5G (28-40 GHz) Substrates and Antennas

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Georgia Institute of Technology

Target 5G Frequency Bands

- 28 GHz (US),
- 39 GHz (EU)
- 60 GHz

Two-Year Project Objectives

- Comprehensive characterization data on low-loss laminate, ceramic and glass packages up to 100 GHz leading to design guidelines and package design kits
- Chip-package co-design to achieve lowest insertion loss (dB/mm)
- Design and demonstrate reliable, high performance, miniaturized and cost-effective mm-wave modules with integrated antennas enabled by 3D packaging architectures

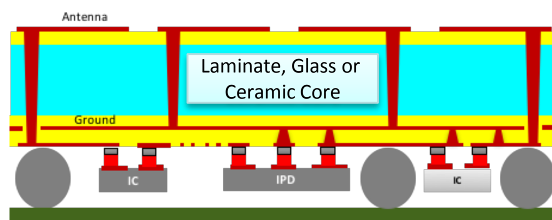
R&D Targets

Parameters	Objectives
Transmission lines	• < 0.05 dB/mm insertion loss @ 28-33GHz • Total transmission loss ~0.5dB at 10mm length
Antenna array	• BW ~20% is the goal, greater than 10% minimum • 24.5 to 29.5GHz and 37.0 to 43.5GHz • Element gain ~5dBi for broadside element and ~4dBi for endfire element • Element size < lambda/2 • Phased array design • Array size: 1x4 for linear and 2x4 for planar

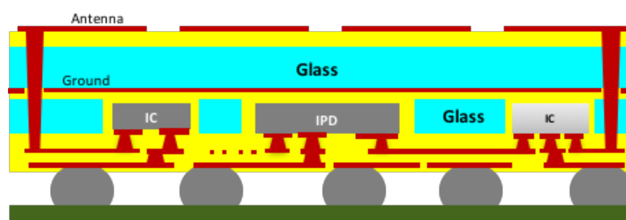
GT Module Approach

2. Antenna Arrays

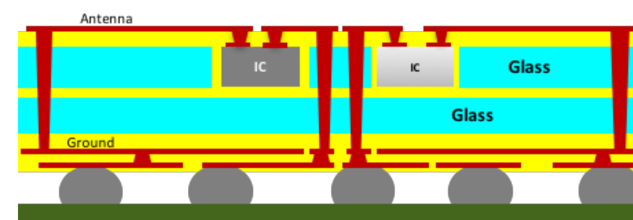
3. Chip Package Interconnect



3D Package



GFO Package A

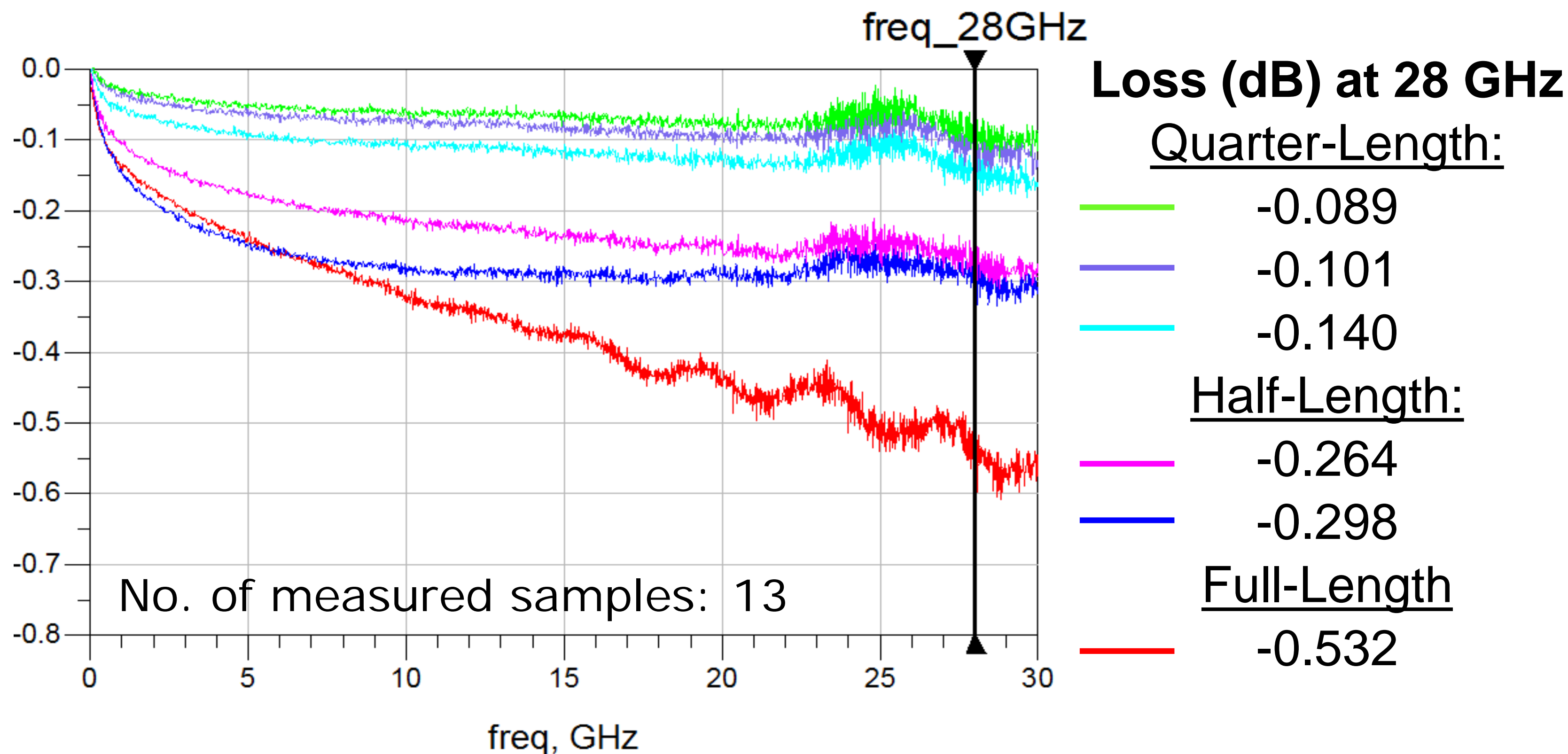


GFO Package B

1. Substrate Materials & Structures

4. 5G Module Integration

28 GHz Tranmission Lines on Glass



- Glass Through Vias add much lower loss compared to laminate

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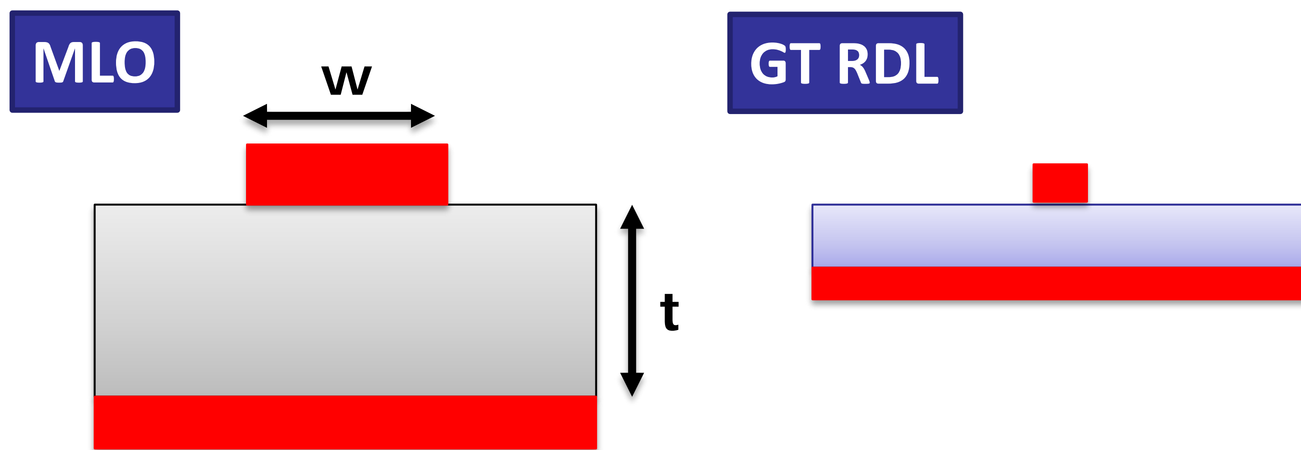
GT RDL Focus vs. Multilayer Organic (MLO)

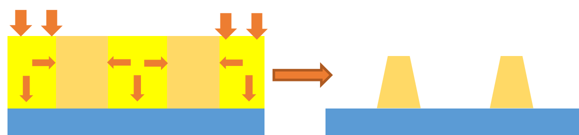


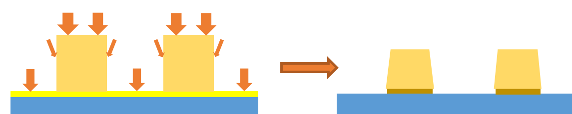
15um Aperture15um Aperture

Parameter	MLO	GT RDL (Laminate or Glass Core)
Dielectric Layer Thickness (t)	50 um (+/- 10um) 100um Typical	15um (+/- 1um)
T Line Width (w) Microstrip	100-200um (+/- 2-4um)	20um (+/- 0.4um) 10um (+/- 0.2um) next gen
Minimum I/O Pitch for Non-Tapered Feed	250-400um	40-80um
Through Via Aperture in Ground Planes	> 300um (60-100um Through Via, 150-250um Pad)	50um (30um Through Via, 40um Pad) RDL Via: 15um Aperture (8um Via, 12um Pad)
Substrate Thickness (6 Layer)	>500um	200um (Gen 1) 150um (Gen 2)

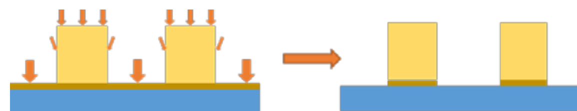
Three Approaches to Precision RDL

Subtractive Etching	Semi-Additive (SAP)	Embedded Cu

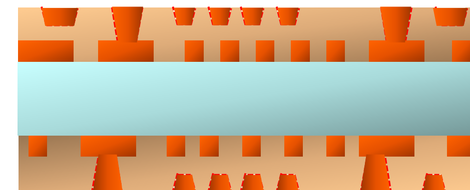




Standard Seed Etch



Differential Seed Etch



Subtractive Etching

- Etch depth – Full copper thickness (e.g. 12um)
- Width variations of the order of few microns

Semi-Additive (SAP)

- Etch depth – Seed copper (e.g. 0.4um)
- Width variations of the order of tenths of microns

Embedded Cu

- Zero etch process
- Width variations from litho only

Ushio Litho Tool @ PRC

Disco Surface Planer @ PRC

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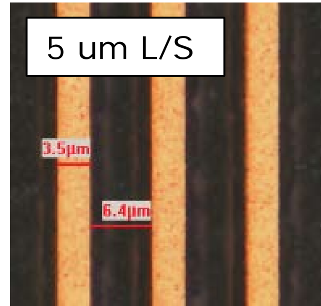
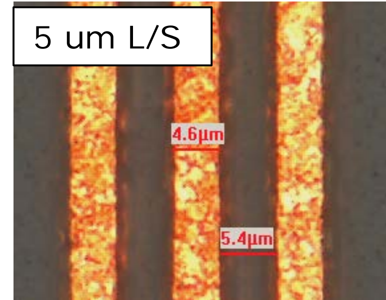
Improving RDL Precision

CONFIDENTIAL

SAP: Smoother Interfaces

Side etch 0.8um





Seed Cu layer thickness: 200nm

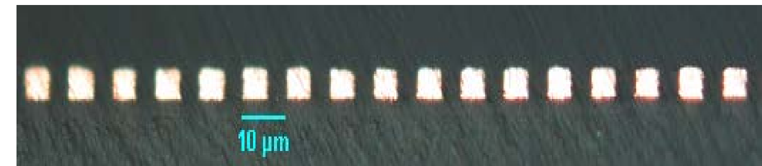
Side etch 0.2um

Eless Pd-Cu seed (Rz 280nm)

Sputtered Ti-Cu seed (Rz 20nm)

SAP: Differential Seed Layer Etching

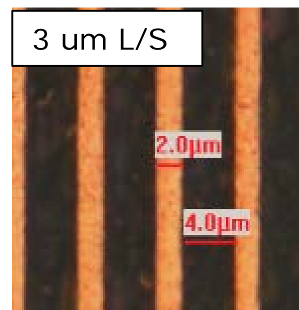
Standard Etching

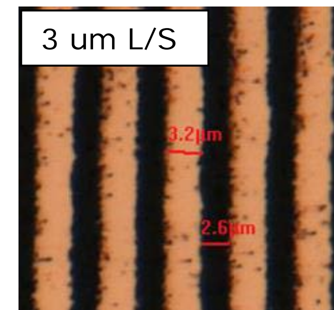


Differential Etching

Embedded Cu vs. SAP: Eliminate etching

SAP Side etch 0.5um





Embedded Cu Zero Side etch

Company: Atotech, AMAT, Veeco, Ajinomoto, Ushio, Disco
GT-PRC team: Hao, Chandra

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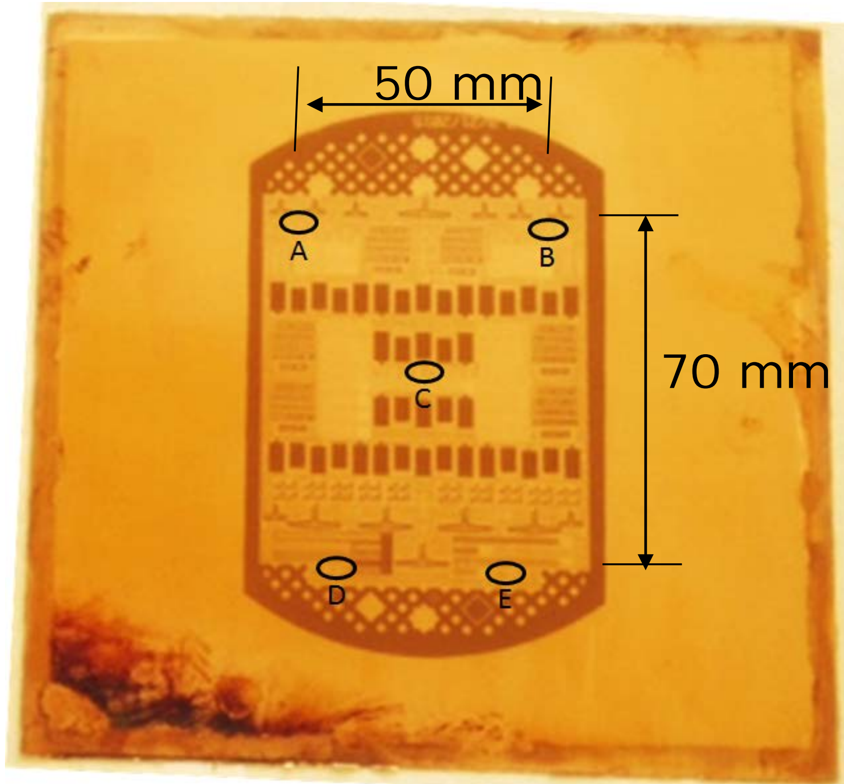
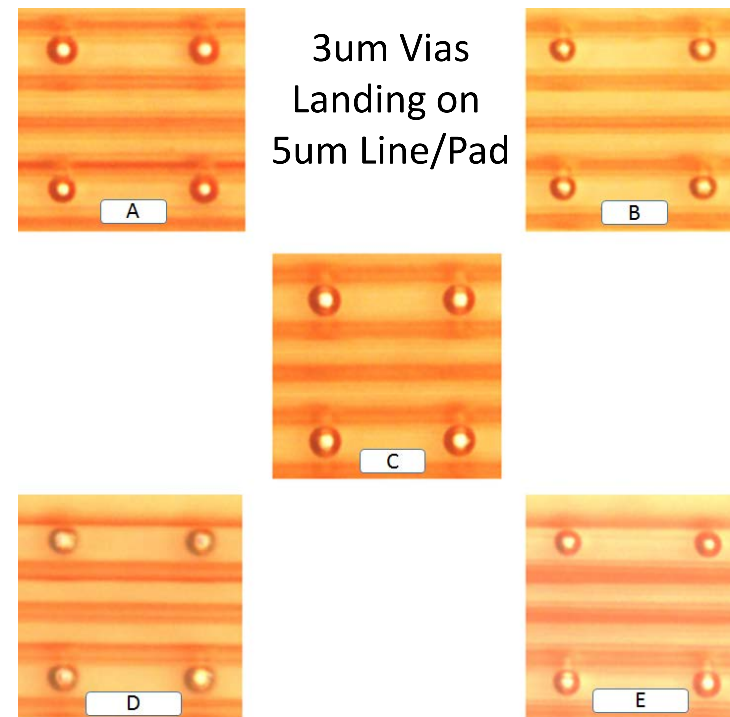
Via/Pad Registration Advantage of Glass



A, B, C, D and E - 5 Coupons selected for Registration Study



Results of Alignment shifts. All the 5 coupons had a systematic shift < 1um. The difference among the 5 coupons was negligible.