Capacitor Technology Trends for Wide Band Gap Semiconductors

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Biography

Daniel West is a Field Application Engineer in the Technical Sales Group at Kyocera-AVX. After two years of supporting the connector division, he transferred to the Technical Sales Group, where he's been a team member for over four years. In this role, he is responsible for engineering support across N.A. on all Kyocera-AVX products. He regularly conducts training at end customer sites, internal technology trainings, and has published numerous articles from energy storage capacitor selection to passive components for WBG applications.

Previously, Daniel served in the U.S. Army 82nd Airborne Division where he was a team leader and combat veteran. He received a BSEE from Mercer University and currently resides in Greenville SC with his wife and two children and is an amateur radio operator. He can be reached at daniel.west@kyocera-avx.com.

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Outline

- The Promises of Wide Band Gap (WBG)
- Capacitors for WBG Power Devices
- Capacitors for WBG RF Devices
- Future Trends
- Summary

Promises of Wide Band Gap

Technology	DC:DC Power Conversion Efficiency	AC:DC Power Conversion Efficiency	DC:AC Power Conversion Efficiency
Si	85 %	85 %	96 %
SiC or GaN	95 %	90 %	99 %

With such efficiency promise, Wide Band Gap (*WBG*) substitute established Si technology

From a power conversion perspective WBG will further accelerate systems by:

› Increases in Switching Frequencies
› Increased Reliability
› Higher Allowable Temperatures
› Increase Operating Voltages
  - Miniature Low Loss, Configurable, High Temp Caps with High Ripple Current Capability

Promises of Wide Band Gap

HIGHER POWER DENSITY (SMALLER VOLUME):

- More power in same die size or smaller die size for similar power compared to Si
- Lower $R_{DS(on)}$
- Higher operational temperatures thus reduced lower cooling concerns

HIGHER SWITCHING FREQUENCY

- Higher frequencies *roughly* translates to smaller value inductors and capacitors
- Smaller passives reduce weight & volume while boosting portability

NEW SYSTEM COST DYNAMICS:

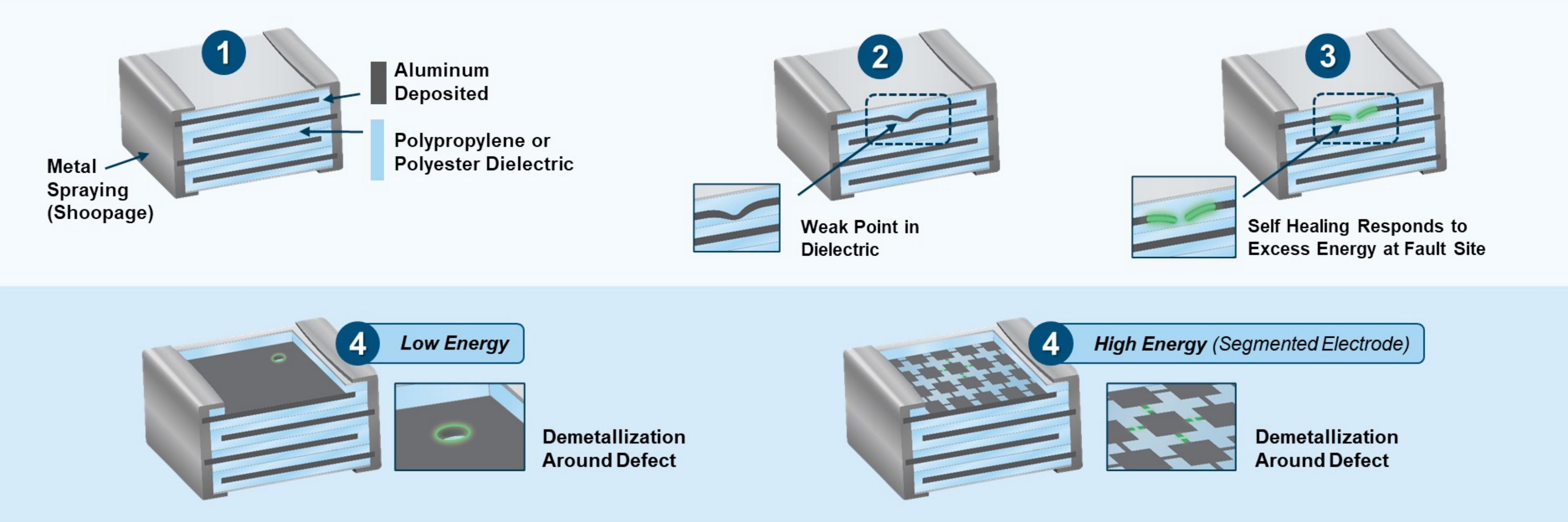
- Higher cost GaN semi but overall reduced cost system due to smaller system size, less cooling (allowed to run hotter), reduced passive count

Capacitors for WBG Power Devices

Self-healing devices are optimal for high power circuits

Metallized film technology offers Controlled Self-healing: Low Energy and High Energy Designs

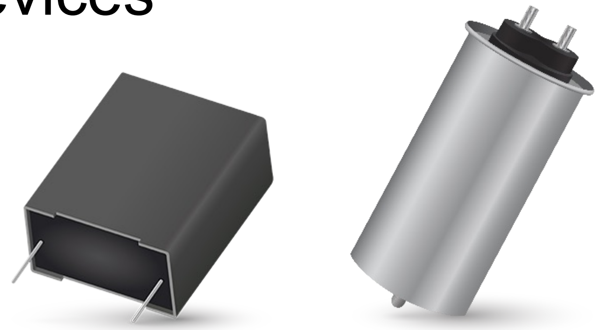
- Low Energy facilitates partial evaporation of electrodes around a fault site
- High Energy utilize fuse isolation of segments of electrodes



Capacitors for WBG Power Devices

End Failure mode is a loss of capacitance (typ. 5%) vs catastrophic failure (possible in Aluminum Electrolytic)

Package materials range from metal can to plastic cans & boxes for integration into wide AC use applications



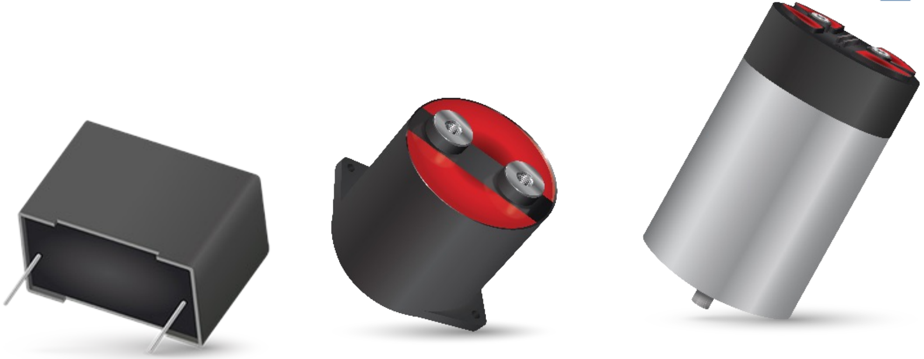
EXAMPLES	Non-impregnated metallized polypropylene, plastic case	Impregnated Metallized polyprop, Al can	Impregnated Metallized polyprop, Al can
Voltage	450Vrms	690Vrms	690Vrms
Capacitance	50µF	600µF	**3 x** 335µF
Temperature	85°C	85°C	85°C
Ripple Current	22Arms	50Arms	43Arms
Dimensions	**W**:35 x **T**:50 x **H**:57.5mm	**D**:106 x **H**:247mm	**D**:136 x **H**:350mm
Applications	Industrial & Energy	Industrial & Energy	Industrial & Energy
Standards	IEC61071	IEC61071, UL810	IEC61071, UL810
Technology	PPY Metallized Film, Dry	PPY Metallized Film, Impregnated	PPY Metallized Film, Impregnated

Capacitors for WBG Power Devices

Low Power DC Filter Capacitors

Maximum package configuration flexibility

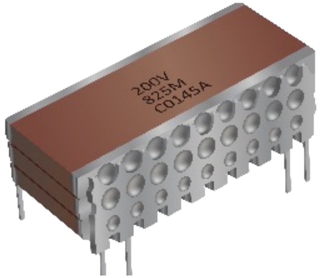
- Voltage: 100 ~ 3000 VDC
- Capacitance: ~ 150 pF to > 2200µF
- Temperature: -40°C ~ 125°C



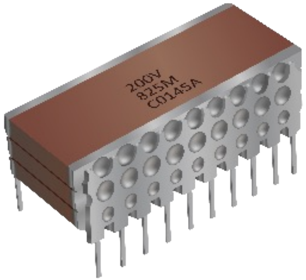
Low Power Examples	1,200Vdc	1,000Vdc	1,200Vdc	1,200Vdc	1,000Vdc	1,200Vdc	1,100Vdc	1,000Vdc
Capacitance	80µF	50µF	22µF	400µF	100µF	100µF	110µF	160µF
Temperature	105°C	105°C	105°C	105°C	105°C	105°C	105°C	105°C
Ripple Current	19Arms	11Arms	14Arms	55Arms	22Arms	28Arms	16.7Arms	33Arms
Dimension (W x H x T)	57.5 x 50 x 35mm	57.5 x 24 x 39mm	42 x 45 x 30mm	57.5 x 80 x 35mm	57.5 x 24 x 70mm	57.5 x 80 x 35mm	32 x 37 x 22mm	36 x 40 x 36mm
Standards	IEC61071	IEC61071	IEC61071, THB Test 85°C 85%HR Undc 1,000h	IEC61071	IEC61071	IEC61071, THB Test 85°C 85%HR Undc 1,000h	IEC61071, IEC61881	IEC61071, IEC61881
Technology	Metallized Film, Dry	Metallized Film, Dry	Metallized Film, Dry	Metallized Film, Dry	Metallized Film, Dry	Metallized Film, Dry	Metallized Film, Dry	Metallized Film, Dry

Capacitors for WBG Power Devices

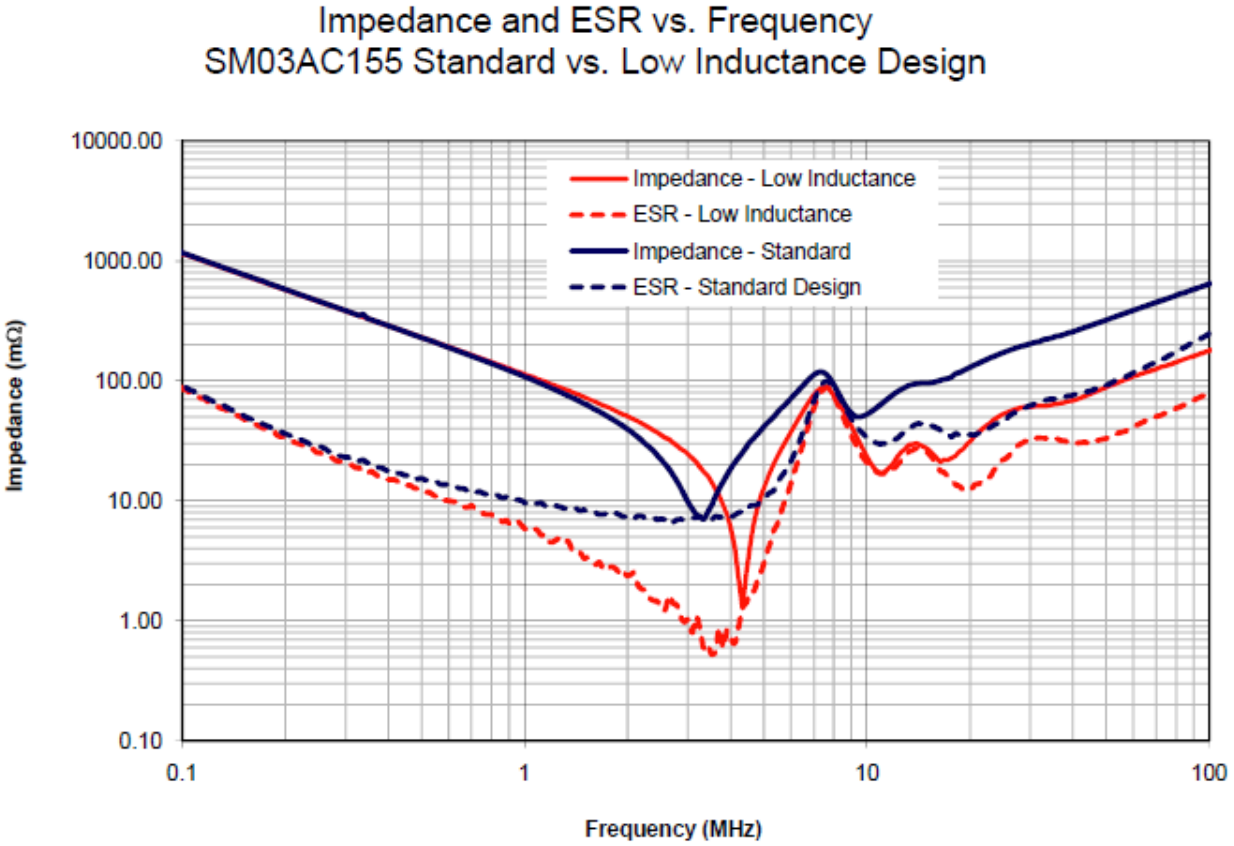
Stacked Ceramic Technology & Lowered Inductance



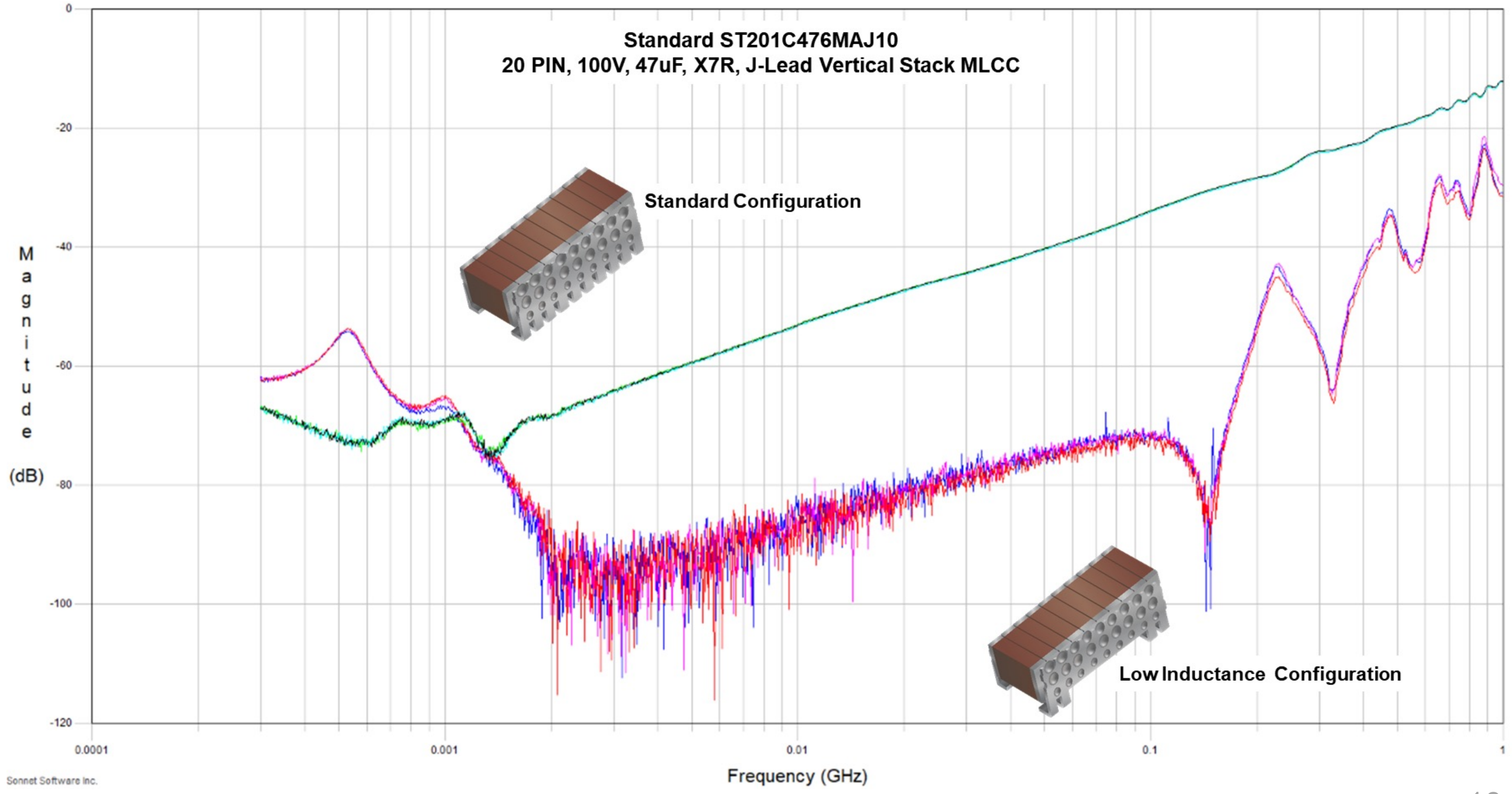
Self-Resonant Frequncy =4.33 MHz
ESR @ Self-Resonance = 1.28 mΩ
Self-Inductance = 0.894 nH
Capacitance = 1.51 µF



Self-Resonant Frequncy =3.25 MHz
ESR @ Self-Resonance = 7.38 mΩ
Self-Inductance = 1.61 nH
Capacitance = 1.49 µF

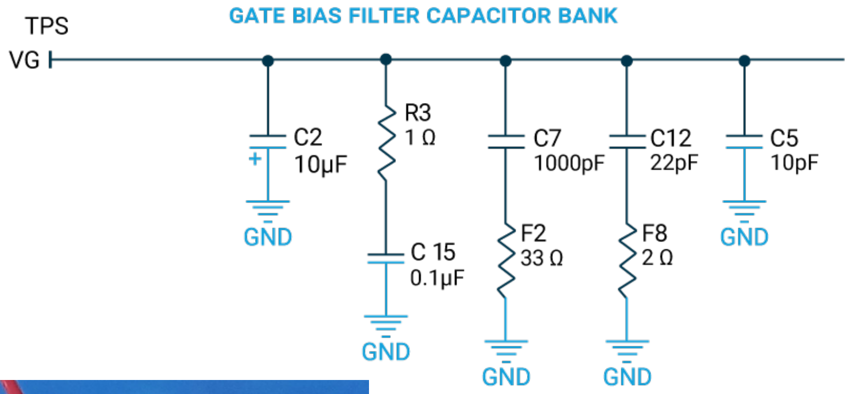


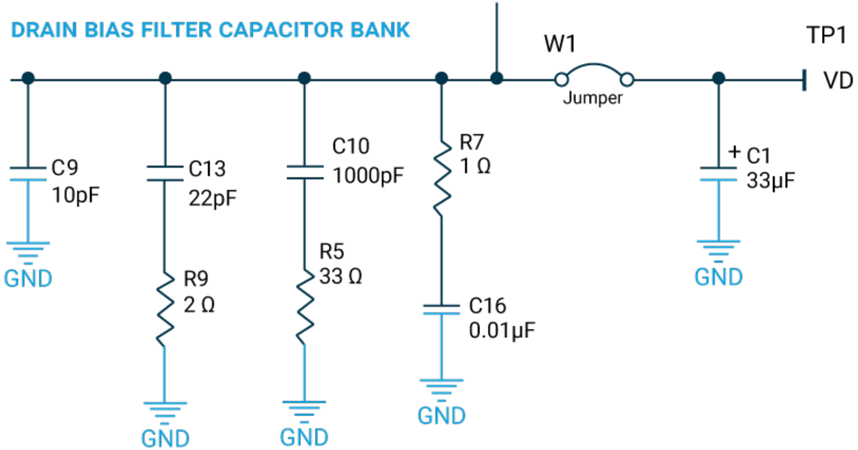
Capacitors for WBG Power Devices

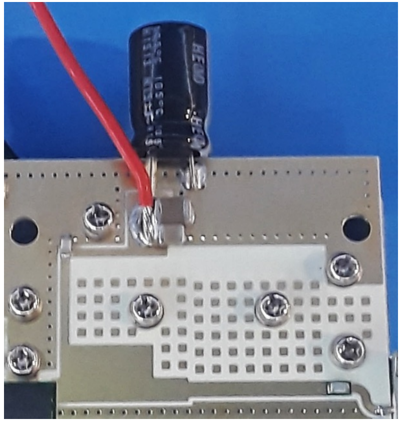


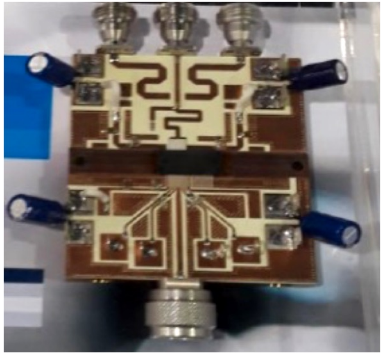
Capacitors for WBG RF Devices

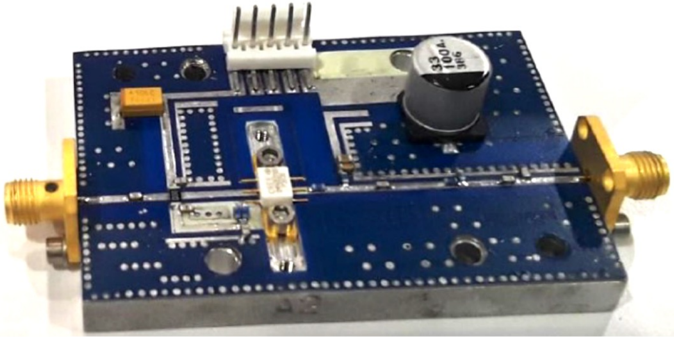
Examples of GaN Gate and Drain Bias Filter Bank Design







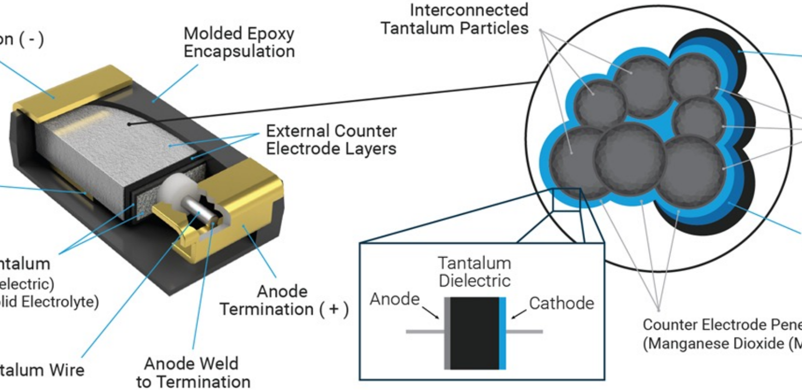




Capacitors for WBG RF Devices

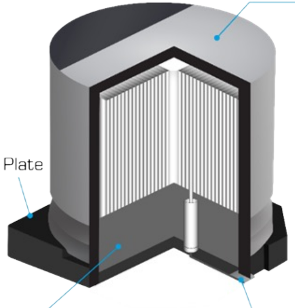
Bias Filter Capacitor Options: Tantalum Polymer and Al-El

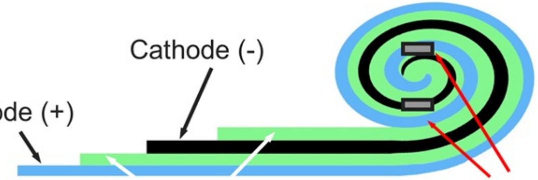
Tantalum Polymer



TANTALUM POLYMER VS ALUMINUM ELECTROLYTIC

Aluminum Chip Capacitors

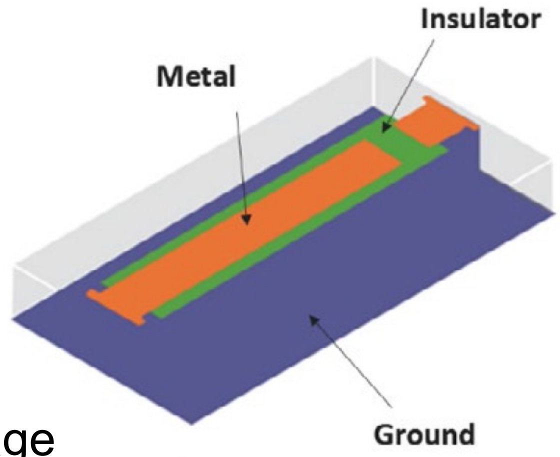


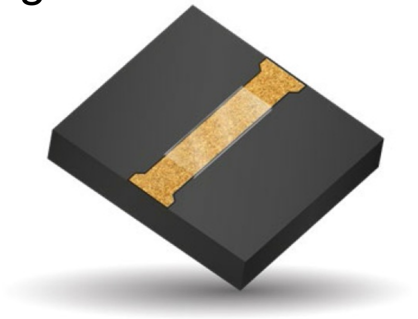


Capacitors for WBG RF Devices

Single Layer Capacitors: Silicon & Ceramic

- Impedance Matching
- Front-end DC Blocking & Broadband Bypass
- Dielectric Stability
- ~40 GHz Range
- Pre-matching from lead frame to gate in WBG package

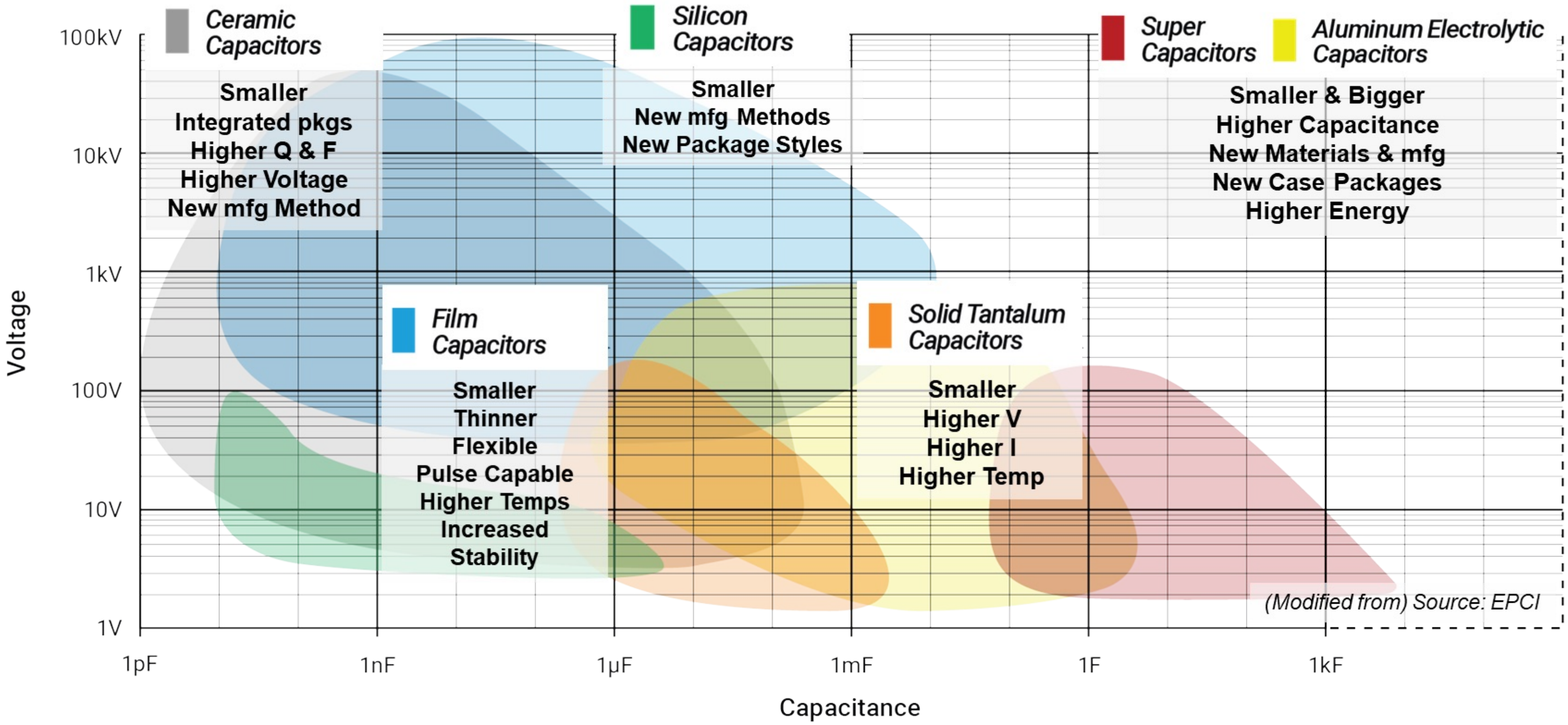




Future Trends

PARAMETER	CAPACITOR TYPE			
	SMALL SIGNAL	RF	POWER	BULK GENERAL PURPOSE
Cap Value	↓↑	↓↑	↑	↑
Rated Voltage	↓↑	↑	↑	↓↑
Size	↓ →	↓ →	↓	↓
Temperature Stability	↓↑	↑	→	↑ →
DC Bias Stability Need	↑	↑	→	↑
Temperature Range	↑ →	↑ →	↑	↑
Frequency	↑	↑	↑	↑ →
Loss Characteristics	↓	↓	↓	↓

Future Trends



WBG Driven Industry Trends: 400V ⇢ 800V 105°C ⇢ 150°C

Summary

- Capacitor trends vary for Power or RF Wide Band Gap Devices
- Power applications focus on enhanced reliability, lower inductance, and low parasitics
- RF applications will need stable dielectrics, and high volumetrically efficient capacitance values
- Future trends include new manufacturing processes and packages

Thank you for your interest.

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