TWENTIETH ANNUAL

TestConX™

March 3 - 6, 2019

Hilton Phoenix / Mesa Hotel
Mesa, Arizona

Archive

Circuit Board Material Properties To Meet The High Frequency Needs Of 5G

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Mesa, Arizona ● March 3 - 6, 2019

For Discussion Today

- Technology Drivers
- Insertion Loss & its effects
- New Developments in Laminate Technology
- Copper Foil Effects on Insertion Loss

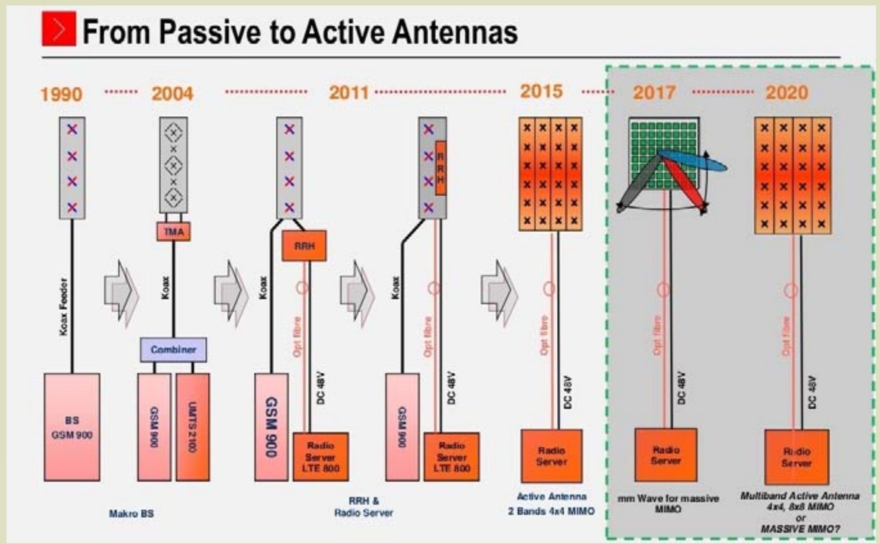
Technology Driving Material Needs

- New infrastructure needs
  - Massive scale cloud architecture
  - >1Gbs (Giga bits per second) data transfers minimum, up to 10Gbs (mobile)
  - Up to 1Tbs (Tera bits per second) B2B (business to business)
  - Lower power consumption (by a factor of 1000x)
  - "Zero second switching"
  - Multiple-Input and Multiple-Output (MIMO) and Multiband Active antennas

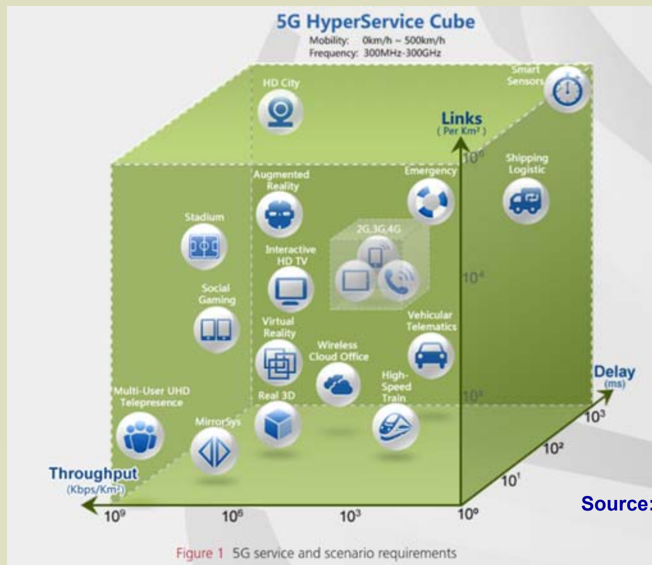
Technology Driving Material Needs

- "Internet of Things"
  - Anything may have an IP address and be connectable
  - IPv6 capable of 3.4×1038 addresses
  - Low (1 millisecond) Latency
- "Faster than thought" M2M (Machine to Machine) communication
  - Remote robot control
  - Mobile operating rooms, search and rescue, military

Technology Driving Antenna Design



Technology Latency and Throughput



Source: Huawei 5G Technology Vision

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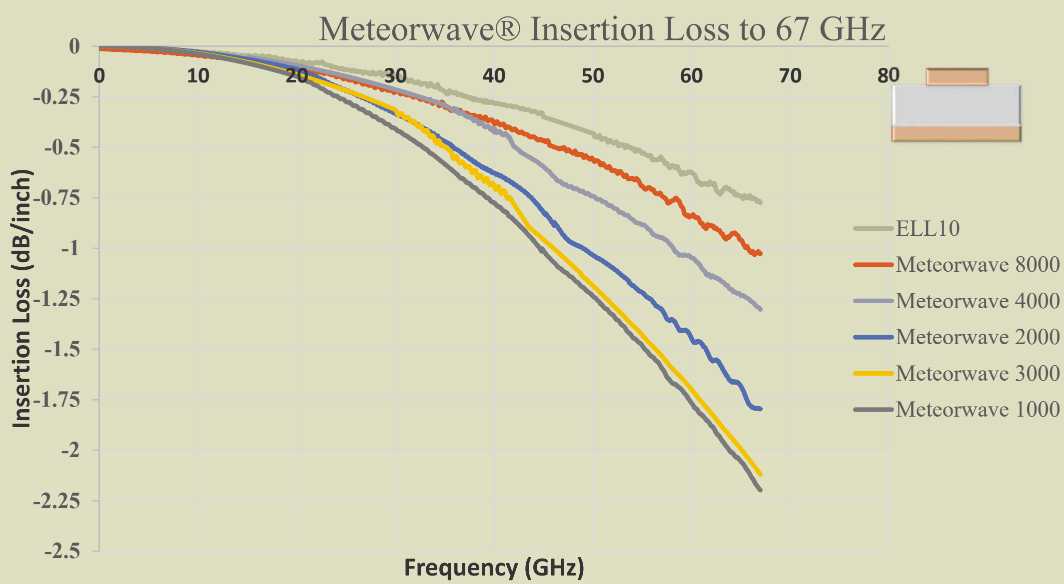
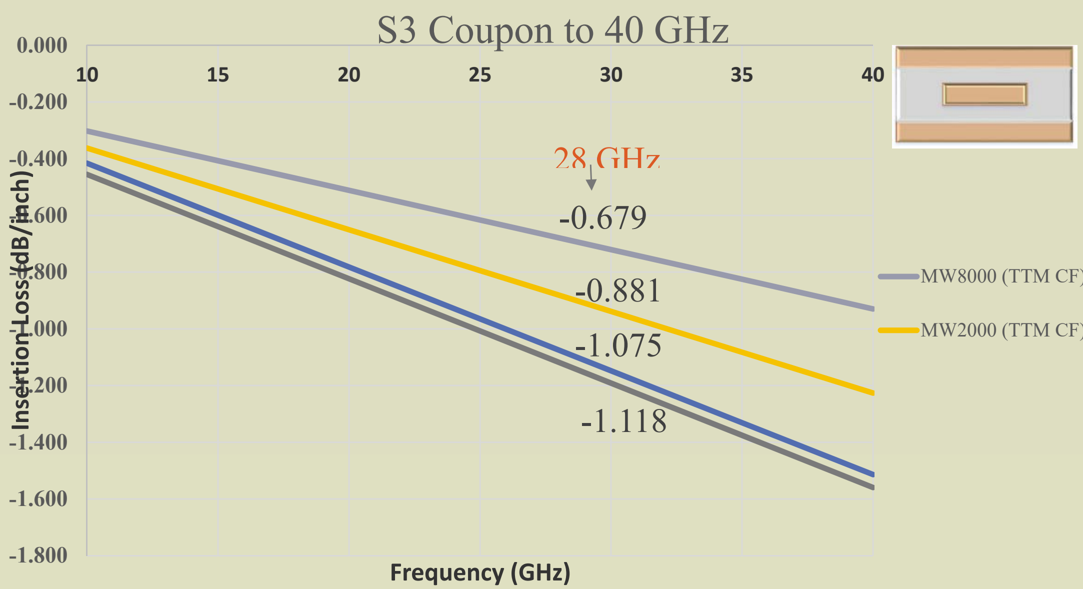
Microstrip Insertion Loss



Stripline Insertion Loss



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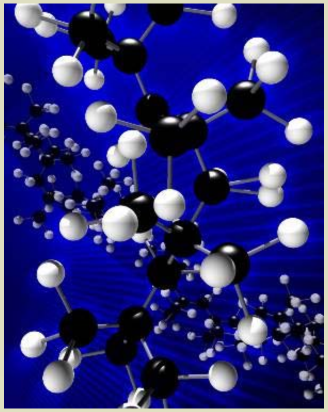
Development Areas

- Polymers
- Fillers
- Cladding
- Reinforcements
- Testing
- Processing

Advanced Polymer Building Blocks

- Low Polarity
  - Reduced loss
  - Lower moisture uptake
- High Tg and Low CTE
  - Lower stresses in assembly
- Very High Thermal Resistance
  - Lead-free resistance
- High Fracture Toughness
  - Eyebrow cracks
  - Pad cratering
- Cost is Always a Consideration

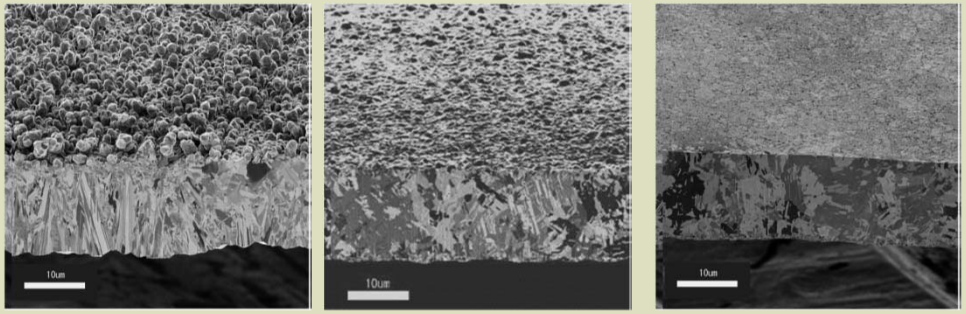


Fillers

- Use of inorganic fillers has grown
- Filler loading has increased
- Their use allows for property improvements unattainable by polymers alone
- Coefficient of Thermal Expansion (CTE), Dielectric properties, Thermal resistance, Thermal conductivity, Crack resistance
- Choice of correct filler is crucial to performance. It is not only the fillers dielectric and CTE properties, but shape and size are also important factors for processing and health

Digital Copper Set

RTFOIL® ≈ 4.5 micron Rz | HVLP & VSP® type foil ≈ 0.8 - 1.5 micron Rz | SI foil ≈ 0.5 micron Rz

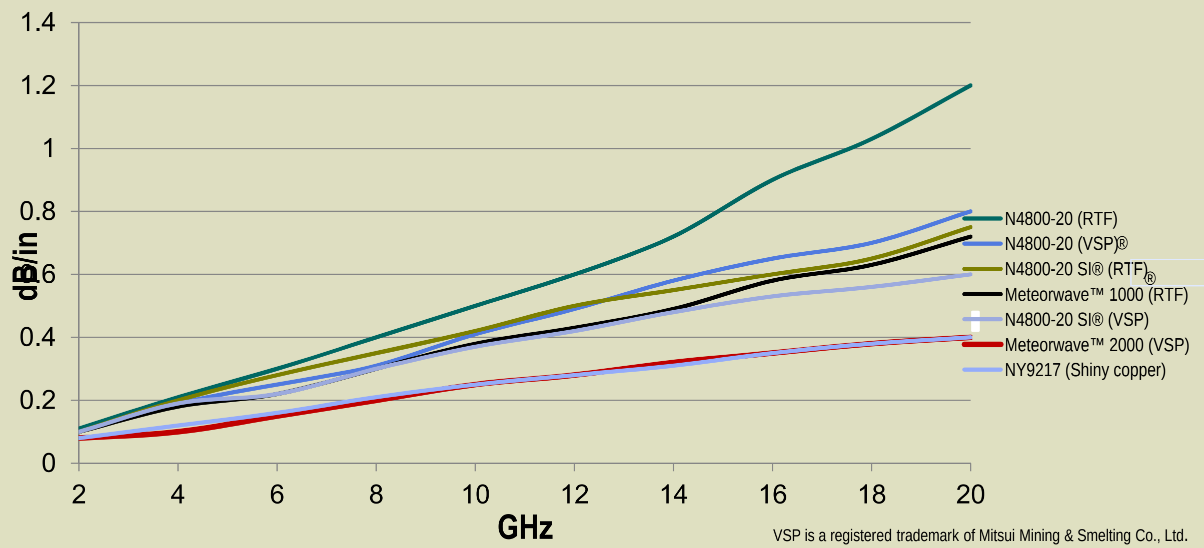


- Lower profile coppers (with acceptable peel strength) reduces skin effect on signal integrity and improves system attenuation

RTF = Reverse Treated Foil VSP® = Very Smooth Profile, is a registered trademark of Mitsui Mining & Smelting Co., Ltd.

SI = Signal Integrity Coper (in development)

Comparison w/ Different Copper Tooth Profiles



VSP is a registered trademark of Mitsui Mining & Smelting Co., Ltd.

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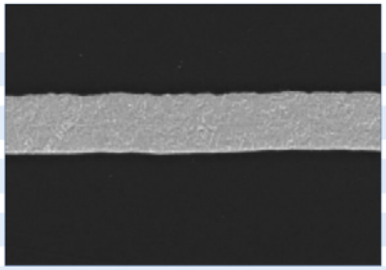
PTFE Copper Set

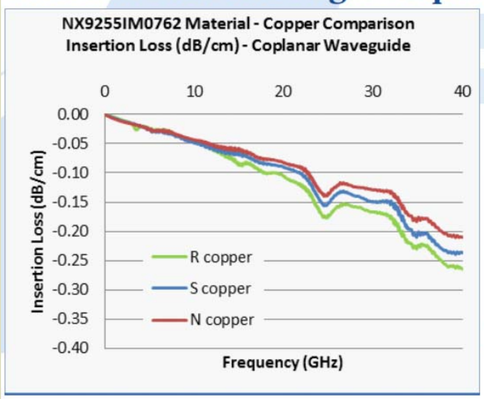
Parameters		Value
Untreated Side Roughness	Ra Rq	< 0.35 µm 0.30 µm
Treated Side Roughness	Rz Rq	≤ 1.3 µm 0.30 µm
Tensile Strength Transverse	Room T°C 180°C	> 207 MPa > 103 MPa
Elongation Transverse	Room T°C 180°C	8 - 30 % 10 - 30 %
Peel Strength After Thermal Stress (20s /285°C)	lbs/in	11.8 lbs/in
Solderability	-	Complies with IPC-4562A specifications

- Ultra flat ED copper foil extreme fine grain structure
- No profile zinc-free and arsenic free treatment
- Ultra-flat profile for minimalist skin effect
- Superior conductor losses and PIM performance



PTFE Copper Set

Insertion Loss and High Frequency Benefits



Material NX9255IM	Insertion Loss (dB/cm)			
	10GHz	20GHz	30GHz	40GHz
R Copper RTF	-0.046	-0.105	-0.166	-0.262
S Copper VLP	-0.048	-0.090	-0.150	-0.236
N Copper VLP No Profile	-0.043	-0.082	-0.129	-0.210

- S Copper / VLP: Up to 10% improvement compared to R Copper RTF
- N Copper / VLP No Profile: Up to 11% improvement compared to S Copper and up to a 20% improvement compared to R Copper

Properties of SI® Glass vs. E-Glass

Property	Units	SI Glass	E-Glass
Coefficient of Expansion	ppm/°C	3.4	5.5
Heat Conductivity	Kcal/mh°C	0.86	0.89
Specific Heat	cal/g°C	0.206	0.197
Dielectric Constant	1 MHz	4.4	6.6
Dissipation Factor	1 MHz	0.0006	0.0012

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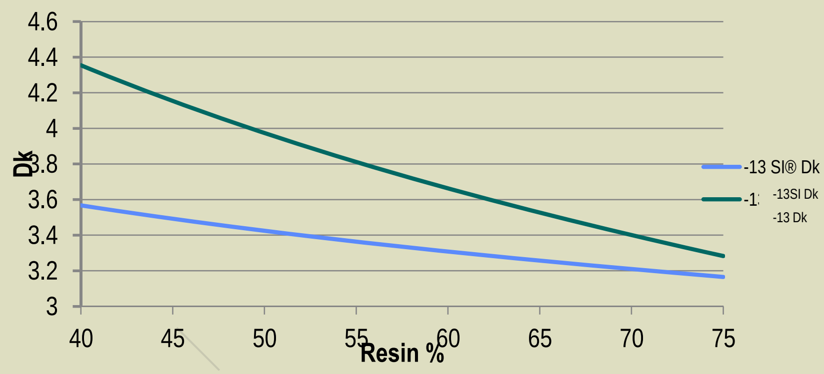
Effect of SI® Technology Dk vs. Resin Content



- Low Loss Glass SI
- Flatter Slope
- Less Sensitivity to Resin Content with D_k
- Less Skew

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New Substrates for Reinforcement

Substrate		SI® Glass	Nittobo NEX	Hi-Silica Fabric	Ultra high density hydrocarbon	Hydrocarbon / E-glass	LCP	Teflon Web
Properties								
	Dielectric Constant (Dk)	4.4	4.4	3.7	2.25	≈ 4	3.0 @ 1 MHz	2.1
	Dissipation Factor (DF)	.0006	0.0009	0.0001	0.0002	≈ 0.0008	0.00018 @ 1 MHz	0.0004
Laminate								
Properties	Dk (AB)	3.44 (52%)		3.36 (40%)	2.67 (66%)		3.2 (47%)	2.56(85%)
	Df (AB)	0.0023 (52%)		0.0016 (40%)	0.0019 (66%)		0.0016 (47%)	0.0017 (85%)
	Dk (IPC)	3.44 (52%)		3.37 (40%)	2.67 (66%)		3.2 (47%)	2.54(85%)
	Df (IPC)	0.0023 (52%)		0.0024 (40%)	0.0023 (66%)		0.0018 (47%)	0.002 (85%)
	DMA Storage Modulus, Mpa			11,500	2500			1375

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Continuous CAF Testing Protocol Quick CAF

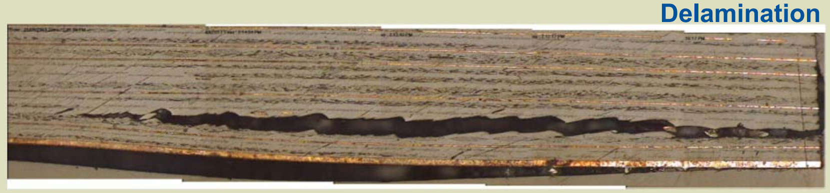
- Allows for faster screening and precise selection of raw materials
- Circuits Tested:
  - 90 degree 7mil, 10mil.
  - 0 degree 7mil, 10mil, 15mil.
  - Environment: 85% RH and 85°C and 100 volts
  - Continuous monitoring throughout test

Fracture Toughness

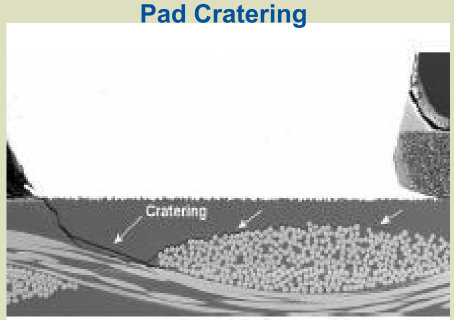
- Fracture toughness (K_{Ic} = √m)
  - measures resistance to the propagation of cracks
- Adopted from composites industry
- ASTM
  - D-5045, standard test methods for plane-strain fracture toughness and strain energy release rate of plastic materials
  - E-399, test method for linear-elastic plane-strain fracture toughness K1c of metallic materials
- Rewritten as IPC TM 650 2.4.52 fracture toughness

Why is Fracture Toughness Important?

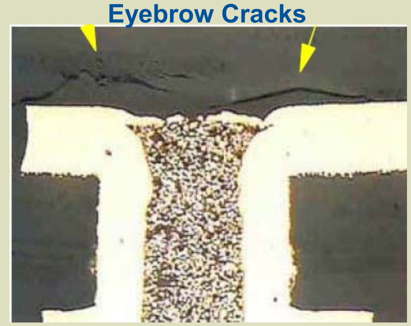
Delamination



Pad Cratering



Eyebrow Cracks



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Summary

- The primary driver for 5G materials is lower attenuation
- Base materials play an important roll in reducing attenuation
- Lowering loss and controlling Dk are the driving forces while maintaining a material that can be processed through todays PWB processes
- Fiberglass has been the prevailing substrate for decades due to its stabilizing influence
- The drive to reduce copper roughness while maintaining bond strength continues