

### **Comparing Advanced Materials Properties for High Frequency Telecommunications Hardware Applications**

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### Agenda

- Introduction to 3M Company & Advanced Material Division
- Material Challenges for 5G and Millimeter Wave Signal Transmission
- 3M Material Solutions and Applications

3M<sup>™</sup> Glass Bubbles

**3M™ Nextel™ Ceramic Fibers** 

- Summary
- Questions during or after the presentation can be asked at <u>3M.com/5G AST</u>



### Who we are – 3M Consists of Four Business Groups

Working together to leverage the breadth of solutions & support

Safety & Industrial



Transportation & Electronics



- Display materials
- Automotive and aerospace
- Electronics materials
- Commercial solutions
- Advanced materials
- Transportation safety

Health Care



Consumer



# At 3M we can help solve your design challenges by leveraging the <u>breadth</u> of 3M Technology

Ad Adhesives	<b>Em</b> Electronic Materials										Display Components	Hd Healthcare Data Management
<b>Bi</b> Biomaterials	<b>Fi</b> lms	<b>Nw</b> Nonwovens							Modeling & Simulation	Acoustic Management	Energy Components	Light Management
<b>Ce</b> Ceramics	Fluoro- materials	<b>Pm</b> Performance Materials	Am Additive Manufacturing	Precision Coating & Web Processing	Radiation Processing	Analytical Science	Process Design & Control	Cv Computer Vision	Ro Advanced Robotics	Biodetection & Microbial Management	<b>Eg</b> Engineered Graphics	Mechanical Fasteners
<b>Co</b> Advanced Composites	<b>Mm</b> Metamaterials	Porous Materials & Membranes	Mo Molding	Pd Particle & Dispersion Processing	Surface Modification	Converting & Packaging	<b>Sd</b> Sustainable Design	Data Science & Analytics	Sensors	Connected Systems	Fe Flexible Electronics	Skin & Wound Management
Dental & Orthodontic Materials	Nano- technology	<b>Rm</b> Release Materials	Micro- replication	Pp Polymer Processing	Thin Film & Plasma Processing	Inspection & Measurement	We Accelerated Weathering	Es Electronic Systems	Software Solutions	Dd Drug Delivery	<b>Fp</b> Filtration & Purification	Tm Thermal Management
Materials			Processing		Capabilities		Dig	Digital		Applications		

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### **3M Technologies for the Electronics/5G Market**





### **5G Customer Challenge: Increased Signal Transmission**

Why this is a design challenge in 5G



### **5G Customer Challenge: Increased Signal Transmission**

#### Why this is a design challenge in 5G



NEEDS: Faster Data Speeds, More connected Devices, Decreased Latency

ENABLING: More Streaming/Gaming, Internet of Things, Autonomous Driving

 Table Source: Cisco Visual Networking Index (VNI) Compete Forecast Update Dec 2018

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#### Driving antenna frequencies up

4G	5G	5G	WiGig	6G
0.7 to 2.6 GHz	3.5 to 6 GHz	28 to 39 GHz	60 GHz	100 GHz to 3 THz
	$\sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{i$			

New materials needed to offset loss

#### Signal Loss $\alpha$ (F \* Df \* $\sqrt{Dk}$ )

- Higher frequency increases loss
- Materials needed with better dielectric properties to help reduce loss

Dk = dielectric constant Df = dissipation factor

### 3M<sup>™</sup> Glass Bubbles

#### Reduces Dk and Df in composite materials

#### Technology

#### 3M<sup>™</sup> Glass Bubbles

Small hollow, thin walled, unicellular spheres primarily composed of soda-lime borosilicate glass

Property	Value						
Shape	Hollow, thin walled, unicellular spheres						
Color	White						
True Density <sup>†</sup>	0.32 - 0.60 g/cc						
Crush Strength*	6000 – 28,000 psi						
Softening Temp	>600° C						
Average Dia	15 - 25 microns						
Moisture	<0.5%						
Dielectric Constant (Dk) @10GHz	1.2-1.5						
Dissipation Factor (Df) @10GHz	0.003-0.005						



Note: The data presented is not for specification purposes

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#### Why is it important to 5G?

#### Impact Dk & Df

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Glass Bubbles Volume %



Glass Bubbles Volume %

### 3M<sup>™</sup> Glass Bubbles for Light-weighting and 5G

RF Transparency, Density Modification, Low Dielectric Constant and Loss



Low Dielectric PCBs



Antenna Transmission Window



Radome Enclosure

#### 5G Benefit for Internet of Things (IoT)



AR/VR & Video Streaming



Smart City



Telemedicine



**Autonomous Driving** 

### **Copper Clad Laminate for Printed Circuit Boards**

**Application Specific Design Challenges:** 

#### **Problem to Solve:**

- Signal / Frequency loss between layers
- Delamination between layers
  - Adhesion Performance
  - Material Expansion (CTE)
- Improve overall cost attractiveness
- Thermal management
- Reduction of overall weight of CCL





### **3M<sup>™</sup> Nextel<sup>™</sup> Ceramic Fibers**

#### **RF** Transparent and High Modulus



	Why is it important to 5G?								
c Fibers?	Low Df Properties, High Modulus	Resin	Properties	Units	15V% Ceramic Fiber Chopped	30V% Ceramic Fiber Chopped	30V% e- Glass Fiber Chopped	53V% Ceramic Fiber	316 Stainless Steel**
	-		Tensile Modulus @ Break	GPa	18	34	15		
with	<ul> <li>Metal-like</li> </ul>	Polyamide (PA)	Dielectric Constant (Dk)	9.5 GHz	3.73	4.4	3.89		
vvitti	mechanical		Dielectric Loss (Df)	9.5 GHz	0.008	0.007	0.01		
	properties	Polycarbonate (PC)	Tensile Modulus @ Break	GPa	16	35	14		
	<ul> <li>RF transparent</li> </ul>		Dielectric Constant (Dk)	9.5 GHz	3.51	4.34	3.65		
	<ul> <li>2X stiffness of GF at</li> </ul>		Dielectric Loss (Df)	9.5 GHz	0.004	0.004	0.007		
	same vol.%	PBT	Tensile Modulus @ Break	GPa		31	17		
	<ul> <li>Ability to thin-wall a</li> </ul>		Dielectric Constant (Dk)	9.5 GHz		4.43	3.74		
	design		Dielectric Loss (Df)	9.5 GHz		0.003	0.007		
	<ul> <li>Match CTE of</li> </ul>		Tensile Modulus @ Break	GPa				181*	160-200
	metal/aluminum	Ероху	Dielectric Constant (Dk)	9.5 GHz				6.4	N/A
	<ul> <li>Fasily processed via</li> </ul>		Dielectric Loss (Df)	9.5 GHz				0.01	N/A

\*Chopped fiber = 3mm, \*53V% Data on 0° laminate, \*\*316 SS properties depend on composition and processing

NOTE: All the data in this table is not for specification purposes. This data is for reference only to show typical property values.

The data presented is not for specification purposes

#### Technology

#### What are Nextel <sup>™</sup> Ceram

Continuous Aluminum Oxide fibers that structurally reinforce to help improve modulus of the composite simultaneous electrical insulation



- 3M<sup>™</sup> Nextel<sup>™</sup> Fibers has the highest known modulus of all continuous, RF transparent fibers
- Low Df, RF transparent
- Excellent chemical resistance
- Thermal conductivity >1.7X vs. chopped glass fiber PMC
- Efficient mfg vs. CNC metal or monolithic ceramic

injection or compression

molding

### **3M™ Nextel™ Fiber Applications in Electronic Devices**



### **Application Areas:**

- Replace metal or carbon fiber composite parts/frames/antenna splits for RF transparency, while providing stiffness and protection
- Parts requiring thin, stiff characteristics where other materials may fail



### **Transmission Loss Test Set-up for 28 – 78GHz**

S21(transmission) measurement using VNA (Vector network analyzer)





### **Transmission Loss Compared to Air and Steel**

Transmission Loss Between 26.5 and 39GHz



- Continuous ceramic fiber compared to GF at 54vol% in an epoxy PMC
- Depending on thickness and frequency, there are ranges where CeF is better than GF



### **Transmission Loss Compared to Air and Steel**

Transmission Loss Between 71 and 86GHz



- Continuous ceramic fiber compared to GF at 54vol% in an epoxy PMC
- Depending on thickness and frequency, there are ranges where CeF is better than GF



### Summary

- 3M has material solutions for next generation devices 5G and mmWave
- 3M<sup>™</sup> Glass Bubbles can be used as a low dielectric additive in polymer composites used in antenna grade PCB CCL, electrical connectors, radome enclosures
  - Reduce signal loss/issues
  - Lower CTE to prevent solder breakage and delamination
- 3M<sup>™</sup> Nextel<sup>™</sup> Ceramic Fibers can be extruded or prepregged with plastic matrices and efficiently molded into parts benefiting antenna applications
  - RF transparency
  - Low loss (Df) at 5G wavelengths
  - Structural mechanical properties
  - Design freedom; thin walling, ease of processing (e.g. injection moldable) and color matching



## **Questions?**

<u>3M.com/5GAST</u>

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