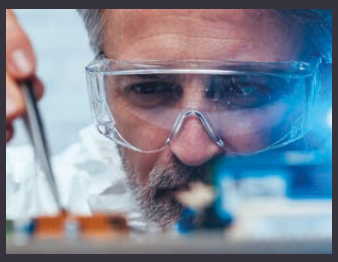
VIBRANTZ TECHNOLOGIES™

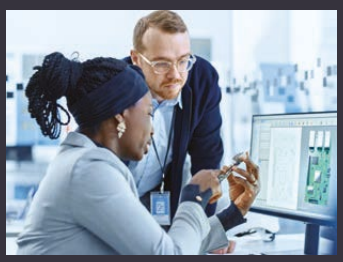
Vibrantz 5G Solutions

Materials and Engineered Products for 5G Applications

vibrantz.com

Why engage with Vibrantz electronic materials?



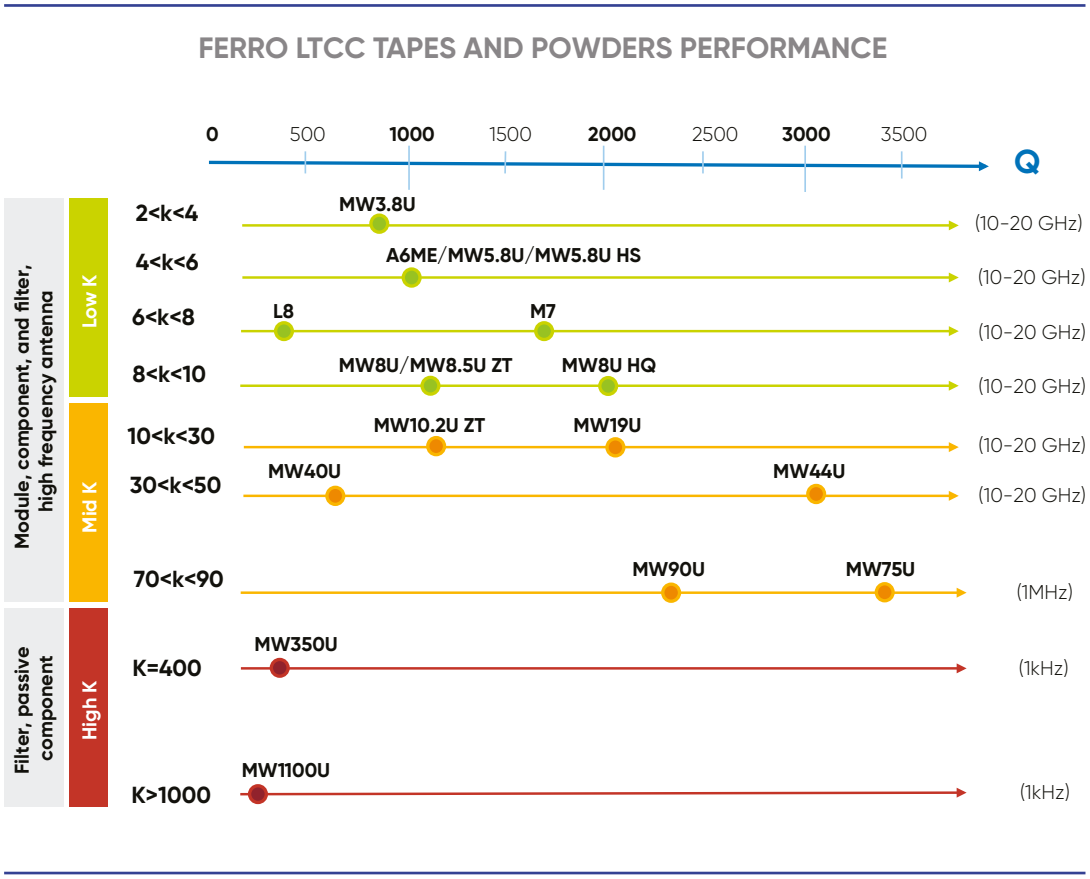
- **Vibrantz is one of the leading manufacturers** of materials and engineered products for devices in the electronic industry. Leveraging our glass, metal, ceramics and organic competencies, we provide our customers with performance-enhancing engineered formulations.
- **Advancing technology through integrated material systems**, we utilize our vertically integrated supply chain to create customized, proprietary products for our customers.
- **Worldwide technology resources** provide our customers with hands-on support to help them design next-generation electronics.
- **Responsible environmental care** is ensured through our offering of REACH and RoHS compliant products. Most of our glass and powder products are REACH registered.

Contents

Vibrantz LTCC Products – At a Glance

For more than 20 years Vibrantz has been a major innovator of low temperature co-fired ceramic (LTCC) products for high-reliability and high-frequency applications.

Our portfolio of LTCC products include pastes, tapes, formulated dielectrics and conductor materials that are recognized as proven leaders for applications in which high frequency, low loss, package volume and weight are critical.



LTCC Tape Systems for 5G Applications

Low temperature co-fired ceramic (LTCC) tape systems

We offer glass-ceramic, lead-free composite formulations with stable K and low loss tangent (up to 60GHz) that are designed for modules, packages, substrates and complex LTCC chip components operating over high frequencies.

Vibrantz's technology experts work with customers worldwide to deliver the best-possible tailored technology solutions for advanced radar, antenna, electronic filter, satellite and telecom applications.

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High frequency LTCC tapes

A6M-E LTCC TAPE | GOLD SYSTEMS FOR HIGH FREQUENCY, HIGH RELIABILITY APPLICATIONS
M7 LTCC TAPE | SILVER SYSTEMS FOR COMMERCIAL APPLICATIONS

	A6M-E	M7
Chemistry	Lead and phthalate-free RoHS and REACH compliant	Lead and phthalate-free RoHS and REACH compliant
Thickness	50, 125, and 250um	50 and 125um
K	6.0 ± 0.1 @ 60 GHz	7.0 ± 0.1 @ 10-60 GHz
Loss Tangent	<0.15% @ 60 GHz	<0.1% @ 10-60 GHz
Q	Q >600 @ 60 GHz	>1000 @ 60 GHz
Flexural Strength	170 MPa	294 MPa
Thermal Conductivity (25°C/77°F, W/m-K)	2.0	5.2
Easy Lamination	Yes	Yes
Firing Condition	850°C, 15min	850°C, 30min
Metal Conductor	Au	Ag
Compatible Conductor Pastes Product	CN30-078PF (via) CN30-080G (surface) CN36-020 (surface) solderable FX30-025G (inner) Mixed metal system available	CN33-793 (via) CN33-795 (surface) CN33-798 (inner)
Electroless Plating	No	Yes

Vibrantz A6M-E AND M7 TAPE SYSTEMS

OUTSTANDING PERFORMANCE FOR 5G APPLICATIONS

5G applications require bigger channels to speed up data, lower latency to be more responsive and the ability to connect a lot more devices at once for sensors and smart devices.

Vibrantz A6M-E and M7 tape systems are specifically formulated to meet the varied and demanding component design requirements of new ceramic materials, providing a perfect fit for 5G applications such as antennae, filters and resonators.

Low-mid frequency LTCC tapes

L8 LTCC TAPE SILVER, GOLD AND MIXED METAL SYSTEMS FOR USE UP TO 40GHz

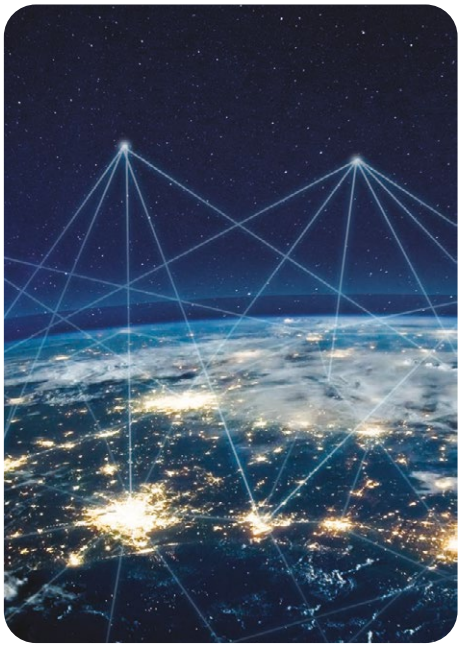
	L8
Chemistry	Lead and phthalate-free RoHS and REACH compliant
Thickness	2, 5 and 10 mil
K	7.4 +/- 0.2 @ 10GHz
Loss Tangent	< 0.0025 @ 10GHz
Insulation Resistance	> 10x10 Ω
Breakdown Voltage	> 900 V/mil
Electrolytic Leakage Current	< 1 µA/cm2
Fired Density	> 3.1
Flexural Strength	275 Mpa
Thermal Coefficient of Expansion	6 ppm/C
Compatible Conductor Pastes Product	825°C, 6-8min

Metal Conductors	Au	Ag
Compatible Conductor Paste Products	FX30-025G (inner)	CN33-498G (inner)
	CN30-087PF (via)	CN33-493 (via)
	CN30-080G (surface) Wire-Bondable	CN33-495 (surface) Plateable
	CN36-020 (AuPtPd surface) Solderable	CN39-001 (AuPtAg surface) Solderable

Additional systems including mixed metal, resistors, dielectrics and post fire solderable and wirebondable conductors are also available.

Vibrantz's L8 LTCC material system can be used in a variety of low-mid frequency and high reliability applications including automotive, aerospace, telecommunication, medical, and other low - to mid-frequency applications.

Ideal solutions for high-speed data transfer



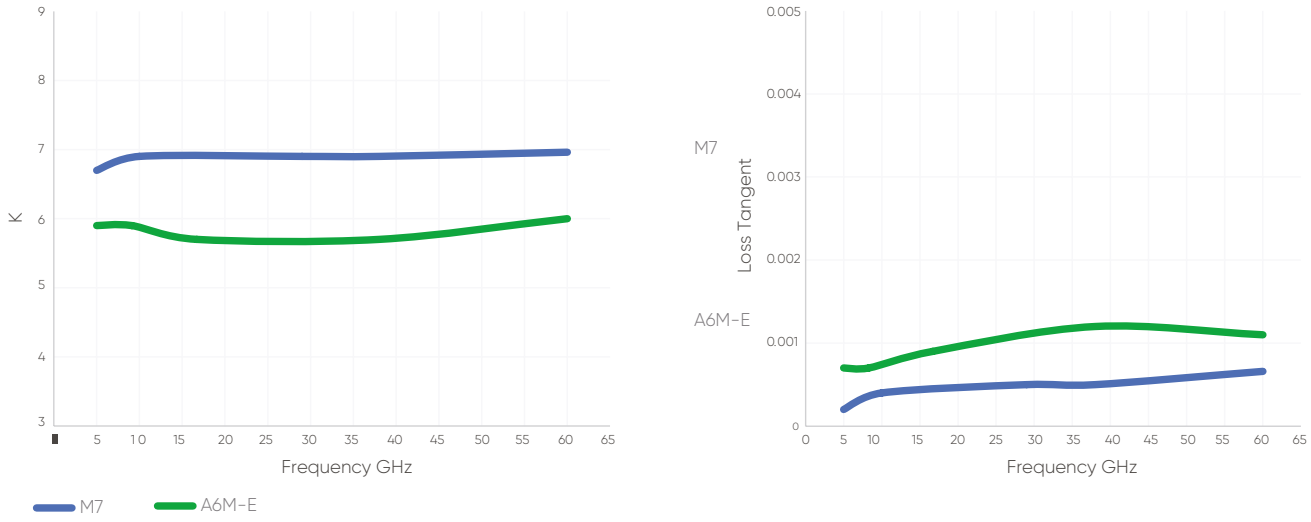
A6M-E LTCC Tape – Gold systems for high-frequency, high-reliability applications.

A6M-E tape systems offer a stable dielectric constant and low loss over a wide range of frequencies from 10 GHz to 60 GHz, making them ideal for high-speed data transfer. Their low loss tangent (high quality factor, Q) enables minimum energy loss and heat generation, while their high temperature stability provides increased reliability and longer lifetime for integrated design in a harsh environment. These attributes make A6M-E tape systems combined with gold (Au) conductor the ultimate solution for 5G applications requiring extremely high reliability.

M7 LTCC Tape – Silver systems for commercial applications.

M7 tape systems build on the proven success of the A6M-E systems. They offer a stable dielectric constant and low loss over a wide range of frequencies, from 10 GHzto 60 GHz. Their compatibility with a low-cost silver conductor make them ideal for high-speed data transfer in commercial applications that must balance costs and performance.

A6M-E and M7 PERFORMANCE FOR 5G APPLICATIONS

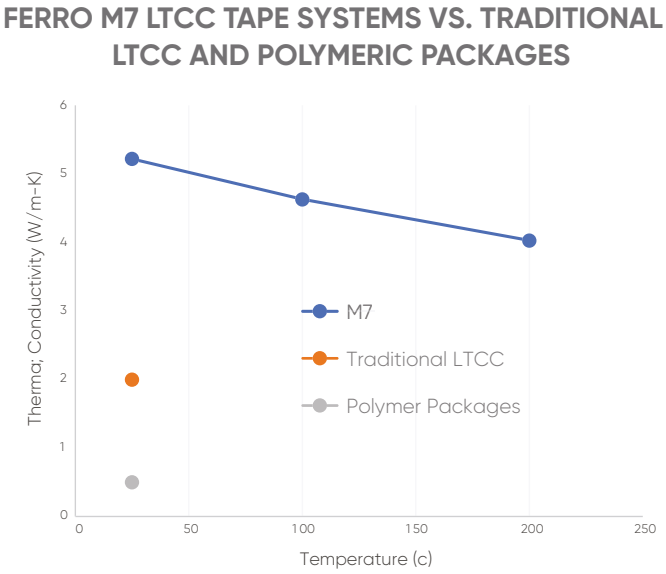


Key competitive advantages – M7

Superior thermal strength

The thermal conductivity performance of 5G packaging substrates is critical for thermal management in high-power applications.

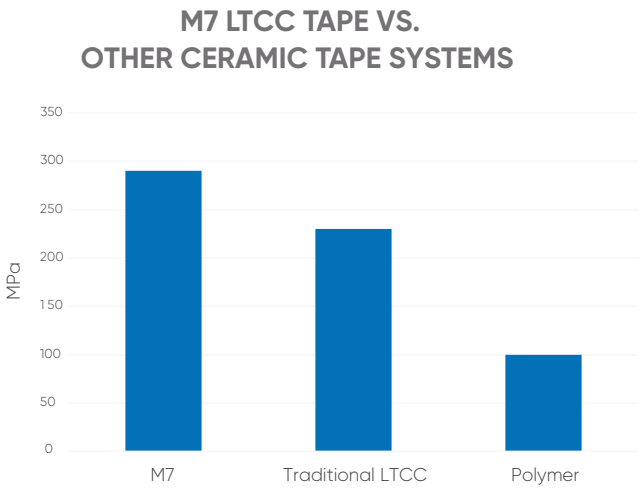
Vibrantz M7 tape systems offer excellent thermal conductivity, far superior to traditional LTCC and polymeric packages.

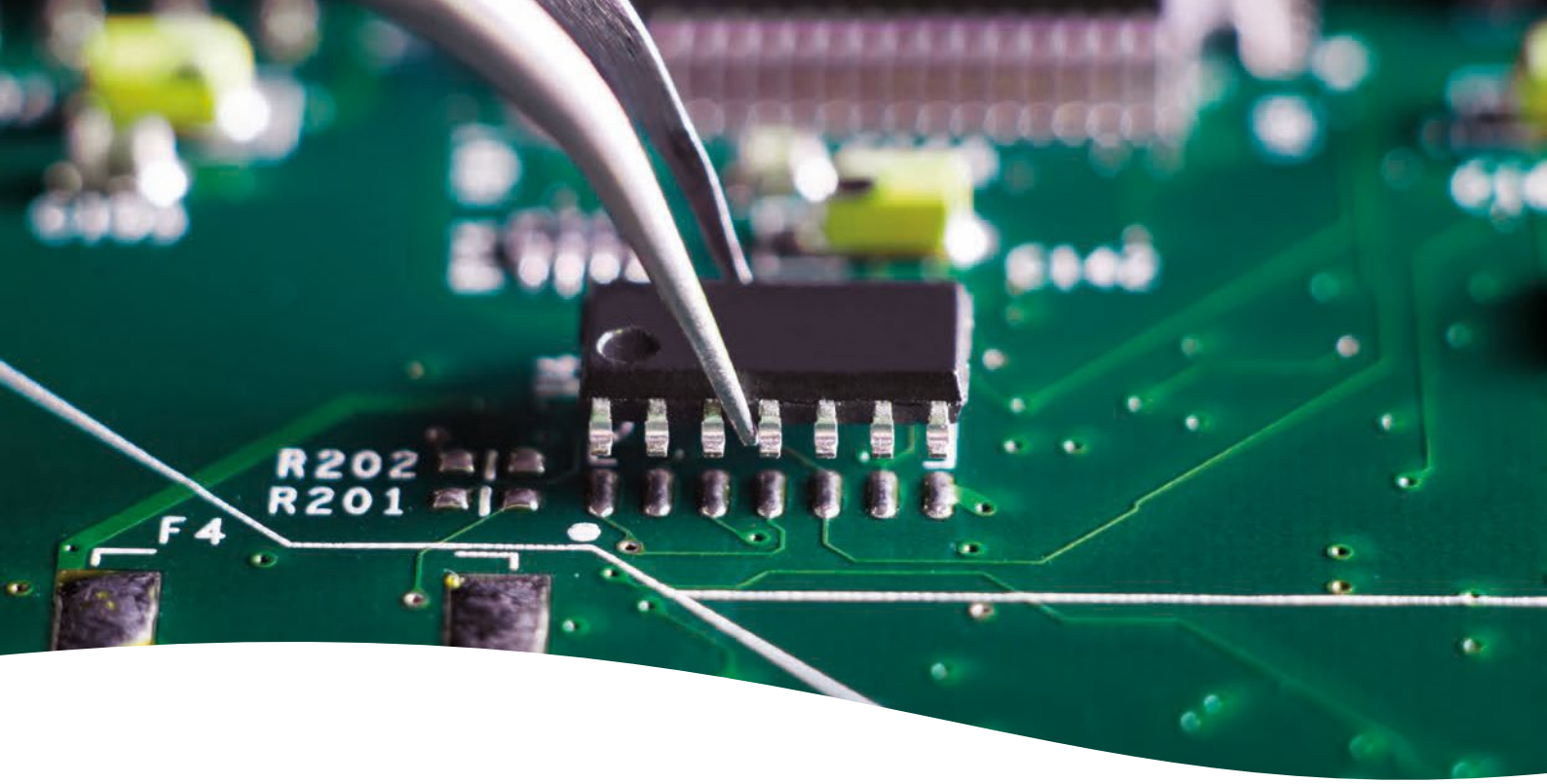


Superior flex strength

The flexural strength of 5G packaging-substrates is critical for package reliability in high power applications.

To this end, Vibrantz M7 tape systems offer significant flexural strength over tradtional crystallizing glass-ceramic based LTCC and polymeric packages.





Ferrite Tape Systems

Ferrite tapes for LTCC systems

Vibrantz manufactures ferrite tapes as base materials for LTCC systems that can be found in many 5G applications. These include small integrated components used in hybrid power electronic circuits, planar transformers and inductors as well as AC-DC converters.

Ferrite (magnetic) materials combined with screen printable silver (Ag) conductors can be designed and fabricated into multilayer structure devices through LTCC processing methods.

Our ferrite tapes can be co-fired with passive dielectric and conductor materials, which allows for the integration of embedded passive components in the multilayer structure to create hybrid power electronic circuits.

Ferrite materials can also be used as a substrate for semiconductor components and/or other devices that are part of the power electronics system. The thickness of the materials can be customized upon request.

Ferrite LTCC tapes provide excellent magnetic coupling, good permeability, high resistivity and low firing temperatures while providing good saturation.

Vibrantz ferrite tape characteristics

Ferrite tape product	40010	40011	40012
Primary Characteristic	Ferrite (magnetic)	Ferrite (magnetic)	Ferrite (magnetic)
Lead-free	Yes	Yes	Yes
Firing Temperature	885°C	885°C	885°C
Permeability	≥ 60	≥ 200	≥ 450
Shrinkage, XY%	17+/-1	17+/-1	17+/-1
Shrinkage, Z%	14+/-1	16.5+/-1	16.5+/-1
Fired Density (g/ml)	5.3	5.3	5.3
TCE ppm	9.4	9.4	9.4
Curie Temperature °C	350°C	150°C	150°C
Thickness*	65-75um	65-75um	65-75um
Ag Conductors	902 (via fill), 903-A (surface), 903-B (inner)	902 (via fill), 903-A (surface), 903-B (inner)	902 (via fill), 903-A (surface), 903-B (inner)
Passive Dielectric Paste	4926R	4926R	4926R

*Material thickness can be customized upon request.

LTCC Dielectric Powders for 5G Applications

LTCC powders

Vibrantz manufactures a wide range of lead-free LTCC powders and high frequency dielectric formulations that offer state-of-the- art,low insertion loss and high mechanical strength for dielectric resonators, filters and antennas used in 5G applications.

Our formulation expertise allows us to provide near-zero tau(f) LTCC dielectrics for applications demanding a high degree of temperature stability.

We offer a complete portfolio of dielectric materials that includes formulations with stable dielectric constants ranging from 3.8 up to 1100 and low dielectric loss in the 5G mm- wave frequency range.

Our formulation expertise allows us to provide near-zero tau(f) LTCC dielectrics for applications demanding a high degree of temperature stability.

Vibrantz dielectric powder range

Low-K powders for LTCC	Dielectric constant	Q factor (1/tan δ)	Loss tangent
MW3.8U	3.8	800	0.00125
MW5.8U HS	5.7	717	0.00139
MW5.8U	5.8	952	0.00105
MW8U	8.0	1160	0.00156
MW8U HQ	8.3	1784	0.00056
Mid-K powders for LTCC	**Dielectric constant**	**Q factor (1/tan δ)**	**Loss tangent**
MW19U	19.4	1932	0.00051
MW40U	41	640	0.00156
MW44U	43.5	3030	0.00033
Temperature stable (zero τF) powders for LTCC	**Dielectric constant**	**Q factor (1/tan δ)**	**Loss tangent**
MW8.5U ZT	8.5	931	0.00107
MW10.2U ZT	10.2	1022	0.00098
High-K powders for LTCC	**Dielectric constant**	**Q factor (1/tan δ)**	**% DF**
MW75U	74	3300	0.03% 1MHz
MW90U	91	2300	0.04% 1MHz
MW1100U	1100	n/a	0.60% 1kHz

HS - High Strength
HQ - High Q
ZT – Zero-Tau(f)
Loss tangents measured at 10-20GHz

High-Fire Dielectric Powders for 5G Applications

Temperature-stable high-fire powders

Vibrantz supplies a wide range of materials for single layer capacitor and substrate applications for 5G technologies.

Our formulation expertise enables us to offer extensive choice for high-fire products with varying degrees of temperature stability depending on the end application, while the mid- to-low-K dielectric powders are specifically designed to have ultra-low loss at mm-wave frequencies.

We also offer a complete lead-free dielectric materials portfolio with dielectric constants ranging from 10 up to 5000.

This customizable range enables production of various device sizes (k), high frequency performance (Q) and degree of temperature stability (Tf) for 5G antenna and resonator applications.

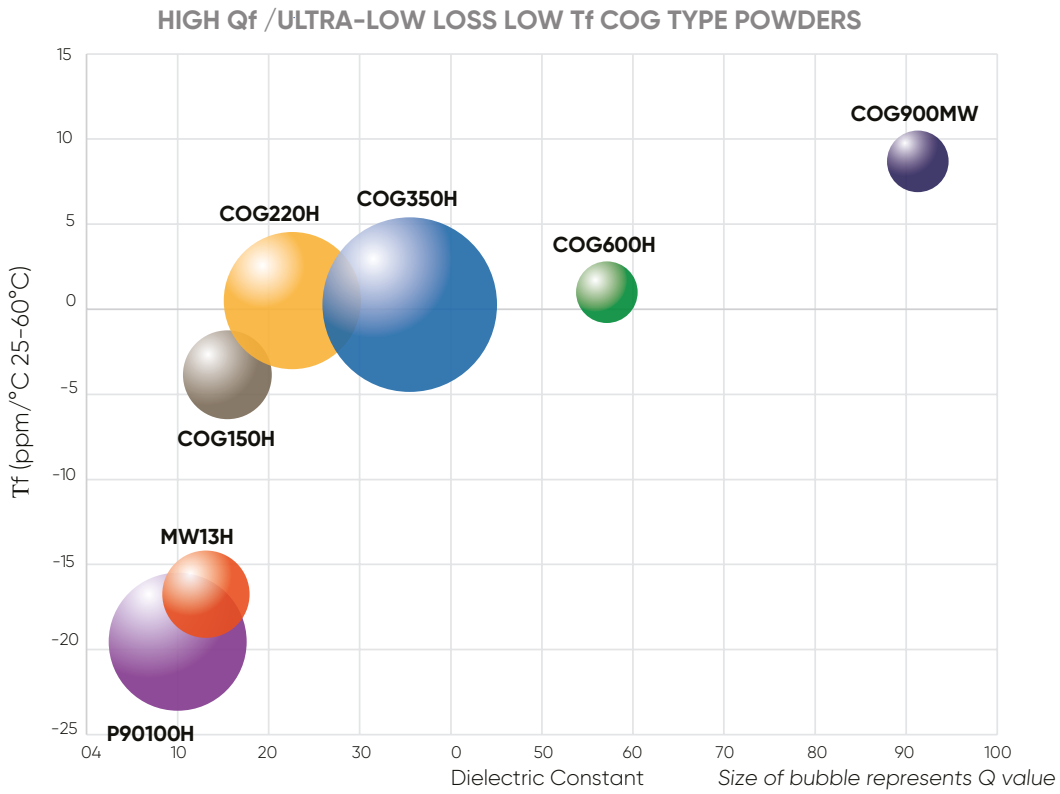
Vibrantz supplies a wide range of material for single layer capacitor and substrate applications for 5G technologies.

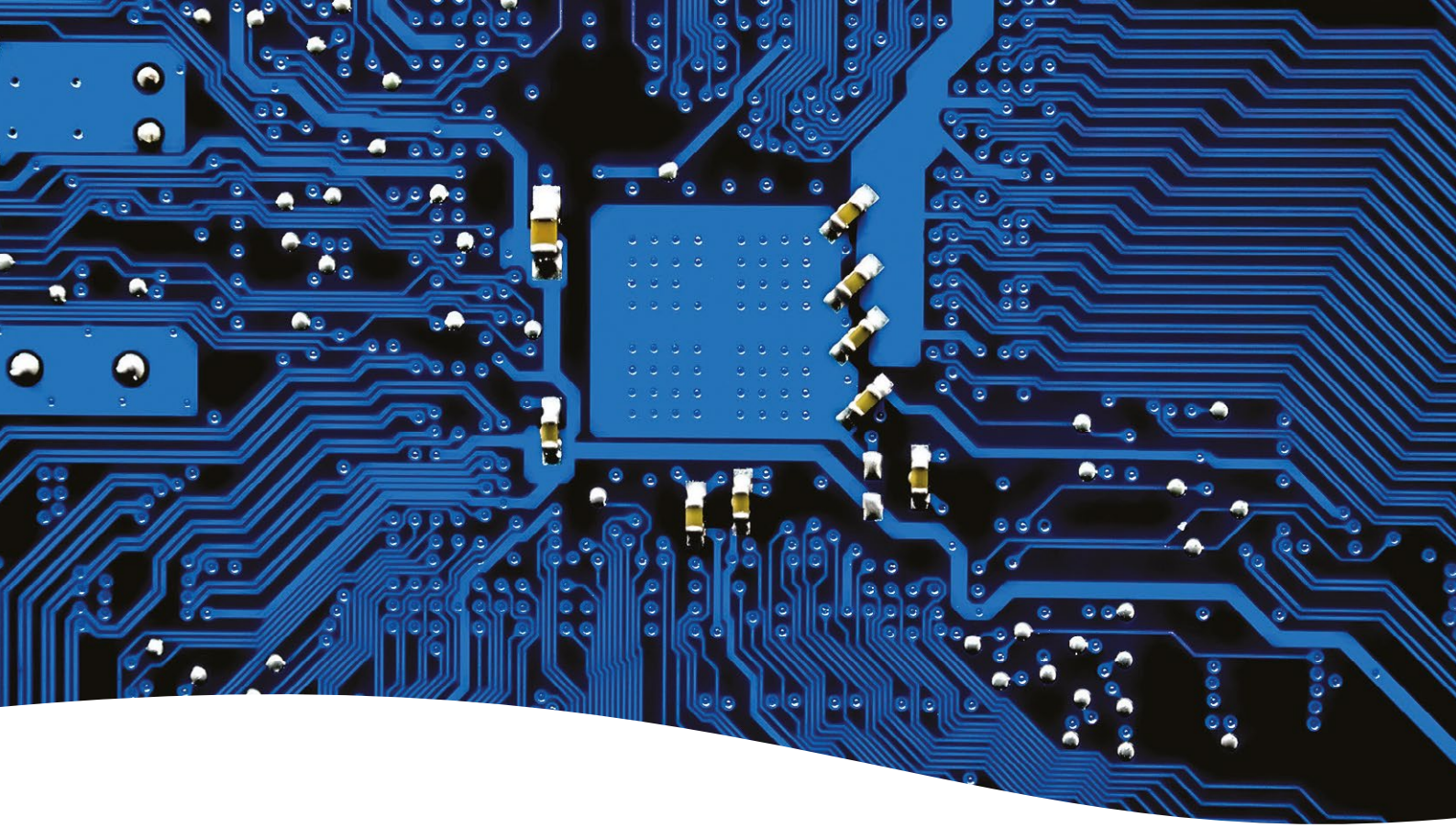
High fire dielectric powders for 5G

Dielectric powder name	Dielectric constant	Q factor (1/tan δ)	Q*f	τf (ppm/°C 25-60°C)
P90100H	9.6	5,510	63,212	-19.5
MW13H	13	2,220	13,682	-16.8
COG150H	15.2	2,288	22,895	-4.00
COG200H	21.2	5,280	51,780	0.5
COG350H	35.4	8,500	36,000	0.25
COG600H	57	1,075	3,686	1.0
COG900MW	91.1	1,101	6,030	8.8

X7R dielectrics

Dielectric powder	Dielectric constant	%DF at 1 kHz	TCC
X5000	5000	1% @ 100 µm	X7R





Electronic Conductive Pastes for 5G Applications

Vibrantz manufactures conductive pastes designed for multilayer ceramic capacitors (MLCC) and non-MLCC devices such as inductors, filters, thermistors and actuators.

Our in-house glass and metal expertise allow us to customize pastes with tailored properties to suit many applications.

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ELECTRODES

INNER ELECTRODE PASTES

- [95Ag/5Pd to 100Pd or 100Pt
- 80Ag/20Pd and 70Ag/30Pd

ELECTRODE PASTES

- Ferrite inductors
- PZT devices
- Thermistors
- Disc varistors

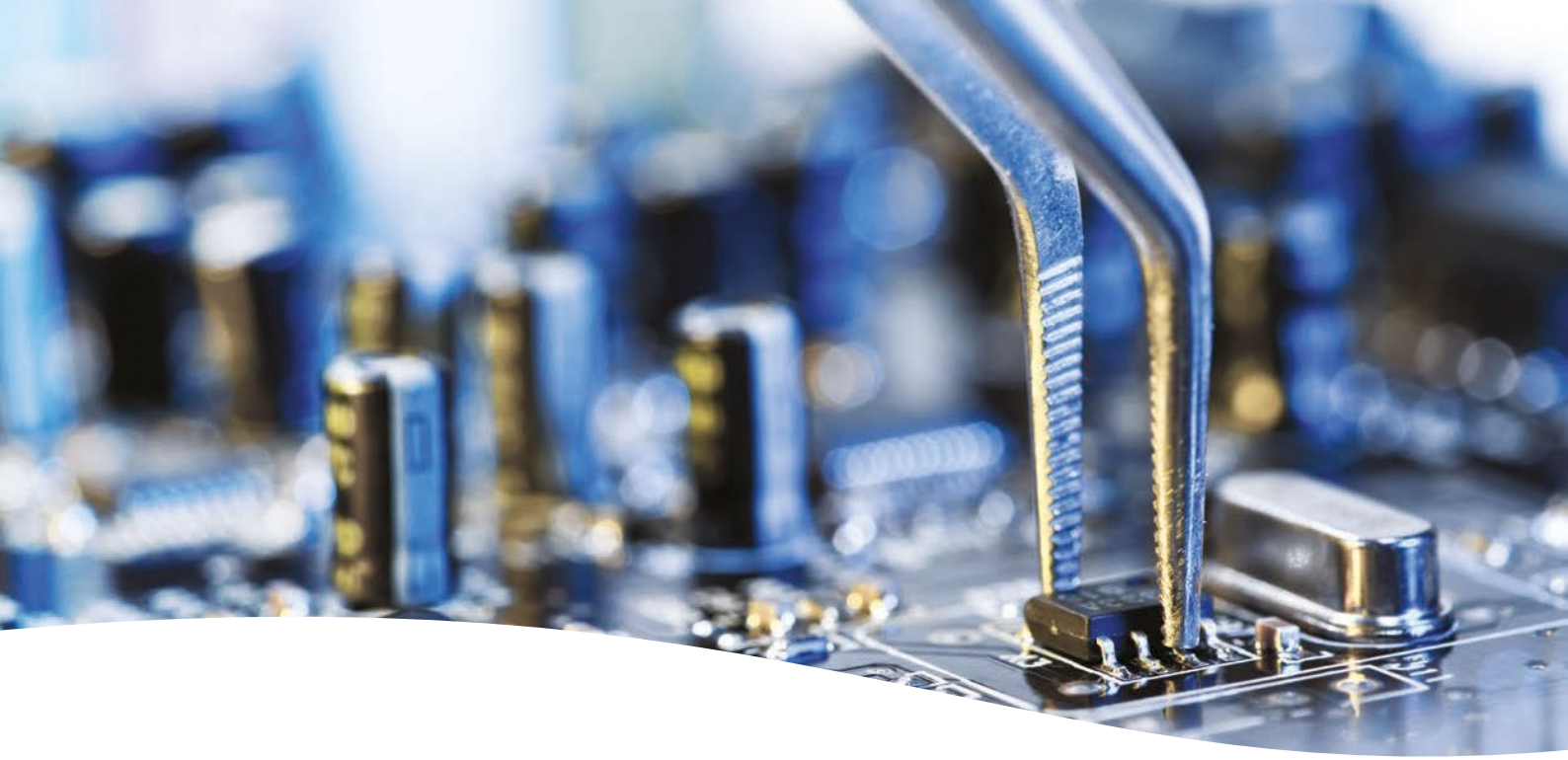
TERMINATIONS

PLATEABLE TERMINATION PASTES

- Ranging from 95Ag/5Pd to 100% Ag
- Ferrite, MLCC, Al2O3 and PZT ceramics
- NTC chip components
- Varistors

SOLDERABLE TERMINATION PASTES

- Ranging from 75Ag/25Pd to 100% Ag
- NTC, MLCC and BaTiO3 electro ceramics



Electronic Glass Materials for 5G Applications

Electronic glass pastes

Our thick film sealing glass pastes are used for sealing ceramic, glass and metal packages for communication modules and sensors for varied 5G applications in the aerospace, automotive, defense & military and telecommunication industries.

Electronic and technical glass powders

We offer a comprehensive range of glass and glass-ceramic based powder products that provide protective and insulating layers. They are used as binding agents in metal or ceramic formulations as well as sealants for a variety of ceramic, metal and glass components.

LTCC glass powders

Our extensive portfolio of LTCC glass powders and low temperature ceramic formulations offer a broad K range from 4.1 to 12.6.

We offer a comprehensive range of glass and glass-ceramic based powder products that provide protective and insulating layers.

Vibrantz glass powders are used in varied components for a wide variety of frequencies including ceramic inductors, fuses, common mode filters, saw devices, antennas, EMI, ESD, and other chip and multilayer components.

	Product code		L4	L4.6	L5	L6	L7	L8	L12
	Composition family		Si-B-Al	Si-Al-B	Si-B-Al	Ba-B-Al-Si	Si-Ba-B-Al-Ca	Si-Ba-B-Al-Ca	Si-Ba-Sr-B-Al-Ca
Thermal Properites	Peak Firing Temperature	°C	850 - 900	850 - 900	850 - 900	850 - 900	850 - 900	850 - 900	850 - 900
	Time at Peak Temperature	minutes	6-8	6-8	6-8	6-8	6-8	6-8	6-8
	CTE at 260°C	x10-7/°C	69	59	49.5	53	52	50	68
	Glass Transition Temp (Tg)	°C	500	500	500	500	785	785	785
Electrical Properties	Typical Fired Density (Tape)	g/cc	> 2.2	> 2.2	> 2.5	> 2.5	> 2.8	> 3.1	> 3.6
	Typical X/Y Shrinkage	%	14.5	12.5	13.5	12.0	14.0	14.0	14.0
	Dielectric Constant (1 MHz)	–	4.0	4.8	5.4	6.2	7.2	7.4	12.6
	Dissipation Factor (1 MHz)	%	< 0.2	< 0.2	< 0.2	< 0.2	< 1.5	< 1.5	< 0.2
	Dielectric Constant (10 GHz)	–	4.1	4.4	5.4	5.8	6.7	7.2	12.0
	Dissipation Factor (10 GHz)	%	< 0.3	< 0.4	< 0.4	< 0.4	< 0.3	< 0.25	< 0.3
	Insulation Resistance (IR)	W-cm	> 1012	> 1012	> 1012	> 1012	> 1012	> 1012	> 1012
	Breakdown Voltage (DWV)	V/mil	> 1000	> 1000	> 1000	> 1000	> 1000	> 1000	> 1000
Powder Properties	d50 Particle Size	mm	2.8	2.7	2.4	2.3	2.4	3.3	3.3
	Surface Area	m2/g	6.3	5.5	5.2	4.6	4.6	2.8	2.6
	Pycnometer Density	g/cc	2.3	2.5	2.8	3.5	3.3	3.3	3.3

Slurry Products for Polishing Silicon Carbide Substrates in 5G Applications

High-purity slurries

Vibrantz is a leading global manufacturer of optimized high-purity slurries designed to create smooth and planar surfaces for metal chemical mechanical planarization (CMP) applications.

We offer a wide range of aqueous slurries that achieve optimal metal CMP removal rates (RRs), resulting in lower cost of ownership and higher productivity while using existing equipment and space.

Many of our slurries can be used for CMP polishing of silicon carbide (SiC) substrate materials, power semiconductors and compound semiconductors in 5G hardware.

In addition, the SN12500 and SN12501 comprise a two-step system to planarize and polish silicon carbide wafers in order to create a wafer with correct thickness and surface quality for semiconductor processing.

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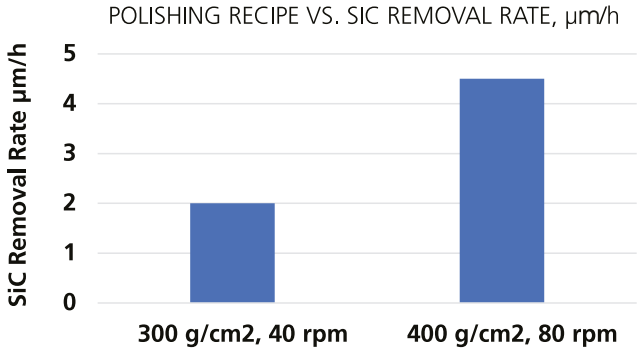
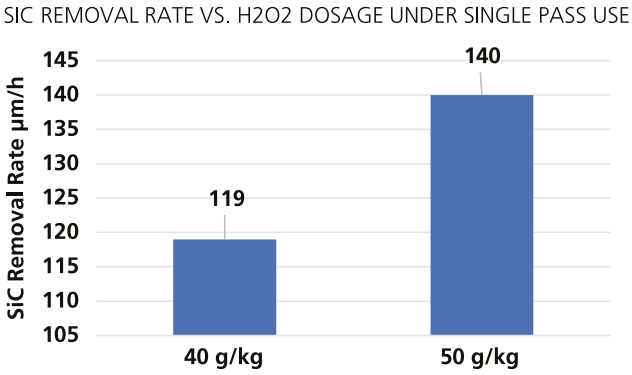
SN12500 SIC BULK POLISHING SLURRY REMOVAL RATE





Al2O3 Abrasive
pH: 8 ~ 10
1 kit package (oxidant inside)
Recyclable/single pass use
Suba 800-like pad was recommended
Ra = 0.7 ~ 0.9 Å (AFM)
No scratch (Laser Tech.)

Colloidal Silica Abrasive
pH: 8 ~ 10
1 kit package
Oxidant: add oxidant before use
Single pass use
Soft pad was recommended
Ra = 0.6 ~ 0.7 Å (AFM)
No scratch (Laser Tech.)

SN13200 polishing slurry for InP STI CMP processes

Vibrantz's SN13200 polishing slurry is specially designed for use in compound semiconductors for high-speed electronics and 5G optical infrastructures.

Our SN13200 slurry delivers the polishing performance needed for Indium Phosphide (InP) STI CMP processes, including good InP removal rates, very low oxide loss, low dishing and minimal or no phosphine evolution.

SN13200 SLURRY ADVANTAGES

- Alumina-based and alkaline
- High removal rates for chemical mechanical polishing of InP
- Low defectivity; prevents most residues
- Good surface roughness for polished surfaces
- Excellent slurry stability and shelf life
- Flexibility of different particle sizes depending on the removal requirements

FSN13200 slurry application conditions – Table polisher

Dielectric powder name	Dielectric constant
Removal Rate (µm/hour)	20 to 36
Platen Size (mm)	380
Head Size (mm)	140
Down Force (g)	2500 (head weight only)
Flow Rate (ml/min)	10
Platen Speed (rpm)	70
Polishing Time (min)	30
Pad	Soft (black color)
Cleaning Process	Hand washing with DI water

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