to optimize hermeticity specifications based on the knowledge gained during correlation study, part testing, and research efforts

Status

- Submitted essential comments to address the tightening of MIL-STD-883 leak rate limits and to clarify CHLD test procedures
- Supported JC-13 Hermeticity Task Group 11-01 formed to investigate the tightening of MIL-STD-883 limits
- Will continue to provide comments to clarify test procedures based on information gained from correlation study, standard development, and part testing

JC-13 Hermeticity Task Group 11-01

Objective

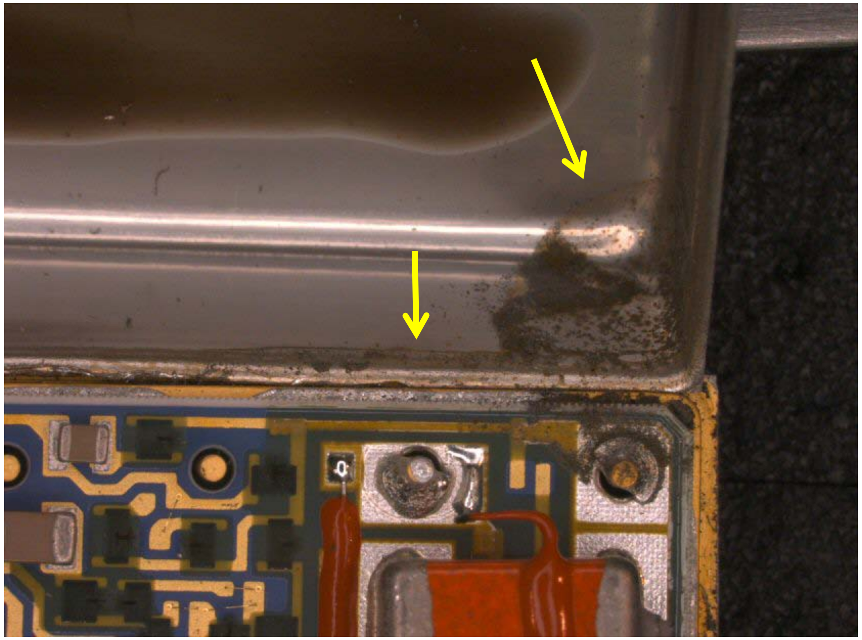
- Crane Electronics chaired a task group to support the tightening of MIL-STD-883 limits.

Synopsis

- Crane Electronics identified a process control issue which resulted in an investigation of a subset of 3000 hybrid microcircuit devices. The devices were originally tested to MIL-STD-883 leak limits and passed. The devices were retested to MIL-STD-750 and numerous failures were discovered.
- Crane requested MSFC to support the internal inspection of four samples that had failed hermeticity and exhibited electrical parametric shifts.
- MSFC found evidence of corrosion and ionic contamination.

OPTICAL PHOTOGRAPHS

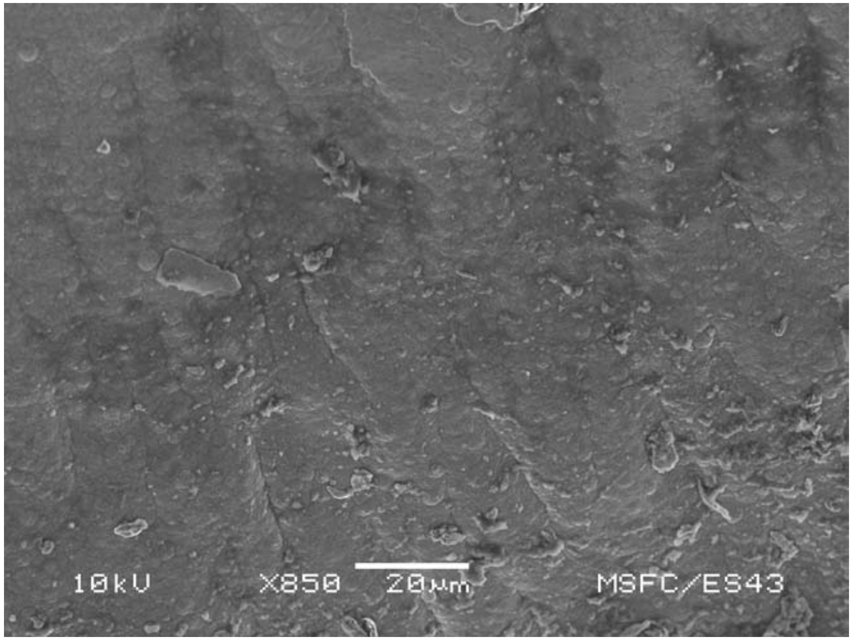
Evidence of corrosion along the edge and inside corner of the device lid



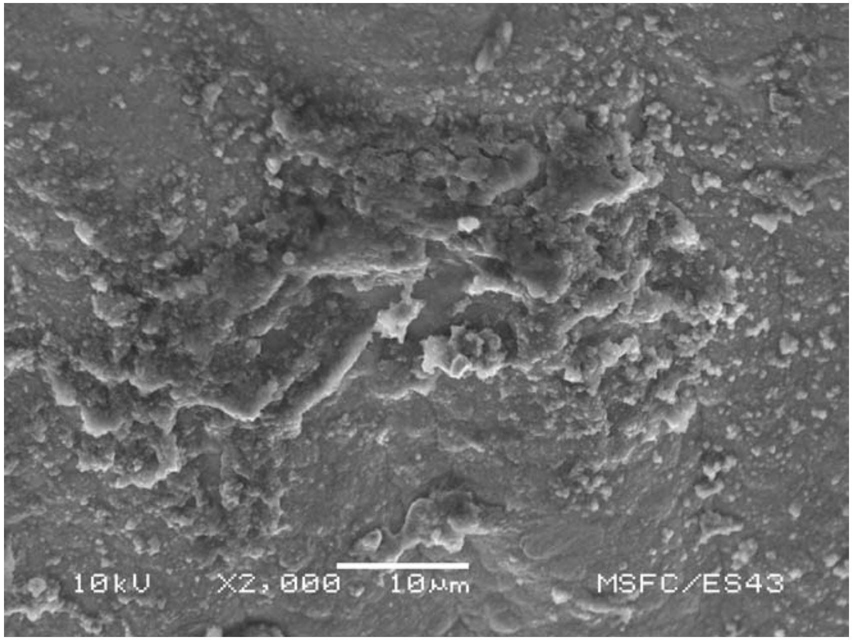
Sample M – Lid

SEM IMAGES

Examination of corrosion area along the edge of the device lid



Darker areas indicate smaller molecular weight material typical of corrosion products



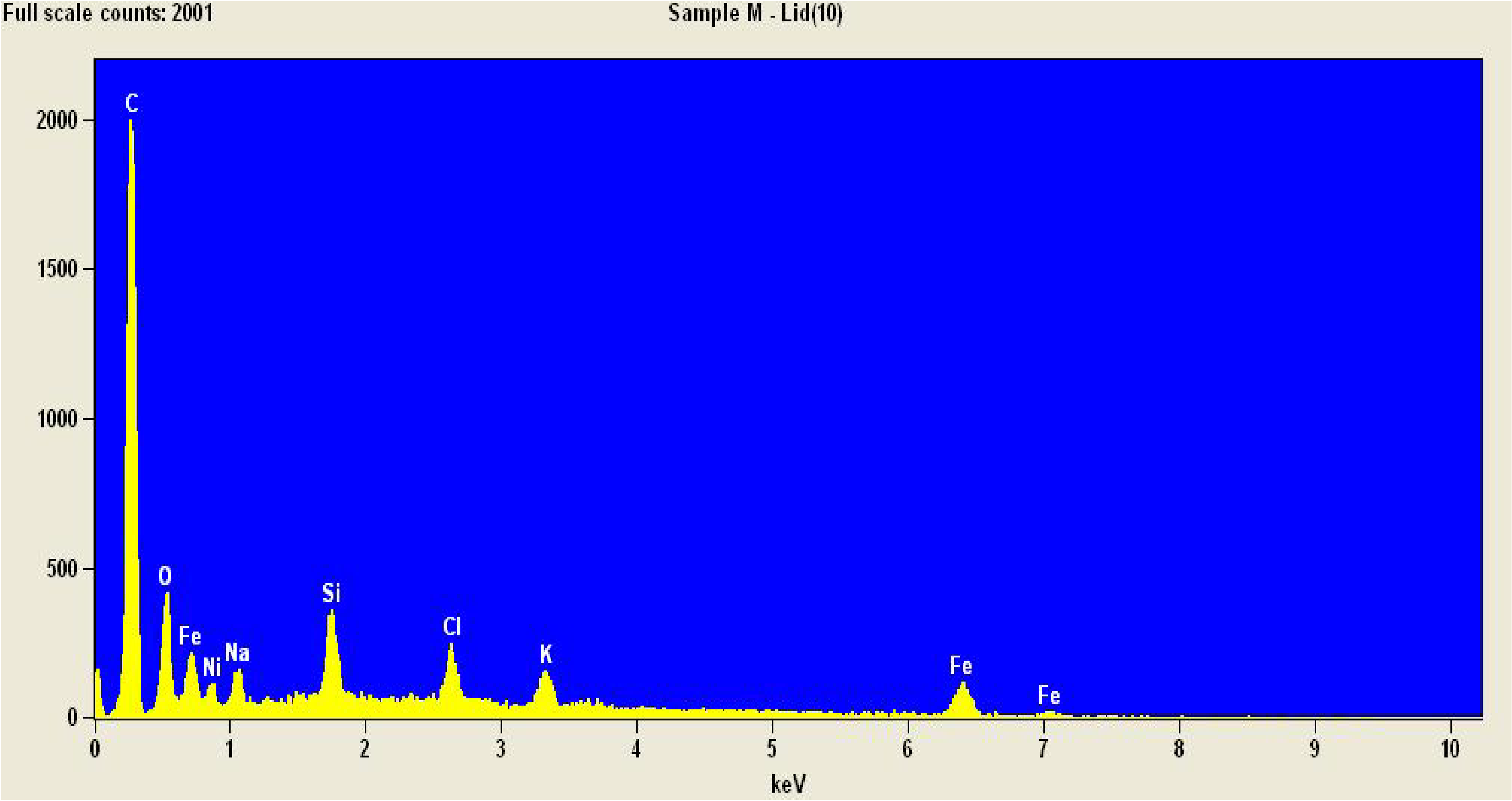
Raised areas indicate corrosion

Sample M – Lid

Test Method Optimization

EDS SPECTRUM

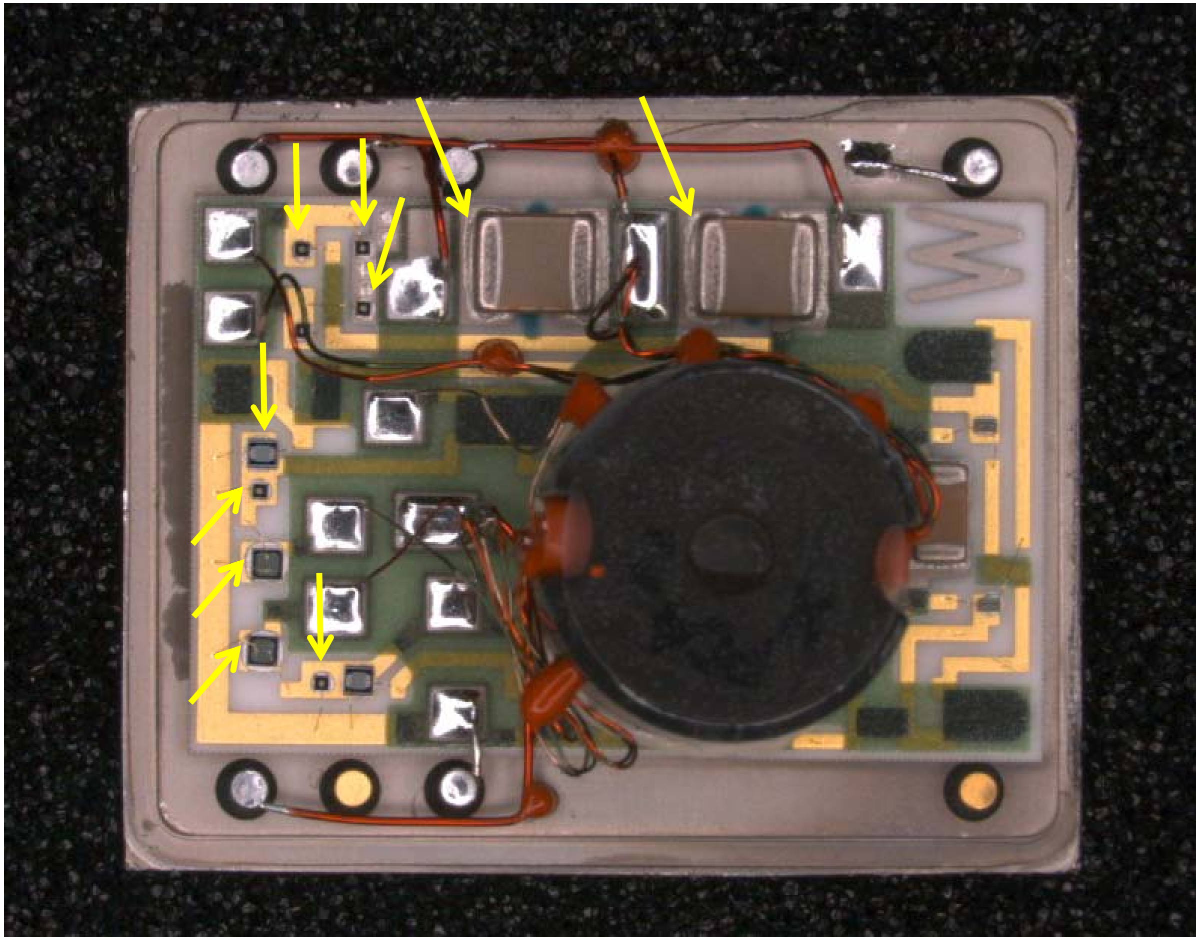
Elemental analysis provides evidence of ionic contamination and corrosion



Sample M – Lid

OPTICAL PHOTOGRAPH

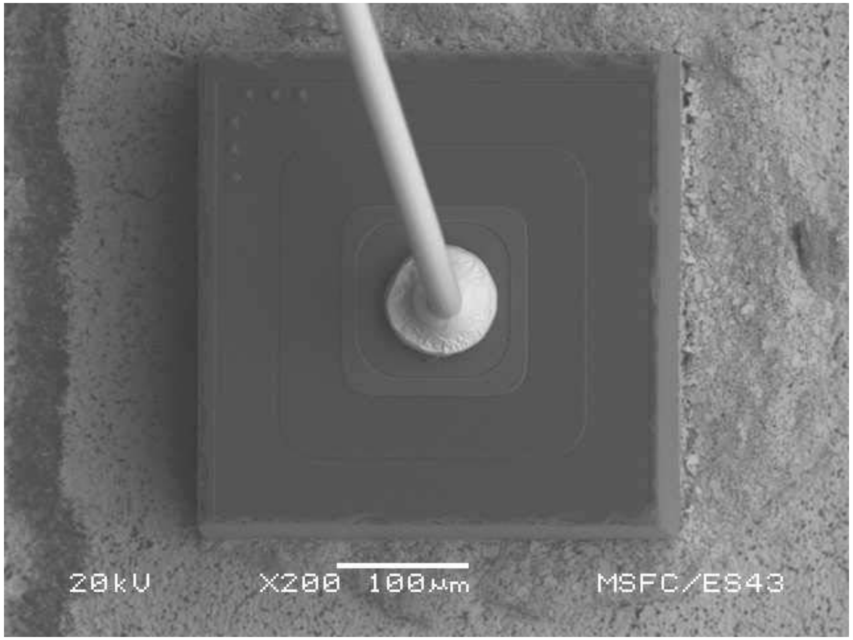
Devices inspected for the presence of Ag_2S corrosion (gross leaker)



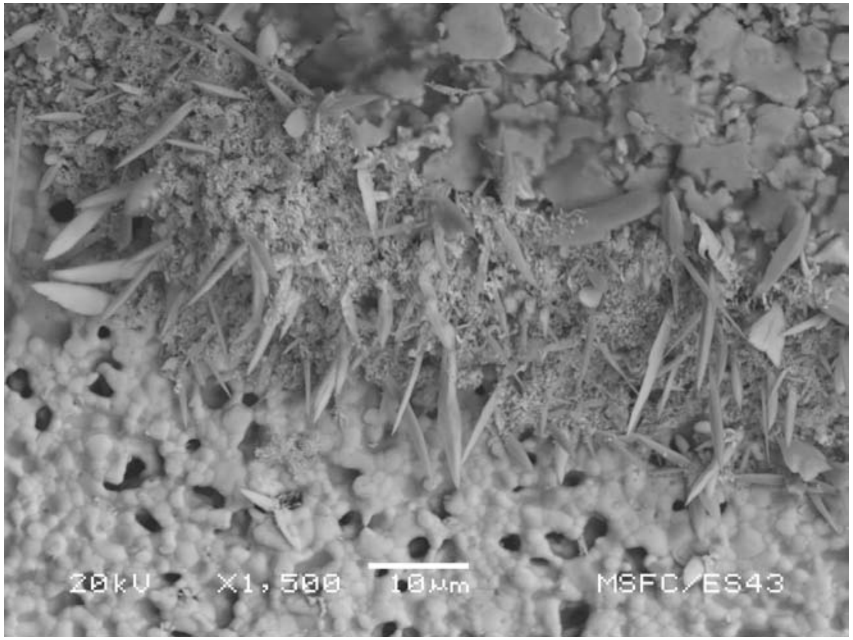
Sample U

SEM IMAGES

Examination of a representative Ag_2S corrosion area



Die and bond area at low magnification



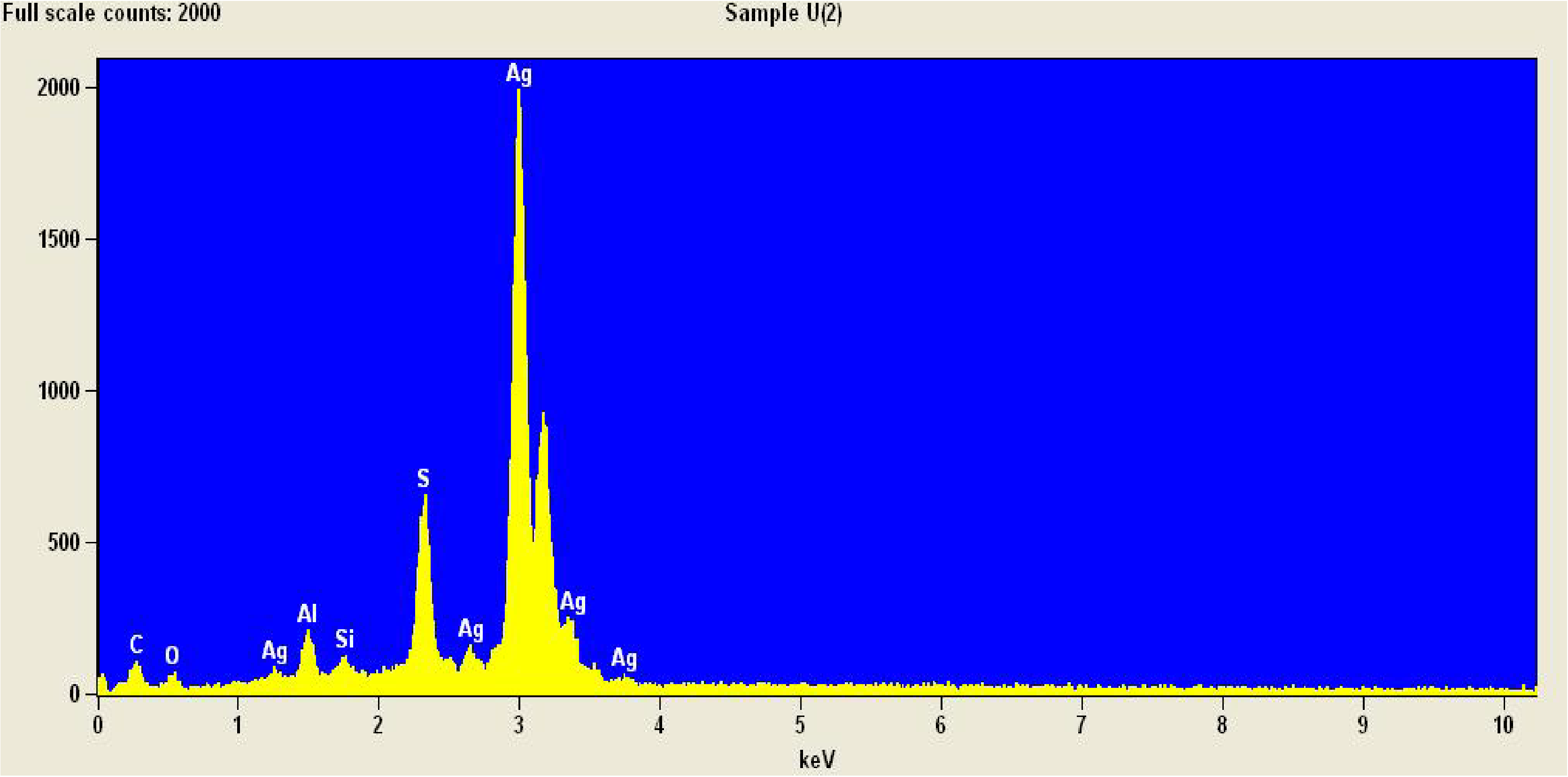
Evidence of heavy growth of Ag_2S along Ag die attach edge and bond pad

Sample U

Test Method Optimization

EDS SPECTRUM

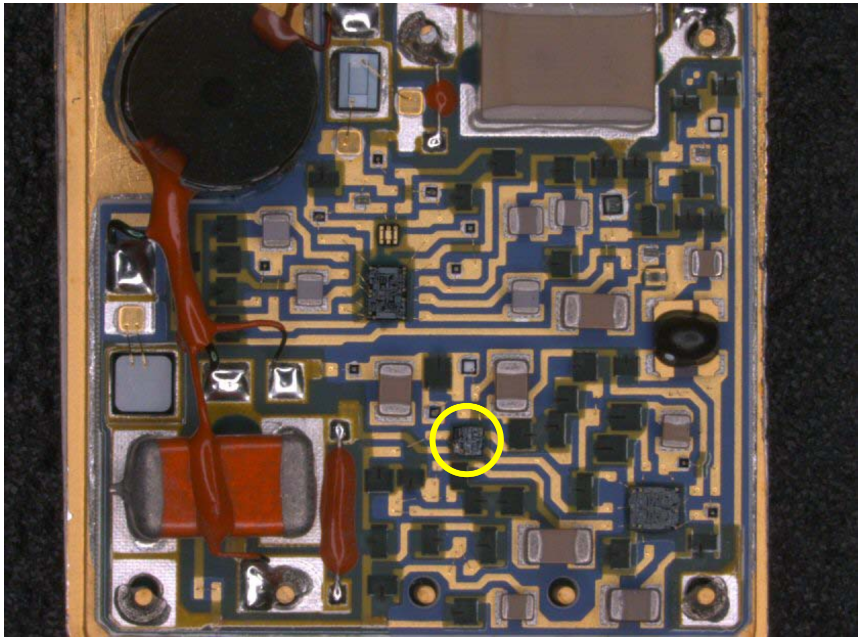
Elemental analysis provides evidence of Ag_2S corrosion

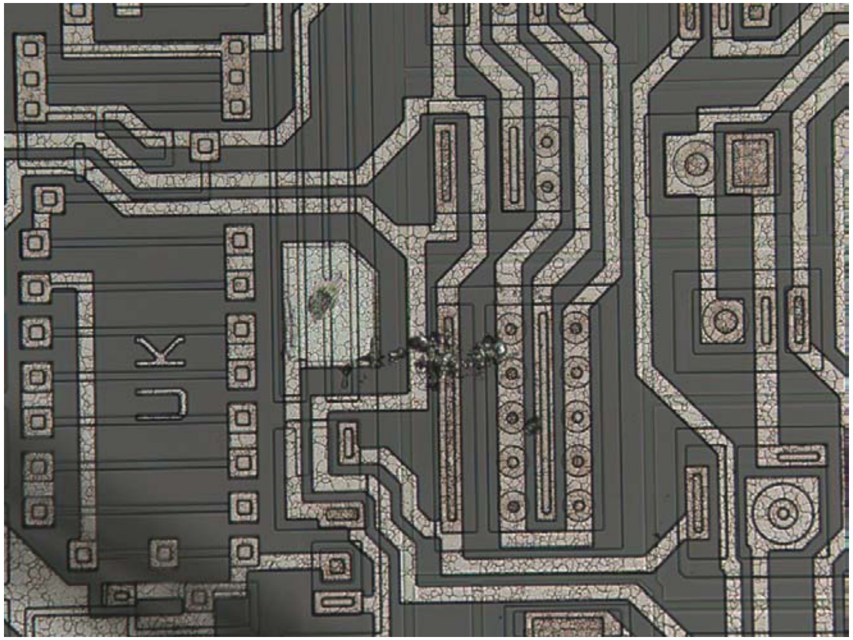


Sample U

OPTICAL PHOTOGRAPHS

Device found with presence of Ag_2S corrosion on top of passivation



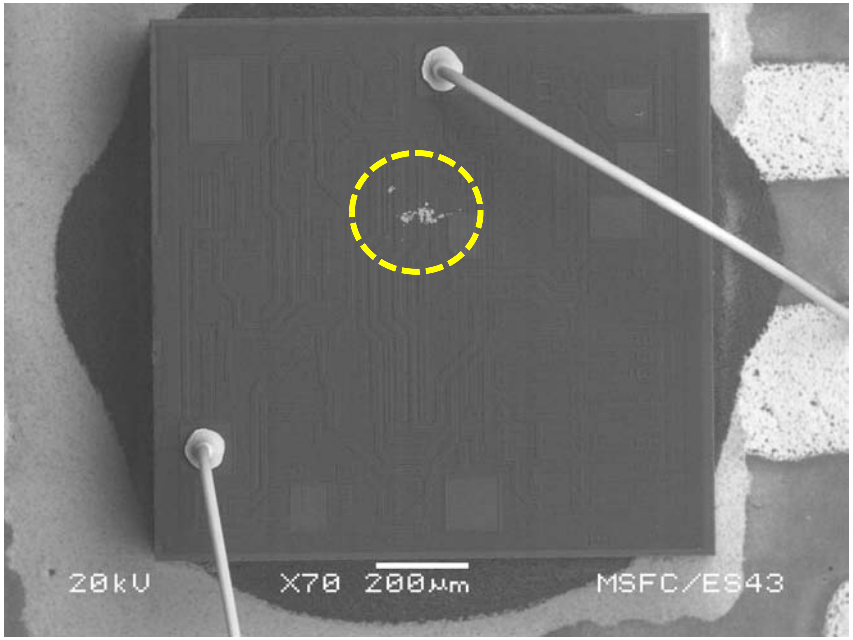


Sample C

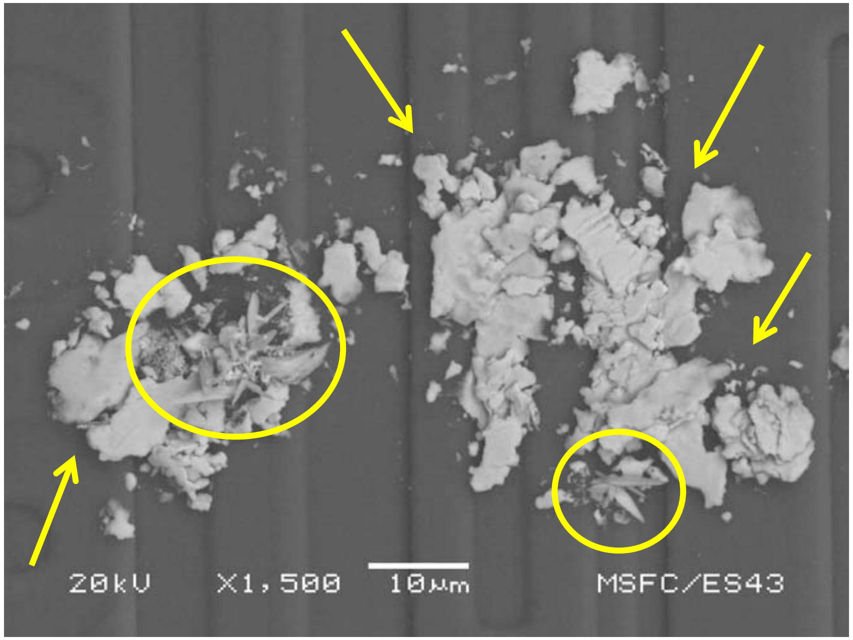
Test Method Optimization

SEM IMAGES

Examination of Ag_2S corrosion area on top of passivation layer



Lighter area indicates a higher molecular weight material than silicon passivation

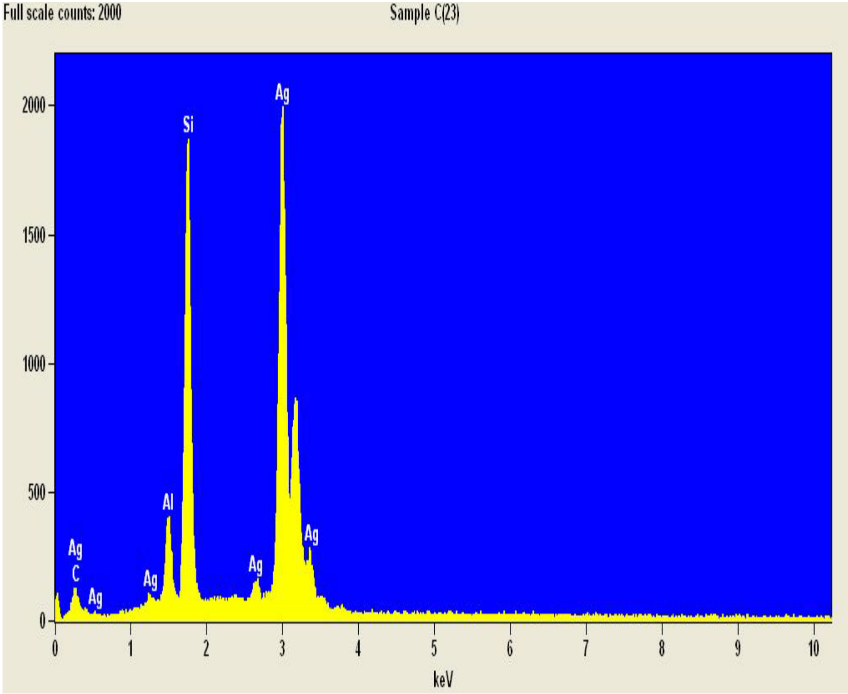


Shape of particles are consistent with silver die attach (arrows) and Ag_2S corrosion (circled)

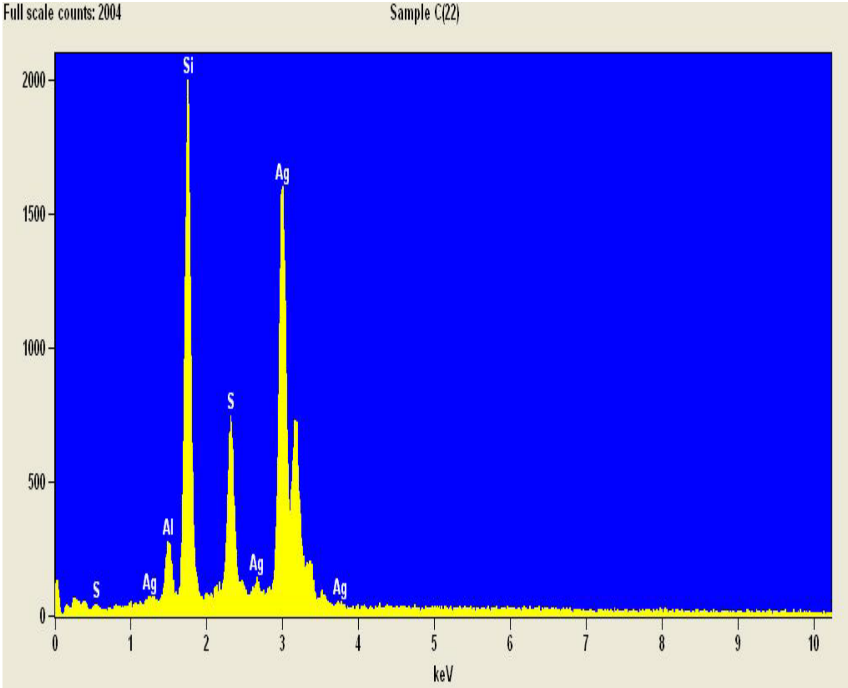
Sample C

EDS SPECTRUM

Elemental analysis of materials on die surface



Spectrum of Ag die attach particles



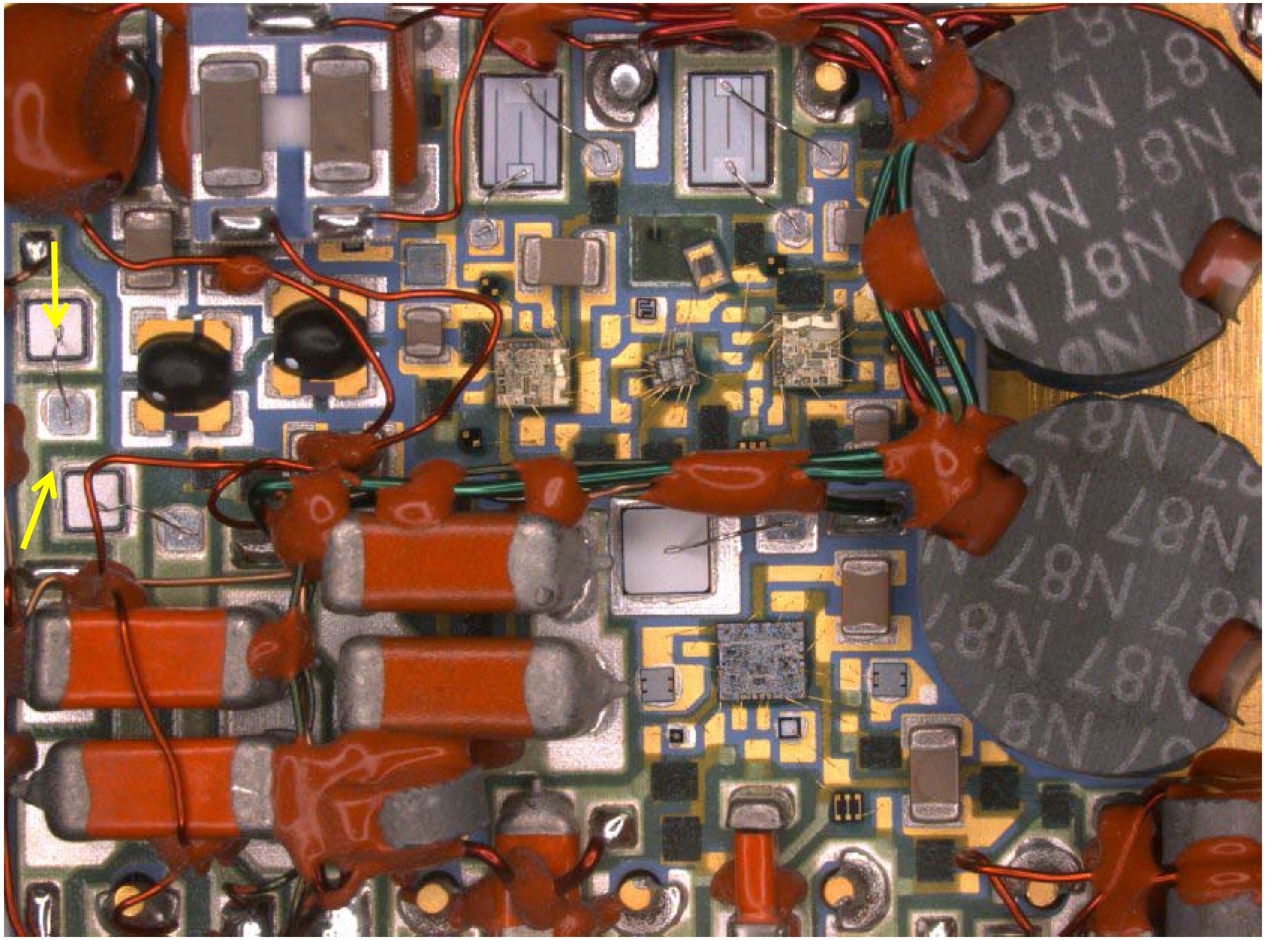
Spectrum of Ag_2S corrosion

Sample C

Test Method Optimization

OPTICAL PHOTOGRAPH

Devices inspected for the presence of Ag_2S corrosion

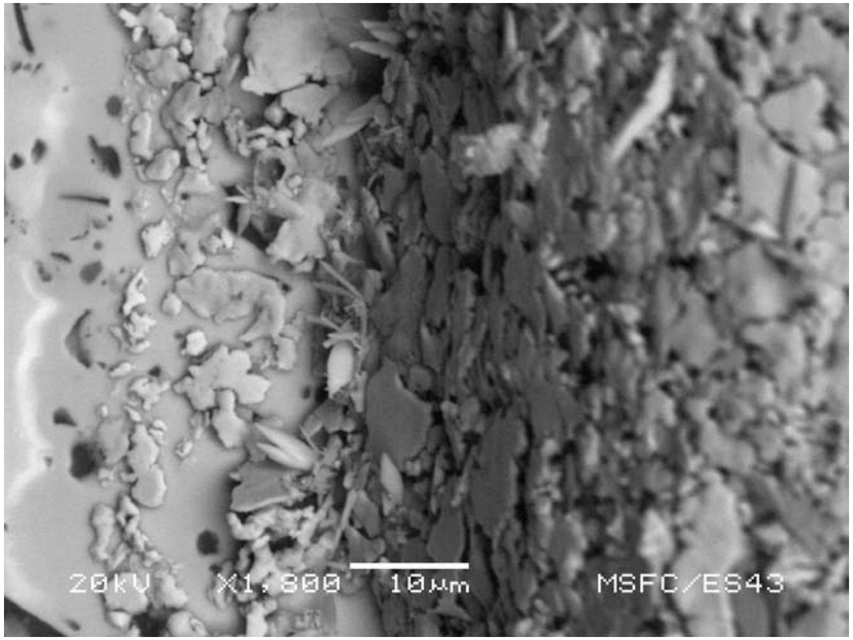


Sample Q

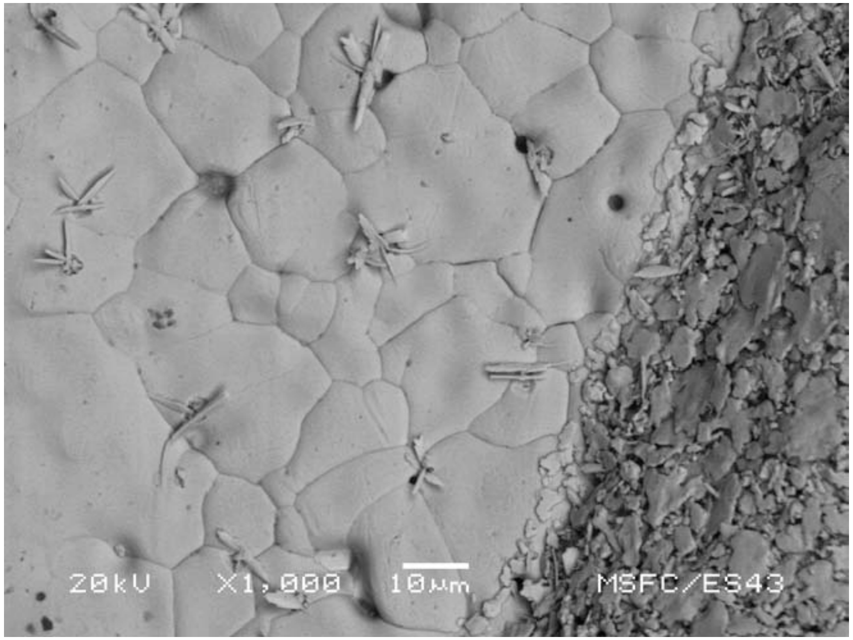
Test Method Optimization

SEM IMAGES

Examination of Ag_2S corrosion on two diodes



Diode 1 shows light Ag_2S corrosion forming on die attach



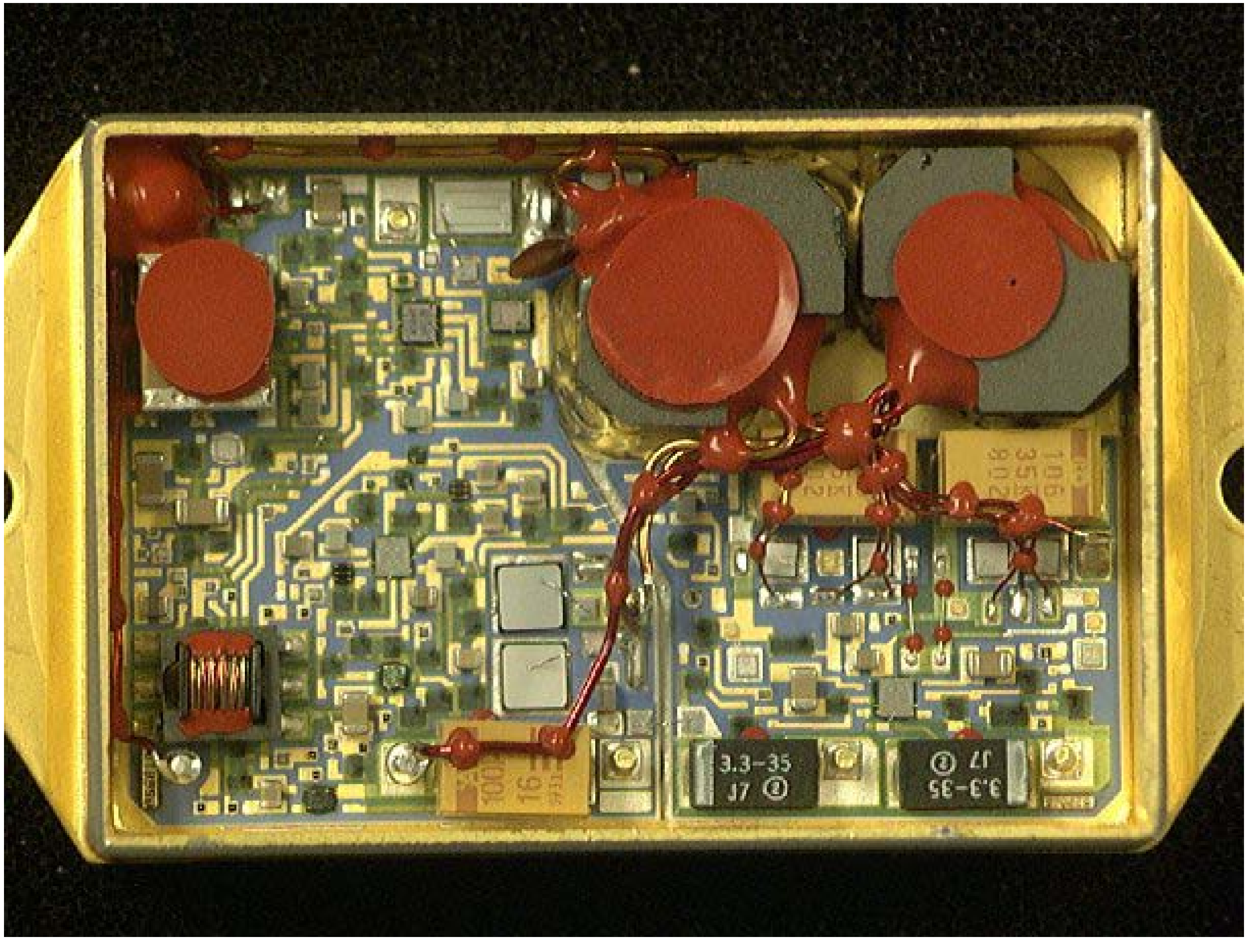
Diode 2 shows light Ag_2S corrosion forming on board bond pad and die attach

Sample Q

Test Method Optimization

OPTICAL PHOTOGRAPH

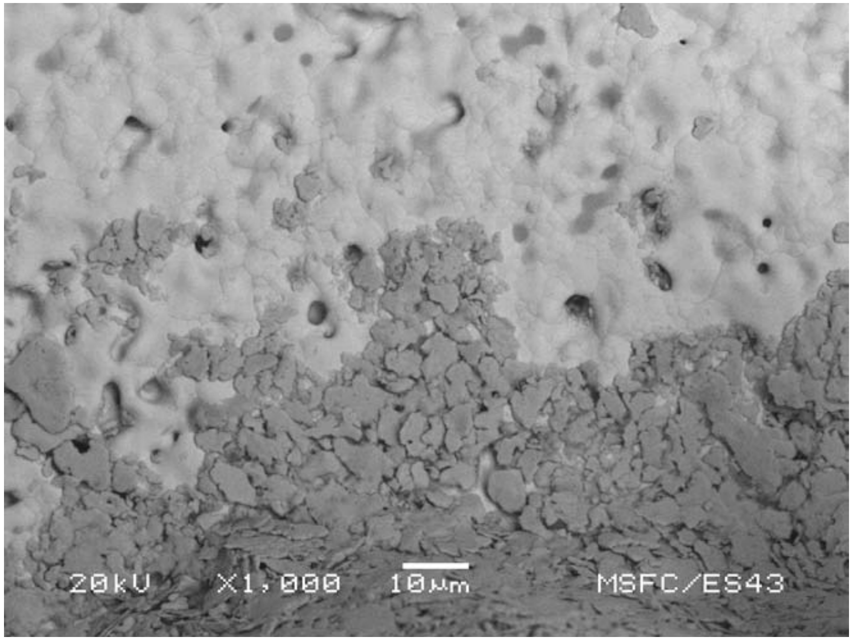
Inspected devices for evidence of Ag_2S corrosion



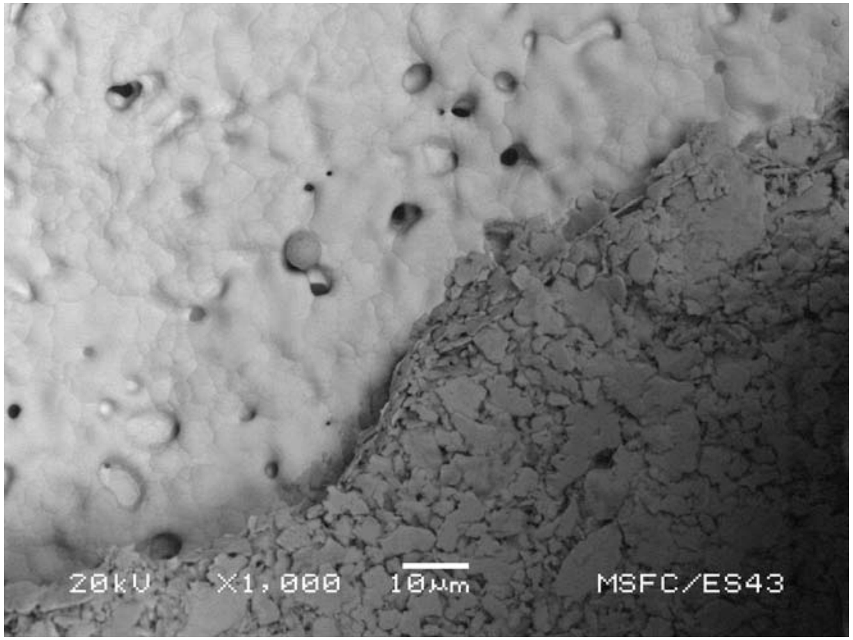
Control Sample

SEM IMAGES

Examination for signs of corrosion



Inspection of stacked capacitor Ag die attach

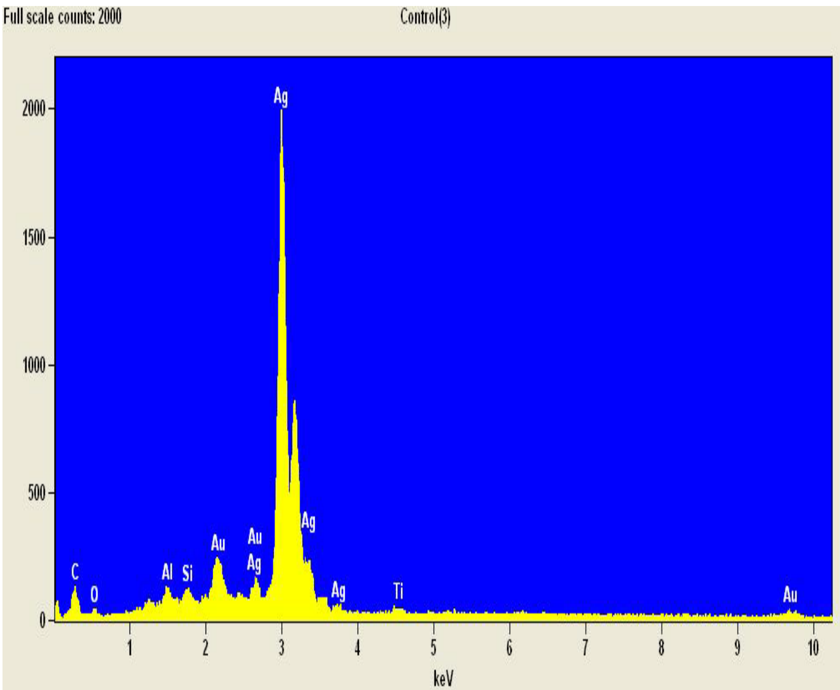


Inspection of a diode Ag die attach

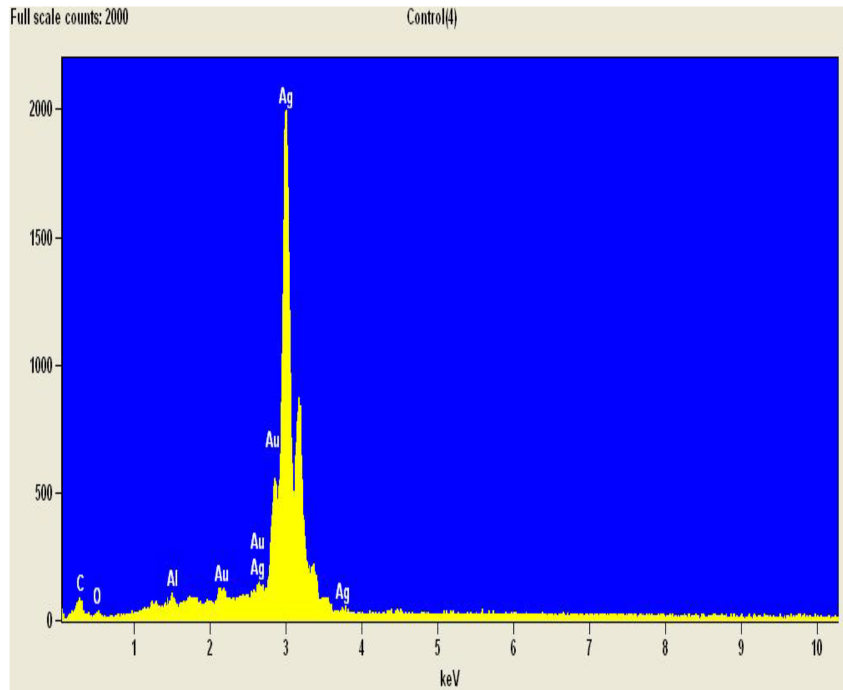
Control Sample

EDS SPECTRUM

Elemental analysis of two representative areas show no signs of Ag_2S corrosion



Spectrum of stacked capacitor Ag die attach



Spectrum of a diode Ag die attach

Control Sample

Test Method Optimization

Control Sample:

- Passed MIL-STD-750 Kr85 leak tests and showed no evidence of corrosion

Suspect Devices:

- All devices showed evidence of corrosion
  - FeO_2 is an oxidation reaction which occurs in the presence of moisture.
  - Ag_2S is a reaction which occurs in the presence of H_2S gas from the atmosphere.
- All devices were Kr85 tested and found to be leakers
  - All devices fixed with Ag die attach showed evidence of Ag_2S corrosion.
    - Sample U was a gross leaker and showed heavier concentration of Ag_2S.

Future Work

Helium and Kr85 Desorption Issue

- Research and document the influence of component part material on resultant leak rate data

Instrument Correlation Study

- Complete Kr85 correlation study, perform IGA to quantitatively determine constituent gas ratios and moisture content, and present findings
- Support a second instrument correlation study of MIL-STD-883 devices

Leak Standard Development

- Ensure hermeticity of fabricated devices, machine holes and obtain standardized gross flow rates, and obtain leak rate data
- Conduct patent research and obtain NIST certification

Test Method Optimization

- Provide input to optimize specifications based on the knowledge gained during correlation study, part testing, and research efforts

NASA Electronic Parts and Packaging (NEPP) Hermeticity Task Overview

Questions?