

# Polymer Enabled Ultra-thin Package solutions for Heterogeneous, package-in-package and embedded ICs

**Doug Hackler**



1. Ultra-thin SoP packaged flexible SOC ICs
2. Ultra-thin die assembly including ACA and ACF
3. SoP in thin packaging
4. New production capacity for ultra-thin IC packaging and FHE assembly

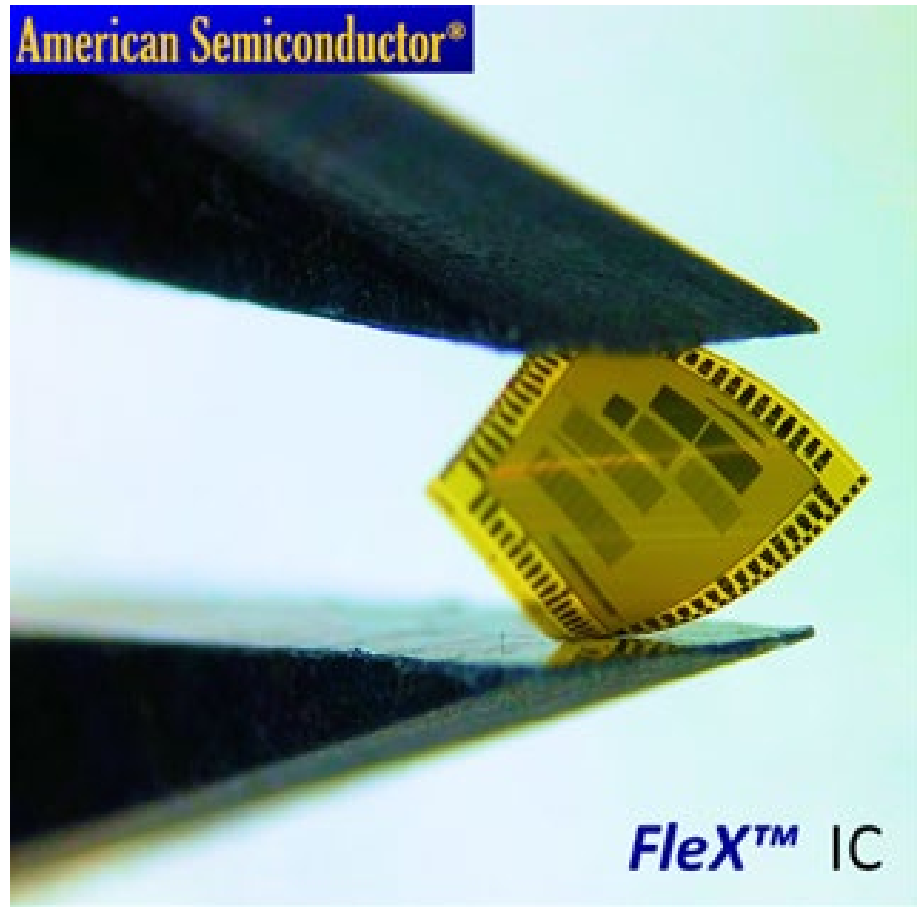


- **Die** – unpackaged ICs. As defined by Dr. “Subu” Iyer, Director of the CHIPS program at UCLA
- **Chips** – packaged ICs, Dr. Iyer 2019 CHIPS Workshop
- **Chip Scale Package (SCP)** – a package that is less than 1.2X the size of the die. Intel 2000, ASI
- **Semiconductor-on-Polymer (SoP)** – WLCSP polyimide encapsulation of ultra-thin die. ASI
- **System-On-Chip (SOC)** – is an IC that integrates all components of an electronic system. They typically include a CPU, memory, input/output ports, secondary storage, analog, mixed-signal, and often RF functions – all on a single microchip of only a few mm<sup>2</sup>. Wikipedia
- **Flexible Circuit Board (FCB)** – an outline of conductive traces bonded on a flexible substrate such as PET, Polyimide, Pyralux<sup>®</sup> Paper, etc. Yun Industrial
- **Flexible Hybrid Electronics (FHE)** – the combination of FCB and high performance components such as SOC. ASI



# Introduction – SoP WLCSP

- SoP (Semiconductor-on-Polymer) WLCSP (Wafer Level Chip Scale Package) process technology
- SoP is a ultra-thin polyimide encapsulation
- SoP enables semiconductor material thicknesses less than possible with bare die
- SoP provides package protection that is not possible with bare die
- SoP CSP improves thin device reliability
- SoP ICs (Flex-ICs) are ultra-thin and can be physically flexible

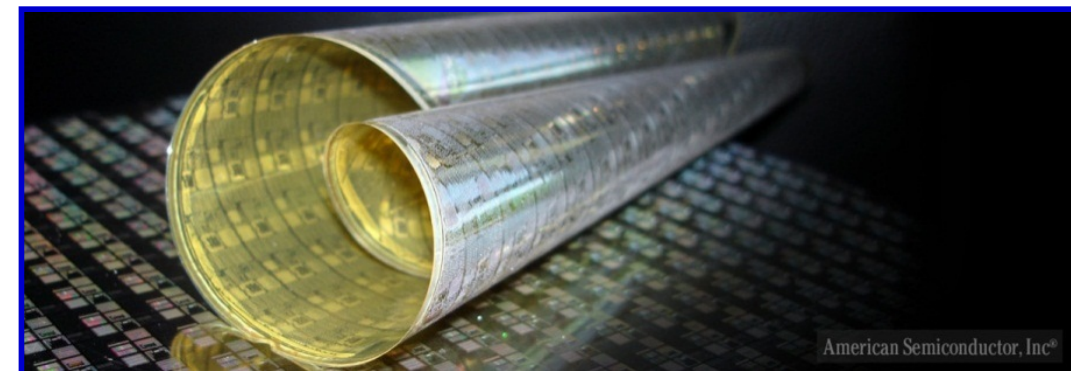


**Flex™ IC**

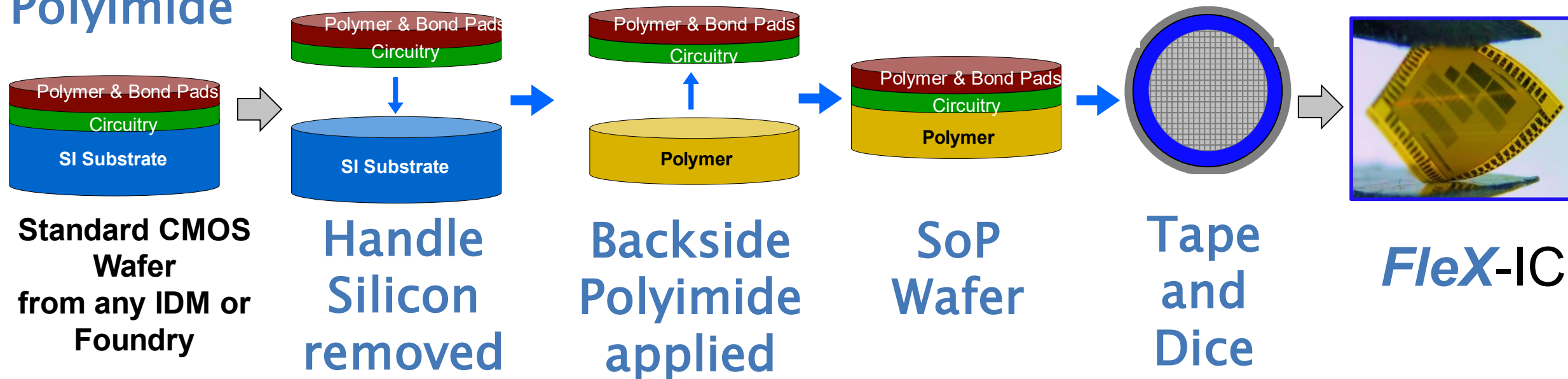
**Semiconductor-on-Polymer**  
**US Patent 9082881**



# Basic SoP WLCSP Process

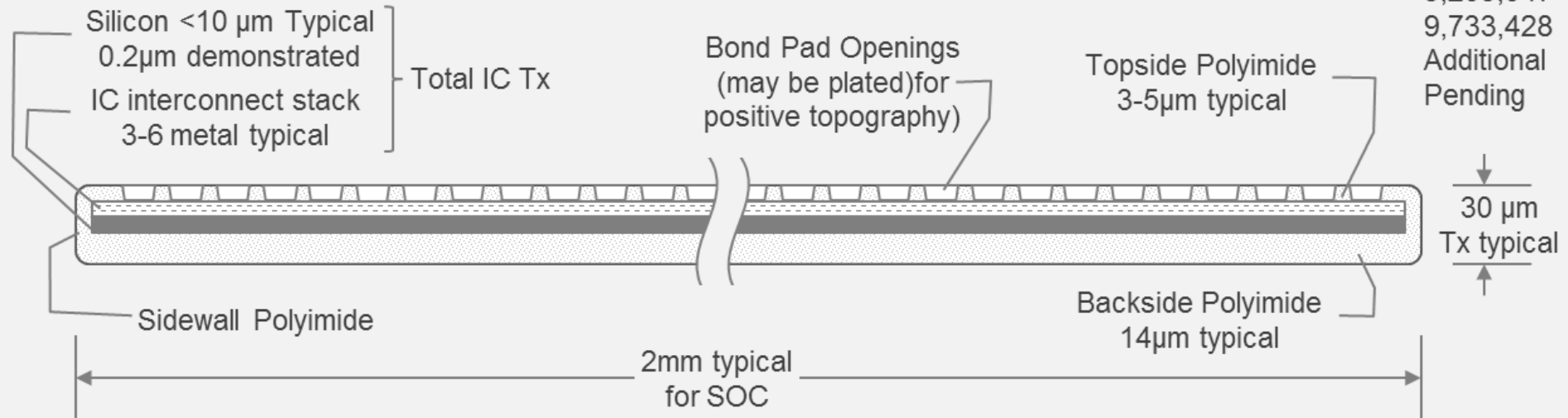


Frontside  
patterned  
Polyimide



# Advanced SoP Chip-Scale-Packaging (ultra-thin)

## *FleX-IC*™



**PATENTS:**  
9,082,881  
9,209,047  
9,733,428  
Additional  
Pending

### NOTES:

- Semiconductor-on-Polymer (SoP) is a wafer scale conversion process technology that results in fully coated ultra-thin wafers.
- SoP restores ultra-thin processed wafer mechanical stability for reliability during dicing, handling, pick & place and application.
- FleX ICs are the singulated devices from SoP processed semiconductor wafers.

**FleX IC characteristics:** Physical flexibility. Surface protection on all sides. Ultra-thin.

**Alternative Descriptions:** Advanced Package Technology (APT), Chip-scale-packaged IC (CSP), Embedded IC package, Ultra-thin Silicon, Wafer Level Package, Flexible IC, Ultra-thin IC, flexible chip

**American Semiconductor**  
Engineering Schematic  
**PROPRIETARY**

**DESCRIPTION:** **Semiconductor on Polymer FleX IC**  
**Physically flexible fully integrated chip-scale-package ultra-thin silicon. Wafer level processing with full polyimide coating.**

**ORIGINATING ENGINEER:**  
D. Hackler  
**NOT TO SCALE**

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# Package Thickness Scaling



| Attribute                  | SOIC-16 (D) <sup>1</sup> | SSOP-16 (DB) <sup>1</sup> | TSSOP-16 (PW) <sup>1</sup> | TVSOP-16 (DGV) <sup>1</sup> | QFN-16 (RGY) <sup>1</sup> | Direct Chip Attach (DCA) <sup>2</sup> | Flex-SoP (SoP) <sup>3</sup> |
|----------------------------|--------------------------|---------------------------|----------------------------|-----------------------------|---------------------------|---------------------------------------|-----------------------------|
| Length, mm                 | 9.90 ±0.10               | 6.20 ±0.30                | 5.00 ±0.10                 | 3.60 ±0.10                  | 4.00 ±0.15                | 2.51                                  | 2.163±0.01                  |
| Width, mm                  | 6.00 ±0.20               | 7.80 ±0.40                | 6.40 ±0.20                 | 6.40 ±0.20                  | 3.50 ±0.15                | 2.51                                  | 2.283±0.01                  |
| Height, Max. mm            | 1.75                     | 2.00                      | 1.20                       | 1.20                        | 1.00                      | .075                                  | 0.025                       |
| Pitch, mm                  | 1.27                     | 0.65                      | 0.65                       | 0.40                        | 0.50                      | RDL                                   | <0.1                        |
| Footprint, mm <sup>2</sup> | 59.40                    | 48.36                     | 32.00                      | 23.04                       | 14.00                     | 6.3                                   | 4.94                        |
| Encapsulated               | Yes                      | Yes                       | Yes                        | Yes                         | Yes                       | No                                    | Yes (PI)                    |
| Weight, g                  | 0.150                    | 0.140                     | 0.062                      | 0.040                       | 0.036                     | ~.0008                                | .00023                      |
| SoP area save, %           | 91.6                     | 89.8                      | 84.6                       | 78.6                        | 64.7                      | NA                                    | –                           |



1. Quad Flatpack No-Lead Logic Packages, TI Application Report SCBA017D – February 2004 Morton, Wright
2. NHS3100, Bumped Die, NXP Product Data Sheet (NFC-SOC)
3. AS\_CY8C20 Flex-SoC Data sheet, American Semiconductor, 2018

| Product     | Description                                                                                                                 | Datasheet Link            |
|-------------|-----------------------------------------------------------------------------------------------------------------------------|---------------------------|
| AS_ADC100x  | FleX-ADC Analog-to-Digital Converter: 8-channels, 8-bits<br><a href="#">ASI (TowerJazz Semiconductor Foundry)</a>           | <a href="#">Datasheet</a> |
| AS_ADC2001  | FleX-ADC Analog-to-Digital Converter with 3 Configurable Op Amps<br><a href="#">ASI (TowerJazz Semiconductor Foundry)</a>   | <a href="#">Datasheet</a> |
| AS_CY820x   | FleX-SoC (System-on-a-Chip) with Capacitive Sense<br>Cypress Semiconductor PSOC® CY8C20XX6A/S                               | <a href="#">Datasheet</a> |
| AS_EM4325P  | FleX-RFID 900MHz RFID Communication Temperature Monitoring IC<br><a href="#">EM Microelectronics</a> EM4325                 | <a href="#">Datasheet</a> |
| AS_NHS3100P | FleX-NFC Temp Logging IC with ARM® Cortex-M0+<br><a href="#">NXP Semiconductor</a> NTAG SmartSensor with Temperature Sensor | <a href="#">Datasheet</a> |
| AS_AM39513  | FleX-NFC Sensor Tag IC<br><a href="#">AMS (Austria Microsystems)</a> AS39513 NFC Sensor Tag IC                              | In Development            |
| AS_OPA4002  | FleX-OpAmp Quad High Performance Op Amps<br><a href="#">ASI (TowerJazz Semiconductor Foundry)</a>                           | <a href="#">Datasheet</a> |
| AS_OPA4003  | FleX-OpAmp Quad Output Transconductance Op Amps<br><a href="#">ASI (TowerJazz Semiconductor Foundry)</a>                    | <a href="#">Datasheet</a> |
| AS_CY8C424  | FleX-BLE Bluetooth Low Energy with ARM® Cortex-M0<br>Cypress Semiconductor PSOC® 4 Bluetooth LE                             | In Development            |
| AS_NRF51822 | FleX-BLE Bluetooth Low Energy with ARM® Cortex-M0<br><a href="#">Nordic Semiconductor</a> nRF51822                          | <a href="#">Datasheet</a> |

**SoP CSP is available for all customer specified device types on request**



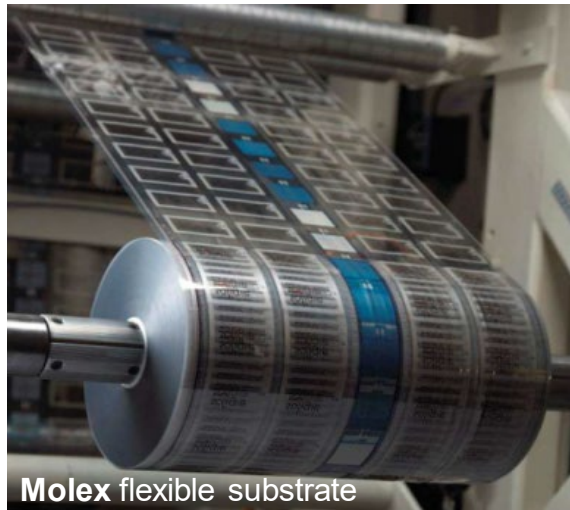


# Flexible Hybrid Electronics (FHE)

Hybrid systems provide a flexible product solution that combines the best of silicon based components and flexible organic and printed electronics

## Flexible Circuit Board (FCB)

Large Format, Thin

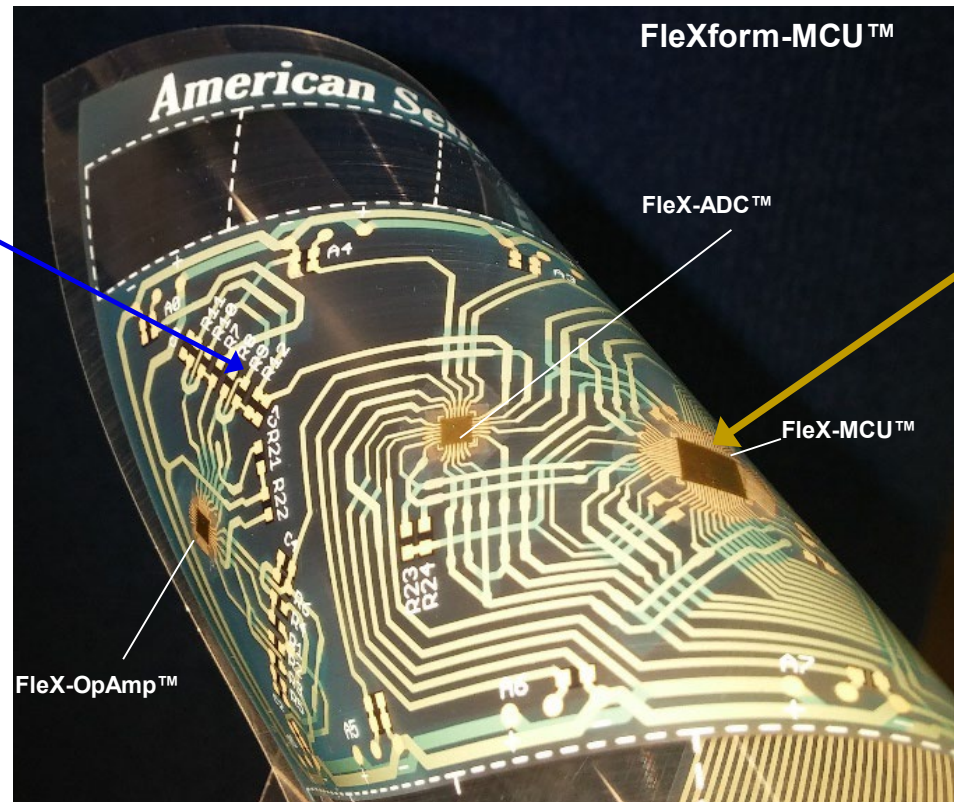


- Sensors
- Interconnects
- Antennas
- Displays



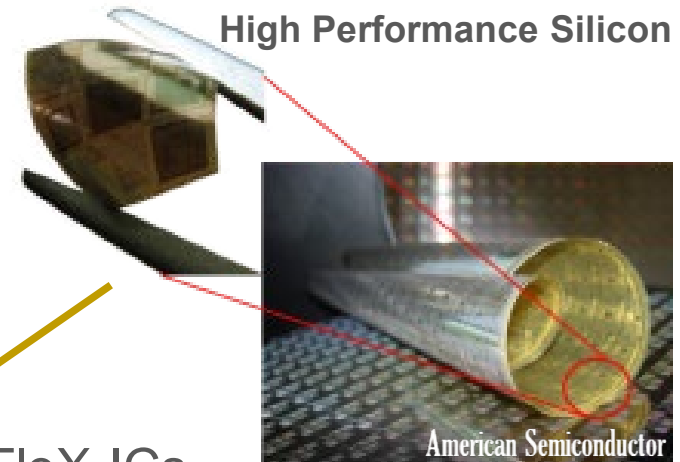
## Flexible Hybrid Electronic (FHE) System

Combination of printed materials and high performance components to create a new class – “flexible electronics.”



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## Flexible *FleX*-ICs High Performance Silicon

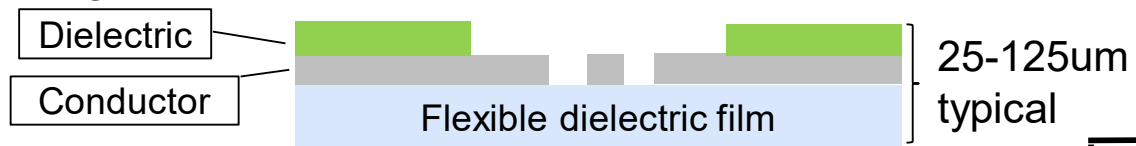


## FleX-ICs

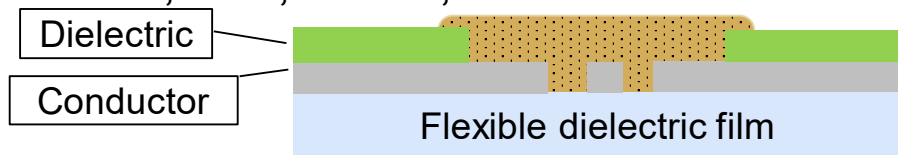
- Sensor Signal Processing
- Data Processing
- Data Storage
- Communications
- Low Cost, High Performance
- ***FleX*** is a Semiconductor-on-Polymer (SoP) conversion process that results in **chip scale packaging**.

# Flex-on-flex™ Direct Interconnect Ultra-thin Die Assembly

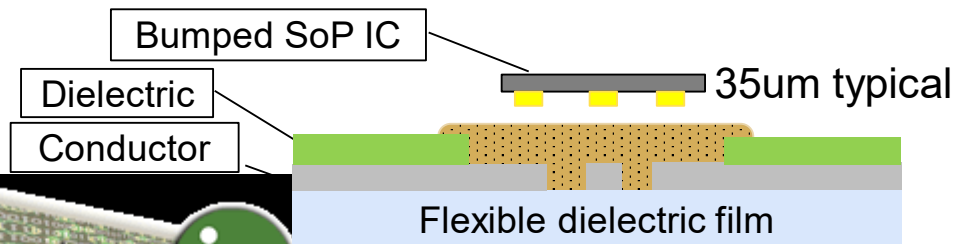
## 1. Circuit on flexible circuit board (FCB) Ag-on-PET, Cu-on-PI, etc.



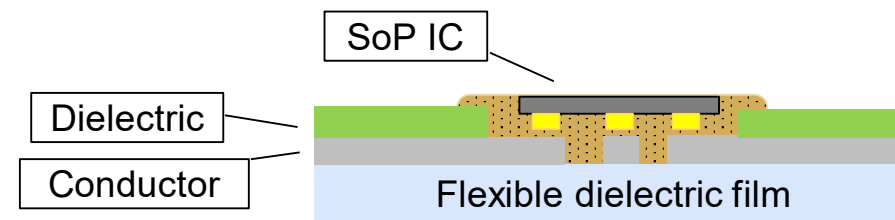
## 2. Add connective material ACA, ACF, Solder, etc.



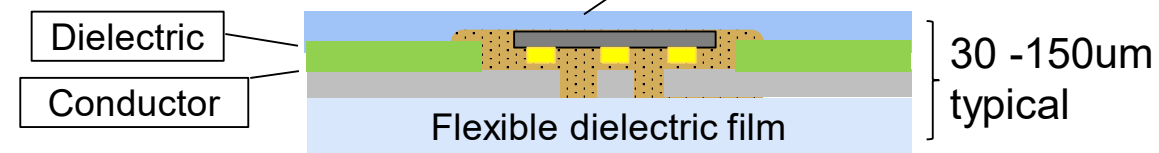
## 3. Flip-chip SoP IC placement 2-100 pad typical at 100um pitch or greater



## 4. Flip-chip SoP IC Bonding 2-100 pad typical at 100um pitch or greater



## 5. Cover Layer applied Coat or laminate



**FHE System**  
**Ultra-thin, physically flexible.**

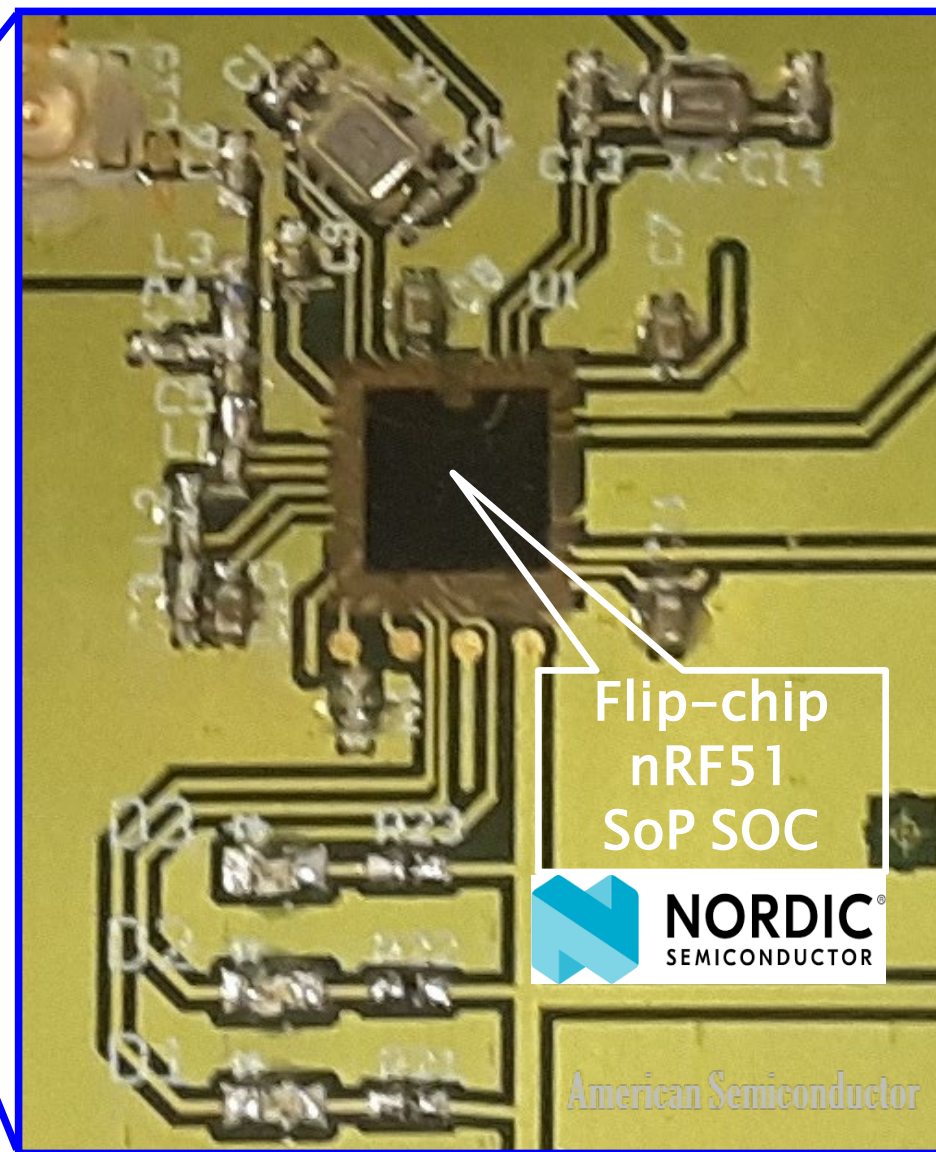
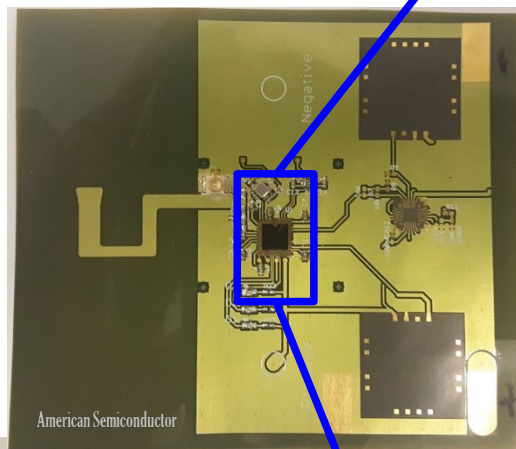
## 6. Ready for conformal surface mounting, molding, etc.





## **Bluetooth Development Kit**

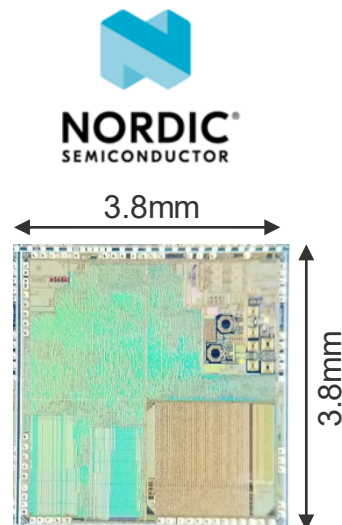
- Flip-Chip ACA (DI)
- SoP SOC
- 64 pads
- 100um pitch (50/50)
- Chips on flex
- Flip chip
- Quad OPAMP
- XO
- Caps
- Resistors



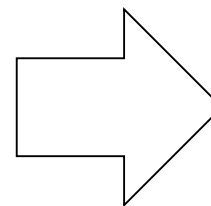
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## Ultra-thin Packaging

- PoP
- Interposer
- FHE
- Anti-cracking
- Sidewall protection
- Anti-edge chipping



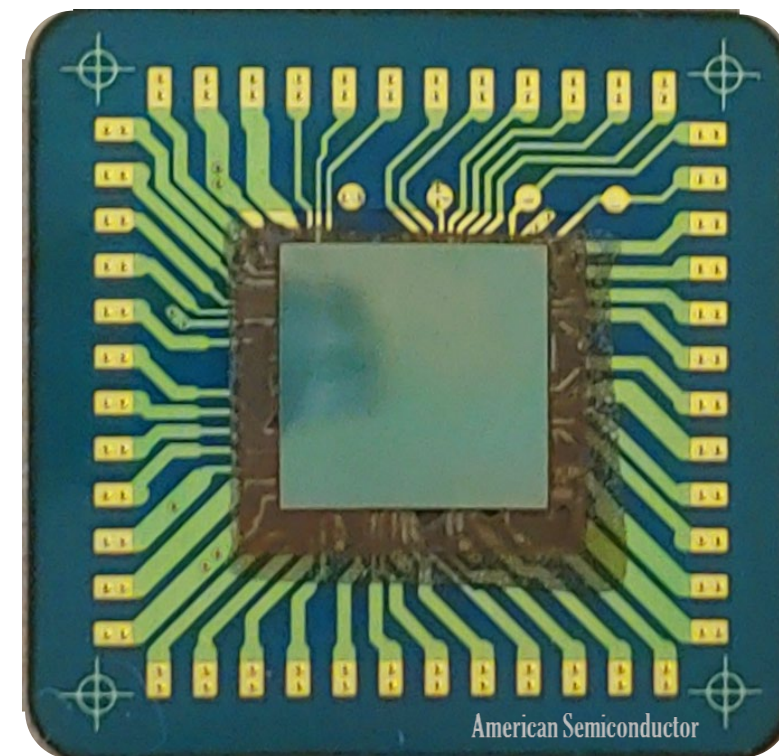
**DI Fan-out**



### AS\_NRF51 SoP BLE IC

BLE: 2.4GHz Bluetooth Low Energy, 32-bit ARM Cortex-M0, 256kB Flash, 32kB SRAM, ADC, Temp Sensor  
Package Thickness: 35um  
Min. Pad Pitch: 100um

Ultra-thin  **Bluetooth**



### BLE FHE Assembly

Flipchip SoP DI (Direct Interconnect)  
SoP BLE (35um)  
Flex Inlay (125um)  
Total Tx = ~160um



# Next Generation DI

## DI Assembly TODAY

Flip-chip

64 Pads

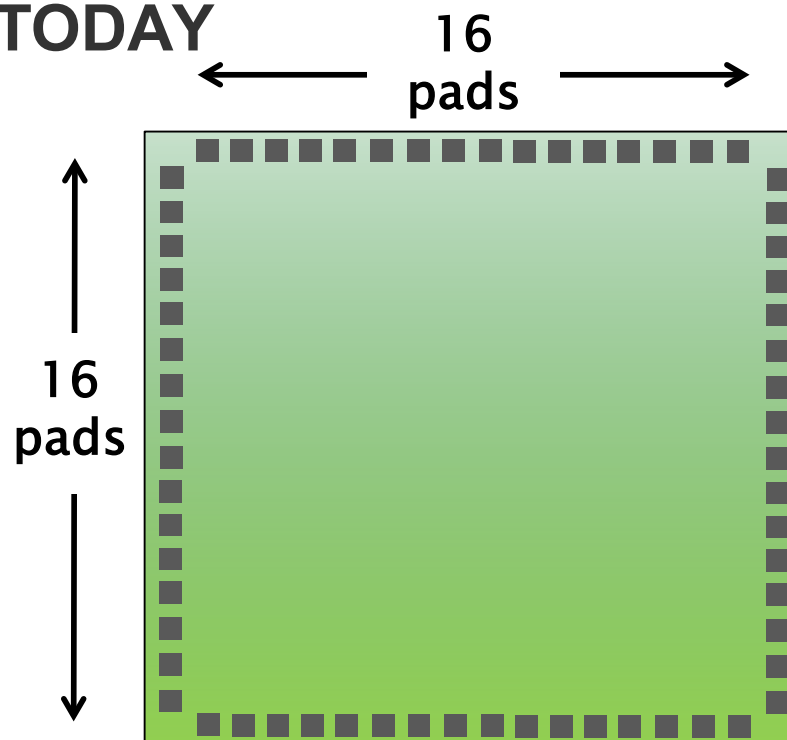
100um Pitch

50um Feature

50um Space

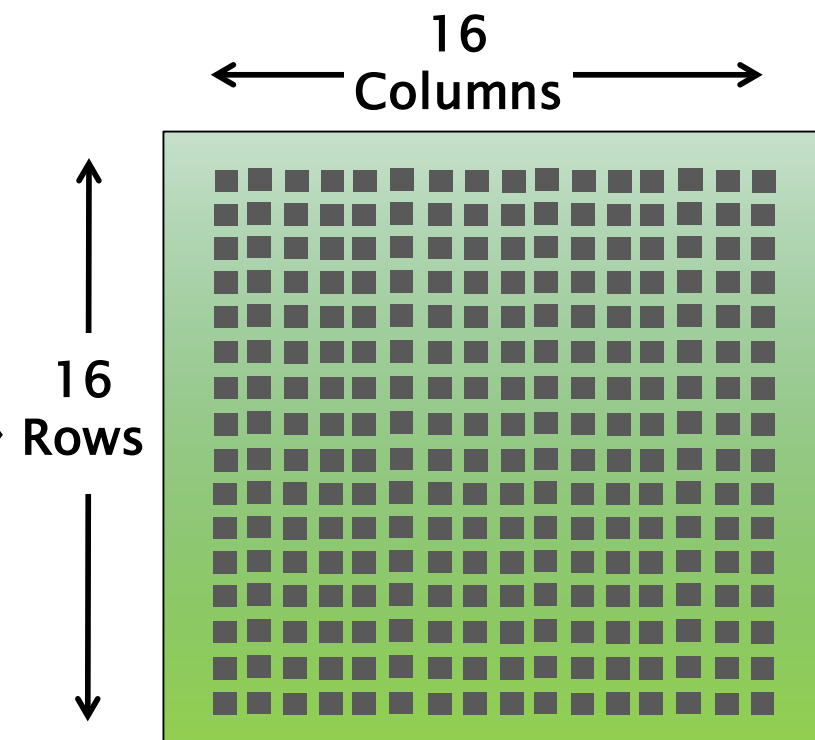
ACA

Flexible



$4 \times 16 = 64$  pads

**Current FCB Capability  
demonstrates feasibility  
for high density DI Fan-In**



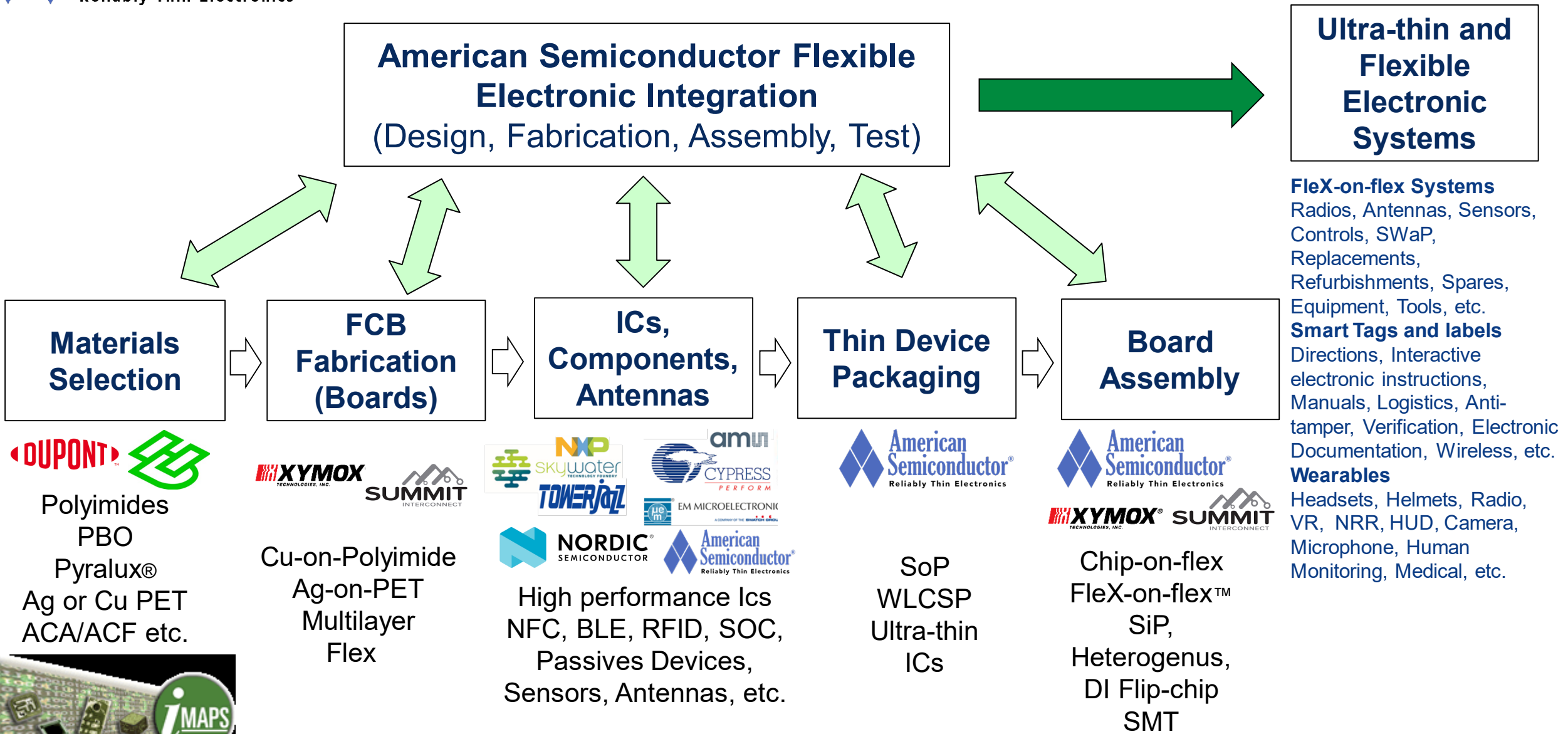
$16 \times 16 = 256$  pads

**DI FCB Fan-In  
Development**



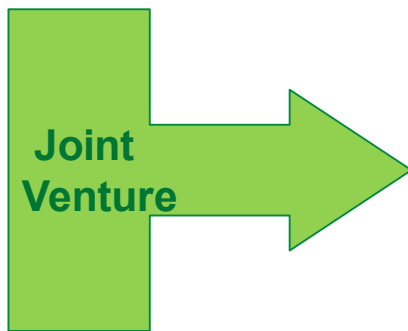


# ASI Thinnerization Eco System

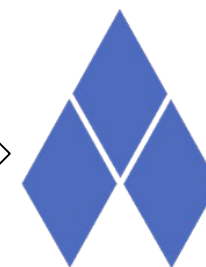
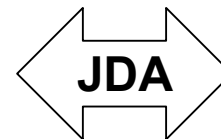




# New FHE and SOC Production Capacity



**HD Microsystems™**  
An Enterprise of Hitachi Chemical and DuPont Electronics



**American Semiconductor®**  
Reliably Thin Electronics



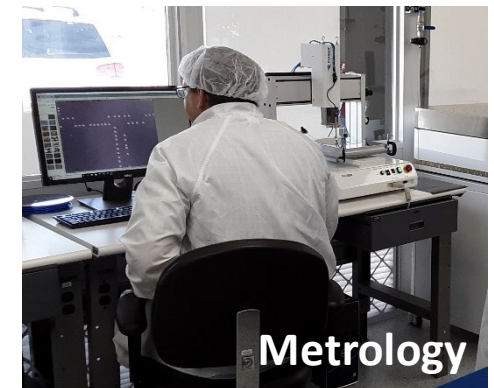
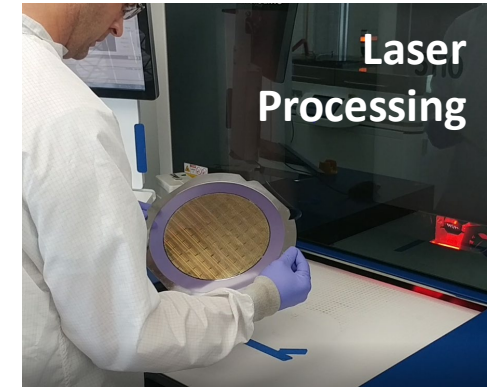
- HD Microsystems is the world market share leader for semiconductor polyimide materials
- American Semiconductor is a technology leader in ultra-thin IC advanced packaging and assembly
- In February 2019, HD Microsystems and American Semiconductor announced a joint development agreement to establish production for Semiconductor-on-Polymer WLCSP.



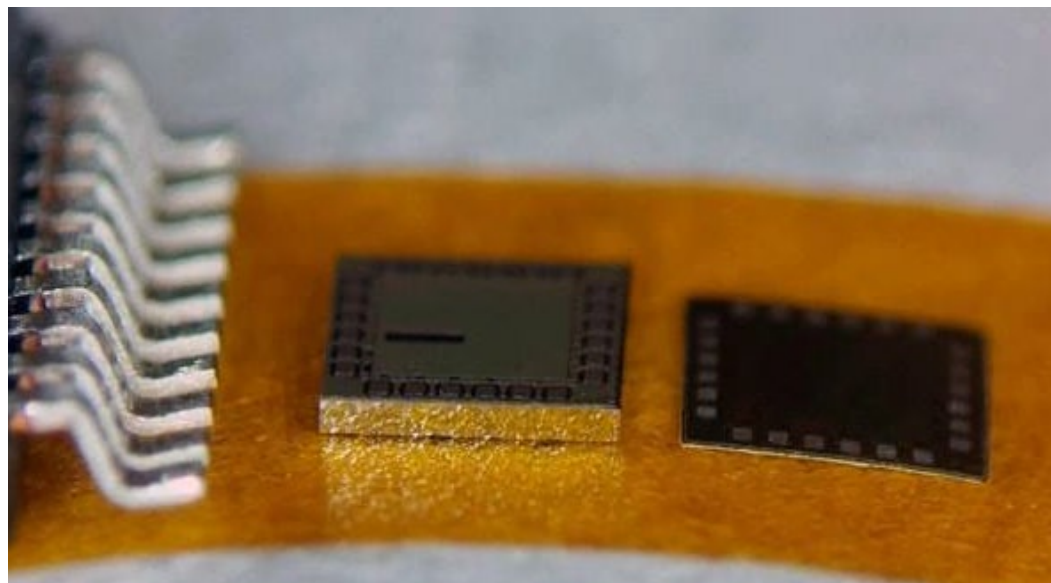
# The world's first volume production facility for Flex™ Semiconductor-on-Polymer™ (SoP) Chip Scale Packaging (CSP)



OSAT for CSP, Assembly & Test



This is how die thickness scaling looks in real life:



SOIC

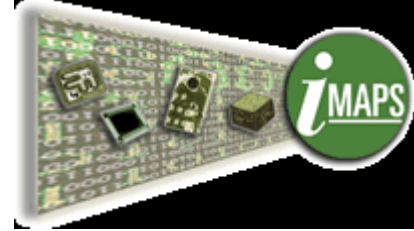
Bare Die

Flex SoP CSP IC

American Semiconductor produces  
the thinnest ICs in the world







# Thank You

®