



A Novel K7 / K50 Co-Fireable PME LTCC Dielectric System for Microwave Filter Application

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April 17th, 2025



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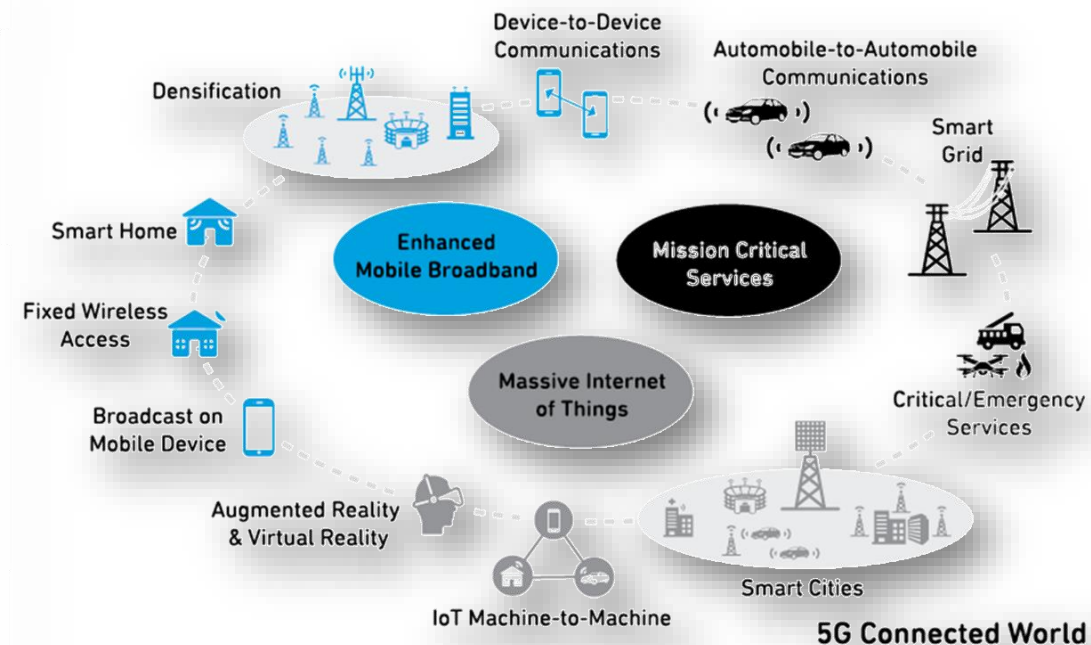
Outline

- Wireless Communication and Spectrum Congestion
- Microwave Filters and their Dependence on Properties of LTCC Dielectrics
- Traditional and New Generation LTCC Dielectrics
- Advantages of Multi-Material Designs for Microwave Filters

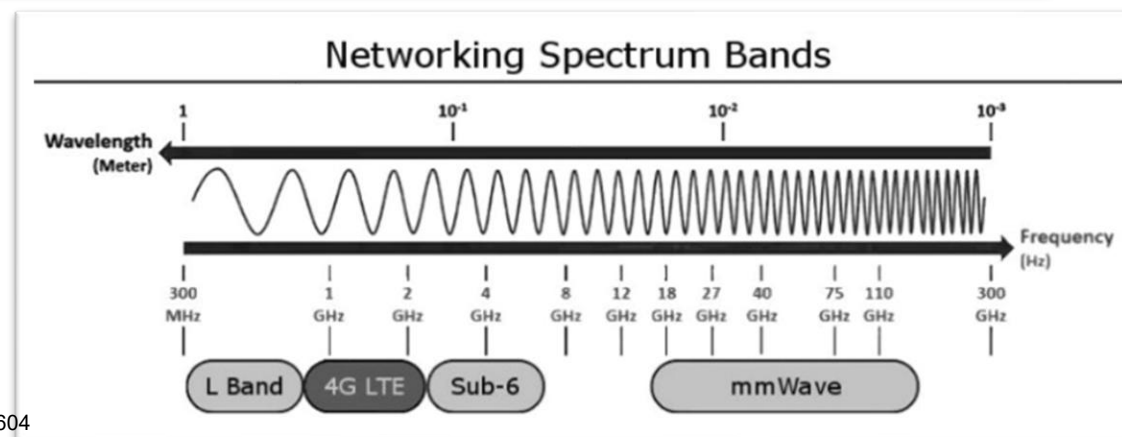
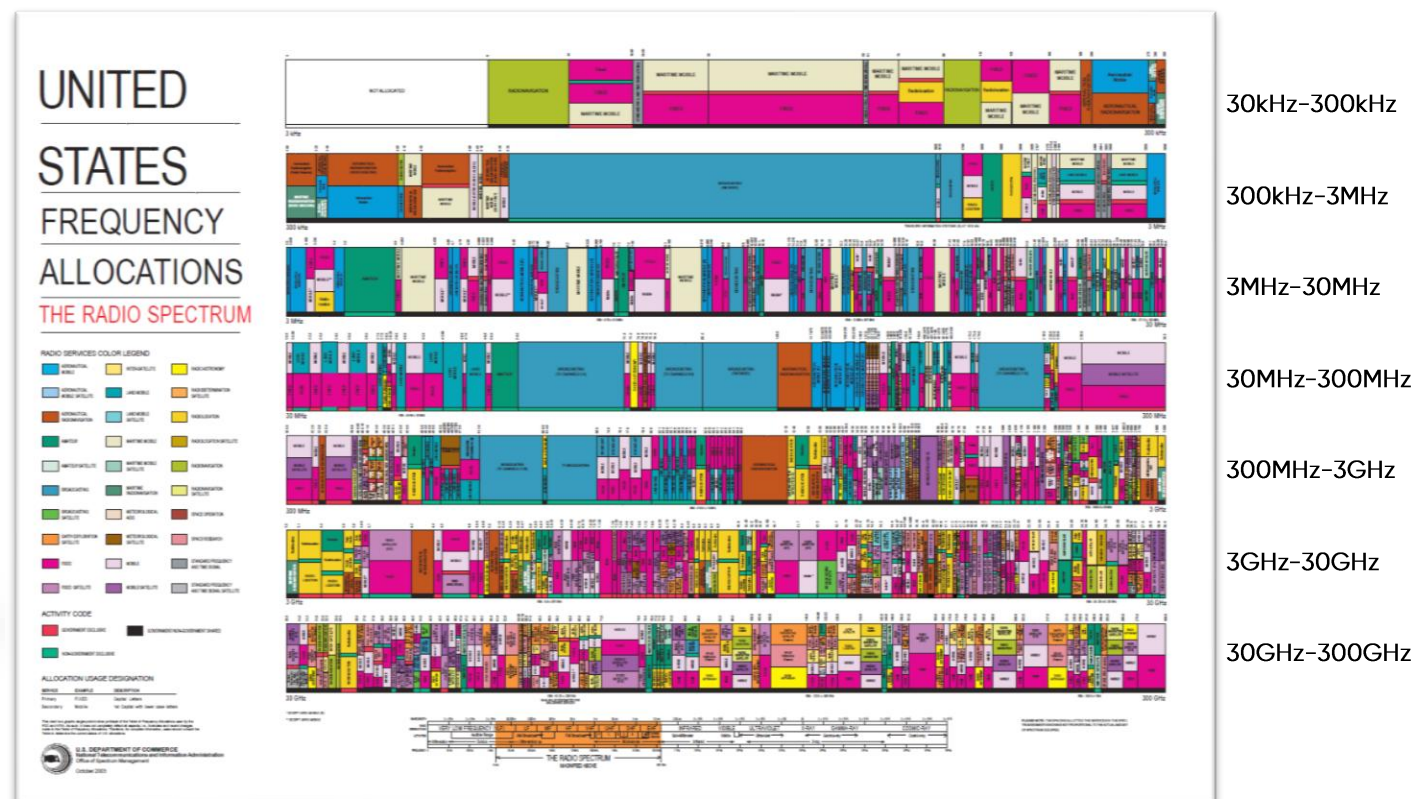
- MW7U and MW50U New Co-fireable LTCC Dielectric System
 - ✓ Basic Properties
 - ✓ Tape Casting and Shrinkage
 - ✓ Co-Firing
 - ✓ Compatibility with Silver Electrodes
 - ✓ Compatibility with Chemical Attacks during Plating
 - ✓ Performance evaluation

- Conclusions

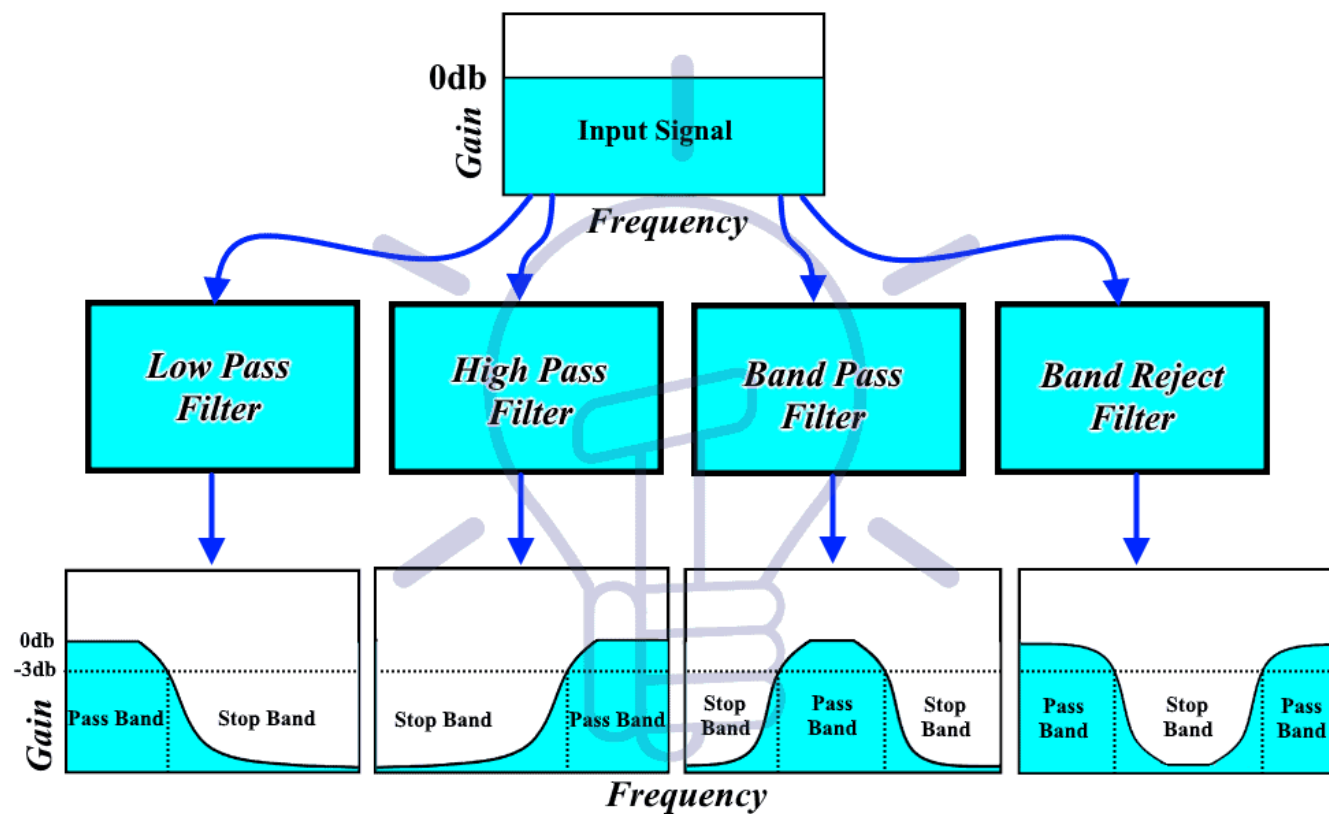
Wireless Communication



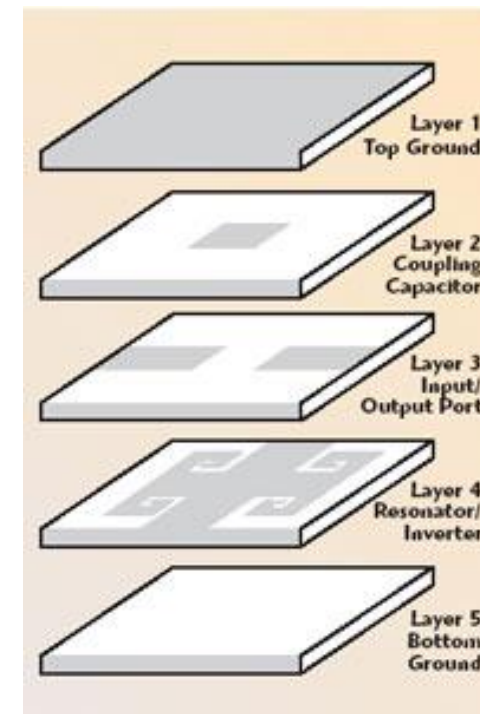
In a congested microwave spectrum, it is essential to use high quality microwave filters with good selectivity to extract only a desired wavelength for further processing.



Microwave Filters



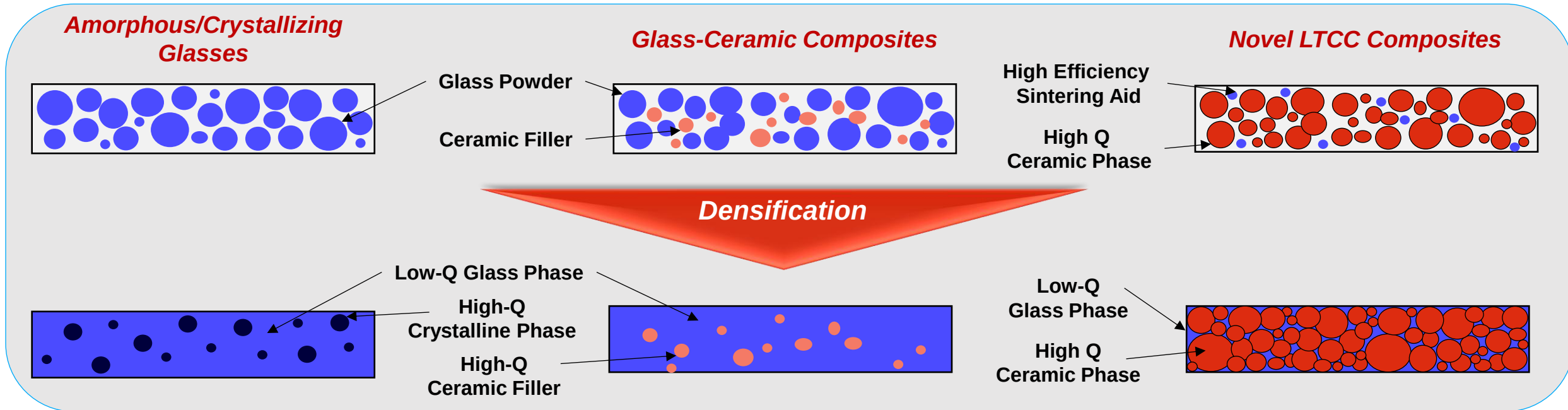
Properties of microwave filters heavily depend on properties of LTCC dielectrics.



Essential microwave filter properties dependable on dielectric performance

- Filter size
- Center frequency
- Insertion loss
- Filter selectivity
- Environmental (temperature, humidity, vibration)
- Power handling capability
- Mechanical integrity

Traditional and New Generation LTCC Dielectrics

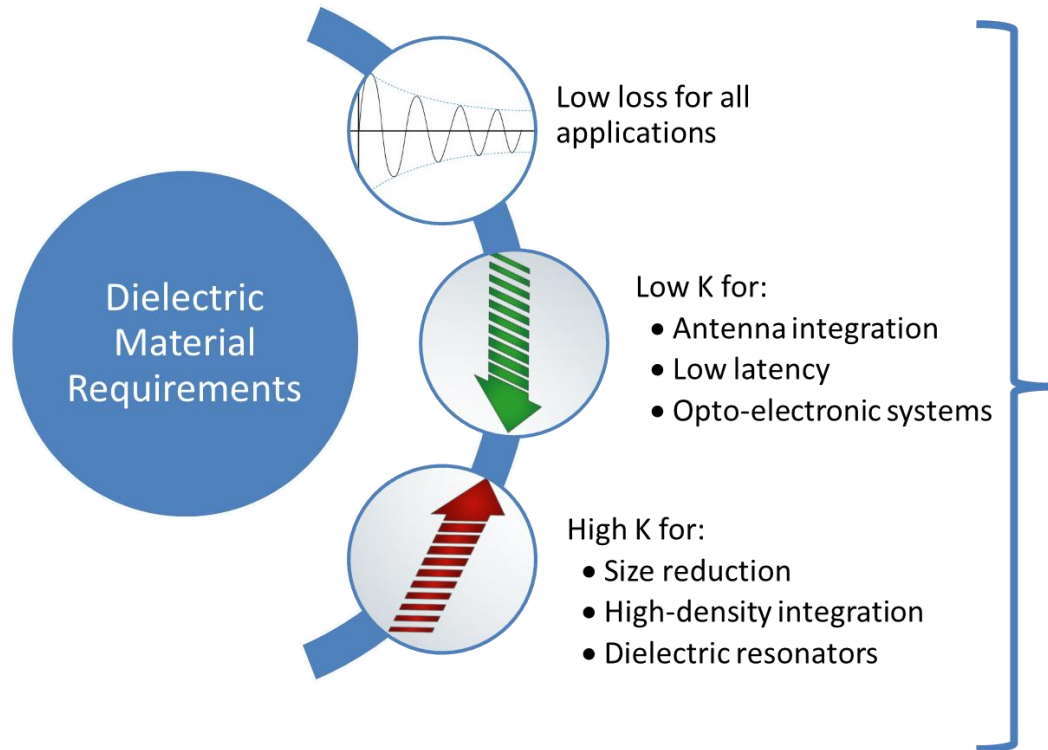


$$Q^{-1} = (V_1)Q_1^{-1} + (V_2)Q_2^{-1}$$

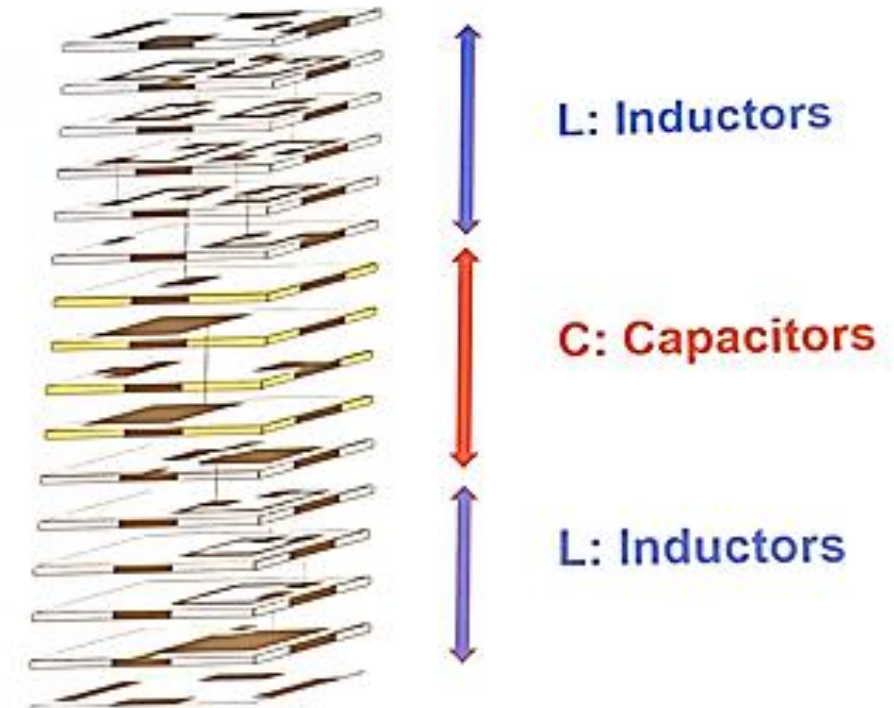
	Q (total)	V1	Q1	V2	Q2
Historic LTCC Materials	Low	High	Low	Low	High
	332	0.9	300	0.1	10,000
Novel High-Q LTCC Materials	High	Low	Low	High	High
	2,362	0.1	300	0.9	10,000

High ceramic and low glass contents result in high Q (low dielectric loss) of LTCC dielectrics.

Advantages of Multi-Material Designs for Microwave Application



Best met with multiple dielectrics



The Structure of BPF

	Small Size	Low Latency	High Fabrication Tolerance
Low K	−	+	+
High K	+	−	−
Notes	Size reduction: $\sim \frac{1}{\sqrt{K}}$	Latency increase: $\sim \sqrt{K}$	Not a critical limiting factor with a good 000607 process

Advantages of Multi-Material Designs for Microwave Filters

Lumped Element Filters

Lumped Element: The physical size of the element is negligibly small when compared to the wavelength of the electromagnetic wave propagation.

Example: Resistor, Capacitor, Inductor, etc.

- Low K for inductors
 - ✓ low parasitic capacitance
 - ✓ higher self-resonance frequency
- High K for capacitors
 - ✓ higher achievable capacitance values
 - ✓ smaller size
- ✓ Mixed dielectrics
 - ✓ higher performance
 - ✓ reduced size

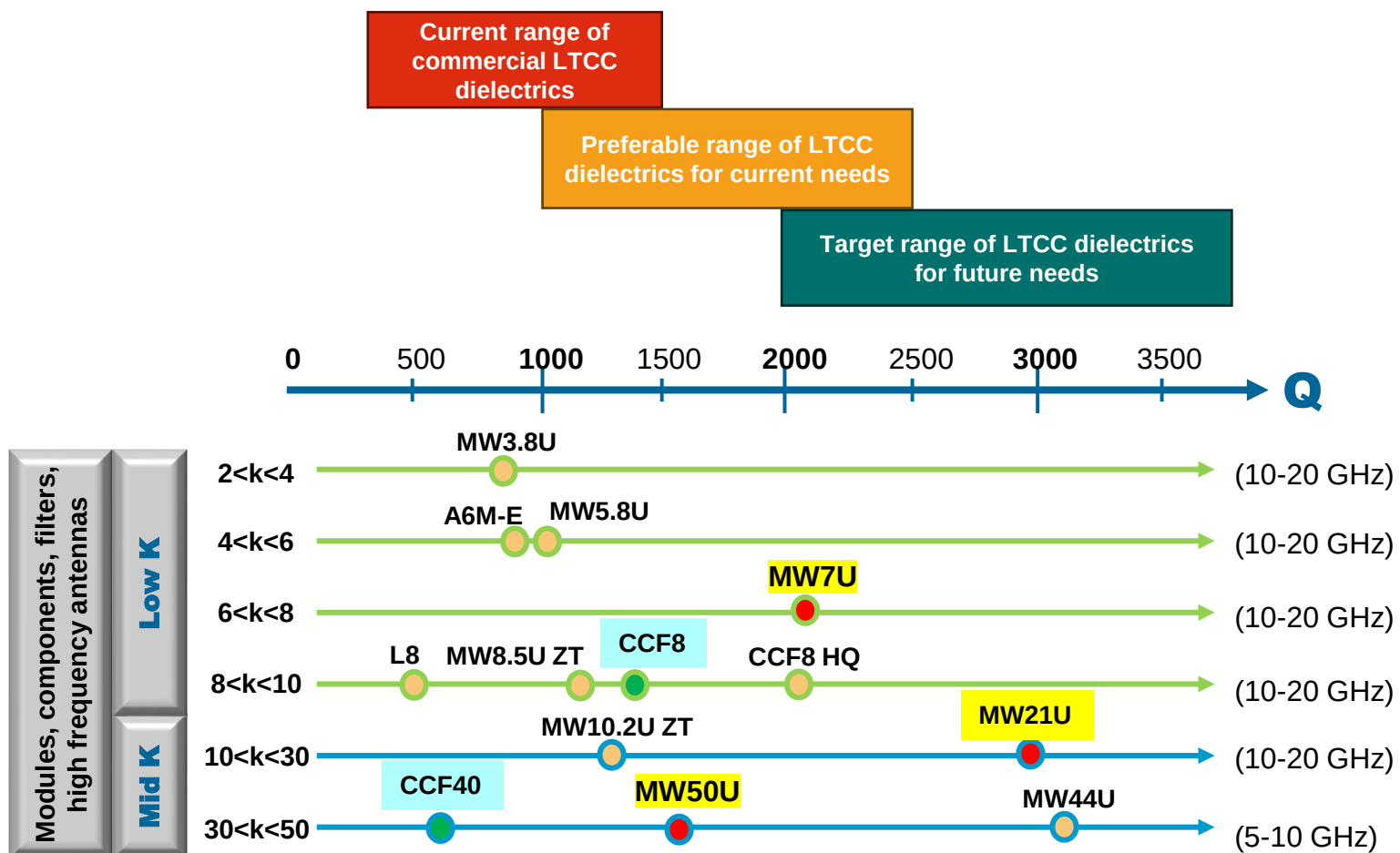
Distributed Element Filters

Distributed Element: The physical size of the element is comparable to the wavelength of the electromagnetic wave propagation.

Example: Transmission line.

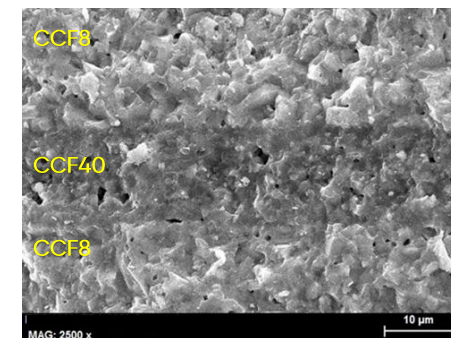
- Low K dielectrics (interfacing to filters)
 - ✓ for low-latency parts of RF sub-systems
 - ✓ for printed antennas
 - ✓ for small surface mount components
- High K dielectrics
 - ✓ for reduced-size distributed transmission line resonators
 - ✓ for small-size dielectric resonator 'pucks'
- ✓ Mixed dielectrics
 - ✓ for achieving optimal size/performance

Vibrantz LTCC Dielectrics Portfolio

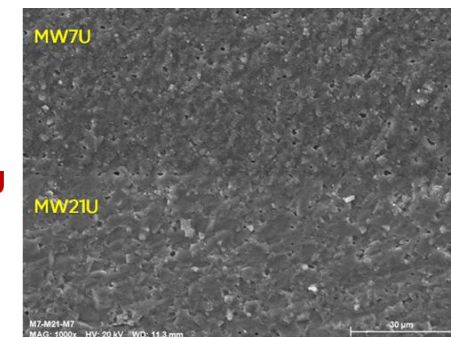


Vibrantz Co-fireable LTCC Systems

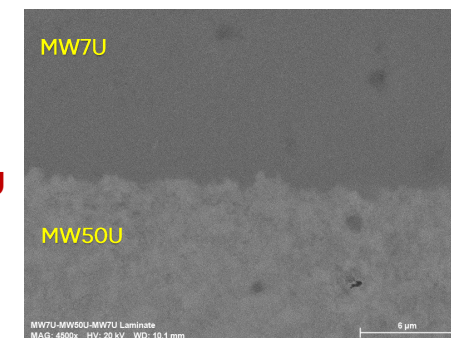
CCF8 – CCF40



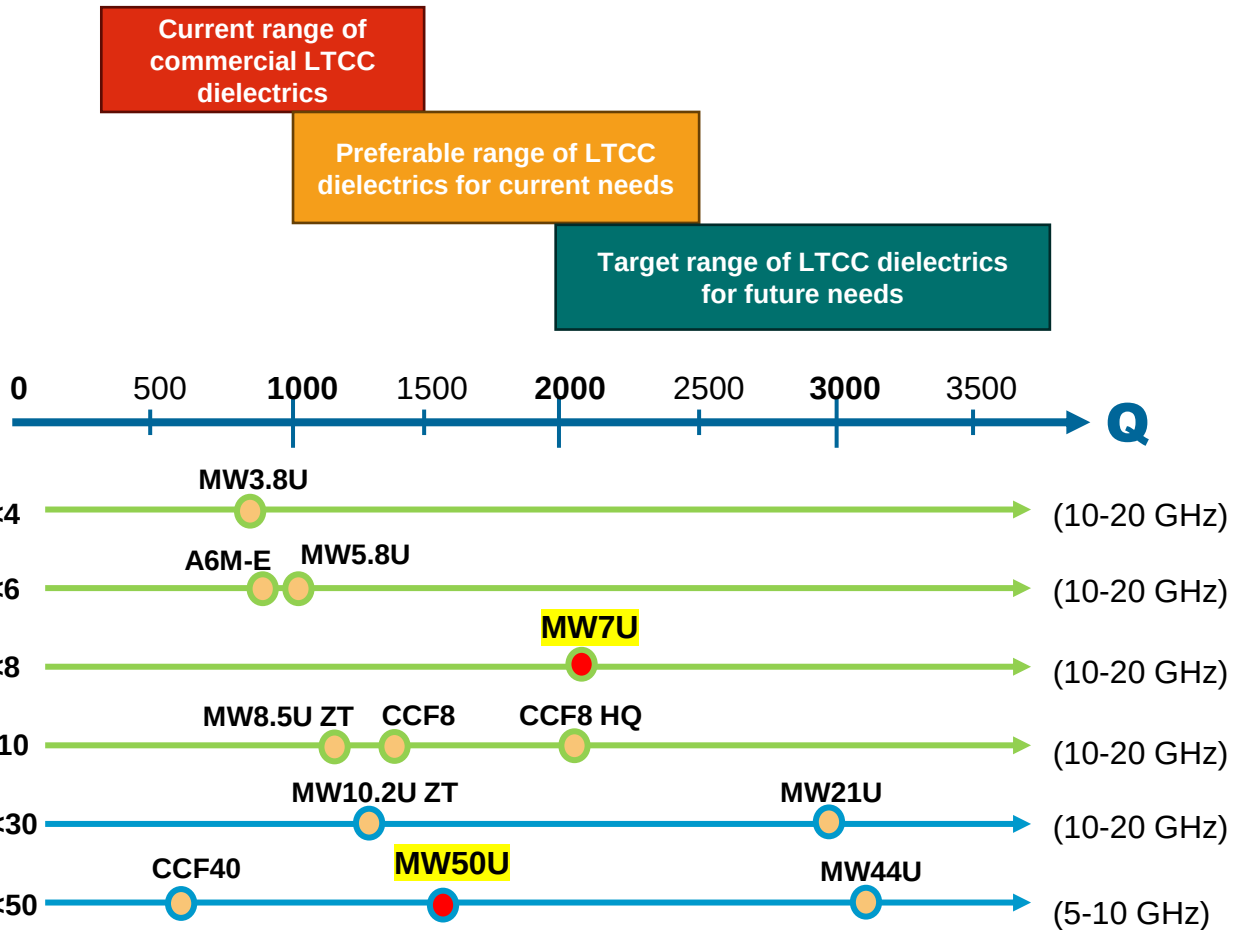
MW7U – MW21U



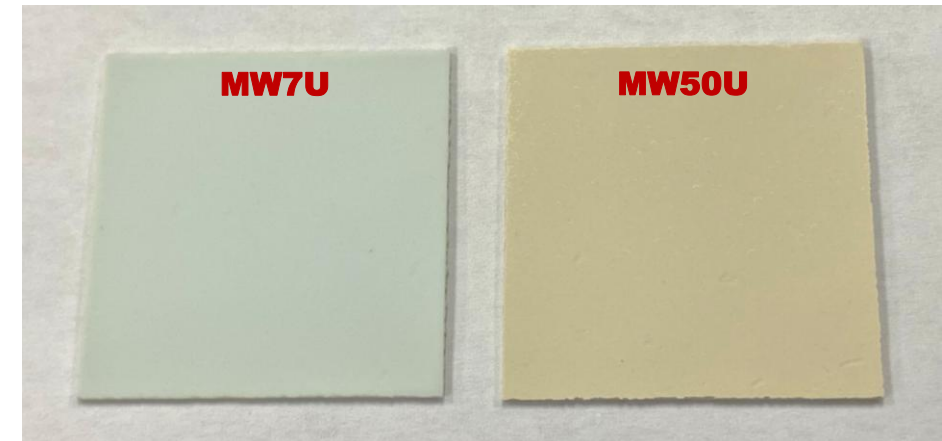
MW7U – MW50U



MW7U and MW50U LTCC Dielectrics – Basic Properties

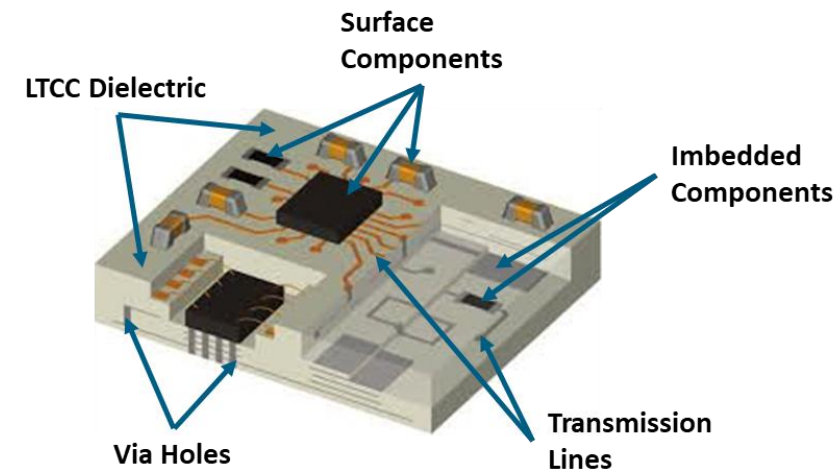
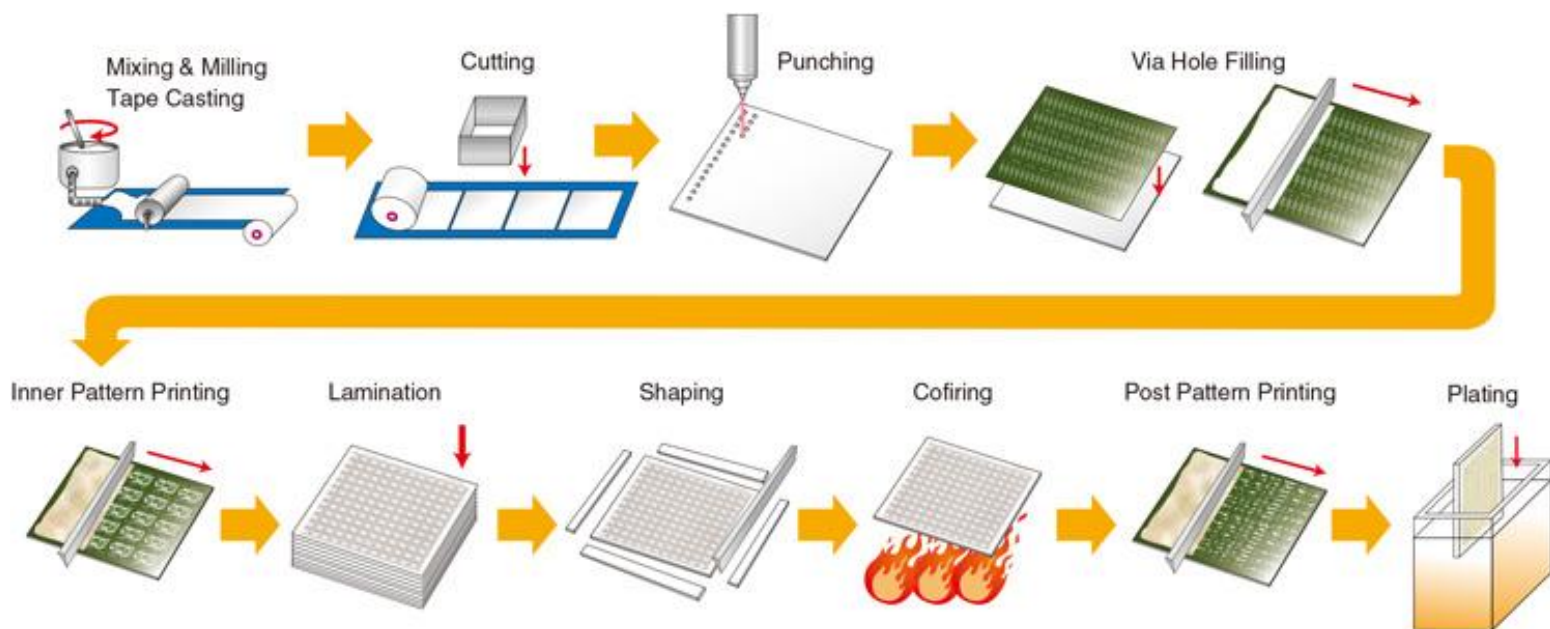


Ceramic Properties (Fired @ 900°C/30min)	MW7U	MW50U
Fired Density, g/cm ³	3.1	3.8
K @ Fr, GHz	7.0	51.6
Q @ Fr	2,095	1,650
Q*F, GHz	32,741	11,560
Fr, GHz	15.6	7.0
τ_f , ppm/°C (between 25°C and 60°C)	-27	169
MOR, MPa	210	168
CTE, $\mu\text{m}/\text{m}^{\circ}\text{C}$	10.7	11.8



MW7U and MW50U LTCC Dielectrics – Readiness for LTCC Components Production

Typical LTCC Production Process



Critical applicability parameters for dielectrics

- Tape casting and shrinkage
- Co-Firing
- Compatibility with silver electrodes
- Resistance to chemical attacks during plating

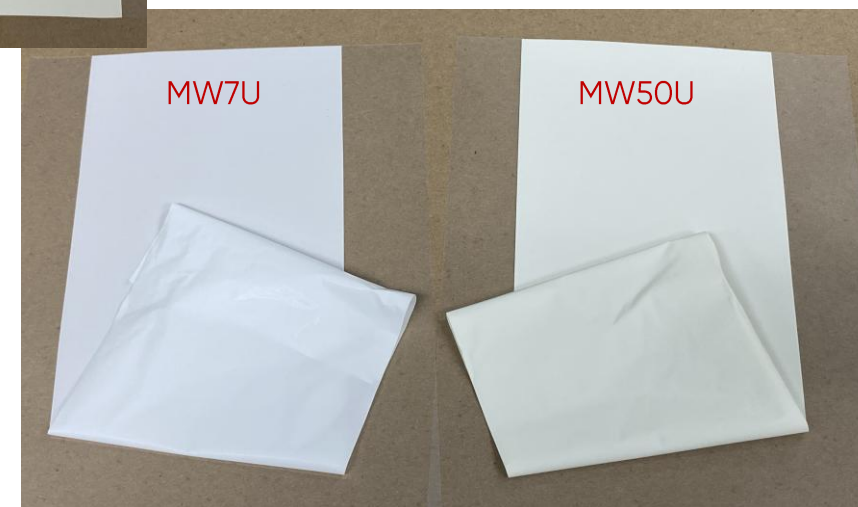
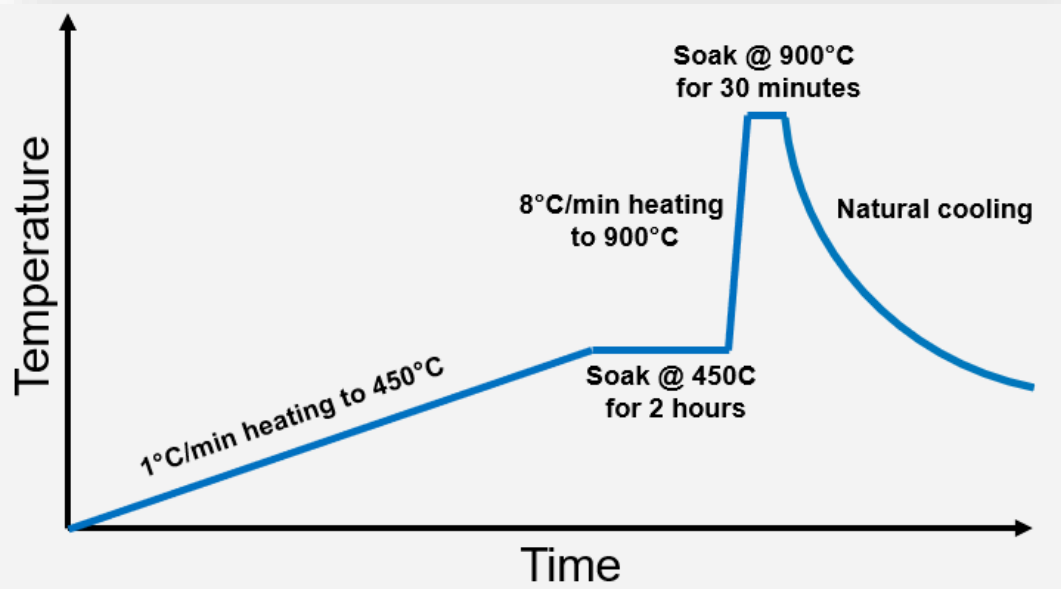
MW7U and MW50U Dielectrics – Tape Casting and Shrinkage

Typical Powder Properties	MW7U	MW50U
Particle Size, D_{50} , μm	1.0	0.8
Surface Area, m^2/g	12.5	6.3
Powder Density, g/cm^3	3.1	3.9

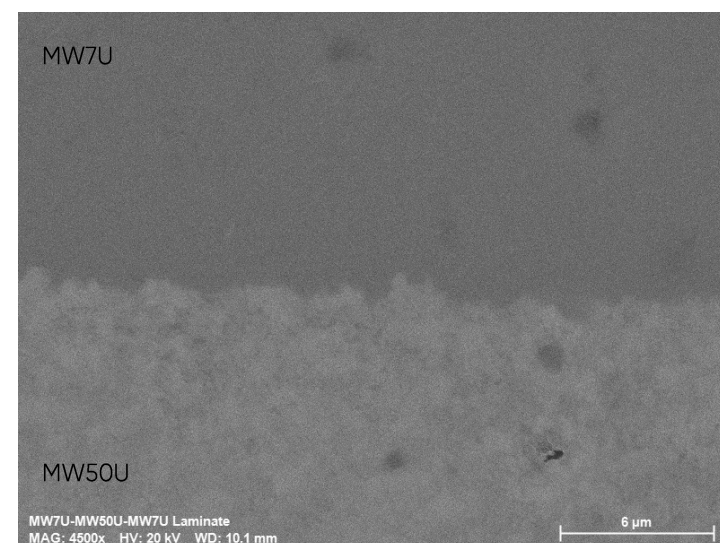
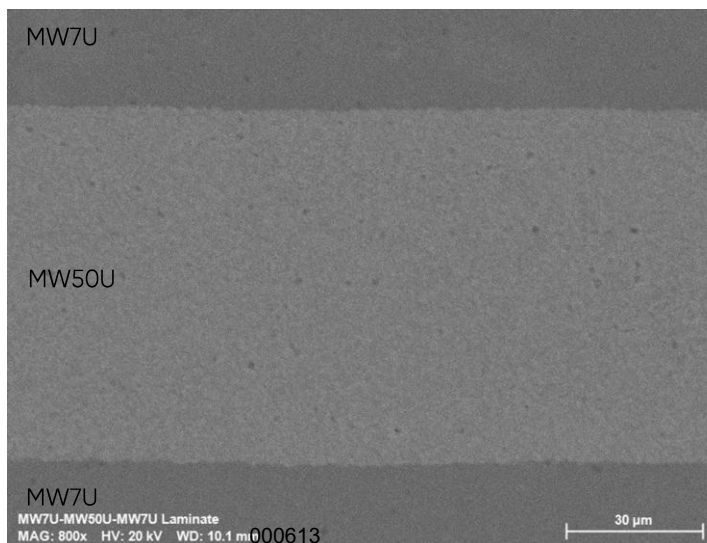
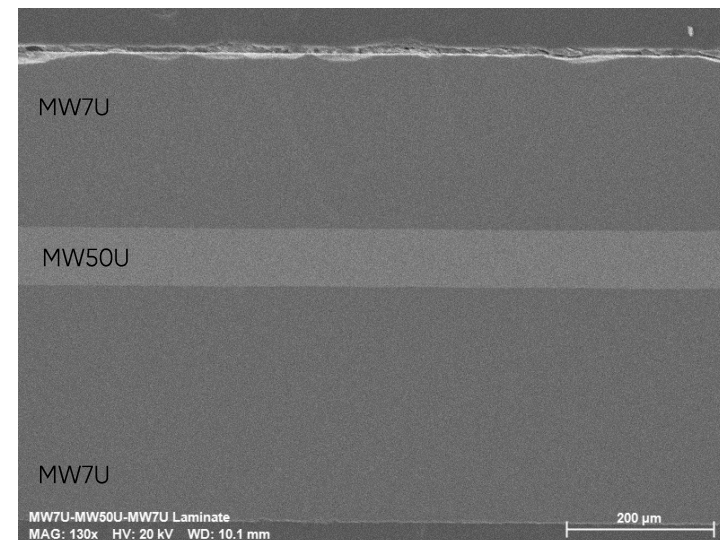
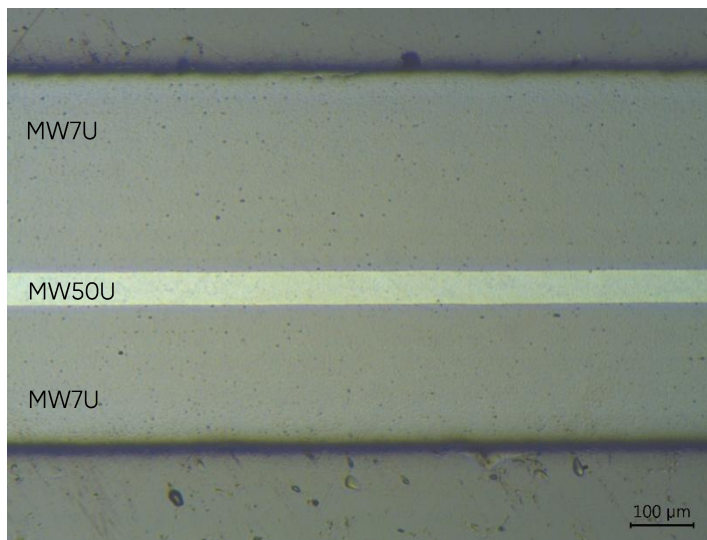
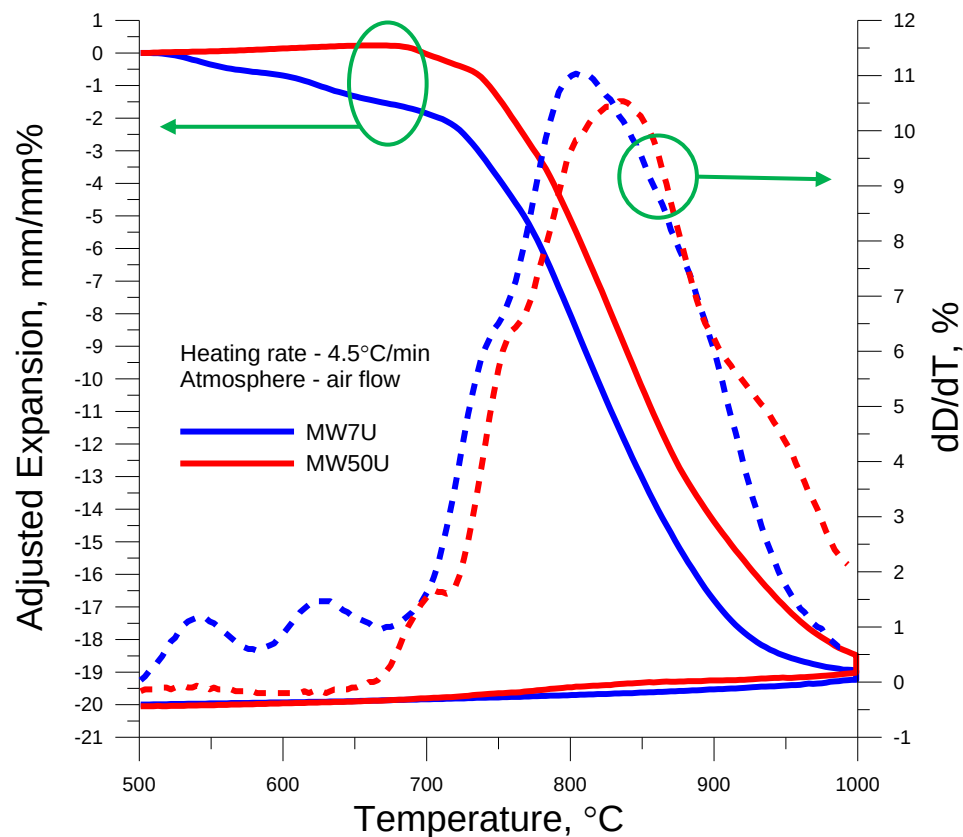


MW7U and MW50U can be casted into a defect free high-quality tape using a PVB-based binder system.

Recommended Firing Profile

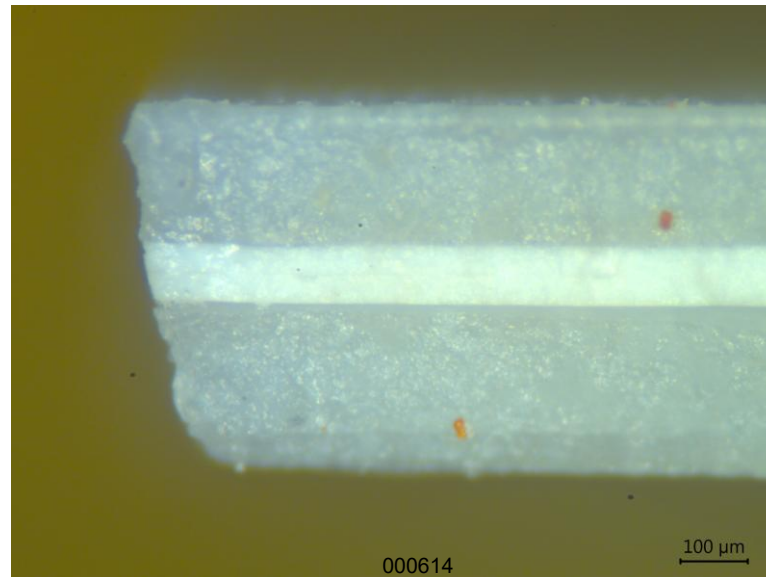
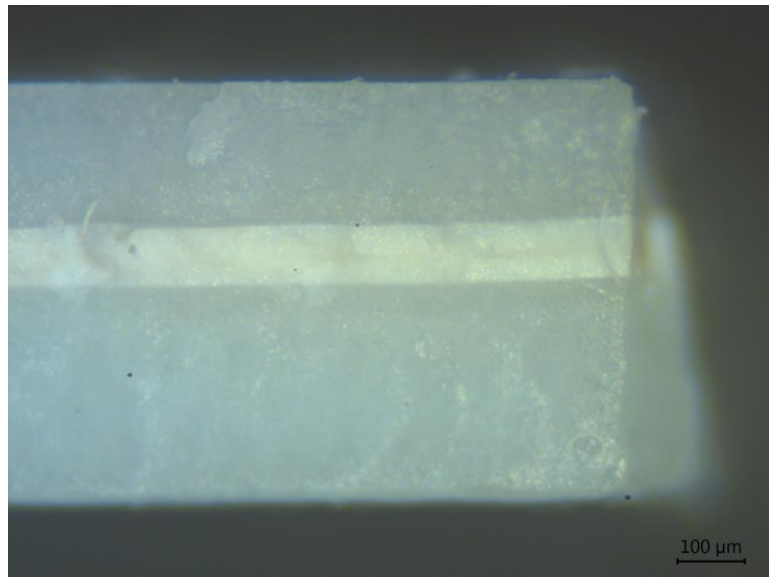
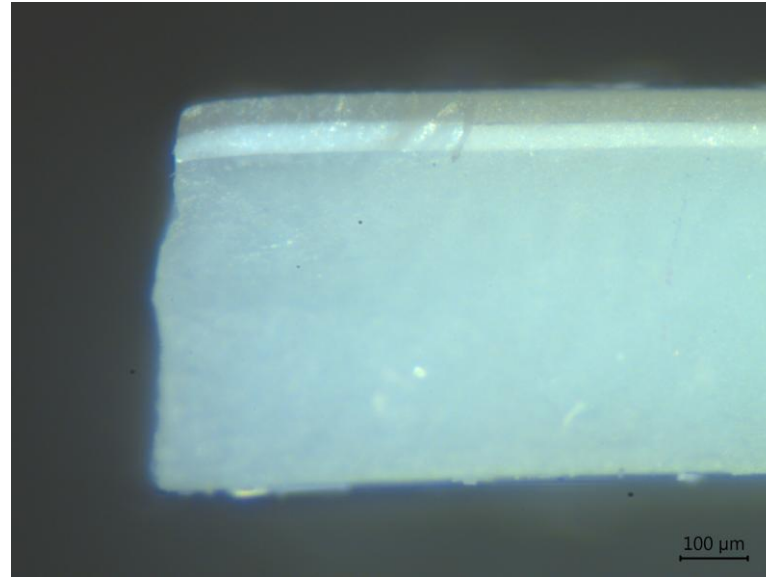
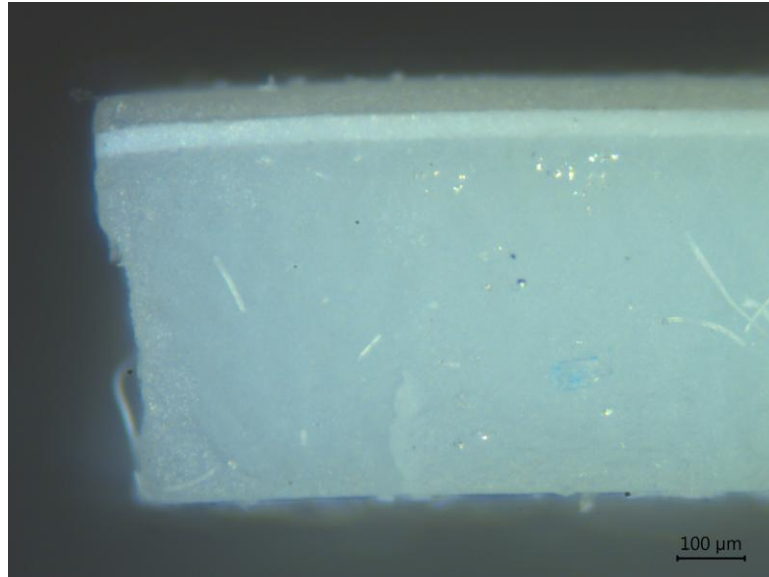


MW7U and MW50U Dielectrics – Co-Firing



MW7U and MW50U laminates exhibited dense and fully developed microstructure after firing @ 900°C/30min.

MW7U and MW50U Dielectrics – Co-Firing



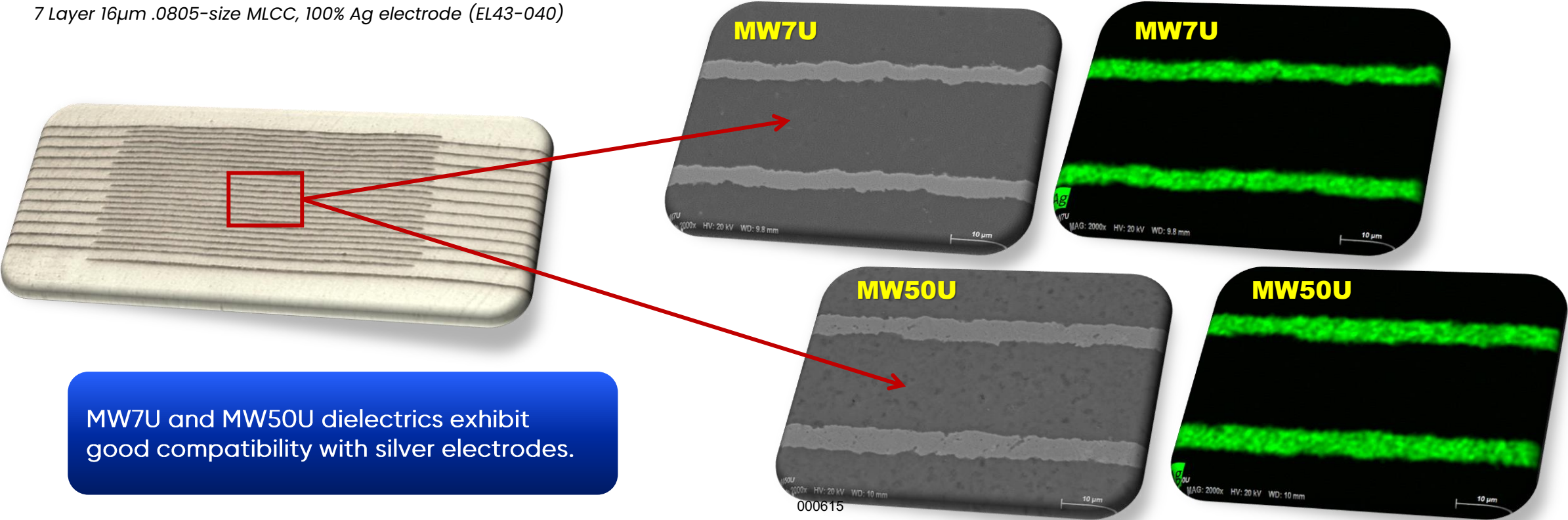
MW7U and MW50U laminates exhibited very close overall shrinkage after firing @ 900°C/30min.

MW7U and MW50U Dielectrics – Compatibility with 100% Silver Electrodes

Electrical Properties in MLCC Design

Dielectric	Sintering	Cap (pF)	Thick. (μm)	k	Df MHz (%)	TCC -55°C (ppm/°C)	TCC 125°C (ppm/°C)	50V IR 25°C (GΩ)	50V IR 125°C (GΩ)	VBD (V/μm)
MW7U	900°C/30min	59.9	14.5	7	0.001	118	134	>20,000	650	184
MW50U	900°C/30min	238.2	17.7	50	0.002	-383	-298	1,600	12	80

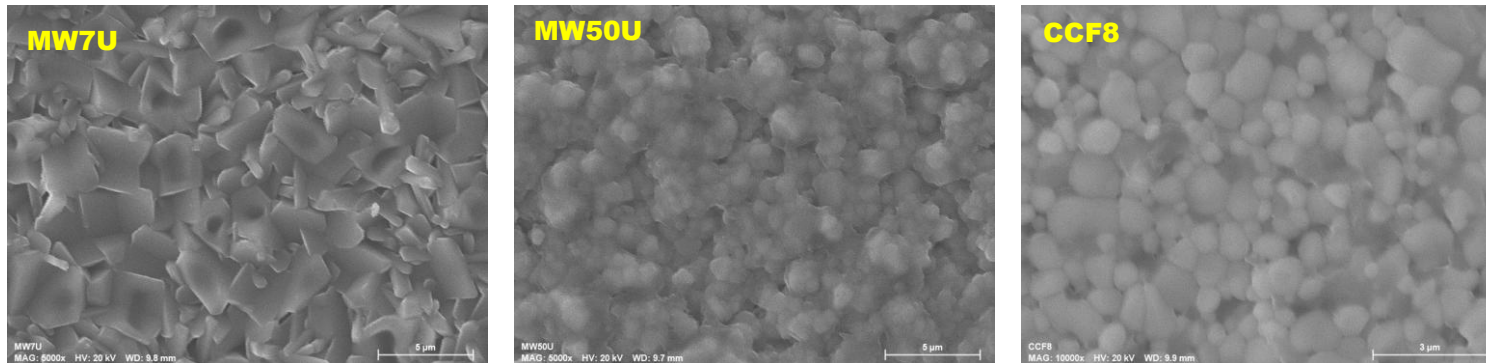
7 Layer 16μm .0805-size MLCC, 100% Ag electrode (EL43-040)



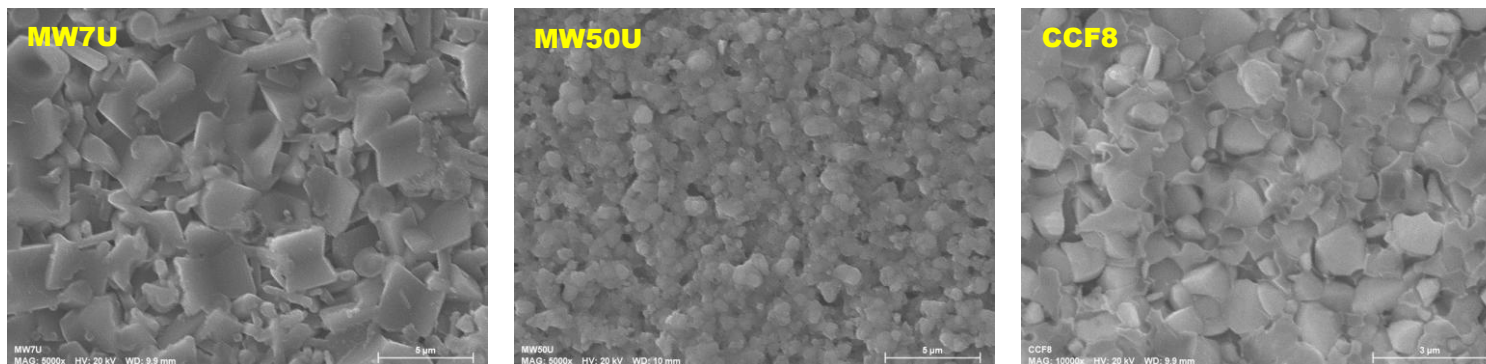
MW7U and MW50U dielectrics exhibit good compatibility with silver electrodes.

MW7U and MW50U Dielectrics – Resistance to Chemical Attacks during Plating

Ceramic surface BEFORE Ni solution soak test



Ceramic surface AFTER Ni solution soak test



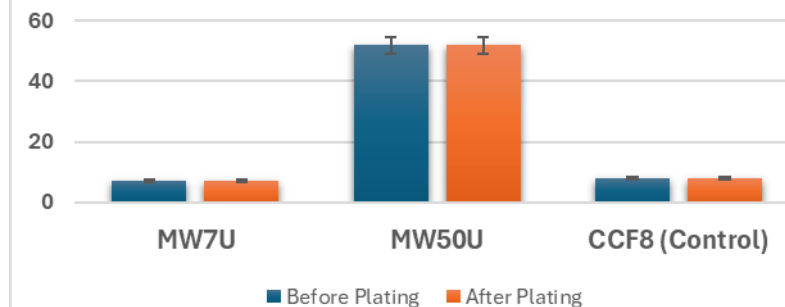
Weight loss ~0.15%

Weight loss ~0.08%

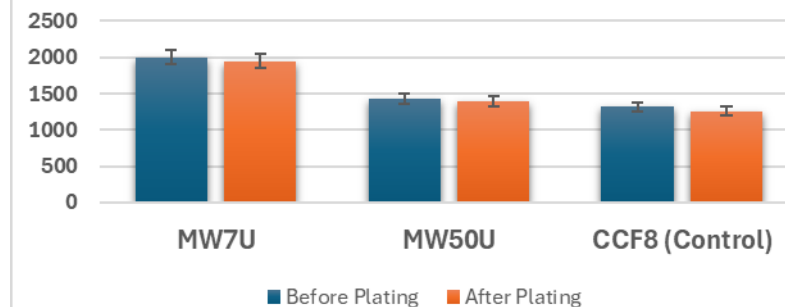
Weight loss ~0.21%

Ni solution soak test conditions: Nickel Sulfamate RTU, Technic Inc., soak fired substrates in the solution at 50°C for 5 hours, pH=3.84, under constant agitation.

Dielectric Constant (K)



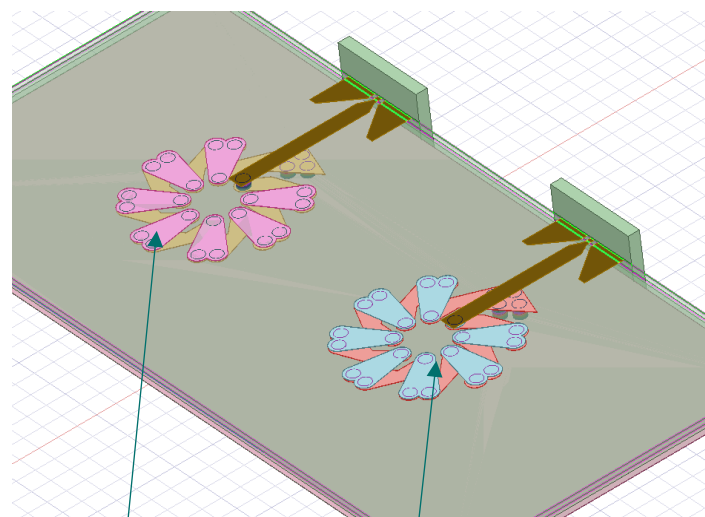
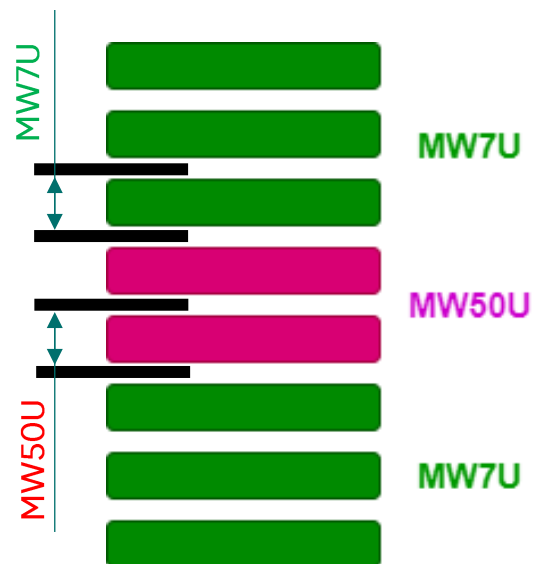
Quality Factor (Q)



Both MW7U and MW50U exhibited an adequate resistance to chemical attack during plating compared to CCF8 used as a control.

MW7U and MW50U Dielectrics – Performance Evaluation: Lumped components

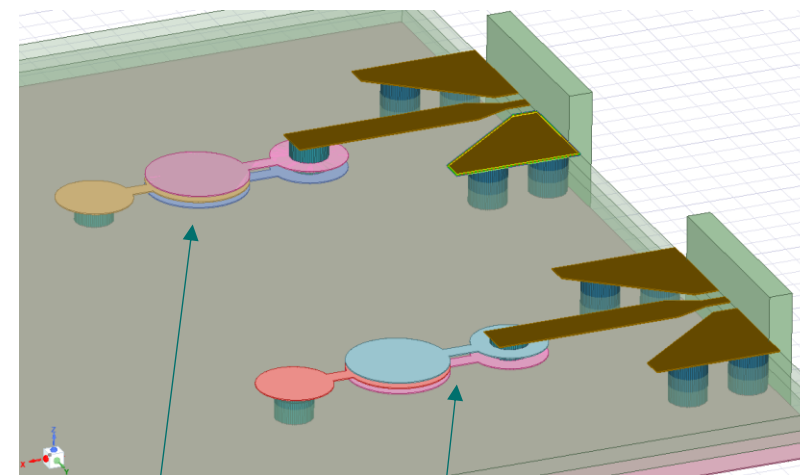
Inductors designed in
MW7U and MW50U layers



MW50U
inductor

MW7U
inductor

Capacitors designed in
MW7U and MW50U layers



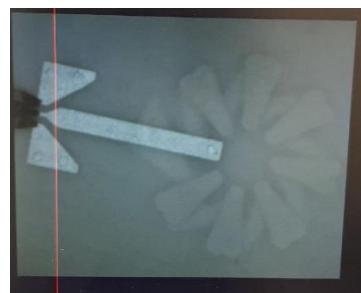
MW50U
capacitor

MW7U
capacitor

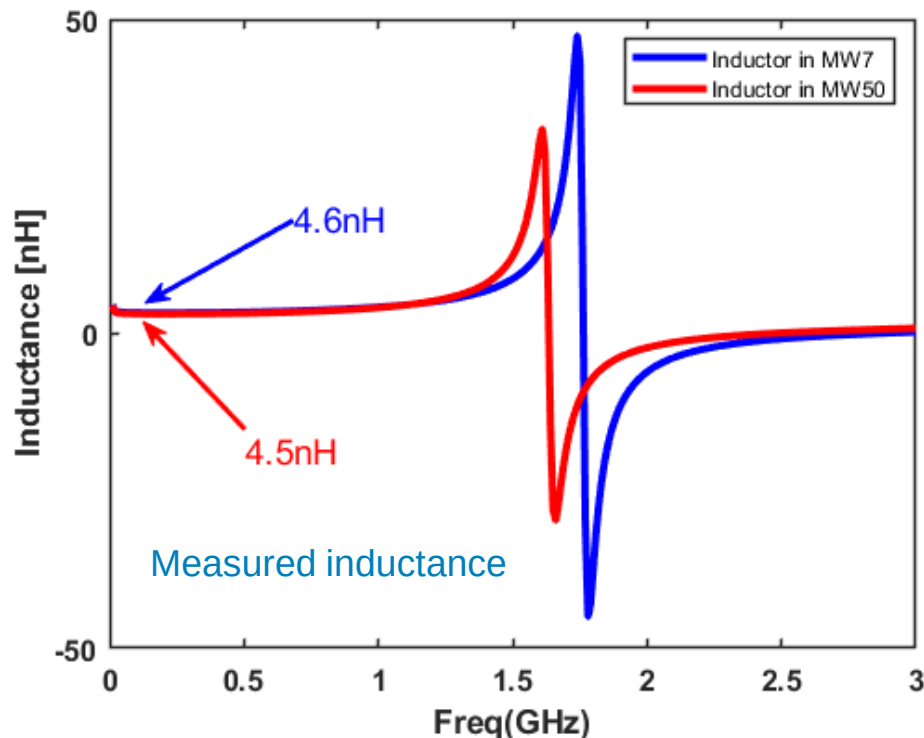
Both inductors and capacitors have the same dimensions.

MW7U and MW50U Dielectrics – Performance Evaluation: Lumped components

Inductor Results

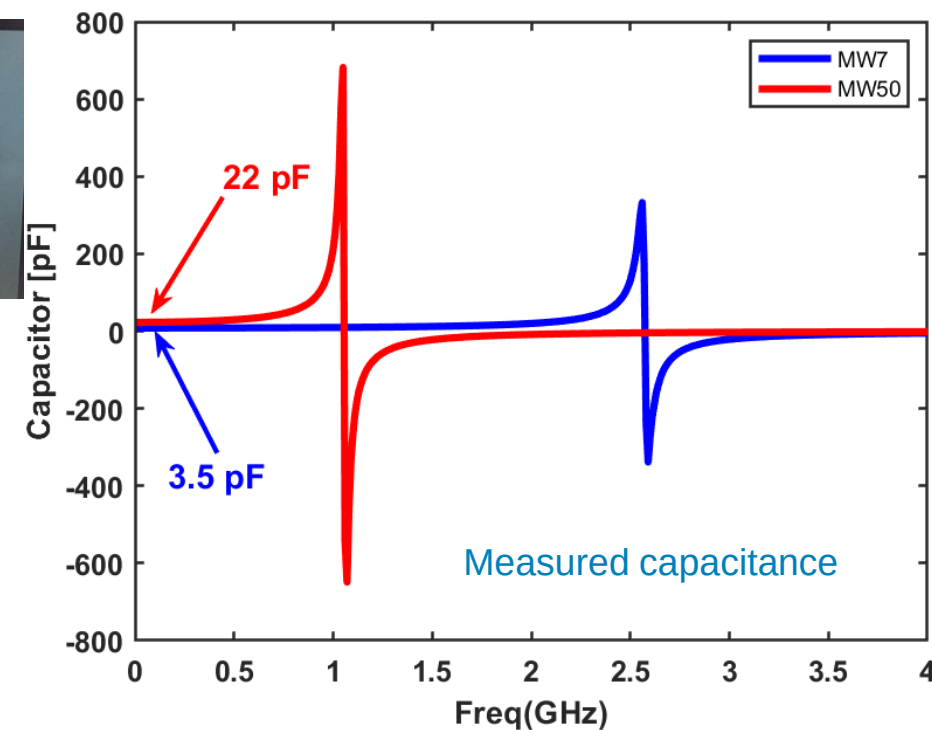


Fabricated Inductor



Fabricated Capacitor

Capacitor Results



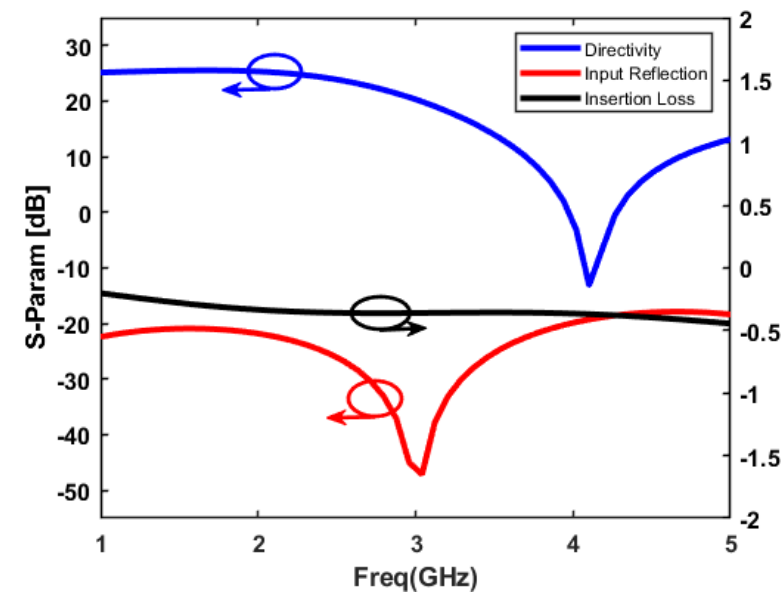
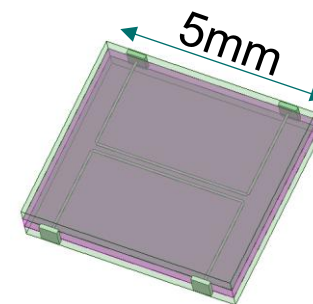
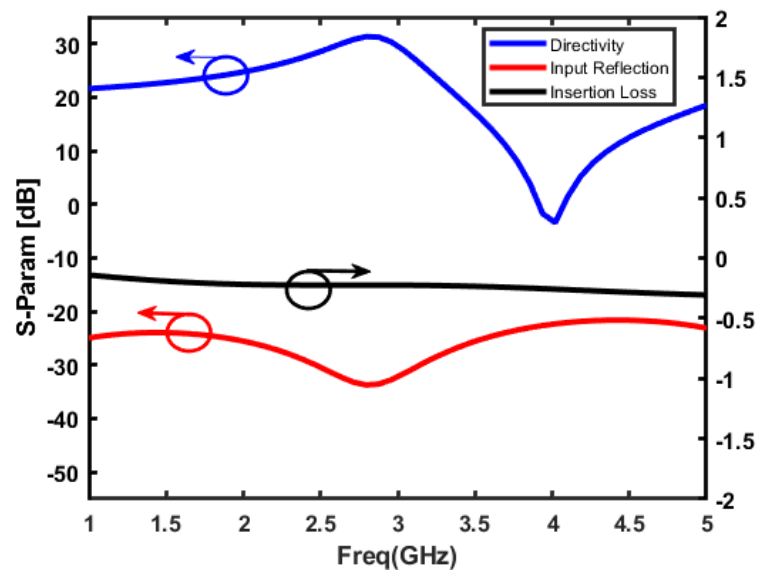
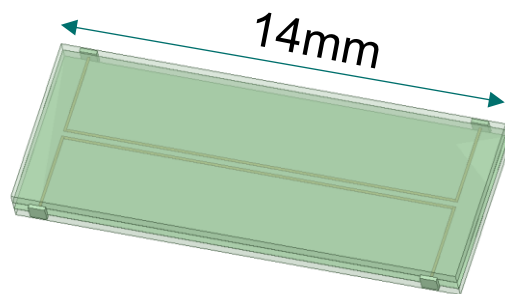
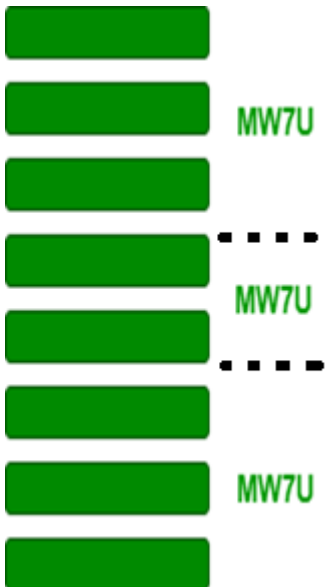
- Inductance value is comparable – as expected
- MW50U has lower self resonance frequency due to higher parasitic capacitance

- MW50 capacitance is 6.3 higher for the same size – expected

$$\frac{C_{MW50}}{C_{MW7}} = \frac{22}{3.5} = 6.3, \frac{K_{MW50}}{K_{MW7}} = 7 \text{ the difference is due to fringing fields}$$

MW7U and MW50U Dielectrics - Performance Evaluation

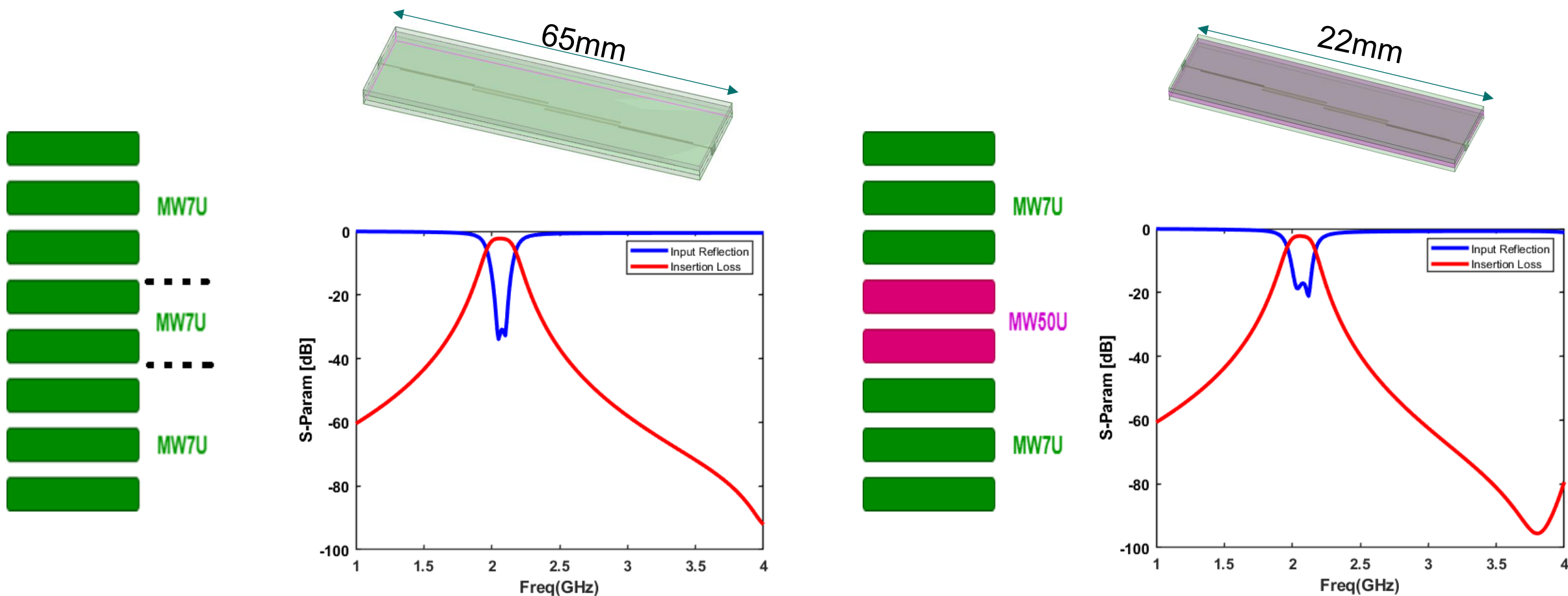
Distributed components: L/S band coupler



Comparable performance at ~1/3 the size

MW7U and MW50U Dielectrics - Performance Evaluation

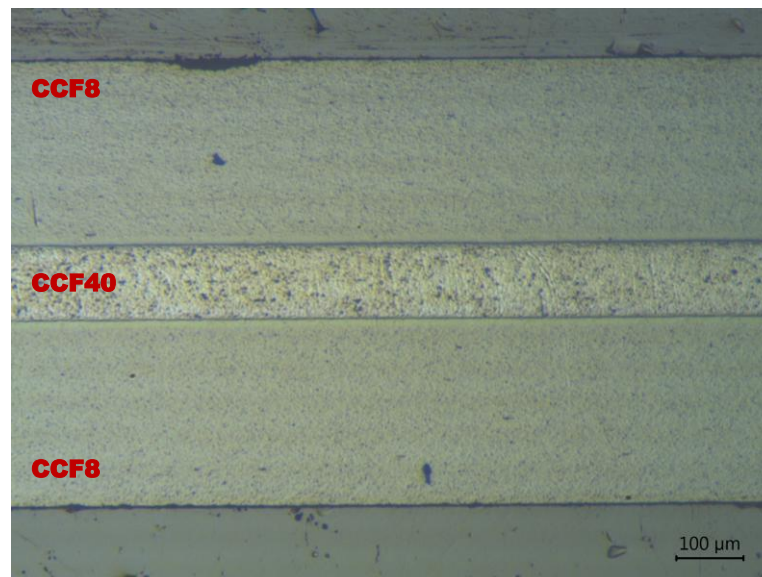
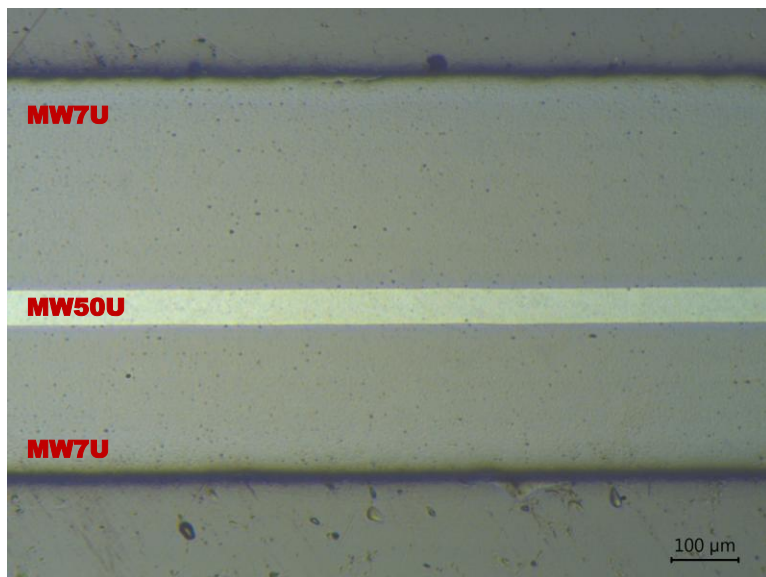
Distributed components: 2.4 GHz 3rd-order Butterworth coupled-line filter



Comparable performance at ~1/3 the size

000620

MW7U and MW50U Dielectrics – Advantages for Microwave Filter Application



Advantages of MW7U / MW50U LTCC System

- Lower ceramic density – lower cost per volume.
- Wider K range – wider design capability.
- Higher quality factor – better filter selectivity.
- Higher mechanical strength – more user friendly.
- Lower combined τ_f – more temperature stable.
- Higher resistance to plating – more user friendly.

Co-Fireable System	Electrical Properties	Firing Conditions	Fired Density, g/cm ³	X*Y*Z Shrinkage, %	K @Fr	Q @ Fr	Q*F, GHz	MOR Strength, MPa	τ_f , ppm/°C	Weight loss during Ni plating test, %
MW7U / MW50U	MW7U	900°C/30min	3.11	17.6	7.0	2,065	32,258	230	-27	0.15
	MW50U		3.88	17.7	51.8	1,650	10,560	170	169	0.08
CCF8 / CCF40	CCF8	850°C/30min	5.28	19.8	7.9	1,190	18,192	108	-22.4	0.21
	CCF40		4.55	19.4	40.8 000621	640	5,261	200	414	0.52

Thank you!

Questions?