WEDNESDAY, JUNE 21, 2017

6	**A**	**8:00 AM - 9:25 AM**	**SESSION 6: STANDARDS & RELIABILITY**	**SPONSORED BY:**	
6.1	A	8:00 AM	Recent developments in IPC Printed Electronics Standards	Neil Bolding	MacDermid Enthone Industrial Solutions
6.2	A	8:25 AM	Overview of IEC Activities Related to FHE, including IEC TC 110 and TC 119	Kei Hyodo	Konica Minolta
6.3	A	8:45 AM	Advances in Flexible Hybrid Electronics Reliability	Douglas Hackler	American Semiconductor, Inc.
6.4	A	9:05 AM	Accurate Testing of Flexible Hybrid Electronics Using Tension-Free Systems	Naotsugu Ando	YUASA SYSTEM
		9:25 AM	**MORNING BREAK**	**SPONSORED BY:**	SCREEN

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Advances in Flexible Hybrid Electronics Reliability

2017 FLEX

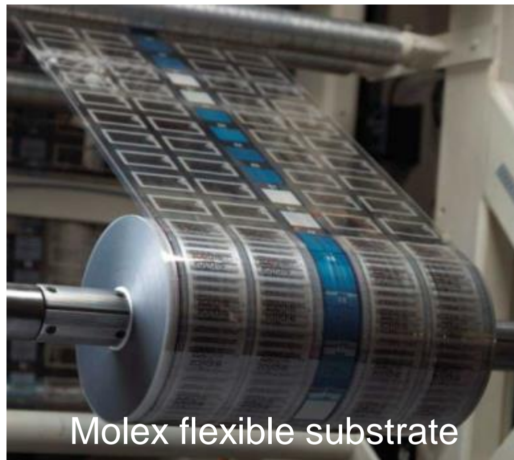
RAPID REACTION Technology Office

This work sponsored in part by the Air Force Research Laboratory, Wright-Patterson AFB and Rapid Response Technology Office, under the programs Enabling Flexible Materials, Devices and Processes for Defense and *Advanced FleX SoC Microcontroller.*

Doug Hackler
President & CEO
American Semiconductor

What's Flexible Hybrid Electronics?

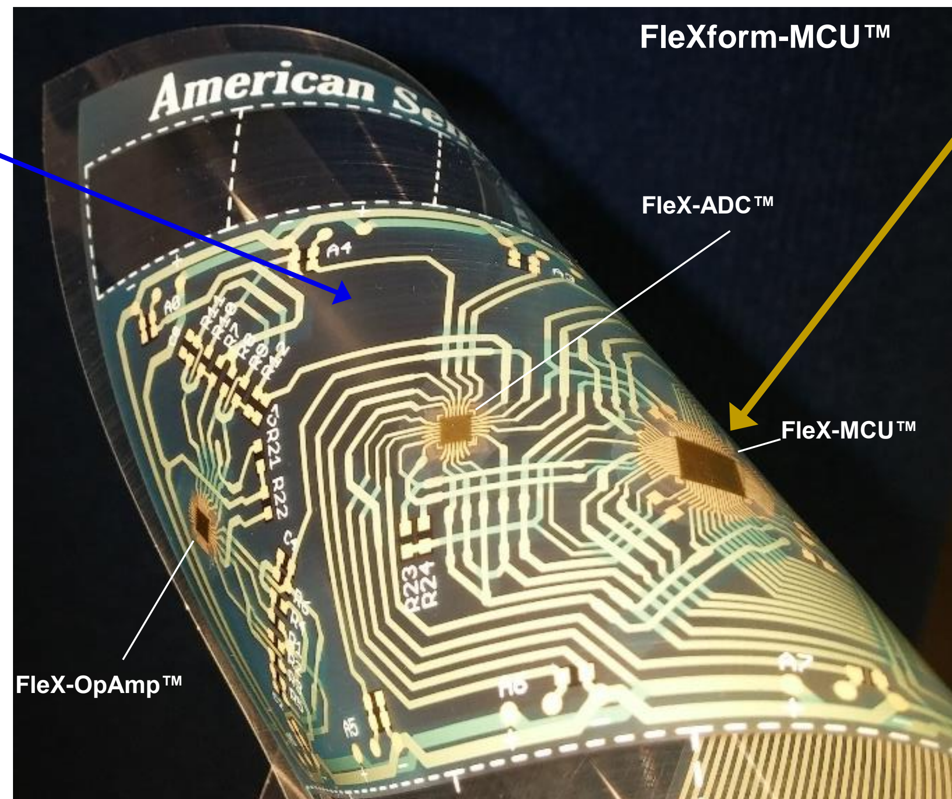
Printed Electronics
Low Cost, R2R, Large Format



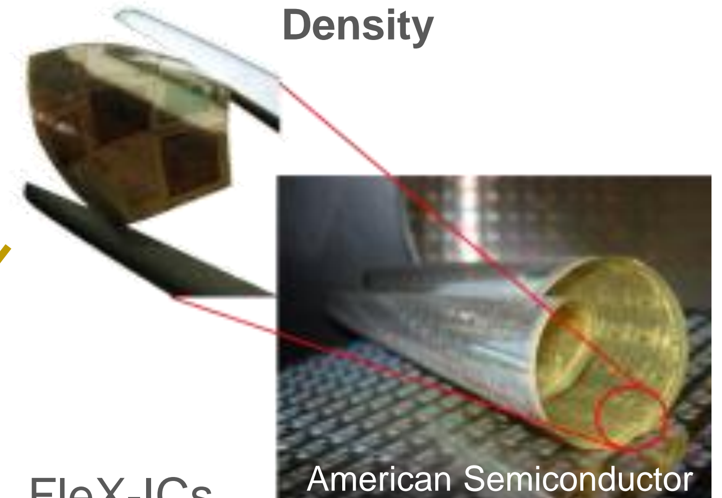
Printed Electronics
- Sensors
- Interconnects
- Substrates
- Displays

- Low Cost, Large Format
- Roll-To-Roll, Screen, Inkjet Print, …

Flexible Hybrid System
"Combination of flexible printed materials and flexible silicon-based ICs to create a new class of flexible electronics."



Flexible *FleX*-ICs
High Performance, High Density



FleX-ICs
- Sensor Signal Processing
- Data Processing
- Data Storage
- Communications

- Low Cost, High Performance
- Compatible with Printed Electronics
- Foundry CMOS + FleX Processing

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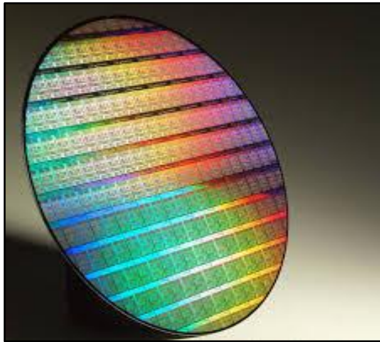
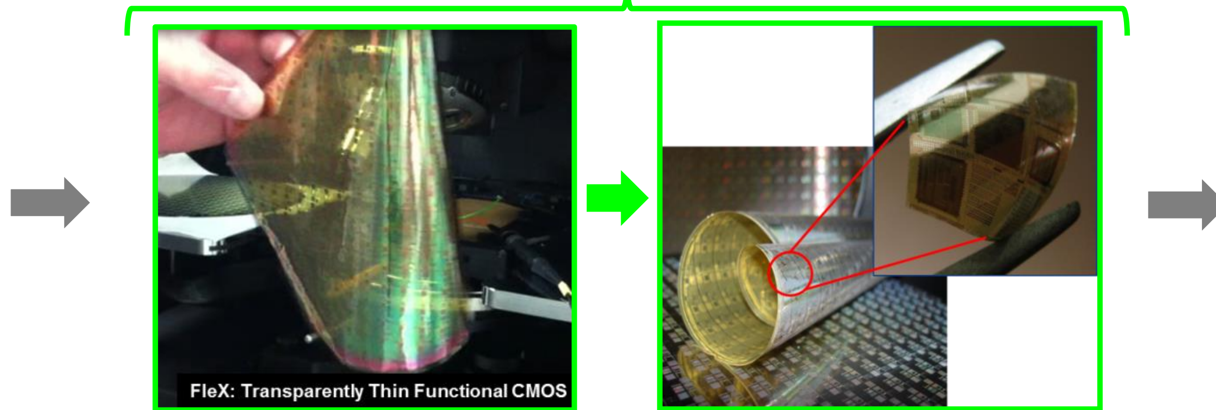
Wafer Conversion Process

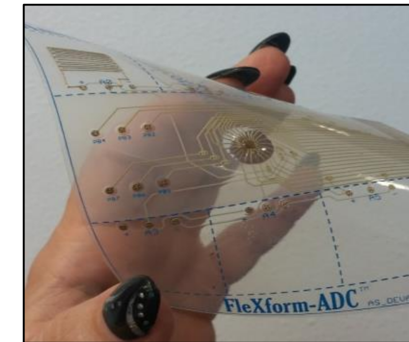
Wafers from Foundry

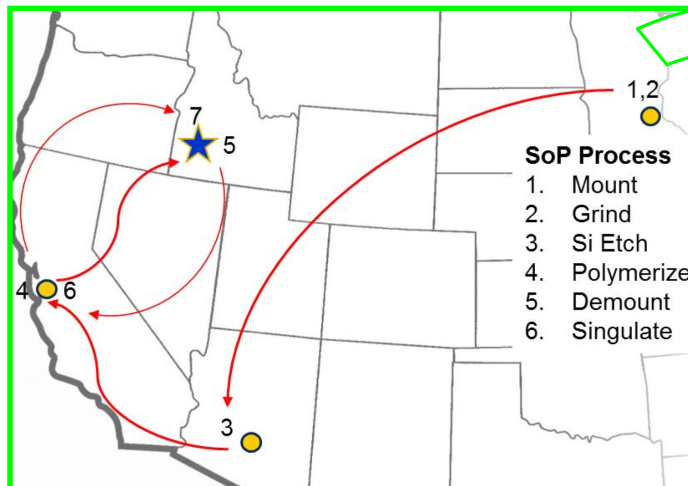


"*FleX*" SoP Conversion Process



Assembly Contractor or Customer





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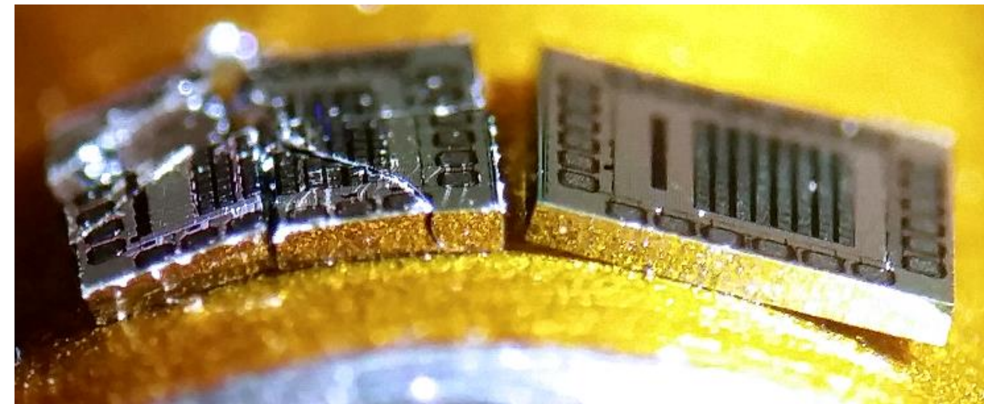
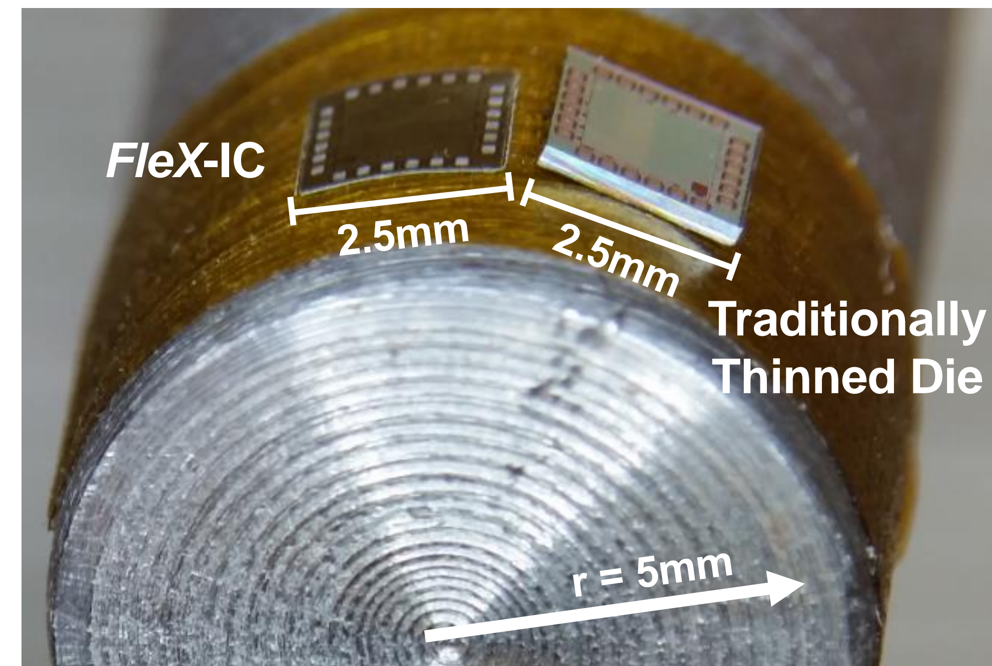
Why Flexible Chips?

- New Applications
  - Internet of Things (IoT)
  - Wearables
  - Structural
- New Requirements
  - Conformal and/or Flexible
  - Ultra thin
  - Ultra light weight
- Improved Reliability
  - No Die Cracking
  - Reduced Breakage of Interconnects



Traditional Thinned Die Failures



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New FHE Test Procedures

FHE RELIABILITY TESTING				
	Test	Conditions	ASI Procedure	References
1	High Temp Life	125C	**ASI TEST008**	ISO 10373-1 JESD22-A108
2	Low Temp Life	-25C	**ASI TEST009**	JESD22-A108
3	ESD	HBM and/or CDM	**ASI TEST010**	ANSI-ESDA-JEDEC_JS-001 and JS-002
4	Static and Dynamic RoC	Concave/convex Bend Test	**ASI TEST003** **ASI TEST005**	ASTM D522-93a ISO10373-1, ISO 7816
5	Axial Torsion	Bend Text	**ASI TEST006**	ISO10373-1, ISO 7816
6	SEM Inspection	Post SoP conversion	**ASI TEST007**	MIL-STD-883: M2018
FLEXIBLE MEMORY TESTING				
M1	Data Retention	150 C, non-biased	**ASI TEST_tbd**	JESD22-A117, JESD22-A103
M2	RoC Data Retention	Concave and convex RoC	**ASI TEST_tbd** **Based on 005**	ISO10373-1, ISO 7816

Distribution

- NextFlex Stds Test & Rel TWG
- AFRL/RX
- Available on request

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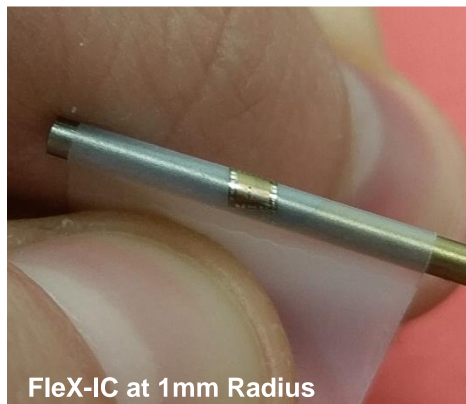
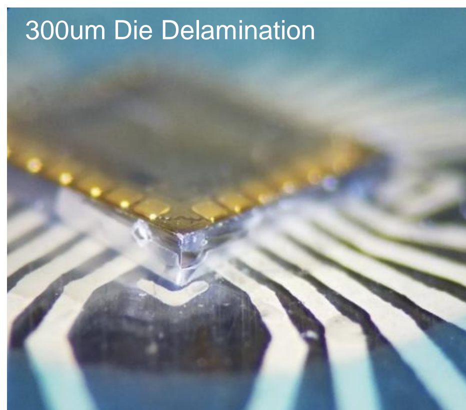
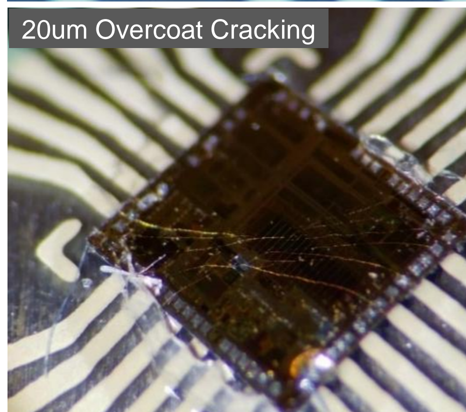
Radius of Curvature (RoC) Testing

Per ASI Procedure TEST003


FleX-IC at 1mm Radius


300um Die Delamination


20um Overcoat Cracking

Testing Overview

- Multiple die sizes: 2.2mm X 2.2mm → 5.0mm X 5.0mm
- Bend die around precision mandrels until mechanical and/or electrical failure
- 40 → 1 mm radius or curvature
- Functional Electrical Test
- Microscopic visual inspection for Mechanical failure
- Minimum of 3 samples
- Observed Failure methods
  - Die delamination from the substrate
  - Materials cracking

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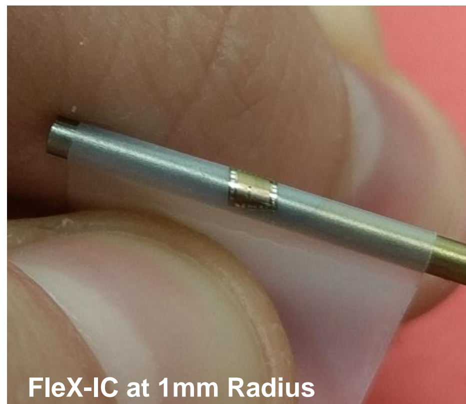
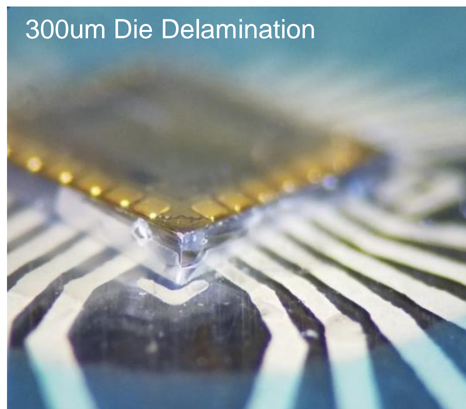
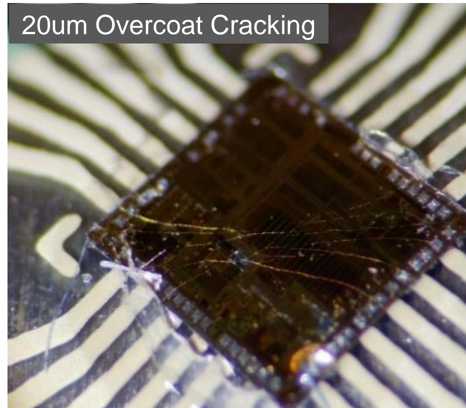
Radius of Curvature (RoC) Testing

Per ASI Procedure TEST003


FleX-IC at 1mm Radius


300um Die Delamination


20um Overcoat Cracking

Results – ICs on PET Substrates

Thinning Method	Thickness (um)	Die Size (mm)	RoC Failure (mm)	Failure mode
No thinning	725	5.0 X 5.0	20	Delamination
		2.5 X 2.5	12	Delamination
Conventional thin die	300	5.0 X 5.0	30	Delamination
		2.5 X 2.5	12	Delamination
	40	2.2 X 2.2	10	Delam & Materials Crack
	20	2.2 X 2.2	10	Delam & Materials Crack
FleX™	SoP	2.5 x 2.5	5	PASS

Results – ICs without Substrate

Thinning Method	Thickness (um)	Die Size (mm)	RoC Failure (mm)	Failure mode
FleX™	SoP	2.5 x 2.5	1	PASS

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FHE Dynamic Reliability Testing

Per ASI Procedure TEST003

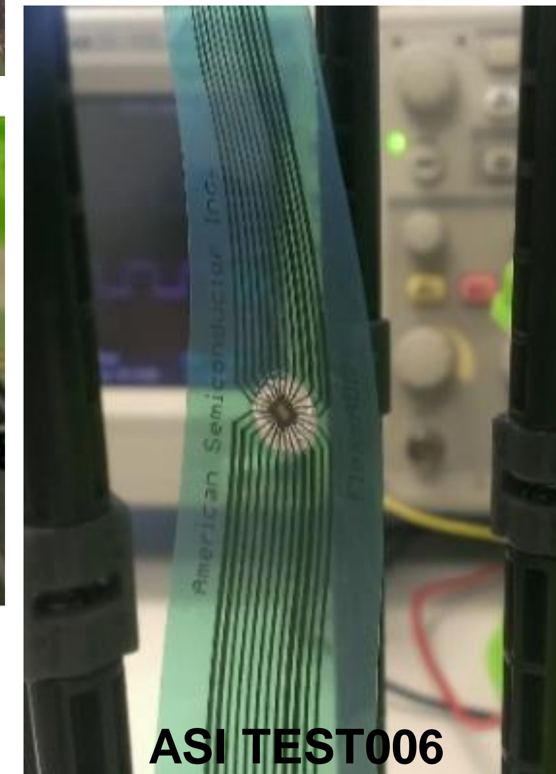
FleX Dynamic RoC Testing

- Robotic flex FHE to 15mm RoC
- Continuous electrical testing
- Test 1 – 10K cycles convex PASS,
  13.6K cycles concave PASS
- Test 2 – 11K cycles concave PASS, Convex test to failure: 15.8K cycles
  - Crack VDD epoxy interconnect

Dynamic Torsion Testing

- Robotic flexure ±60 or ±90 degrees
- Continuous electrical testing
- Test 1 – 10K cycles of ±60 degrees followed by test to failure: 92K cycles at ±90 degrees

ASI TEST005



ASI TEST006

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ESD Testing

Per ASI Procedure TEST010

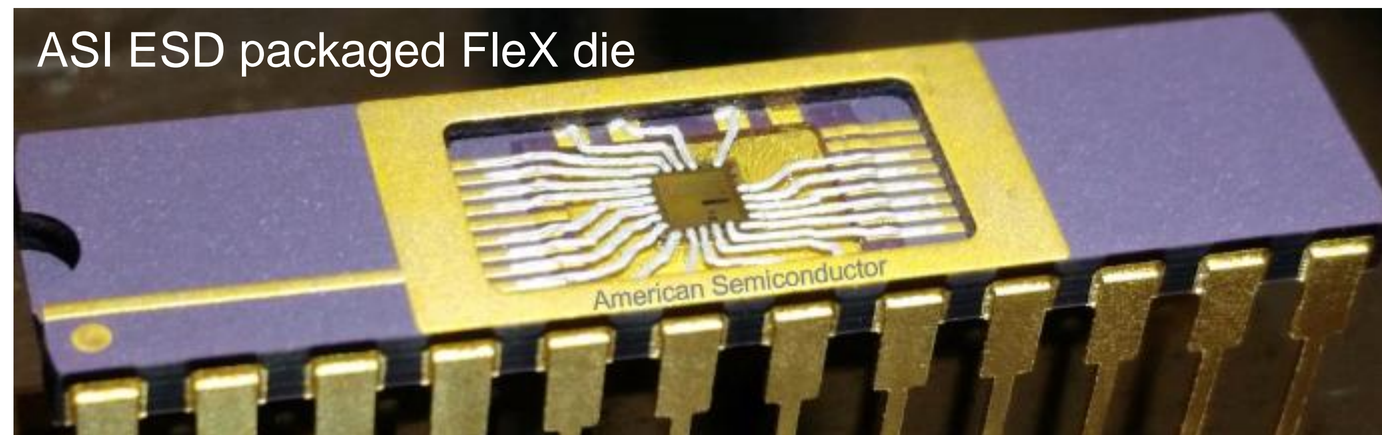
TEST 1 – Rigid, Full Thickness Die (baseline)

- AS_ADC1004.pkg packaged ADCs using full thickness die wire bonded to the lead frame
- **RESULT**: Pass human body model (HBM) testing

TEST 2 – Ultra-thin FleX Silicon-on-Polymer Die

- AS_ADC1004.fxd FleX-ADC die on PET in ESD Package
- Mounting designed to accommodate standard ESD test equipment
- Pin leakage testing
- **RESULT:**

SoP Passed 4KV HBM



Industry first: FHE ESD reliability testing

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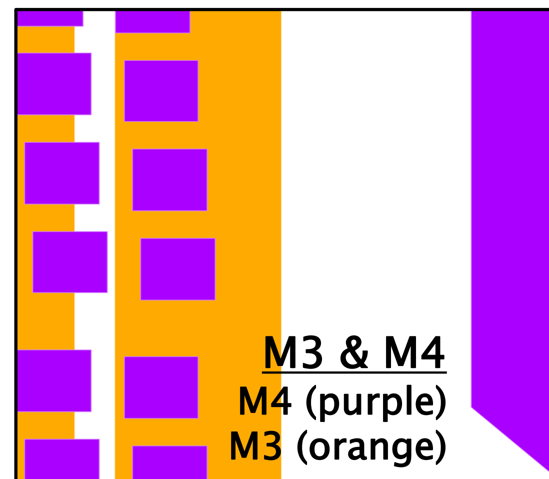
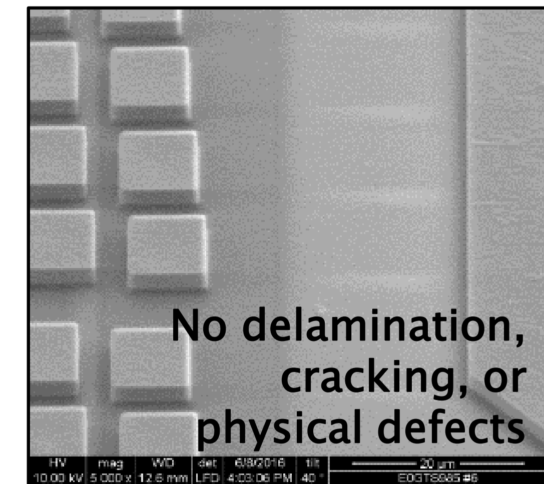
Scanning Electron Microscope (SEM) inspection

- Layer by layer deconstruction of all passivation and all 4 metal layers
- Inspection for cracking, delamination, or other visual defects
- Flexible FleX-ADC die, AS_ADC1003.fxd, used for analysis
- **RESULT**: **PASS. No defects attributed to the FleX SoP process.**
  - Expected result, consistent with functional testing of FleX-ICs before and after FleX conversion

Industry first: Flexible Die Delayer Test



Layout View



SEM Analysis

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HTOL and LTOL for FleX-IC Die

Per ASI Procedures TEST008 and TEST009

HTOL Testing of FleX-IC Die

- Passed 168 hours at 125C
- Tested at 1, 24, 48, 72 and 168hrs

FleX-IC Die in Oven

LTOL Testing of FleX-IC Die

- Passed 168 hours at -25C
- Tested at 1, 24, 48, 72 and 168hrs

FleX-IC Die in Freezer

Industry first: Flexible Die Lifetime Tests

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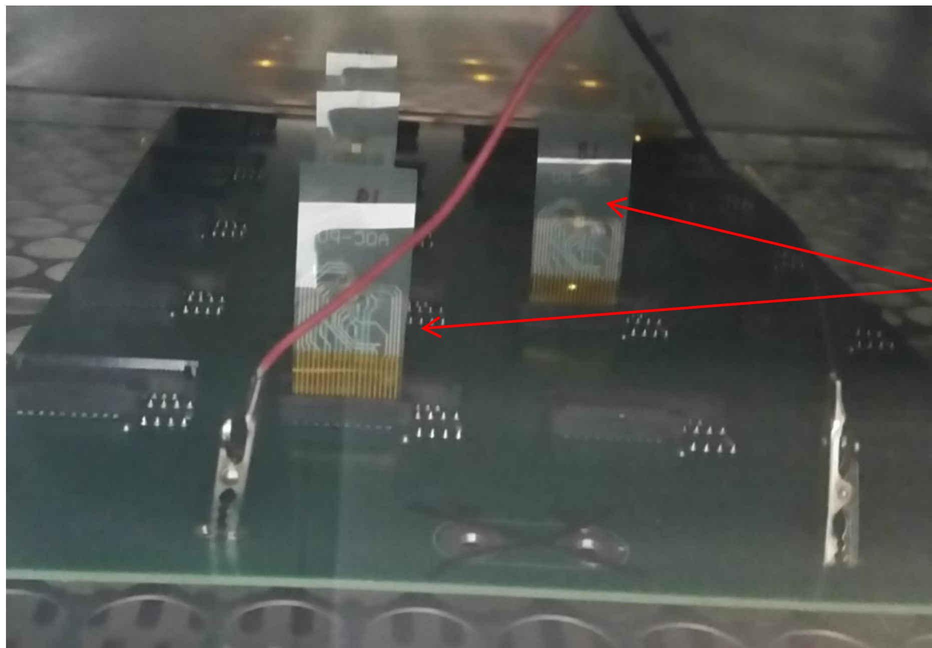
HTOL FHE Systems in progress

- Assembled using ASI FHE PoR
- 168 hours @ 125C in ambient
- FHE systems under bias and electrically active during the stress



FHE HTOL Test Coupons

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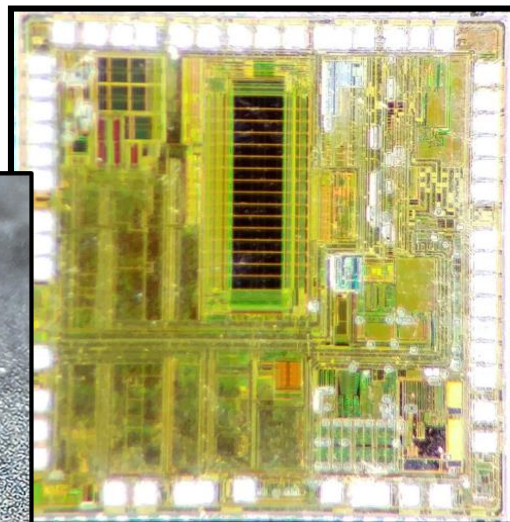
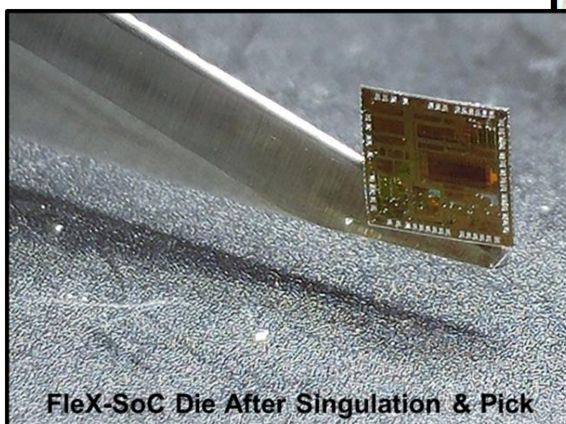
Features:

- Cypress CY8C20XX6A/S
- 8-bit Microcontroller Core
- 1.7 – 5.5V Operating Range
- Low Power, Including 0.1uA Deep Sleep
- **32KB (256Kb) Flash NVM**
- 2KB SRAM
- USB 2.0 – 12Mbs Full-Speed Compliant
- 10-bit Analog-to-Digital Converter
- 2 Analog Comparators
- Low Power Sense Module
- 36 Programmable Input / Output Pins
- 6/12/24MHz Internal Oscillator

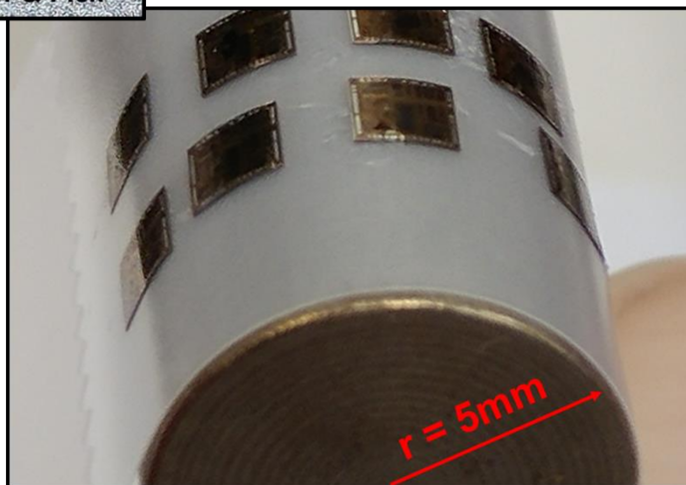
***FleX*-SoC Die**
2.16 x 2.28mm





FleX-SoC Die After Singulation & Pick

RAPID REACTION Technology Office



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FleX Non-Volatile Memory Radius of Curvature Testing

- First demonstration of a flexible, high density non-volatile memory element
  - Data retention demonstrated successfully down to 5mm RoC in both convex and concave directions

FleX Non-Volatile Memory Radius of Curvature Testing

Idrain (A)

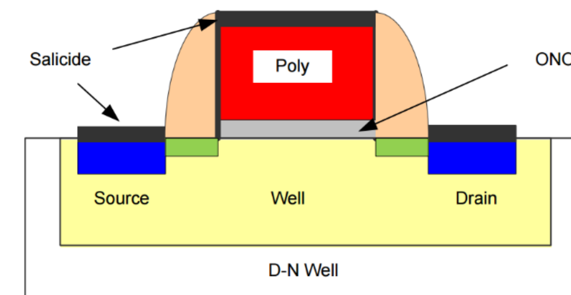
1.0E-04
1.0E-05
1.0E-06
1.0E-07
1.0E-08
1.0E-09
1.0E-10
1.0E-11
1.0E-12

-3.0 -2.0 -1.0 0.0 1.0 2.0 3.0

Vgate (V)

Pass

Pass



- SONOS Erased No RoC W=25u L=25u
- SONOS Erased 40mm RoC W=25u L=25u
- SONOS Erased 20mm RoC W=25u L=25u
- SONOS Erased 10mm RoC W=25u L=25u
- SONOS Erased 5mm RoC W=25u L=25u
- SONOS Erased -40mm RoC W=25u L=25u
- SONOS Erased -20mm RoC W=25u L=25u
- SONOS Erased -10mm RoC W=25u L=25u
- SONOS Erased -5mm RoC W=25u L=25u

- SONOS Programed No RoC W=25u L=25u
- SONOS Programed 40mm RoC W=25u L=25u
- SONOS Programed 20mm RoC W=25u L=25u
- SONOS Programed 10mm RoC W=25u L=25u
- SONOS Programed 5mm RoC W=25u L=25u
- SONOS Programed -40mm RoC W=25u L=25u
- SONOS Programed -20mm RoC W=25u L=25u
- SONOS Programed -10mm RoC W=25u L=25u
- SONOS Programed -5mm RoC W=25u L=25u

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FleX-SoC Flash NVM Data Retention Testing

- Flash NVM high temp data retention passed 500hrs @ 150C
- Flash NVM passed solar irradiance data retention testing at AFRL/RX
  - Oriel solar simulator
  - Air Mass AM 1.5G
  - 100mW cm^2 solar simulated illumination
  - Class B for spectral match, irradiance spatial non-uniformity, and temporal instability
  - 300mW full spectrum
  - Calibrated to a KG-5 filtered Si reference cell
  - Passed 8 hours exposure

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Thank You

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