Advanced Packaging : Advanced Packaging I

Session We-A-2
September 3, 2008

Fabrication Process For A Novel High Speed CoPlanar-to-Coaxial Off-Chip Interconnect

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Introduction

- Drawback of wire bonds
- Use of coax cable to overcome drawbacks
- Use of cable of chip
- Fabrication process
- Early Results
- Future work

Wire Bonding

- Electrical Drawbacks
  - Unshielded nature
    - Generates considerable signal cross-talk

$$K_f = \frac{1}{2 \bullet vel} \bullet \left(\frac{C_M}{C_L} - \frac{L_M}{L_L} \right)$$ → Forward cross-talk (FEXT)

$$K_b = \frac{1}{4} \bullet \left(\frac{C_M}{C_L} + \frac{L_M}{L_L} \right)$$ → Reverse cross-talk (NEXT)

Where,

$$FEXT = \frac{V_f}{V_a} = \frac{L}{RT} * k_f \qquad NEXT = \frac{V_b}{V_a} = k_b$$

Wire Bonding

- Electrical Drawbacks (cont)
  - Self Inductance of the return path

$$V_{bnc} = N \bullet L_{ret} \frac{0.8 \bullet V_{sig}}{\tau_{rise} \bullet Z_0}$$

Voltage Bounce due to inductive return path

N – number of signals sharing common return path
L_{ret} – self inductance of wire bond providing return path

Wire Bonding

- Electrical Drawbacks (cont)
  - Reflected energy due to impedance discontinuities

$$Z_{wb} = \sqrt{\frac{L_{wb}}{C_{wb}}}$$

Impedance of wire bond

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

Reflection coefficient
- ZL – Load impedance
- Z0 – Source side impedance

Coaxial cable

- Reasons for cable use
  - Signal cross-talk is reduced by shielded cable

$$K_f = \frac{1}{2 \bullet vel} \bullet \left(\frac{C_M}{C_L} - \frac{L_M}{L_L} \right) \qquad K_b = \frac{1}{4} \bullet \left(\frac{C_M}{C_L} + \frac{L_M}{L_L} \right)$$

  - Self Inductance is significantly less due to number of signals sharing return path

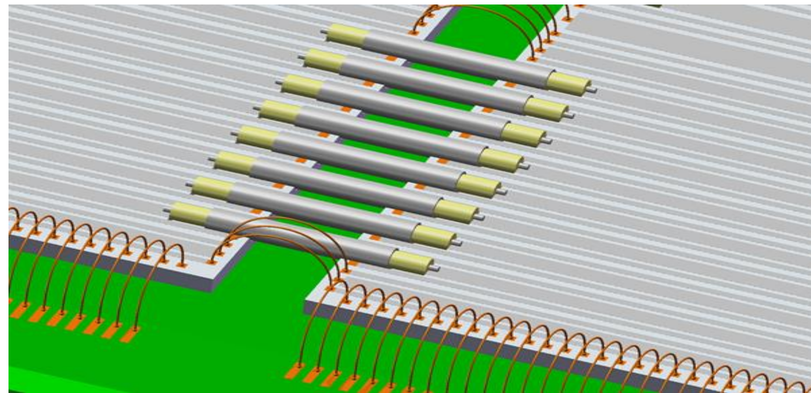
$$V_{bnc} = N \bullet L_{ret} \frac{0.8 \bullet V_{sig}}{\tau_{rise} \bullet Z_0}$$

  - Reflected energy is reduced by controlled impedance of the cable

$$Z_c = \sqrt{\frac{L_c}{C_c}} \qquad \Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

What's the Target Goal?

- Provide a chip-to-chip interconnect system
- Replace critical wire bond interconnect
- System will provide
  - Shielding (reducing cross talk)
  - Matched impedance transmissions
  - Increased signal transmission lengths
  - Increased speed



Major steps

- Cable selection
- Wafer selection
- Design waveguide dimensions
- Trench fabrication
- Waveguide fabrication
- Assembly and Testing

Cable selection

- Impedance equal to 50Ω
- Size less than 600µm
- Bigger than 300um
- Type - Semi-rigid
- Outer shield is the ground path

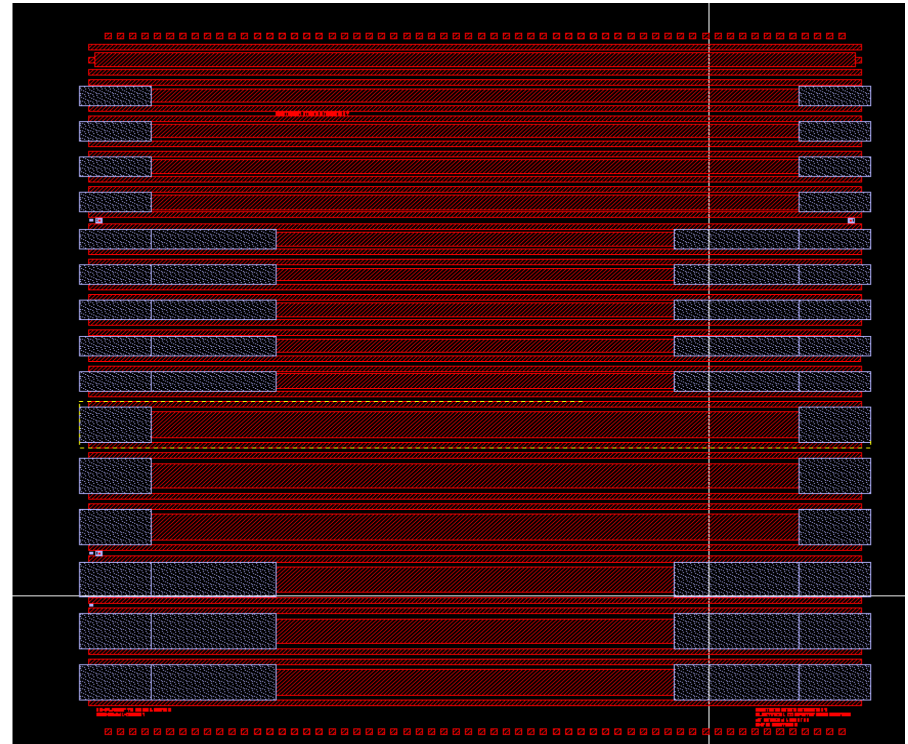
Selected cable

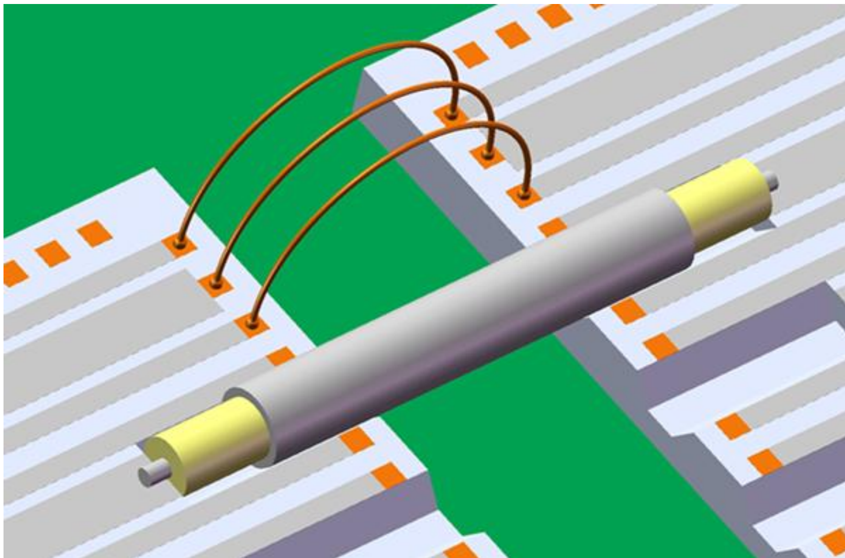
- MICRO– COAX
  - UT-020 & UT-013 semi-rigid cable

	UT – 013	UT – 020
Outer Dia (um)	330 (+/- 25.4)	584 (+/- 25.4)
Dielectric Dia (um)	254	419
Center Conductor Dia (um)	78.7 (+/- 12.7)	127 (+/- 12.7)
Impedance (ohms)	50 +/- 2.0	50 +/- 2.0
Material - Outer conductor	Copper	Copper
Material - Dielectric	PTFE	PTFE
Material - Center Conductor	SPCW	SPCW

Test Chip Layout

Test chip layout





3D model of Chip-to-Chip interconnect

Process Steps

Sio2
Si

Mask 1

PR
Sio2
Si
PR

PR
Sio2
Si
Sio2
PR

Sio2
Si
Sio2

Al
Sio2
Si

Mask 2

PR
Al
Sio2
Si

PR
AL
PR
AL
Sio2
Si

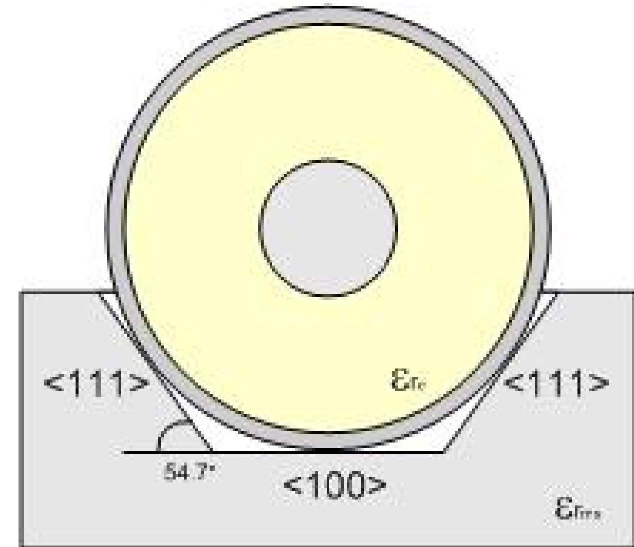
AL
AL
Sio2
Si

Trench Etching

- Anisotropic etch
  - TMAH
- SiO_2 as mask
- Depth of trench:

$$\frac{\text{Outer Cable Dia}}{2} - \frac{\text{Inner Cable Dia}}{2}$$

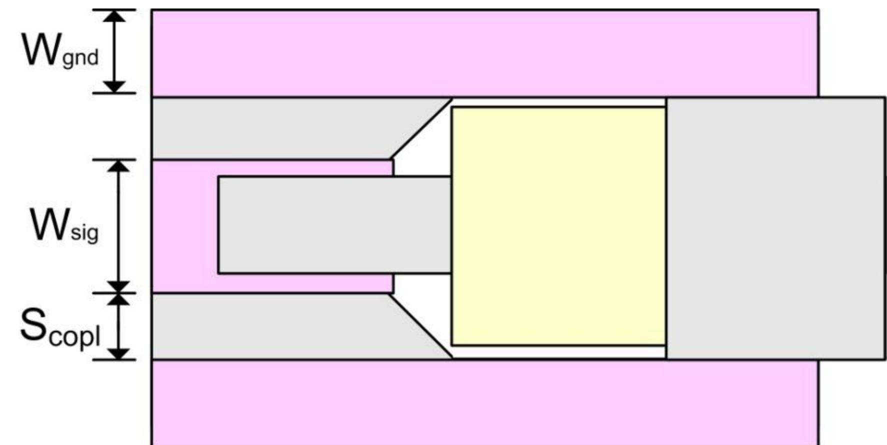
- Trench run from Gnd trace to Gnd trace



Co-Planar WaveGuides

- Why was Co-Planar chosen?
- Overall structure size

  $2W_{gnd}+W_{sig}+2S_{copl}$
- W_{sig}, S_{copl}, & ϵ determine Z_0
- W_{gnd} set to 100um
- Cable striped in stages
  - Helps reduce edge affects

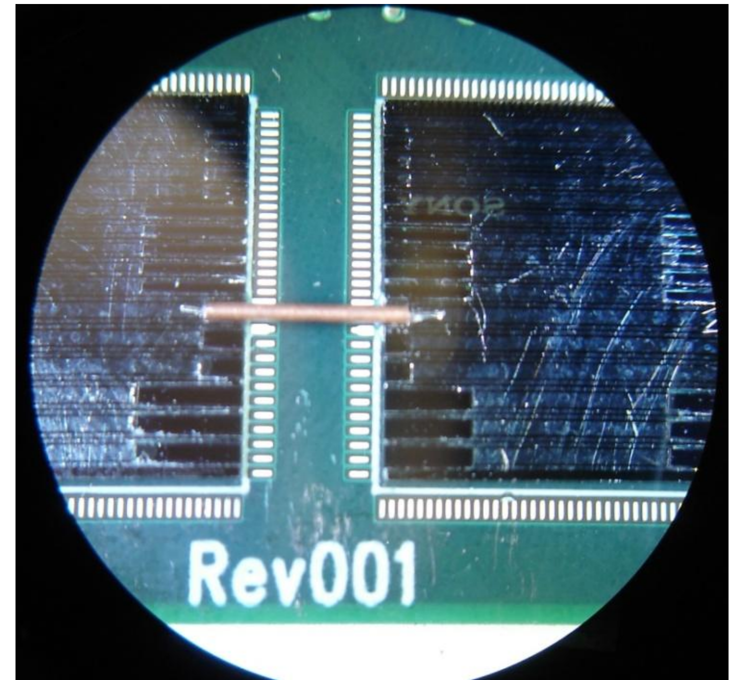


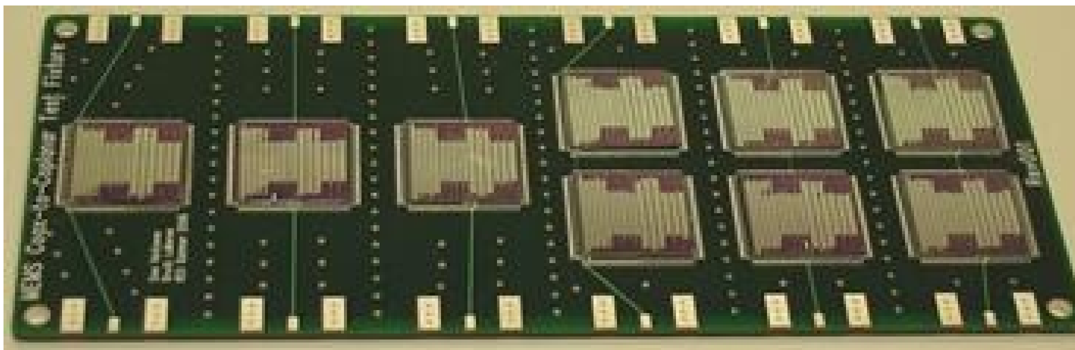
Etched Trenches & WaveGuides

Figures show etched trenches with Aluminum traces deposited

PCB Test Fixture

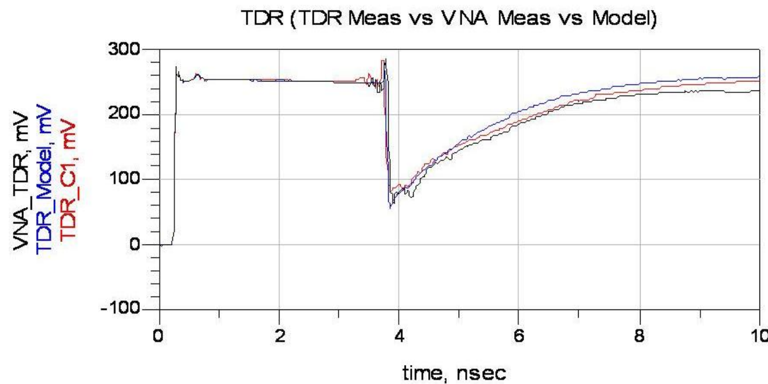
Two dies with Coaxial cable embedded within the etched trenches

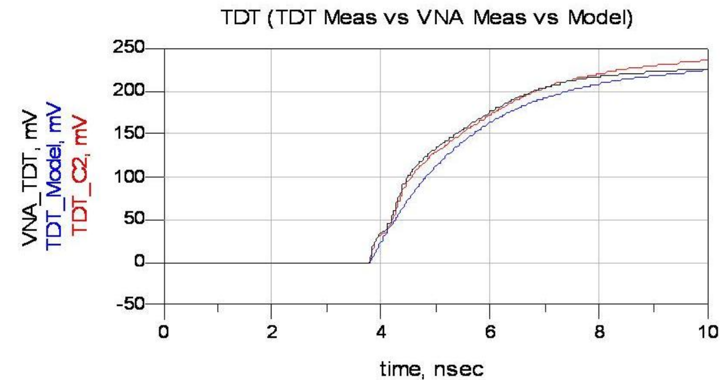


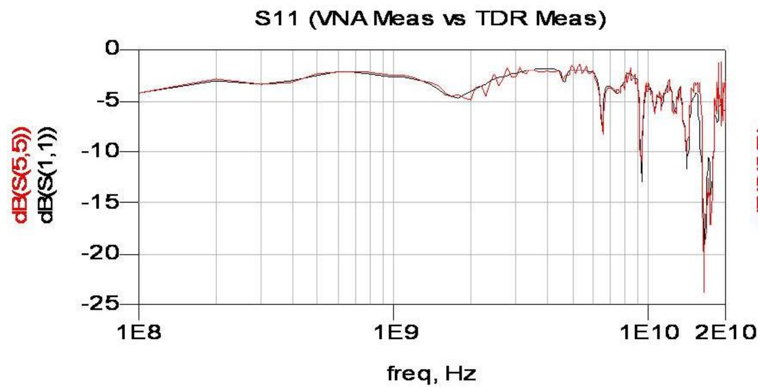


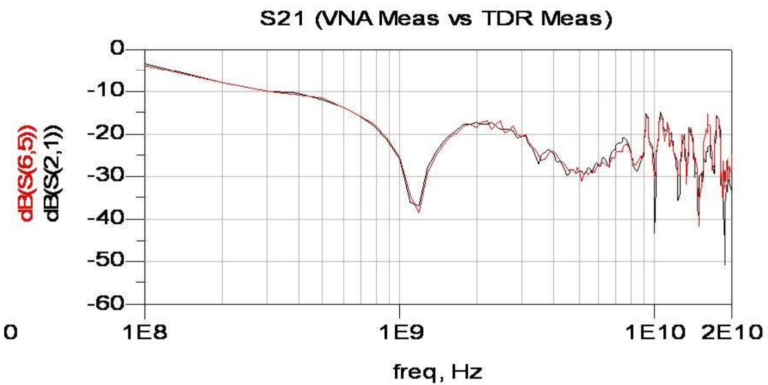
Test PCB boarded used to mount the dies, includes wire bonding pads

Early Results



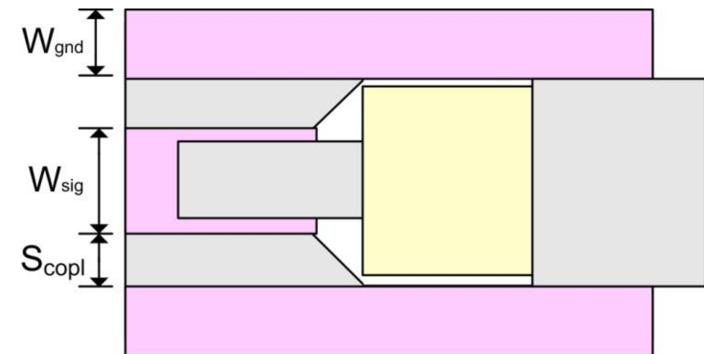






Possible Future Work

- Using UT-008 cable
  - Outer dia 203 μm
  - Gives the following Coplanar dimensions
    - W_{sig} = 120um
    - S_{copl} = 40um
    - W_{gnd} = 50um



- Total structure footprint
  - 300um
  - Footprints 43% less compared to UT-013
- Use of thick dielectric for trench