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Reliably Thin Electronics

Advanced FHE Bend, Twist Testing and Standardization

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semi FLEX
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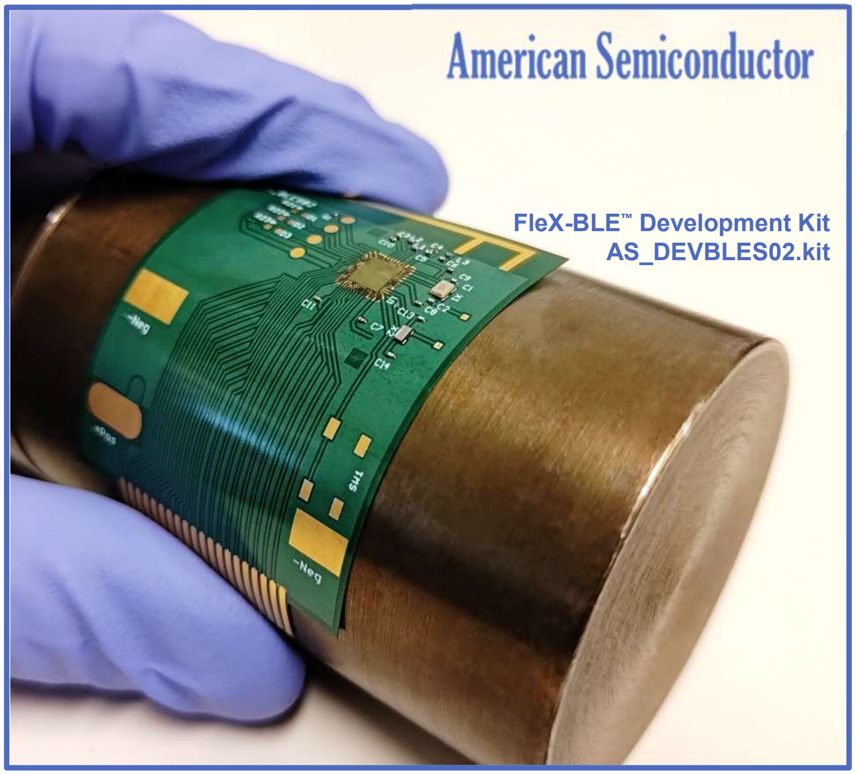
An Evolution in Packaging

- For decades, the microelectronics industry has been pushing towards ever thinner silicon, enabling smaller package sizes and higher die density using traditional rigid packaging
- More recently, the trend towards thinner devices has shifted to include flexible electronics and packaging components
- Flexible Hybrid Electronic (FHE) systems
  - Incorporate both rigid and flex components in a single package
  - Offer more compact, efficient, and lower cost packaging
  - Conformal form factors invite novel applications
    - Medical implants for rapid diagnostics and drug delivery
    - Wearable electronics and human-machine interfaces
    - Smart labels
    - And many more…



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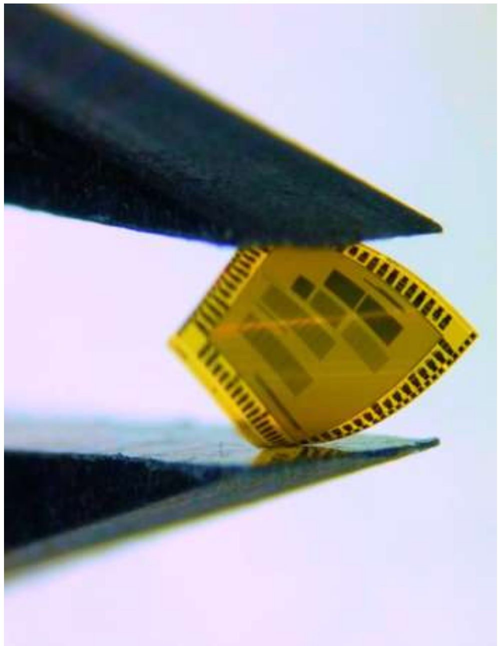
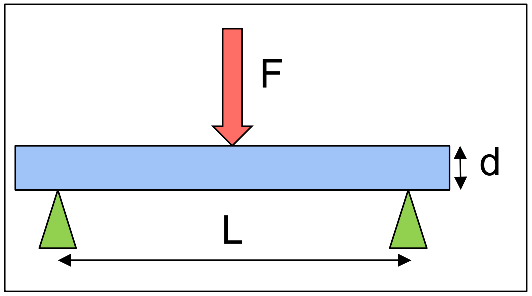
Evolving Electronics Testing

- To enable these new capabilities, flexible packaging is constructed with leading-edge microelectronics and innovative materials
  - Ultra-thin silicon ICs
  - Printed electronics
  - Novel interconnect materials
  - Devices that are designed to conform, bend, and even stretch during use
- But are these flexible microelectronics reliable?
- Do they perform the same as their rigid counterparts?
- Answering these questions requires an evolution in electronic testing systems to evaluate new realms of package performance
  - New test methods and robotic systems are evolving quickly to evaluate flexible systems
  - Environmental exposure testing is being redefined to evaluate reliability in novel environments
    - Ex. Saline saturation tests for medical implants
  - New expectations are being imposed on traditional electronic packaging materials
    - Ex. Stretchable conductors, non-rigid interconnects, biocompatible adhesives, etc.

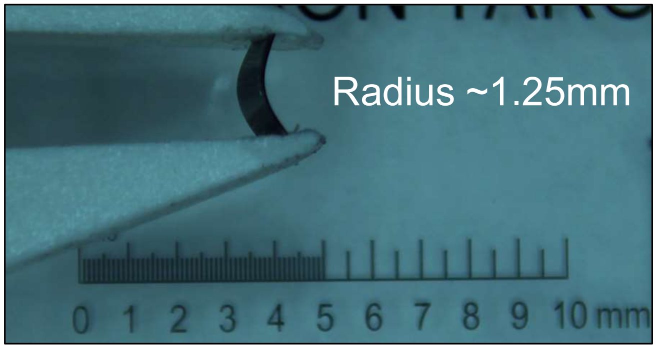


Defining the Right Tests

- This new realm of testing requires alternative approaches to evaluating device performance
- As an example, silicon strength is a key indicator of how an IC will survive package assembly and end use
  - Silicon die strength is typically calculated on a theory which assumes a rigid component being pushed to point of fracture (ex. 3-point bend test)
  - However, test results become questionable as die become thinner and less rigid
    - Semi-rigid die (10-100um) can yield incorrect or misleading results due to incorrect calculations (non-rigid beam)
    - For very flexible die (1-10um), die push through the fixture without breaking, resulting in no usable strength data
- Alternative tests for evaluating flexible die need to focus on characteristics like durability of the die, as opposed to simply the strength of the silicon
- Similar challenges exist for most FHE system reliability and material characterizations



3-Point Bend Test



Adapted from: semi
The Evolution of Electronics Workshop (Jan 2023)

FHE Reliability Test Procedures

- American Semiconductor began focusing on FHE reliability test methods in 2016, while under contract with AFRL

Initial ASI FHE Reliability Tests

Test	Conditions	ASI Procedure	References
High Temp Life	125°C	ASI TEST008	ISO 10373-1; JESD22-A108
Low Temp Life	-25°C	ASI TEST009	JESD22-A108
ESD	HBM and/or CDM	ASI TEST010	ANSI-ESDA-JEDEC_JS-001 & JS-002
Static Radius of Curvature	Concave/Convex Bend	ASI TEST003	ASTM D522-93a; ISO 10373-1; ISO 7816
Dynamic Radius of Curvature	Concave/Convex Bend	ASI TEST005	ASTM D522-93a; ISO 10373-1; ISO 7816
Axial Torsion	Twist Test	ASI TEST006	ISO 10373-1; ISO 7816
SEM Inspection	Post SoP Conversion	ASI TEST007	MIL-STD-883: M2018
Data Retention	150°C, non-biased	ASI TEST009	JESD22-A117; JESD-A103

This work sponsored in part by the Air Force Research Laboratory AFRL/RX

- Since 2016, ASI has continued to develop and advance FHE system characterization methods

New 2020 Tests

- Temperature-humidity-bias (THB 85/85) (ref. JESD22-A101)
- HAST (ref. JESD22-A110)
- Low Temp (ref. JEDEC22-A119)

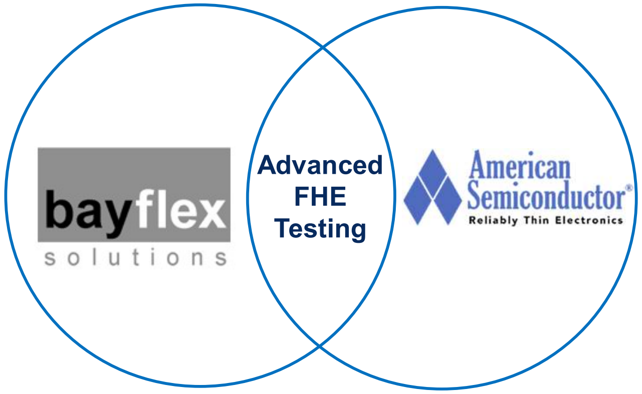
In Development

- Thermal cycling
- Others?

- In 2023, ASI entered a JDA with Bayflex/YUASA to combine our experience in FHE reliability with YUASA's advanced tester and robotics design

American Semiconductor & Bayflex/YUASA

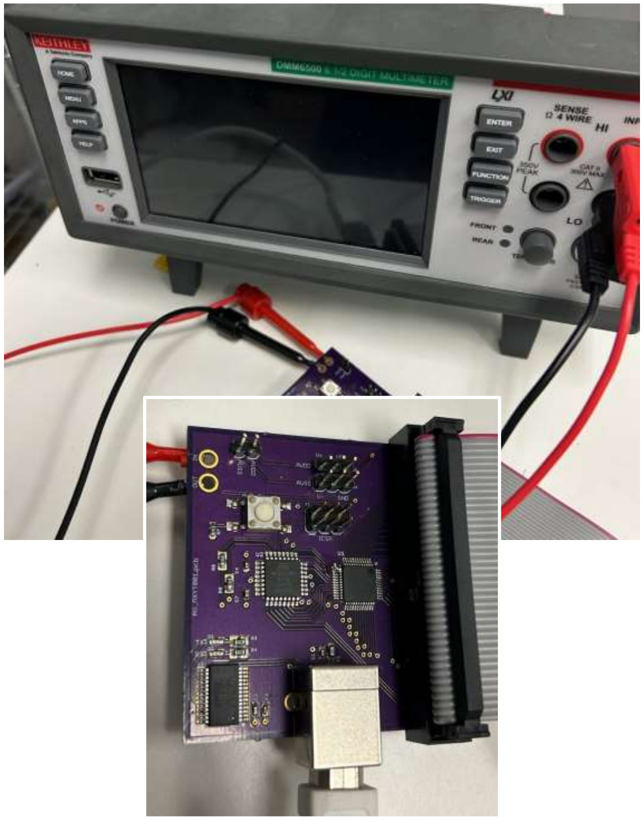
- ASI and Bayflex are collaborating to establish advanced FHE reliability and material characterization test systems
  - Forming methodologies that can be universally adopted across the industry
- Equipment development efforts:
  - Mechanical design: Isolate targeted axis of motion
  - Sample mounting: Universal and repeatable component fixturing
  - Electrical connections:
    - Improved YUASA robot/tester interface expands options for a broader range of test systems
    - Capable of in-situ biasing and data collection
  - Testing efficiency: Batch processing, quick sample swap, etc.
  - Environmental: Temp cycling, humidity, etc.
- Testing parameters:
  - Flexure direction, amplitude, flex rates, and cycle counts
  - Test coupon design rules to keep focus on critical components



10k Cycle RoC Endurance Comparison

- ASI recently performed a side-by-side evaluation between ASI’s home-built system and YUASA radius of curvature (RoC) tester
  - FHE performance was determined by monitoring electrical continuity
    - Resistance of up to 17 circuits measured using digital multimeter
    - Resistance was measured every 10 cycles
  - FHE coupon:
    - ASI’s 10um SoP-TM© test die flip-chip attached with ACA to FCB
  - Each coupon was flexed up to 10k cycles
  - Bend radii of 15mm, 10mm, and 5mm were evaluated
- Results of the side-by-side evaluation indicate both systems demonstrate
  - Equivalent number of cycles to failure
  - Similar failure modes
  - Similar pin location failures
- ASI has validated YUASA system generates equivalent data and plans to continue system development, including harsh environments

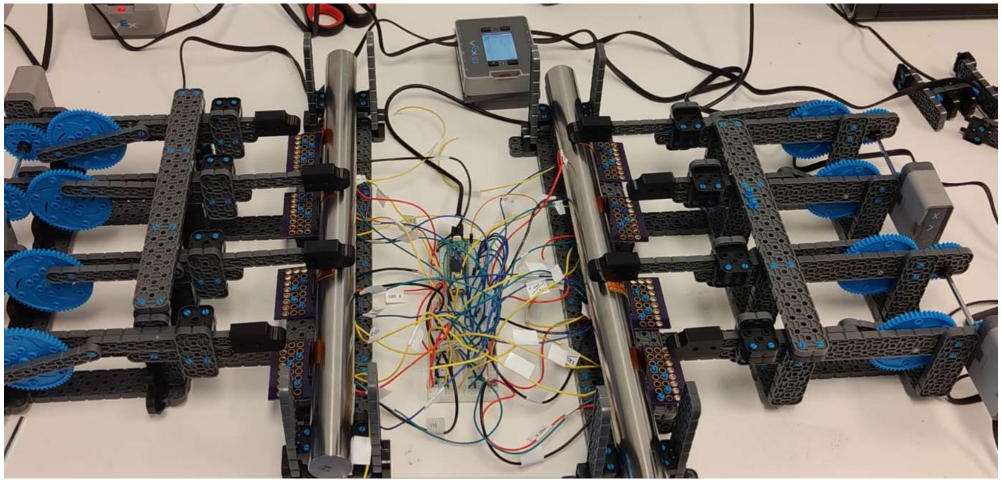
ASI Robot-to-Test Interface



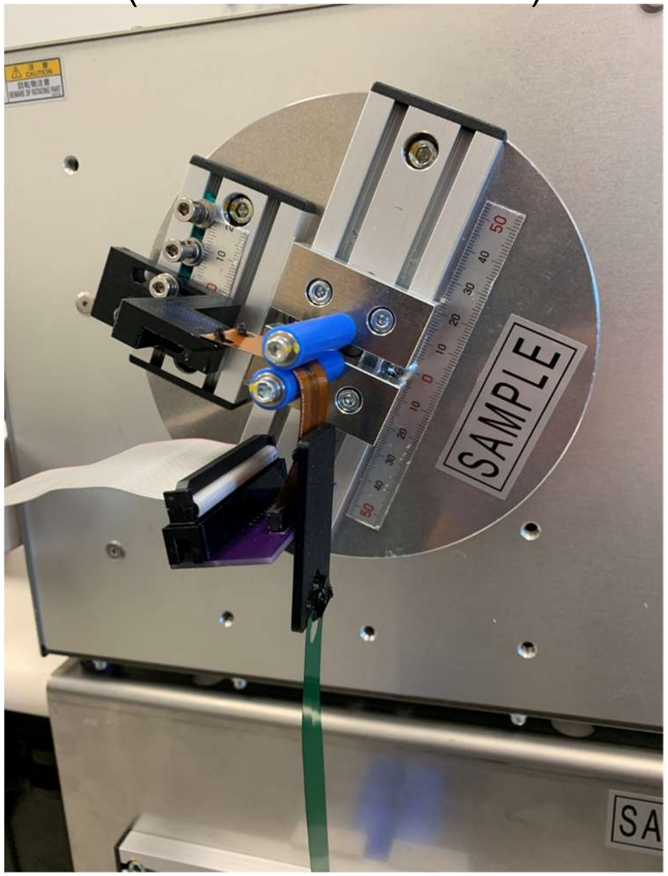
Radius of Curvature (Bend) Endurance Testing

- YUASA system
  - Tidy, compact system
  - Programmable movement with precise and smooth bending motion
  - Sampling trigger to collect incremental in-situ data
  - Quick sample swap
  - ASI has incorporated interconnect capability for simultaneous multi-channel data collection
  - Currently not able to simultaneously evaluate multiple coupons

ASI RoC Endurance Tester



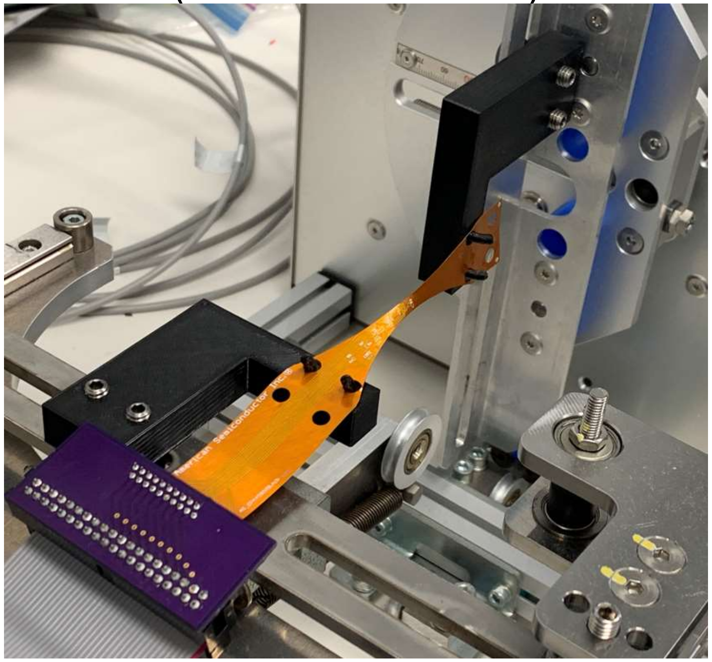
YUASA Endurance Tester
(with 5mm RoC Fixture)



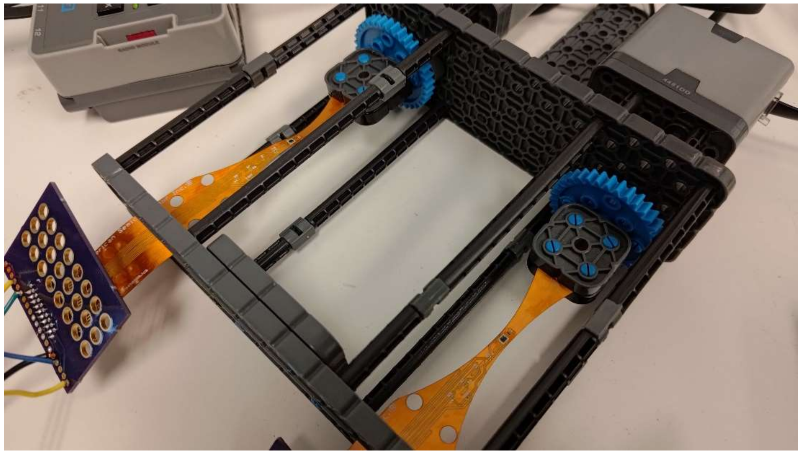
Torsion (or Twist) Endurance Testing

- YUASA system
  - Interchangeable test fixtures to allow different tests to be performed with the same base system
  - Constant tension applied to coupon as sample twists and flexes

YUASA Endurance Tester
(with Torsion Fixture)

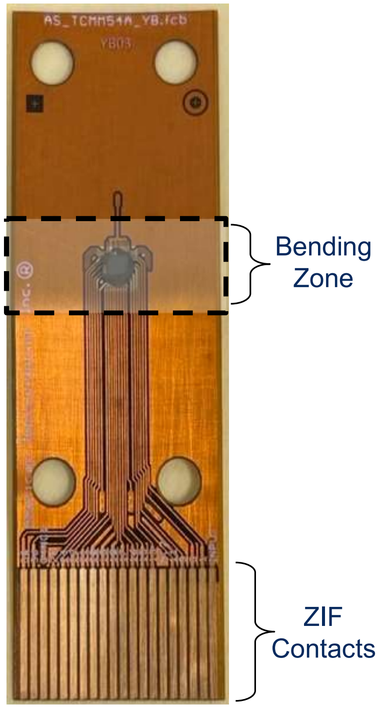


ASI Torsion Endurance Tester



Current Efforts in FHE Testing Development

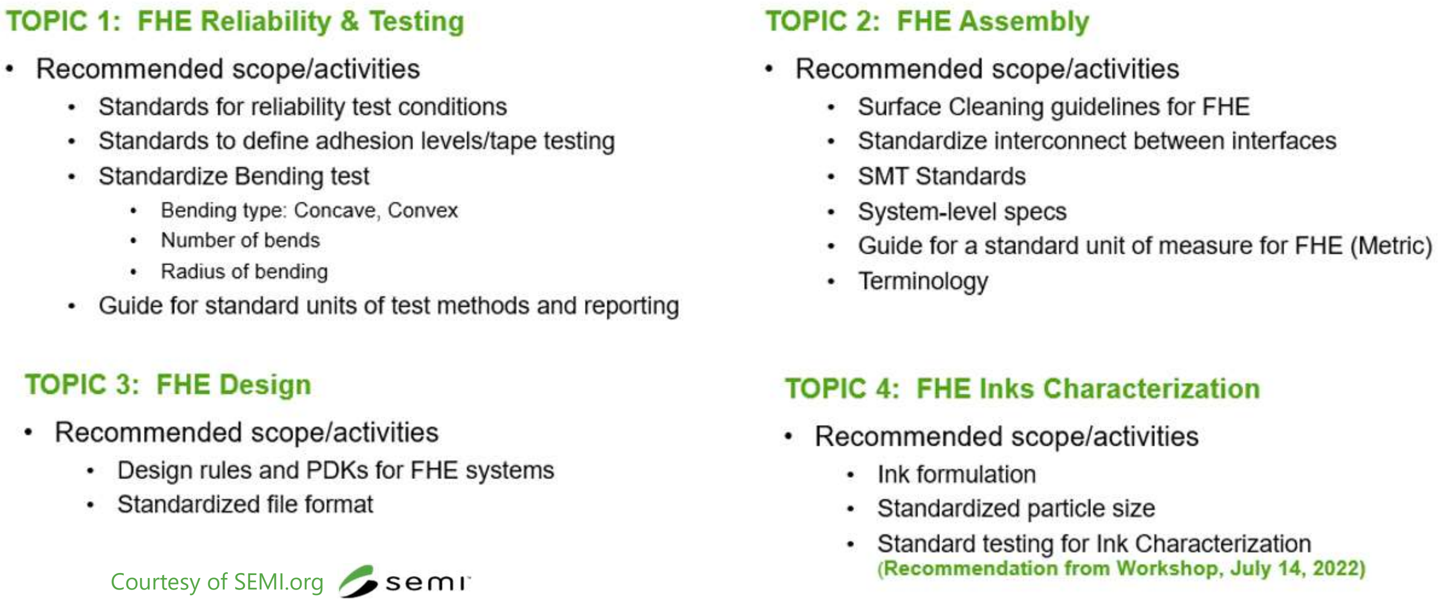
- Test coupon design optimization
  - Layout improvements to prevent flex testing from affecting passive components
  - Improved line/space sizing control
- Continue equipment improvements
  - Data collection advancements
    - Multi-channel robot/tester interface to expand types of data which can be monitored
    - Configurable data collection trigger points (bend angle, cycle count, fixed time, etc.)
    - Automated notifications of test status
  - Fixturing to evaluate multiple coupons
  - Environmental testing options (temperature and humidity chambers)
- Working with SEMI collaborators to establish industry-wide standards for FHE reliability and material characterization



ASI RoC Test Coupon

SEMI FHE Standards Activity

- Efforts are underway in the formation of the North America Chapter of the FHE Standards Technical Committee
  - Basic work groups have already been formed to discuss key FHE standardization efforts
  - More participation from industry and academia is needed
- Anyone who is interested in contributing is encouraged to reach out to the SEMI Standards group and get involved



TOPIC 1: FHE Reliability & Testing

- Recommended scope/activities
  - Standards for reliability test conditions
  - Standards to define adhesion levels/tape testing
  - Standardize Bending test
    - Bending type: Concave, Convex
    - Number of bends
    - Radius of bending
  - Guide for standard units of test methods and reporting

TOPIC 2: FHE Assembly

- Recommended scope/activities
  - Surface Cleaning guidelines for FHE
  - Standardize interconnect between interfaces
  - SMT Standards
  - System-level specs
  - Guide for a standard unit of measure for FHE (Metric)
  - Terminology

TOPIC 3: FHE Design

- Recommended scope/activities
  - Design rules and PDKs for FHE systems
  - Standardized file format

TOPIC 4: FHE Inks Characterization

- Recommended scope/activities
  - Ink formulation
  - Standardized particle size
  - Standard testing for Ink Characterization

(Recommendation from Workshop, July 14, 2022)

Courtesy of SEMI.org semi

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Thank You

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