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Design and Analysis of 3D MEMS Co-axial Structure

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Why Co-axial Structure ?

- Higher performance devices with higher Memory Band Width used in the automotive industry demand higher test speeds.
- Various types of co-axial sockets are available in the industry that use grounding shield. The main challenge is to design and develop one for fine pitch BGA packages.
- The MEMS technology is one of the recommended contact solutions for fine pitch co-axial sockets for achieving high reliability and high electrical and mechanical performance.
- The 3D MEMS co-axial probe can be fabricated with different kinds of shapes depending on customer device specifications.

Challenges and Considerations

- Design and fabrication of 3D MEMS co-axial structure.
  - ✓ Fine pitch, GND shield shape, Contact tip geometry.
- Control of signal impedance.
  - ✓ Relationship between core signal and surrounding outer ground.
- Contact resistance & accuracy.
  - ✓ Various types of contact tip shapes for better contact resistance.
- Electrical characteristics for satisfying high bandwidth.
  - ✓ Low insertion / return loss & Crosstalk noise (near-end & far-end).

Concept of 3D MEMS Co-axial Structure

- Composed of core signal and outer ground shield.
- Protects the inner core signal from electric field interference.
- Keeps the core signal distance from the GND shield with a specific dielectric constant (PDMS, $\varepsilon_r = 2.63$).
- Causes the signal well-defined impedance to high frequency signal quality.

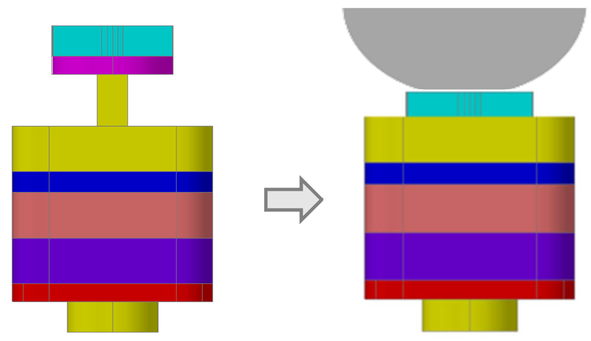
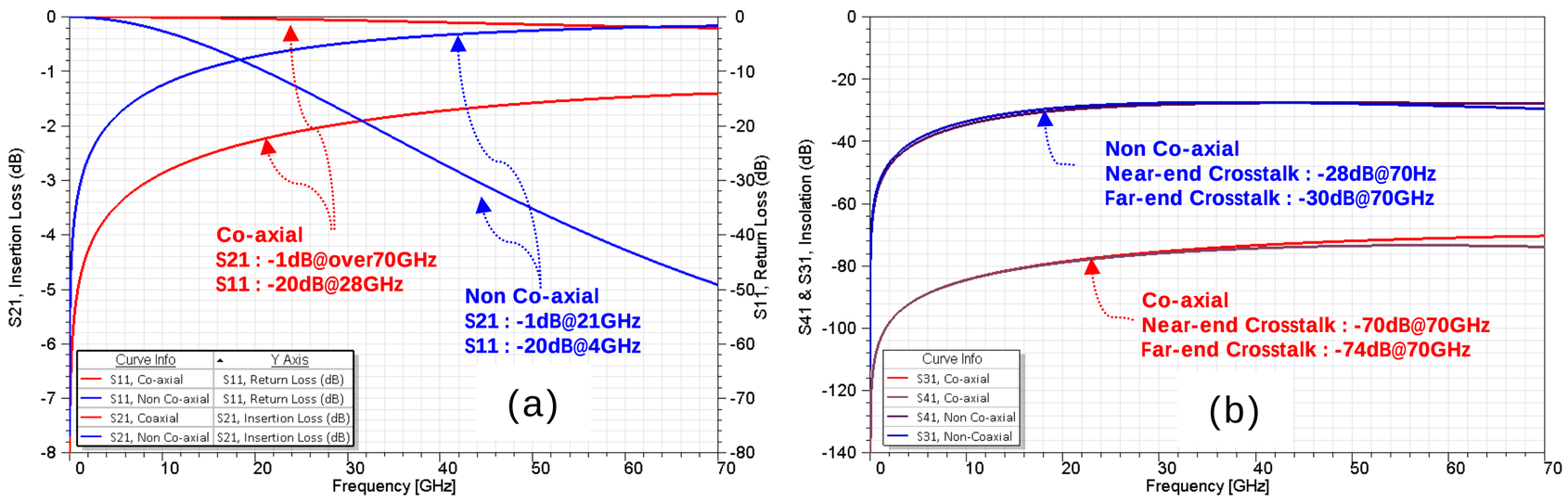


Fig. 3D MEMS co-axial structure



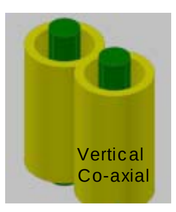


Fig. Electrical characteristics comparison of co-axial and non co-axial

(a) Proposed co-axial S21, Insertion loss is much lower than the non co-axial probe.

(b) Likewise, crosstalk noise has much better performance than the non co-axial probe.

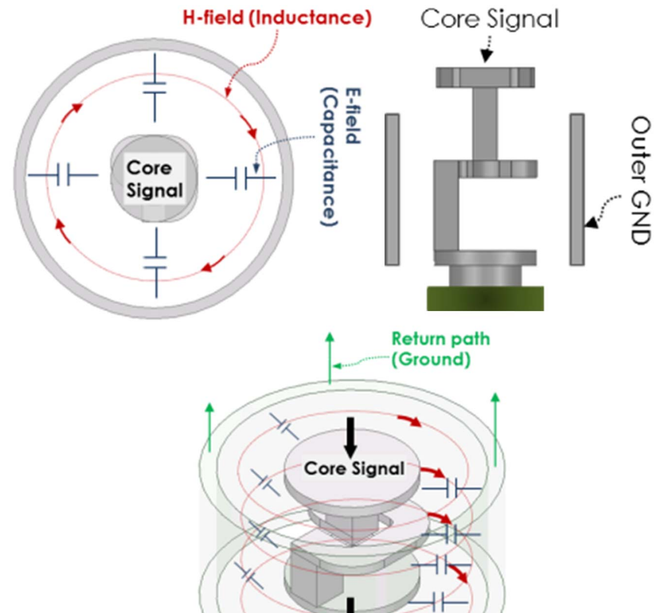


Fig. Coaxial electromagnetic field through structure

Analysis of Co-axial Probe (Circular Shape)

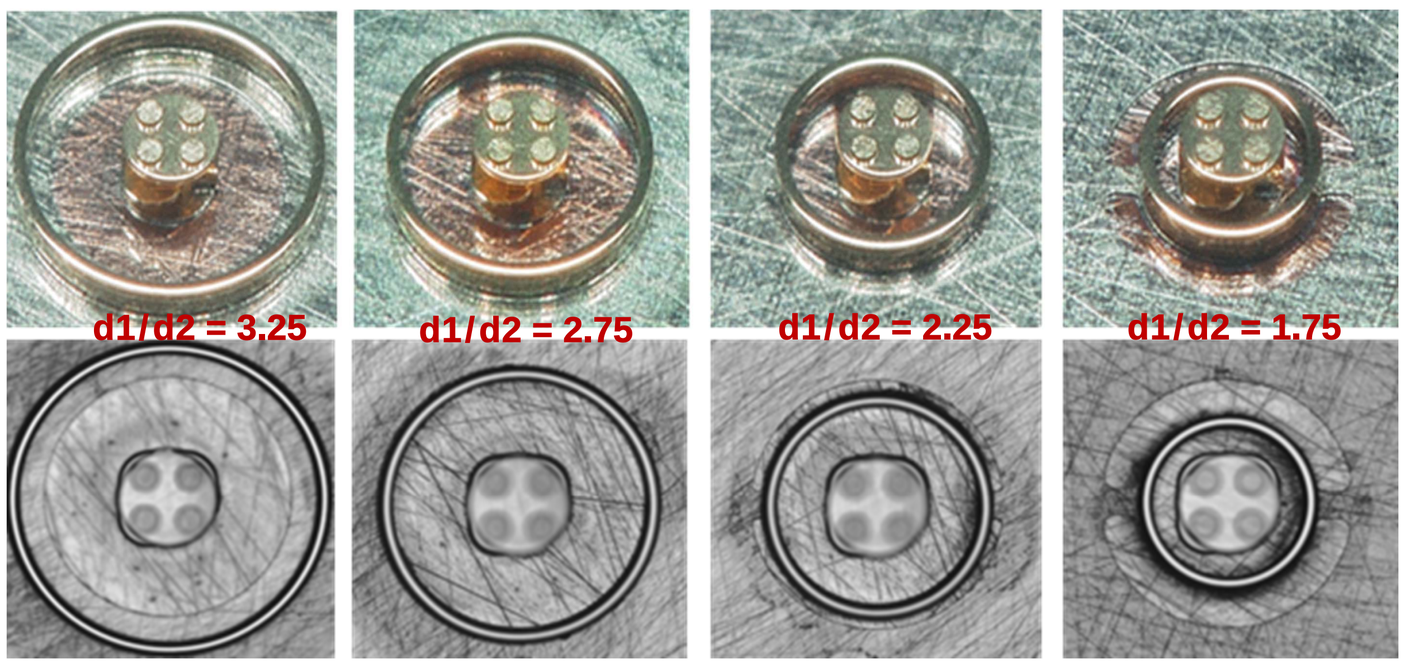
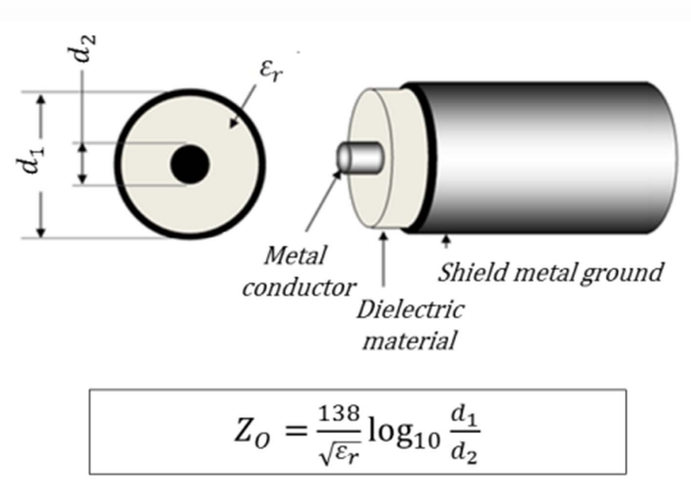


Fig. Co-axial structure distance between signal and ground(circular shape)



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

Fig. Co-axial theory & impedance

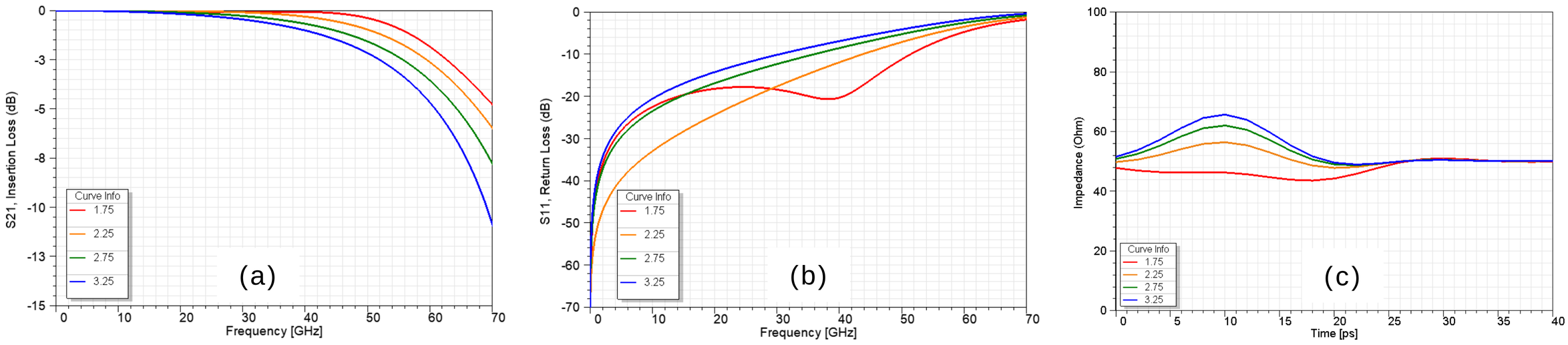


Fig. Analysis of co-axial GND distance (circular shape) (a) S21, Insertion Loss. (b) S11, Return Loss. (c) Z0, Impedance

- For circular shape, the electrical characteristics have been analyzed for distance between core signal and outer ground.
- The larger distance GND gap, the bigger signal impedance.
- Co-axial design is possible to control and match impedance according to device pad pitch.

Electrical Characteristics (HFSS@ANSYS)

Distance (d1/d2)	S21 (@-1dB)	S11 (@-20dB)	Zo
1.75	*56 GHz*	*35 GHz*	*46Ω*
2.25	*50 GHz*	*26 GHz*	*56Ω*
2.75	*45 GHz*	*14 GHz*	*62Ω*
3.25	*40 GHz*	*11 GHz*	*66Ω*

Analysis of Co-axial Probe (Rectangular Shape)

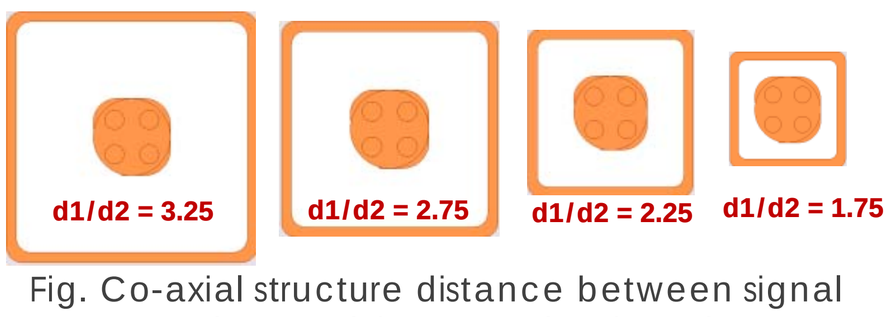


Fig. Co-axial structure distance between signal and ground (rectangular shape)

Fig. Co-axial BGA socket with rectangular ground shape

- For rectangular shape, the electrical characteristics have been analyzed for distance between core signal and outer ground.
- The larger distance GND gap, the bigger signal impedance.
- Co-axial design is possible to control and match impedance according to device pad pitch.

Electrical Characteristics (HFSS@ANSYS)

Distance (d1/d2)	S21 (@-1dB)	S11 (@-20dB)	Zo
1.75	*55 GHz*	*39 GHz*	*49Ω*
2.25	*49 GHz*	*21 GHz*	*58Ω*
2.75	*43 GHz*	*13 GHz*	*63Ω*
3.25	*39 GHz*	*10 GHz*	*67Ω*

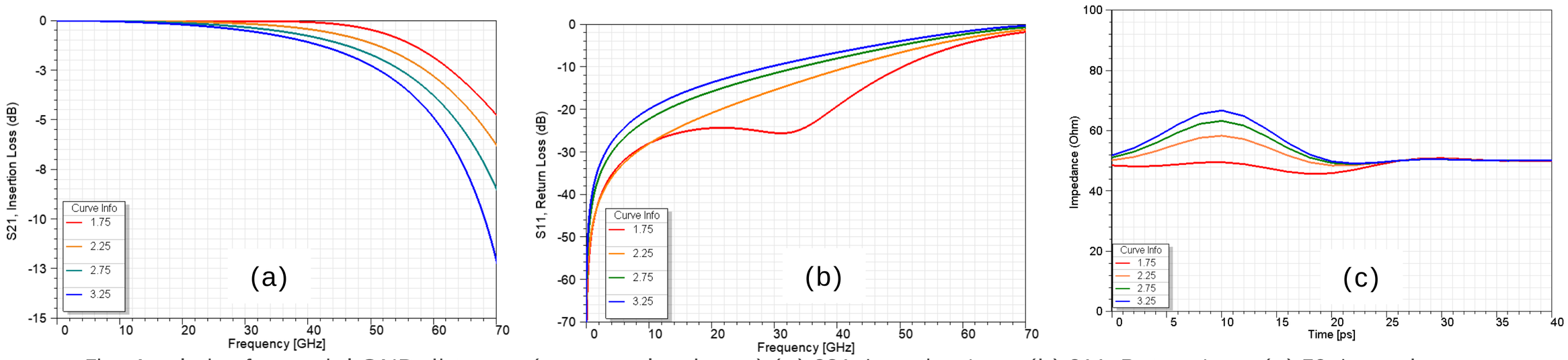


Fig. Analysis of co-axial GND distance (rectangular shape) (a) S21, Insertion Loss. (b) S11, Return Loss. (c) Z0, Impedance

Design of Contact Tip Shape

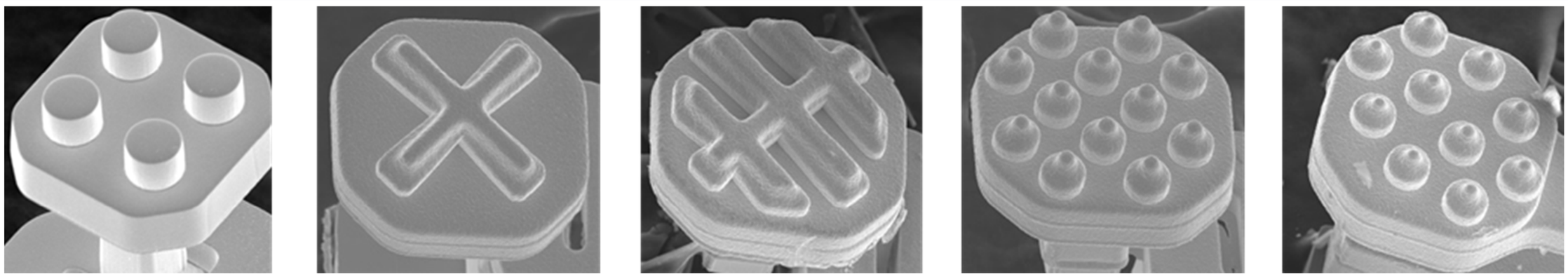


Fig. SEM Images of various 3D MEMS tip shape for better contact solution

- Fabrication of various tip shapes using 3D MEMS process.
  - ✓ 4 points round, Cross, Waffle, Multi-nipple shape.
- Development of best contact solution for BGA ball damage -- less than 5% and lowering contact resistance.
- Design of various tip shapes for co-axial structure with minimum 0.3mm pad pitch.

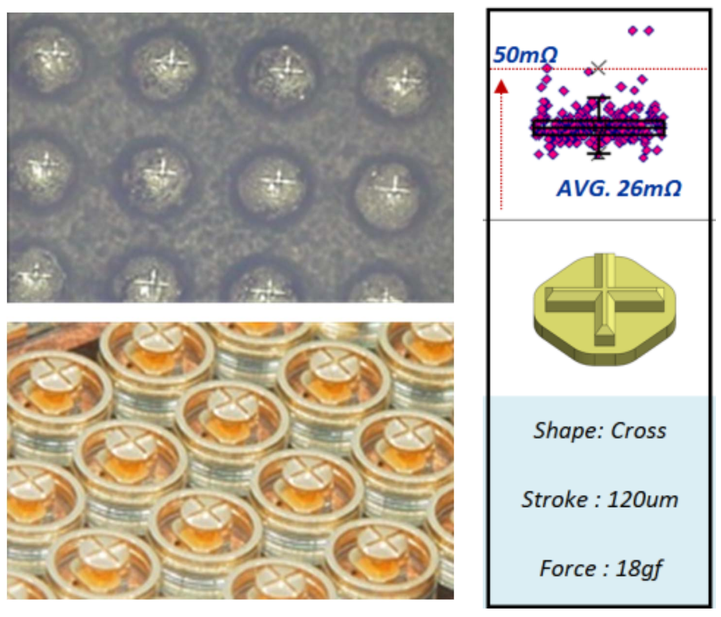


Fig. Cross Tip, Contact Mark, C_Res

Summary & Future Works

- Performed design and analysis of various co-axial probe structures.
  - ✓ Simulation study for different distances between ground and signal.
  - ✓ Analysis of two types of outer GND shape (circular vs rectangular).
- Proposal of contact tip design and fabrication using 3D MEMS technology.
  - ✓ Various tip shapes such as cross, waffle and multi-nipple tip.
- The challenge is for providing measurement results of co-axial structure.
  - ✓ Need to compare experimental results with simulations.