NINETEENTH ANNUAL

BiTS™

Burn-in & Test Strategies Workshop

March 4 - 7, 2018

Hilton Phoenix / Mesa Hotel
Mesa, Arizona

Archive

COPYRIGHT NOTICE

www.bitsworkshop.org

Optimization Design and Analysis of Polyimide Multilayer Test Interposer for BGA Socket with 3D MEMS Probe Contact

Tae-Kyun Kim, Yong-Ho Cho, Sang-Young Lee

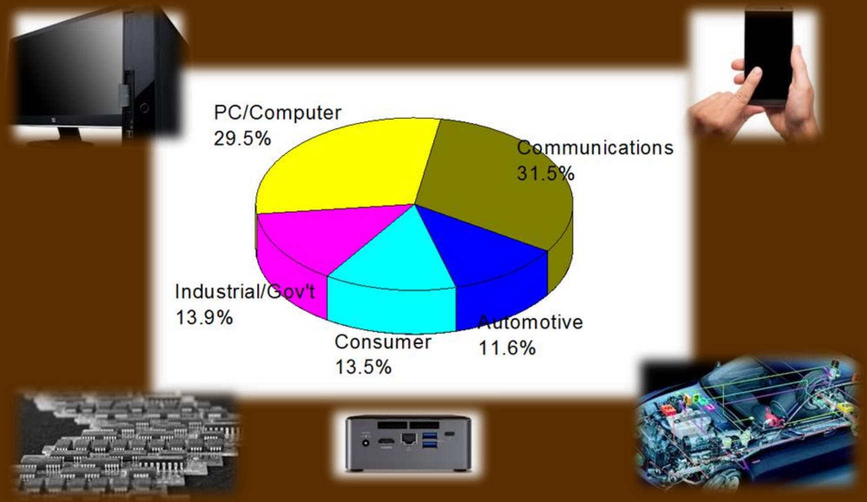
Microfriend Inc.

BiTS Workshop
March 4 - 7, 2018

Contents

- Introduction
- Design Concept of the Test Interposer System
- Signal / Power Integrity Analysis and Verification for Test Interposer System
- Summary

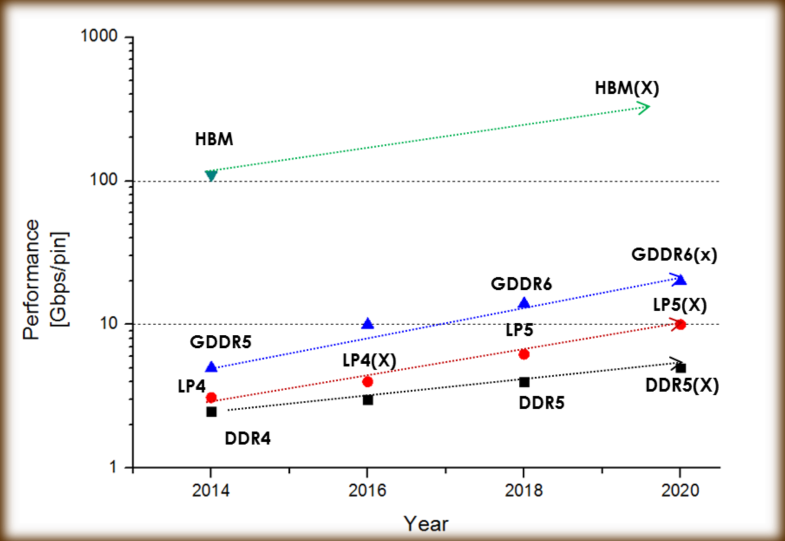
Increasing Market of High Bandwidth Systems



- Increasing the Data Rate of High Performance Device
- Testing Technologies become difficult to approach the Target Specifications

2016 Total Global Semiconductor Market $339 Billion
Source : World Semiconductor Trade Statistics (WSTS, 2016)
Percent of Semiconductor Demand, by END Use

Memory Technology Trends for High Bandwidth



Source : ISCA2016, Samsung Memory Technical Trend

- Technical Trends of Data Bandwidth for Memory
- Difficult to approach the Target Specifications
- Demand for Power Efficiency (Low Power Consumption)

Signal and Power Integrity Problems

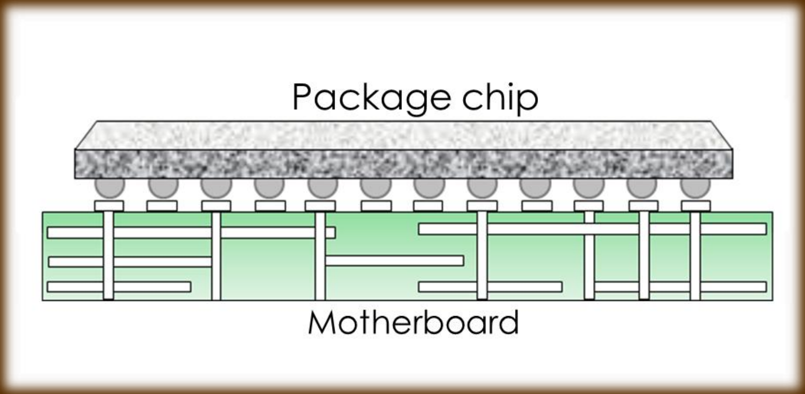


Fig. IC Package Test

- Increasing Signal Integrity Issues Crosstalk, Jitter, Skew, Eye-diagram, Inter-symbol Interference (ISI)
- Reducing / Shrinking Main Board Size and no room for Monitoring Data Signal on Motherboard
- Needs to Test and Analyze for IC Packages before Ball Soldering
- Finding new Testing Method of Packages without Physical Damage

➔ Proposing Test Interposer Systems (Reusability and Accessibility)

Constriction of Design Test Interposer

- Test Interposer material is flexible and bended by nearly 90 degree.
  - ✓ There are many components close to contact pads on Motherboard.
- Multilayer Test Interposer is designed with impedance matching using polyimide.
  - ✓ Signal : Single Ended 50Ω±10%, Differential Pair 100Ω±10%
  - ✓ Layers : Signal1 / Ground (Mesh or Plane) / Signal2 / Power (Mesh or Plane)
- Signal Isolation is very important for high bandwidth.
  - ✓ Adopting Coaxial Contact Probes to prevent from Crosstalk for Data Signals
  - ✓ Designing Circuit Trace with 3W rule on Test Interposer

➔ Proposed for Test Interposer System using Coaxial Socket and 3D MEMS Probes

Concept Design of Test Interposer System

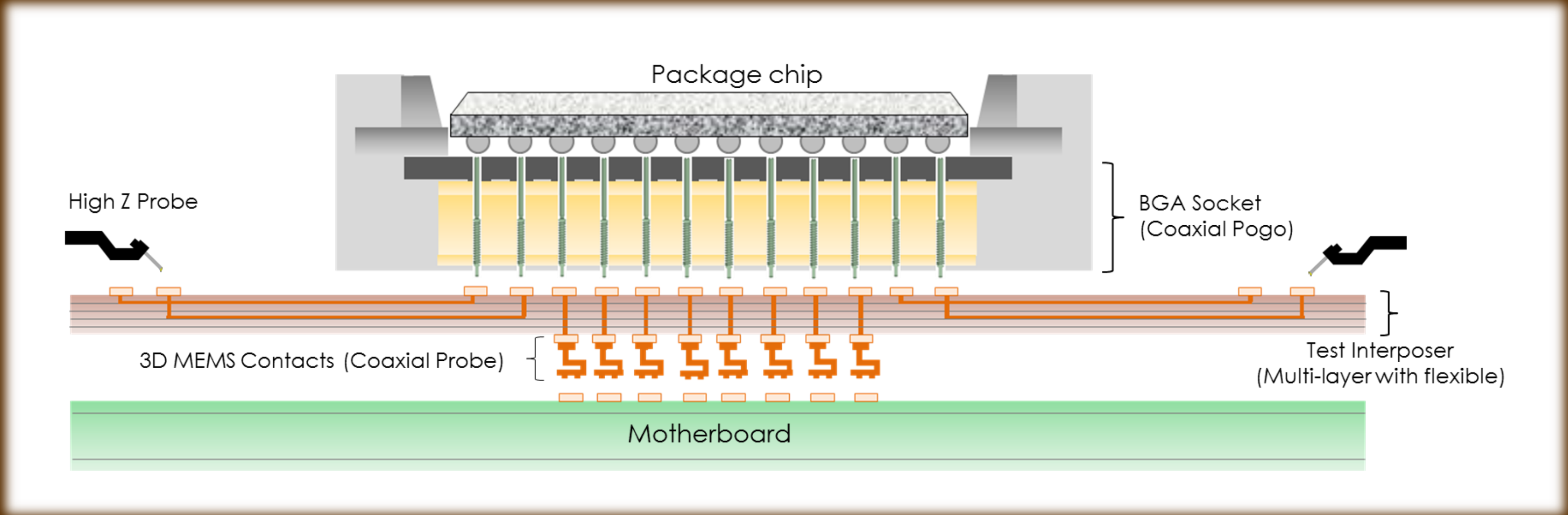


Fig. System consists of Coaxial BGA Socket and 3D MEMS Probes Contact on Test Interposer

Design Considerations for Test Interposer

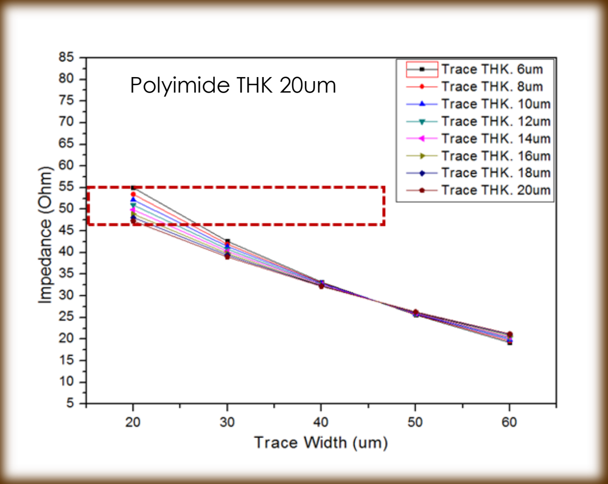


Fig. Impedance Analysis for Circuit Trace Width and THK. with Polyimide thin film thickness 20um

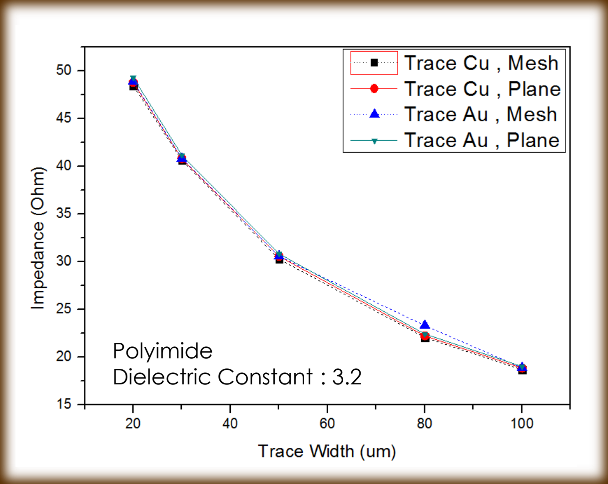
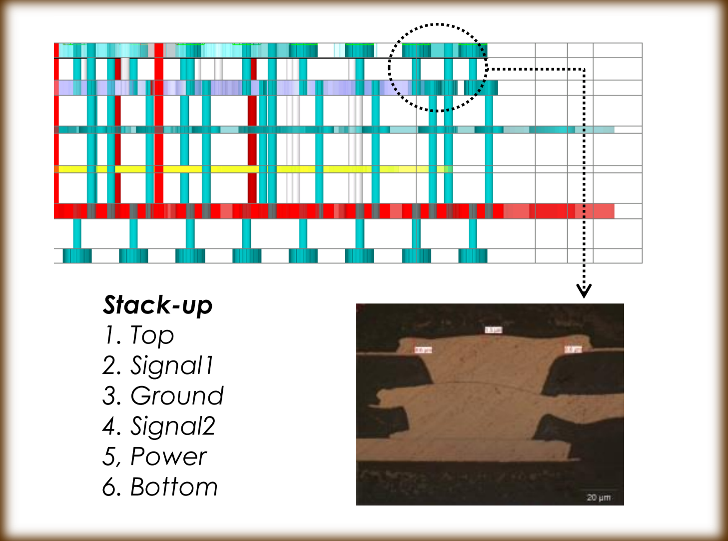


Fig. Impedance Analysis for Materials Copper (Cu) and Gold (Au) with GND type (Mesh or Plane)

Design Considerations for Test Interposer

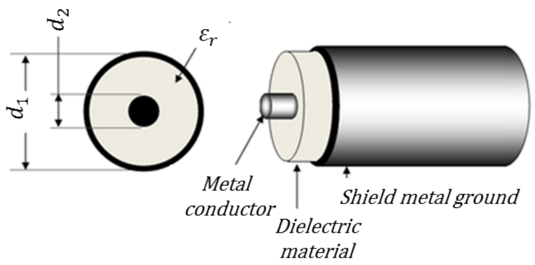


Stack-up
1. Top
2. Signal1
3. Ground
4. Signal2
5, Power
6. Bottom

Fig. Multi-Layer Polyimide Thin Film
(Stack-up & VIA Stacks)

- Multi-Layer Dielectric material :
  Polyimide Thin Film $\varepsilon_r = 3.2$
- Circuit Trace on Polyimide is fabricated by MEMS Process
- Signal Trace : Impedance Matching
  Single ended Line : 50Ω±10%
  Differential Pair Line : 100Ω±10%
- Interposer bending as flexible cable
  Ground (Return Path) : Mesh or Plane
  Power : Mesh / Plane

Design Considerations for BGA Socket



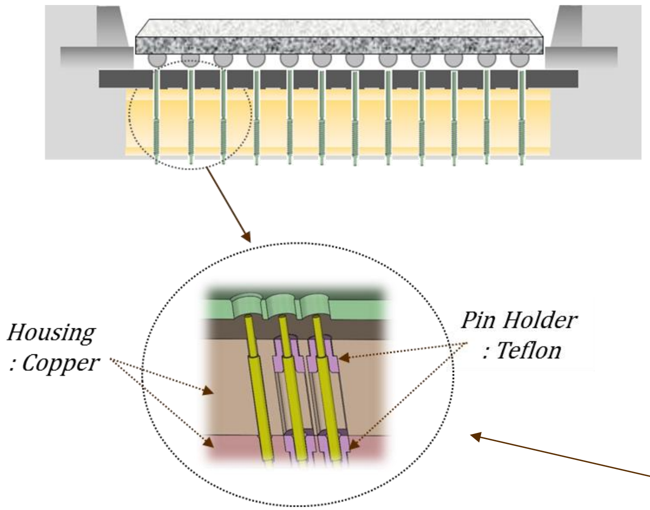
$$Z_O = \frac{138}{\sqrt{\varepsilon_r}} \log_{10} \frac{d_1}{d_2}$$

Where,
Z_O = *Characteristic impedance of line*
d_1 = *Inside Diameter of Outer Conductor*
d_2 = *Outside Diameter of Inner Conductor*
ε_r = *Relative Dielectric Constant*

○ **Basic Theory**

- ✓ Coaxial Transmission Geometry
- ✓ Consist of Core Conductor, Dielectric Material, Outer shield (GND)
- ✓ Signal : Center Conductor
  GND : Outer Conductor
- ✓ Outer Conductor forms a shield preventing external Magnetic-field from Crosstalk

Design Considerations for BGA Socket



- Coaxial BGA Socket Structure
  - ✓ Contacts : Signal , Power, GND
  - ✓ Socket Body : Solid metal conductor
  - ✓ Dielectric material (insulator) : Teflon + Air
- Coaxial BGA Socket Performance
  - ✓ Effective for Crosstalk (Signal Isolation) to avoid loss of Signal and Power

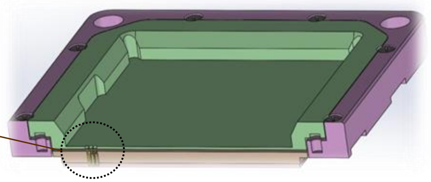


Fig. BGA Socket Structure with Coaxial Pogo Probes

Design Considerations for 3D MEMS Probe

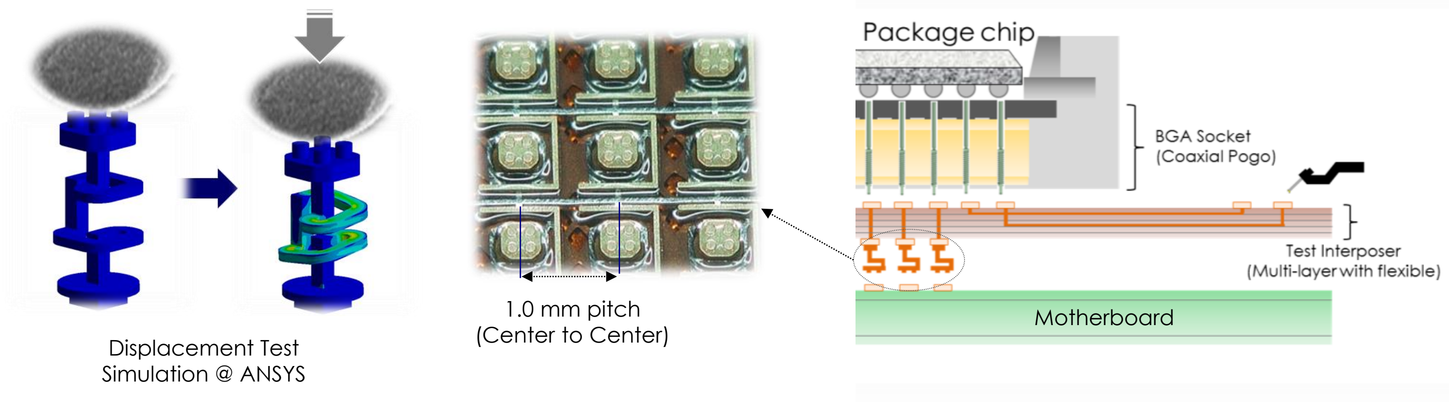


Fig. 3D MEMS Probes (Vertical type)

- 3D MEMS Probes allow direct Contact on Motherboard without any Damages.
- Pin Force can be controlled by changing Geometry.
- The Pitch 1.0mm (Center to Center) / 3D MEMS Pitch Capability Minimum 0.4mm

Design Considerations for 3D MEMS Probe

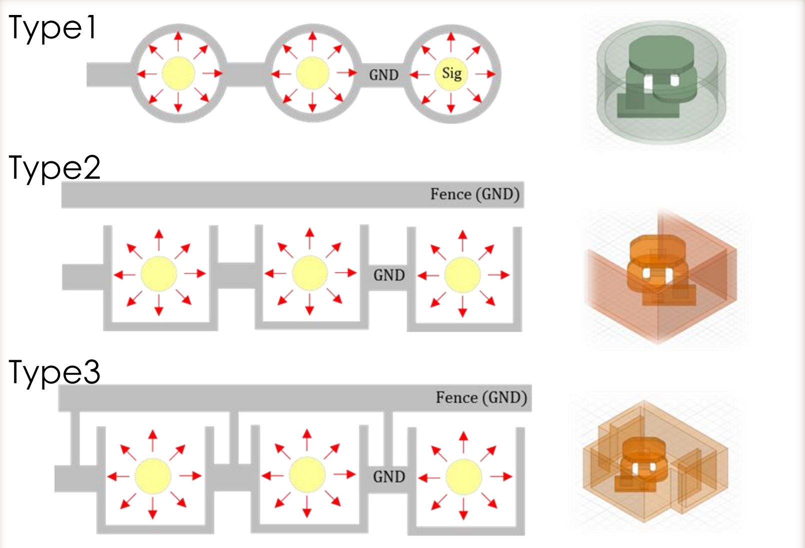


Fig. 3D MEMS Probes with various Coaxial

- Coaxial Probe contains PDMS Material (Polydimethylsiloxane)
- PDMS Relative Dielectric $\varepsilon_r = 2.63$
- PDMS supports 3D MEMS Probe for Positioning and Reaction Force
- PDMS Challenges for filling inside of Shield due to Small Space and its Viscosity
- Pre-simulation and Electrical Characteristics

3D MEMS Probe electrical characteristics

Type	Shape	Insertion Loss @-1dB	Return Loss @-20dB
Type1	Coaxial	46.52GHz	30.33GHz
Type2	Coaxial Open	43.23GHz	24.30GHz
Type3	Coaxial Close	43.94GHz	25.36GHz

@ ANYSS HFSS

Assembly of Test Interposer System

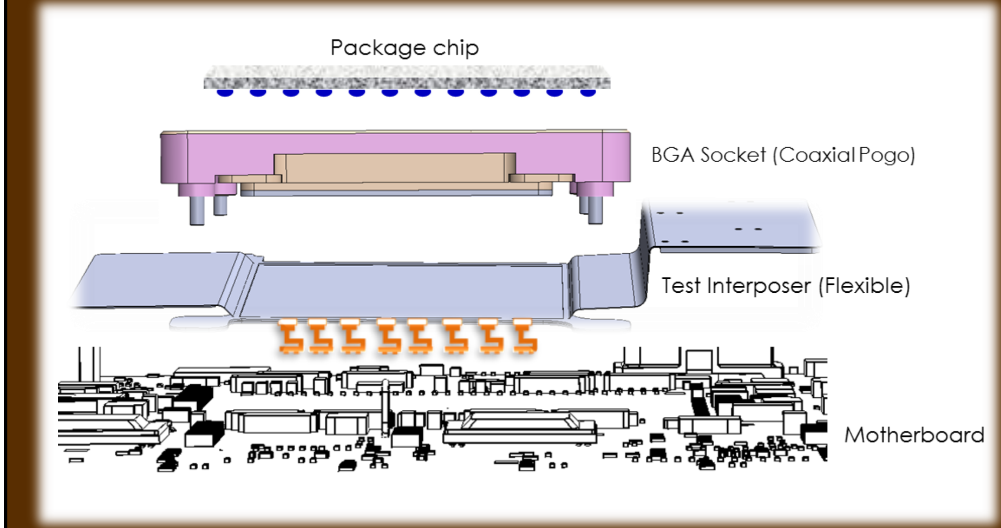
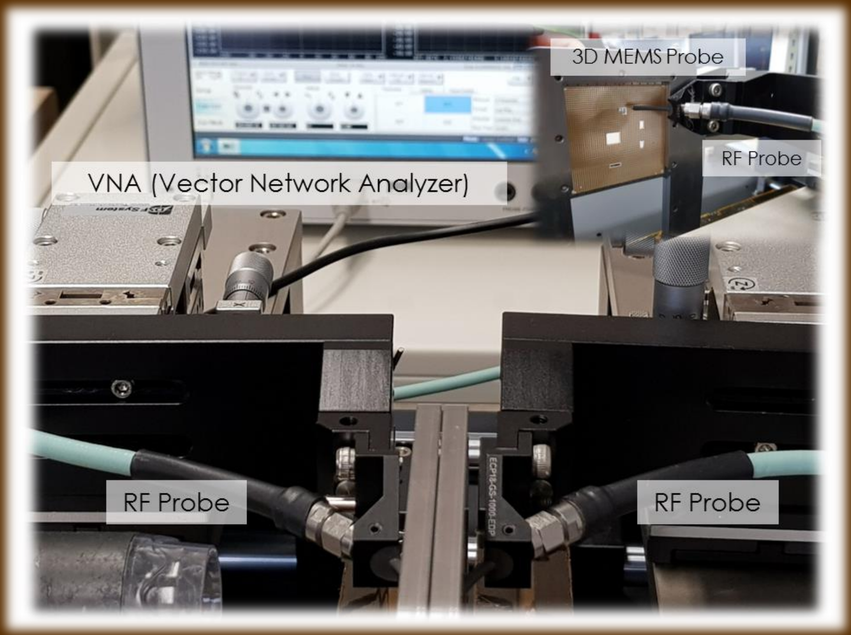
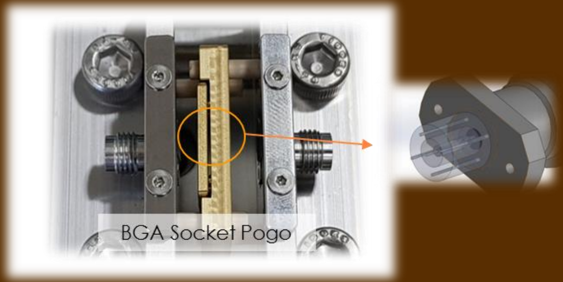


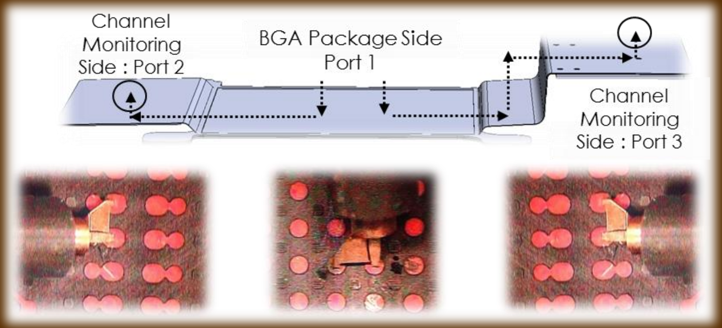
Fig. System consists of BGA Socket and 3D MEMS Contacts on Test Interposer

- **Test Interposer System**
  - ✓ BGA Socket (Coaxial Pogo Probes)
  - ✓ Test Interposer (Flexibility)
  - ✓ 3D MEMS Probe (Coaxial Type)
- **Signal & Power Integrity**
  - ✓ Pre & Post Simulation
  - ✓ Design Considerations (Impedance)
  - ✓ Signal Isolation
- **Fabrication by 3D Full MEMS Process**
  - ✓ Multi-Layer Test Interposer
  - ✓ MEMS Structure stack by stack after fabricating interposer

Measurement Setup to Analyze Test Interposer







Electrical Characteristics of BGA Pogo Probes

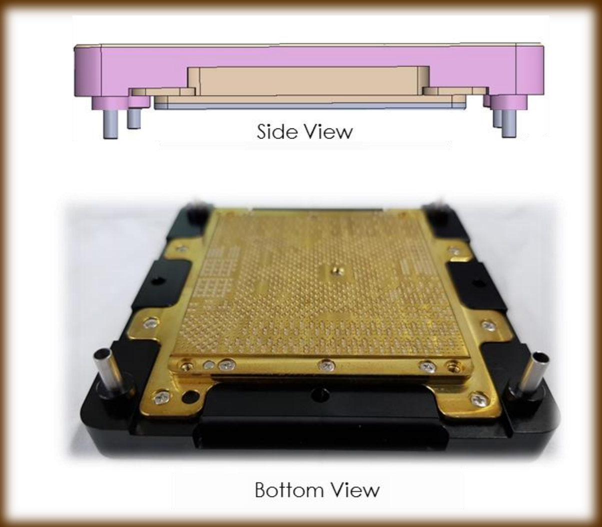
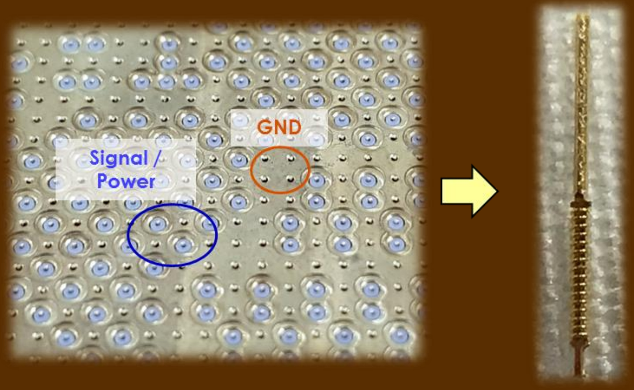
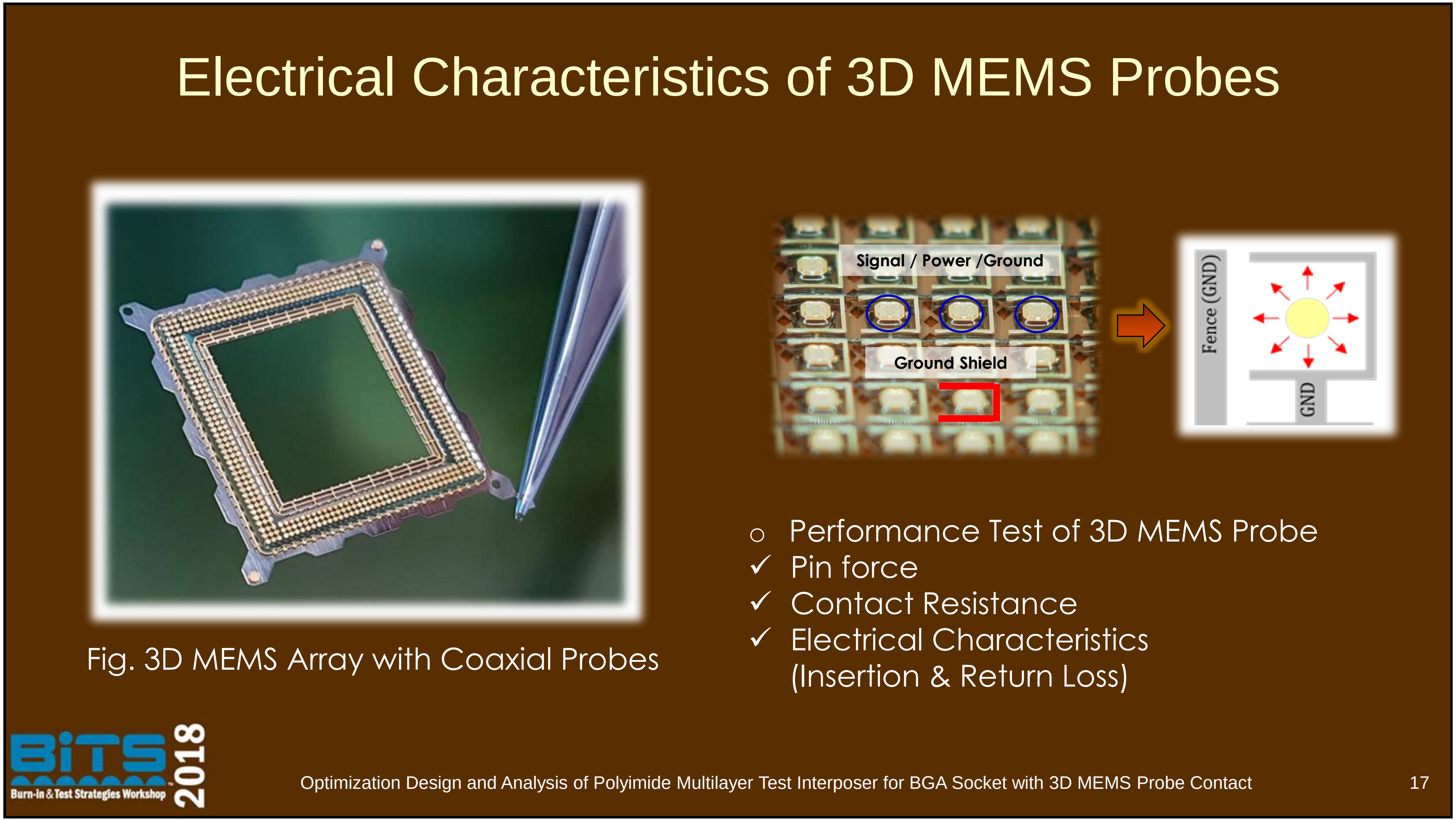


Fig. BGA Socket with Coaxial Pogo



- ○ Performance Test of Pogo Probe
- ✓ Pin force
- ✓ Contact Resistance
- ✓ Electrical Characteristics (Insertion & Return Loss)

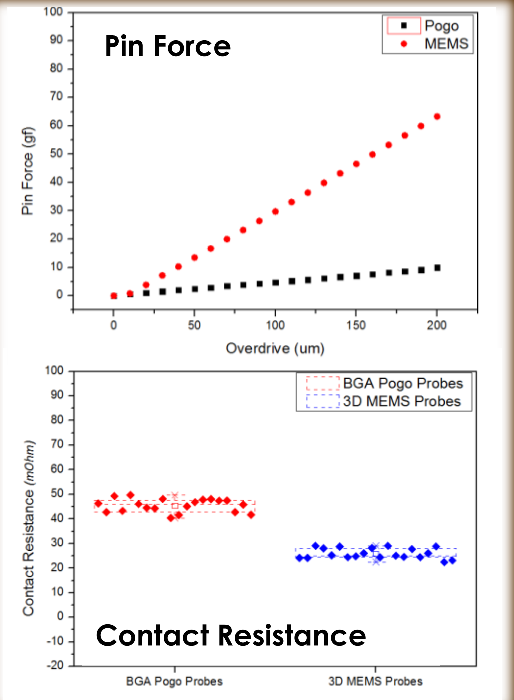


Electrical Characteristics of 3D MEMS Probes

Fig. 3D MEMS Array with Coaxial Probes

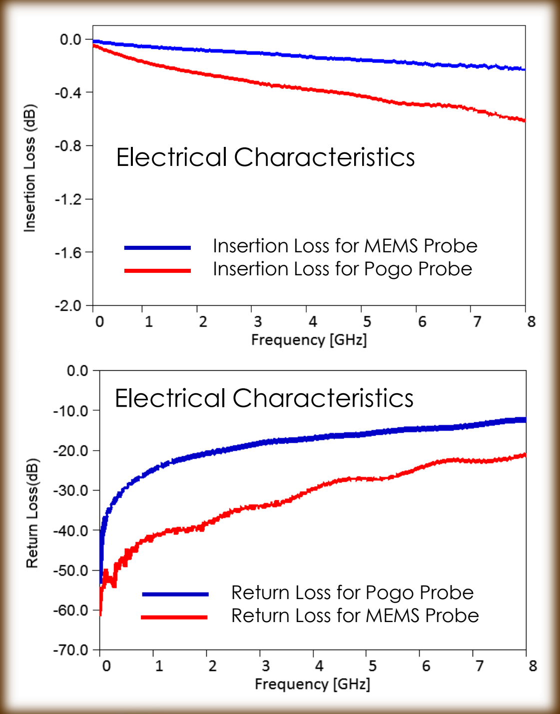
- ○ Performance Test of 3D MEMS Probe
- ✓ Pin force
- ✓ Contact Resistance
- ✓ Electrical Characteristics (Insertion & Return Loss)

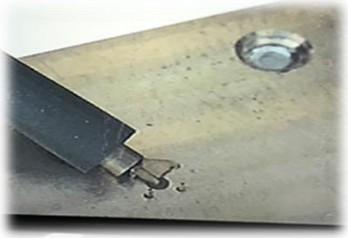
Electrical Characteristics Contact Probes

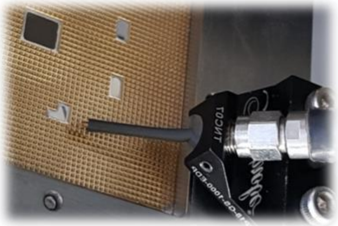


- ○ Results of Pin Force Test
- ✓ BGA Pogo Probes : 4.8 gf / OD 100um (1.2 gf/mil)
- ✓ 3D MEMS Probes : 29.7 gf / OD 100um (7.4 gf/mil)
- ○ Results of Contact Resistance
- ✓ BGA Pogo Probes : Avg. 45.48 mΩ
- ✓ 3D MEMS Probes : Avg. 25.96 m Ω
- ○ Pin Force and Contact Resistance can be controlled by changing Geometry as Customer Demands

Electrical Characteristics Contact Probes

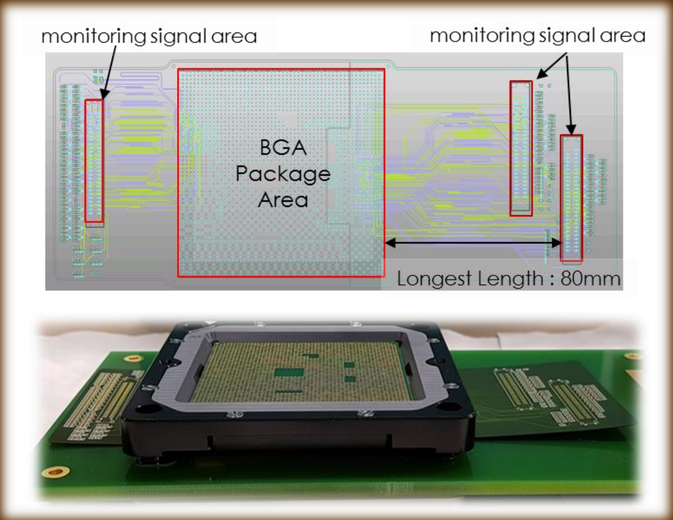


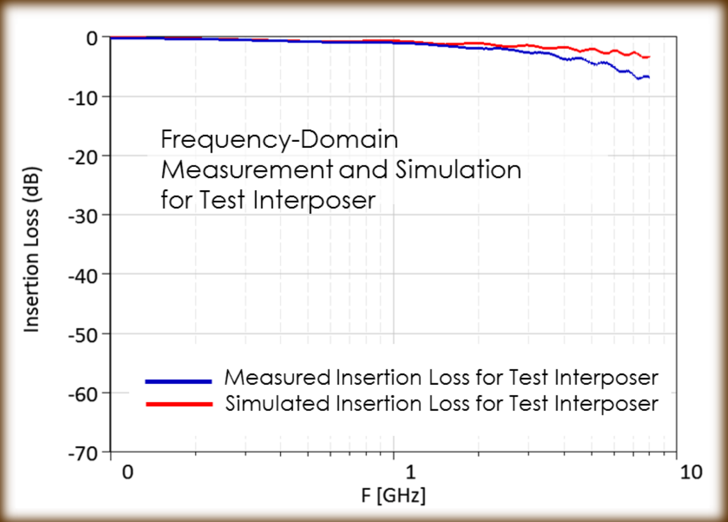

BGA Pogo Probes


3D MEMS Probes

- Insertion Loss (S21)
  BGA Pogo Probes : -0.65 dB @ 8GHz
  MEMS Probes : -0.25 dB @ 8GHz
- Return Loss (S11)
  BGA Pogo Probes : -20 dB @ 2.38GHz
  MEMS Probes : -20 dB @ 8GHz
- Measurement using Giga Probe & VNA
  (Up to 8GHz)

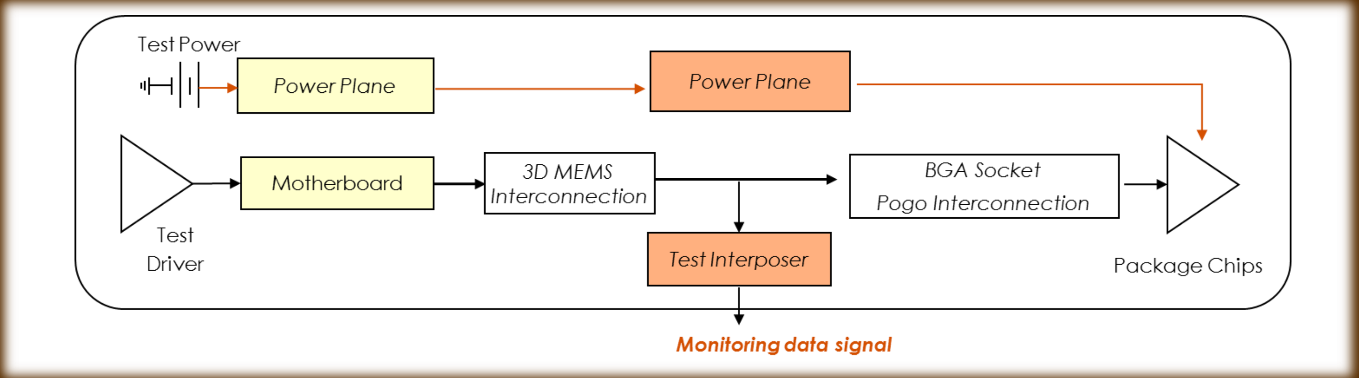
Electrical Characteristics of Test Interposer





- The Results of Measurement and Simulation have differences slightly the frequency range from 1.8GHz that measurement looks more losses than simulation

Simulation Conditions for Test Interposer System



Test Power

Power Plane

Power Plane

Motherboard

3D MEMS Interconnection

BGA Socket Pogo Interconnection

Test Driver

Test Interposer

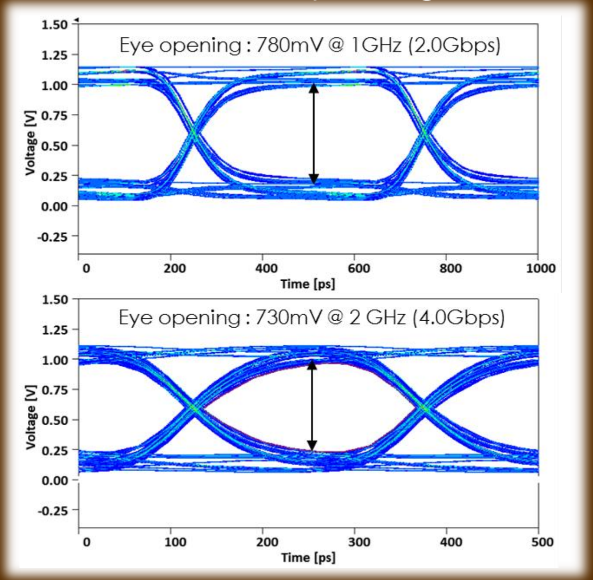
Package Chips

Monitoring data signal

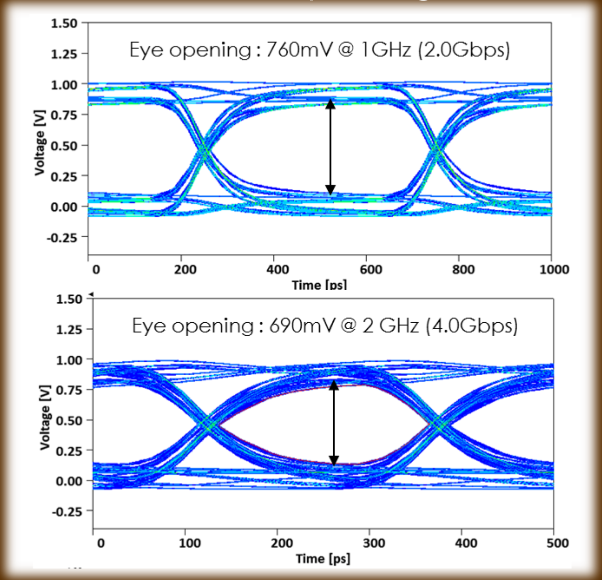
- Time Domain Simulation
- Input Data : PRBS input (Pseudo random binary sequence)
- Amplitude : 0~1.0V
- Data Rate : 1.0 GHz (2.0 Gbps) ~ 2.0 GHz (4.0 Gbps)
- Simulation Tool : Electronics Desktop @ ANSYS

Electrical Characteristics of Test Interposer

Simulated Eye Diagram



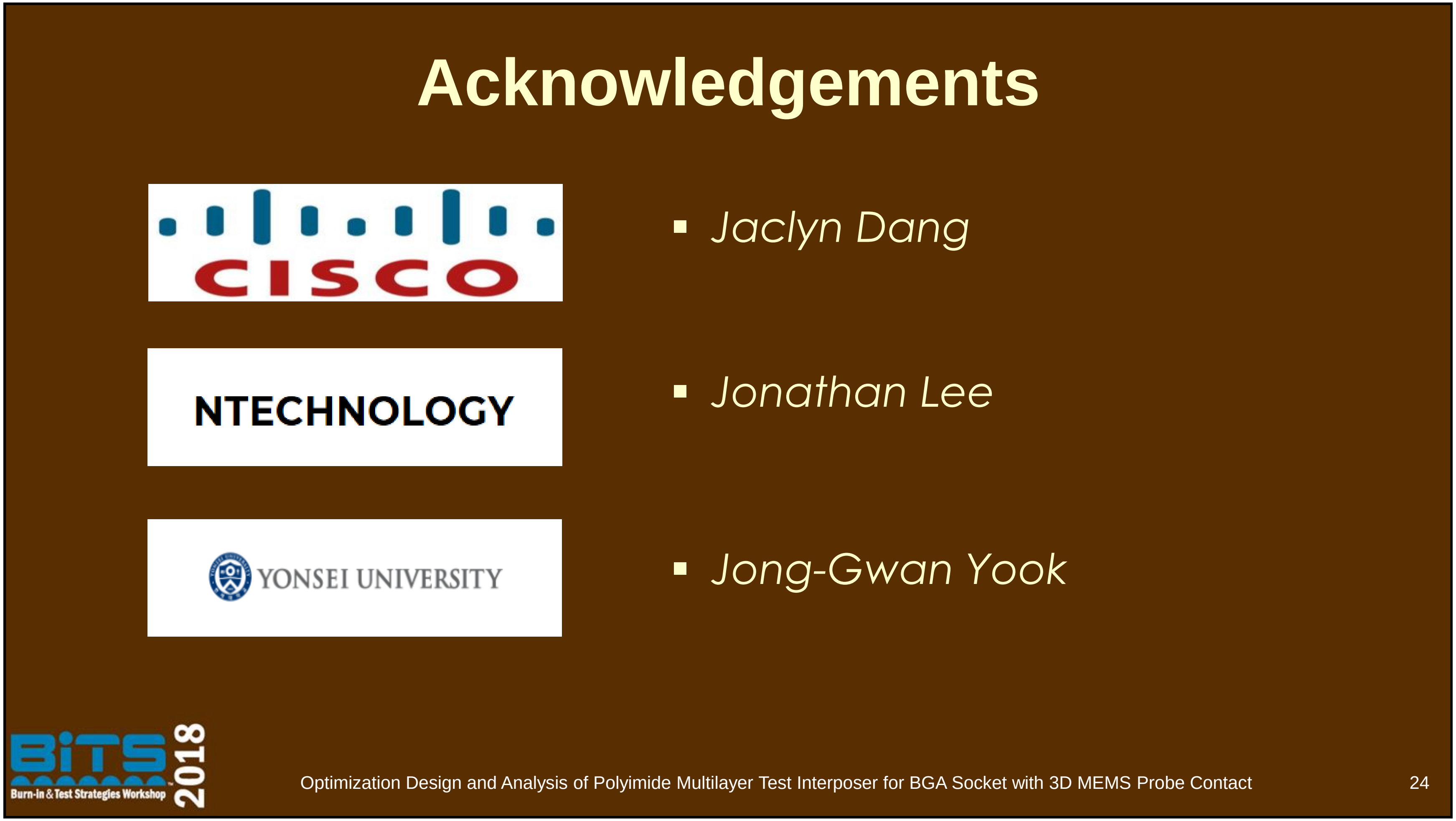
Measured Eye Diagram



- Time-domain Experimental Verification between Simulation and Measurement
- The Measurement Results are lower than Simulation due to losses of Measuring System

Summary

- Proposed **Test Interposer** with BGA Socket and 3D MEMS Probe Contacts for Testing Packages
- Adopted **Coaxial** both BGA Pogo and 3D MEMS Probe for Contact Structure
- Verified the **Performance** of Test Interposer and Contact Probes using Simulation and Measurement
- Analyzed the **Test Interposer System** accessible to Monitor Data Signal of the BGA Package Chip without any Damages



Acknowledgements

CISCO

NTECHNOLOGY

YONSEI UNIVERSITY

- *Jaclyn Dang*
- *Jonathan Lee*
- *Jong-Gwan Yook*