Integration of pre-fabricated ultra-high density (1000 nF/mm^2) capacitor films (50-75 microns) onto wafers and panels

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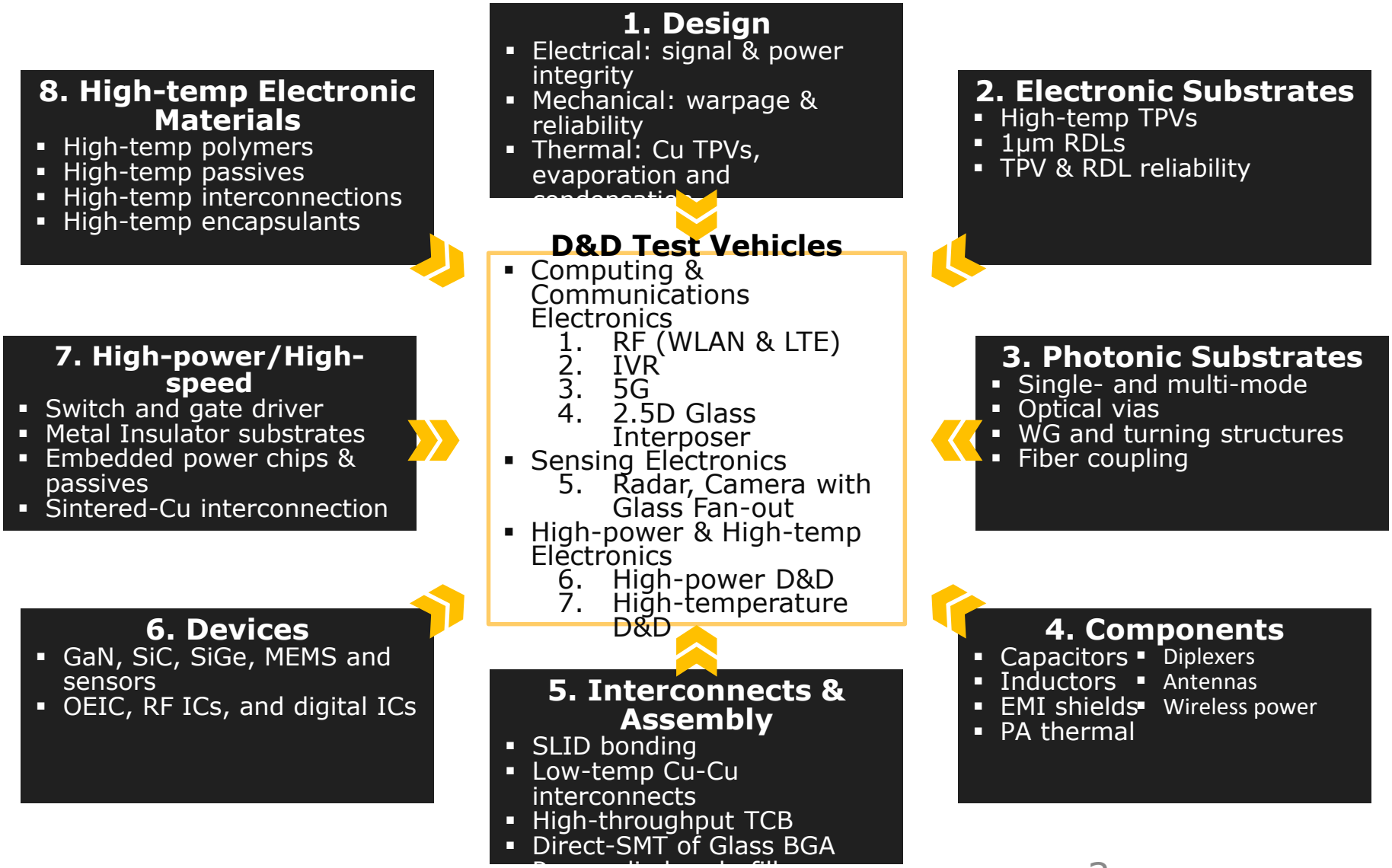
 # A.V.X. Corporation, One AVX Blvd, Fountain Inn, SC 29644

& Heraeus Inc., Leverkusen, Germany.

Outline

- Introduction to GT Packaging Research Center
- Capacitor needs for consumer, telecom and automotive industry
- Capacitor integration strategies
- Tantalum film capacitors on silicon
  - Capacitor Integration
  - Capacitor performance
  - Reliability studies
- Integrated voltage regulator (IVR) with capacitors and inductors

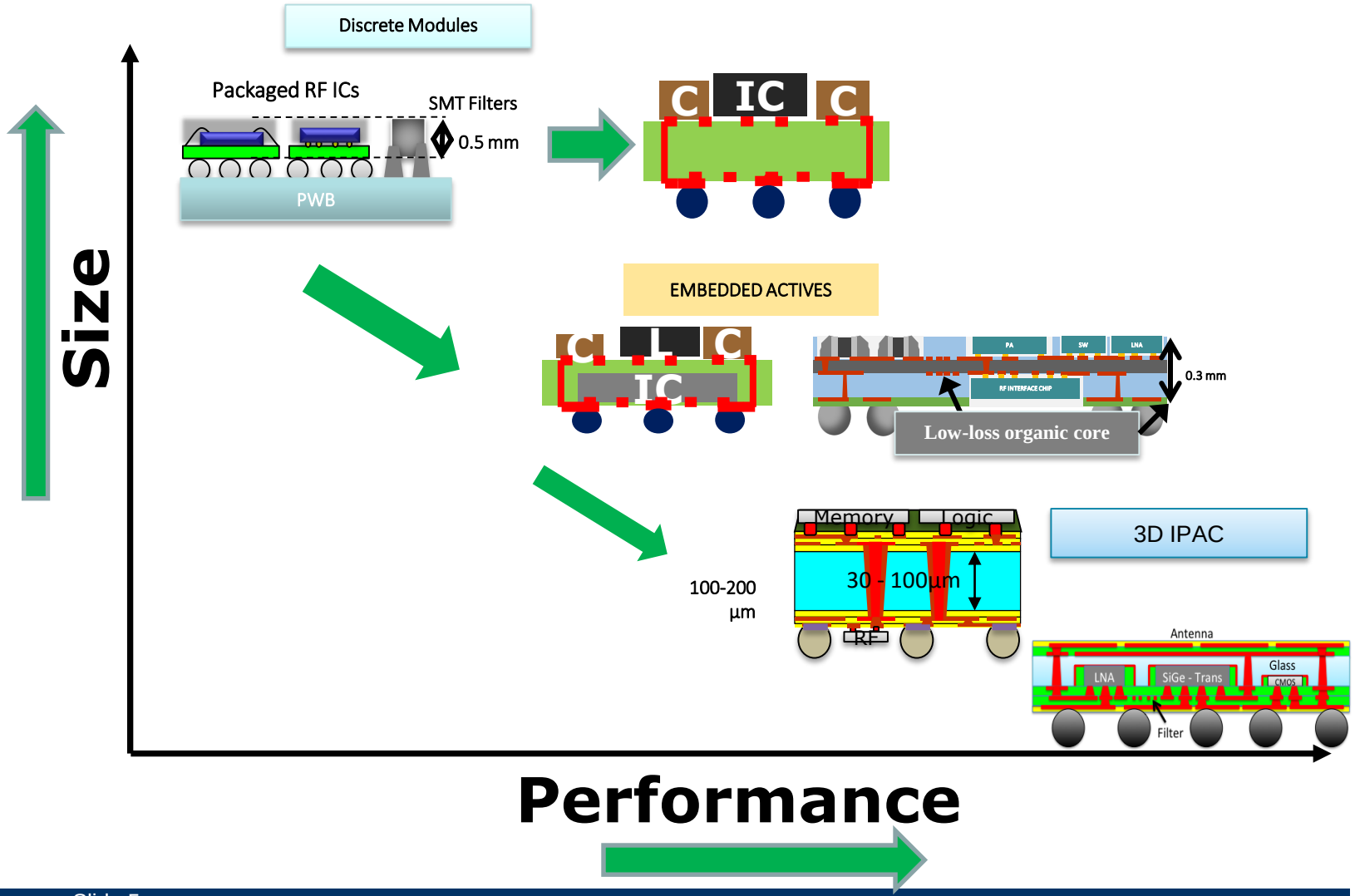
Packaging Research at Georgia Tech



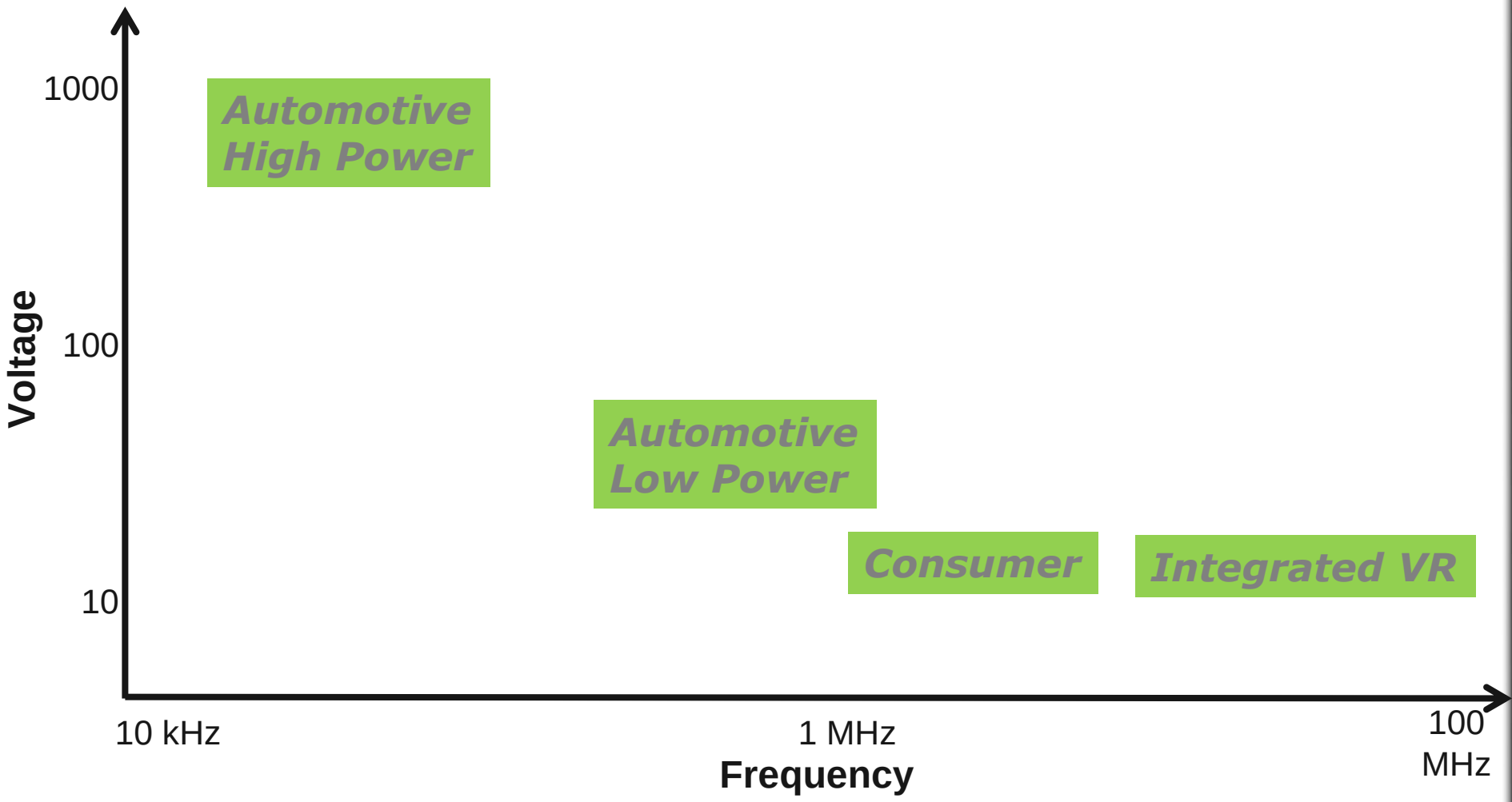
Why Collaborate With Georgia Tech PRC

- No. 1 Academic Leader in IC & Systems Packaging
- Technical Vision Consistent with Market Needs
- Co-development of Panel-based Glass Packaging with 50 Global Researchers, Developers, Manufacturers and users
- Explore and Develop Advanced Systems Packaging Technologies Beyond Industry's 3-year Horizon
- Seamless from R&D, Prototype, and Tech Transfer Enabling Commercialization
- Track Record of Technology Breakthroughs
- Only 300mm Cleanroom Panel Facility in the Academic World
- > 50 Person Co-development Team: Full-time Researchers, Manufacturing Industry Partners, Graduate Engineers, Faculty and On-campus Industry Engineers
- Leverage: $8M/100k

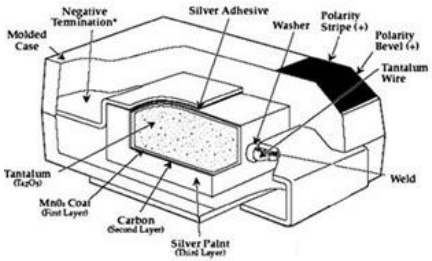
Ultra-miniaturized Power and RF modules with Passive-Active Integration



Capacitor Needs



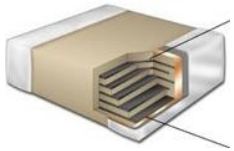
Capacitor Technologies



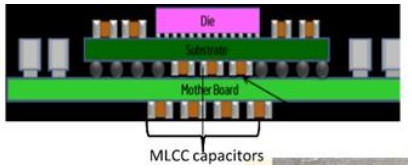
Tantalum

Cap. Density	3 μF/mm^2
Thickness	200-800 μm
Operating Frequency	100 Hz – 0.3 MHz
Leakage current	~0.01 μA/μF
Packaging	SMD

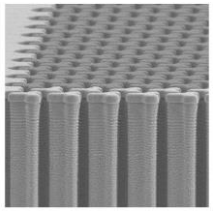
MLCC



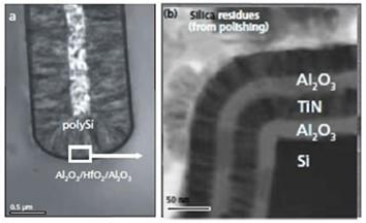
Cap. Density	1 μF/mm^2
Thickness	50-800 μm
Operating Frequency	100 Hz – 1 MHz
Leakage current	~0.01 μA/μF
Packaging	SMD, thin-film



Si Trench



iPDIA



Cap. Density	>0.5 μF/mm^2
Thickness	100 μm
Operating Frequency	100 Hz – 1 MHz
Leakage current	~0.1 μA/μF
Packaging	thin-film

Etched Al

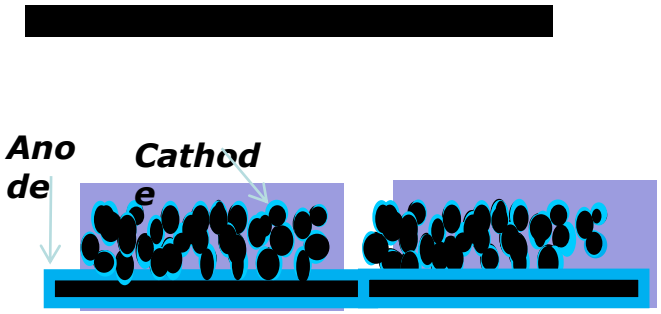
Cap. Density	1 μF/mm^2
Thickness	~1000 μm
Operating Frequency	100 Hz – 0.3 MHz
Leakage current	~0.01 μA/μF
Packaging	SMD

Helsinki

Silicon-Integrated High-Density Capacitors

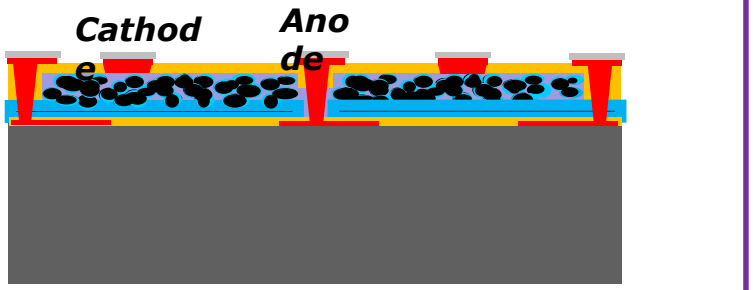
Component Manufacturer (Ex. AVX)

Ta foil



TI
Wafer

Use standard infrastructure with "next-generation" standard materials



Silicon-Integrated High-Density Inductors

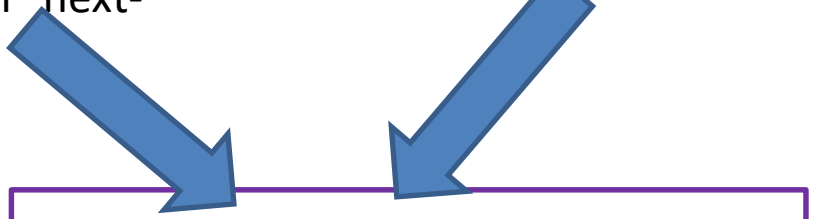
Component Manufacturer (Ex. TDK)

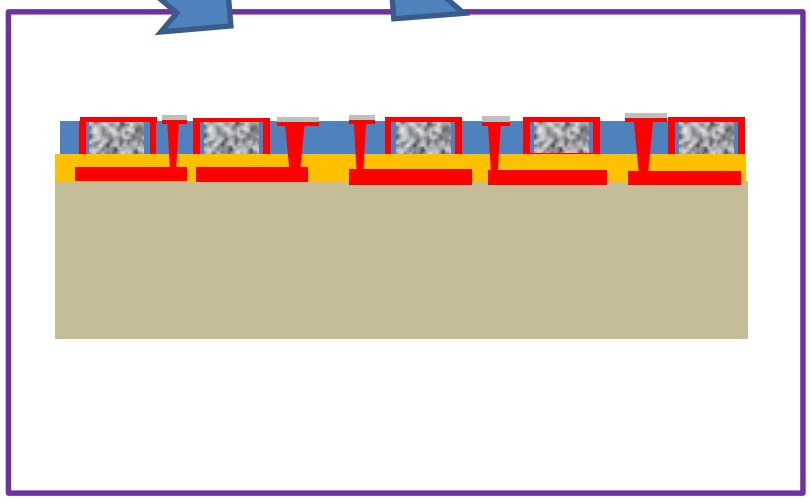
High Thermal conductivity dielectric

Prepattern magnetic core

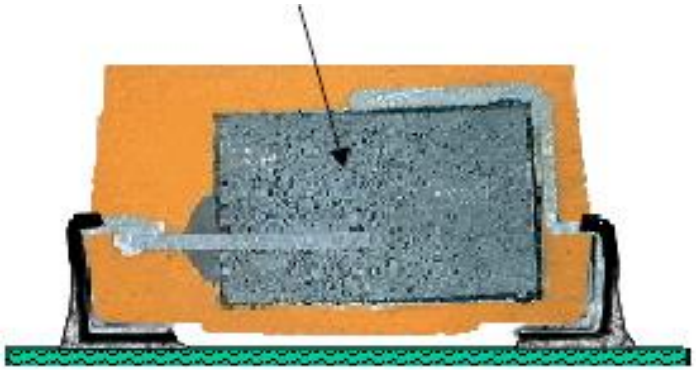
TI Wafer

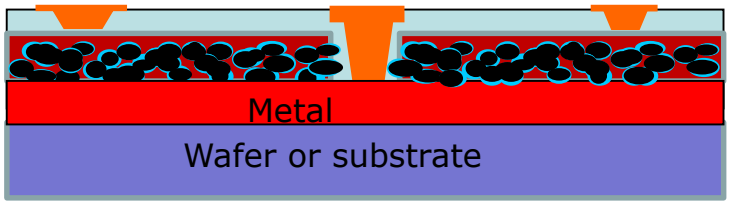
Use standard infrastructure with “next-generation” standard materials





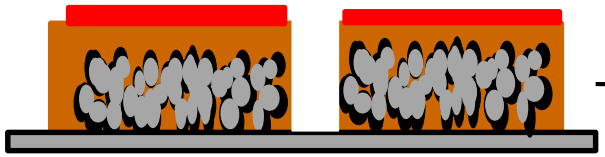
Bulky Ta Vs Silicon-Integrated Ta Film Capacitors





200 micron conducting path	50 micron conducting path
CP/Carbon/Silver paste/lead frame	Minimal interfaces; Direct metallization of CP with Cu/Au
100 milliohms x microfarad	20-50 milliohms x microfarad
1-5 MHz	>10 MHz

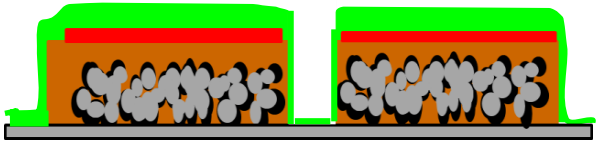
Capacitor Integration scheme



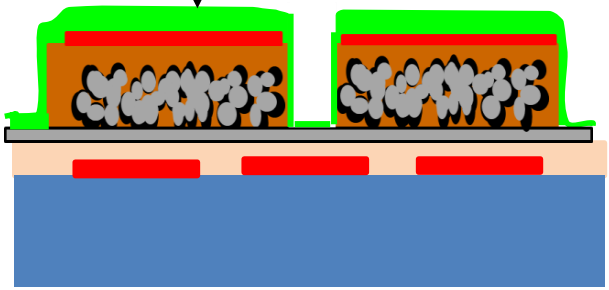
Capacitor foil

I. Passivation

100 nm/ 200 nm



II. Lamination on Si
Vacuum laminator



III. Planarization

IV. Via drill

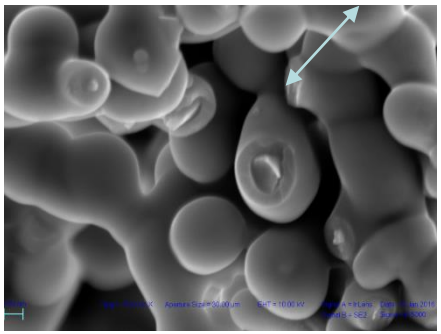
V. Metallization

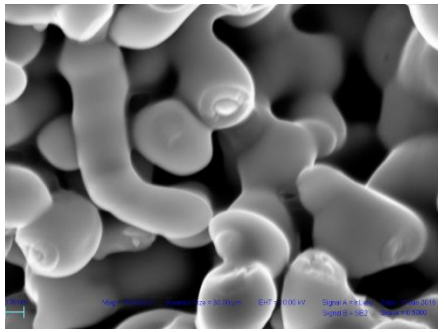
a. Desmearing

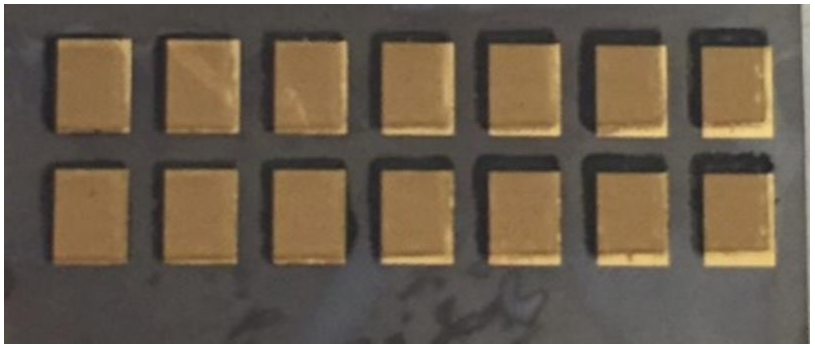
b. Electroless Cu seed layer
c. Photolithography
d. Electroplating

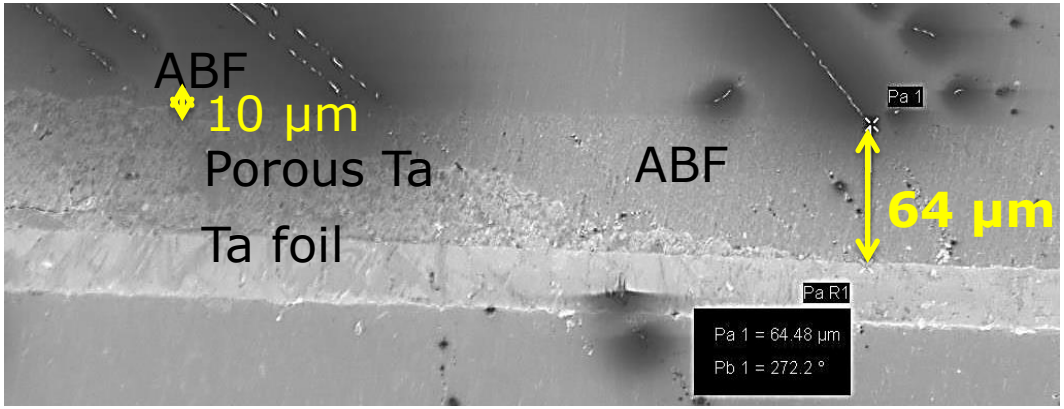
Demo. of Capacitor Integration

- Sintered tantalum electrodes on tantalum films
- Laminated onto Silicon
- Via connections with laser drilling, metallization









- Anodization voltage- 20V

Supply Chain Involvement

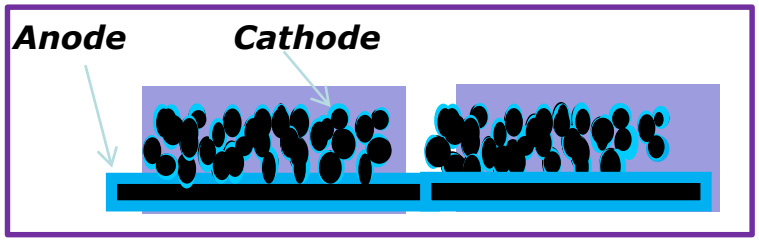
Component Manufacturer (Ex. AVX)

Ta foil

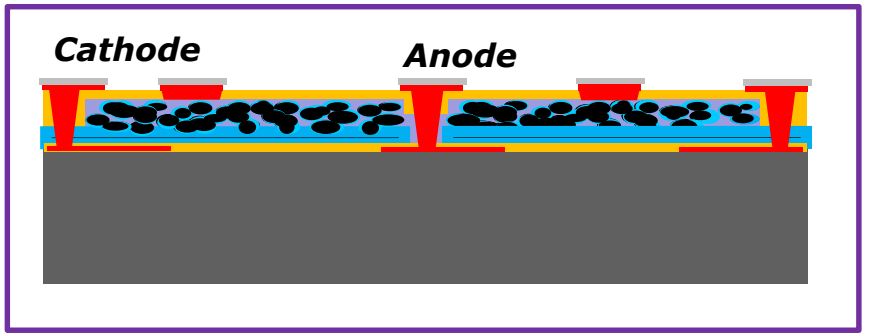
H.C.Starck

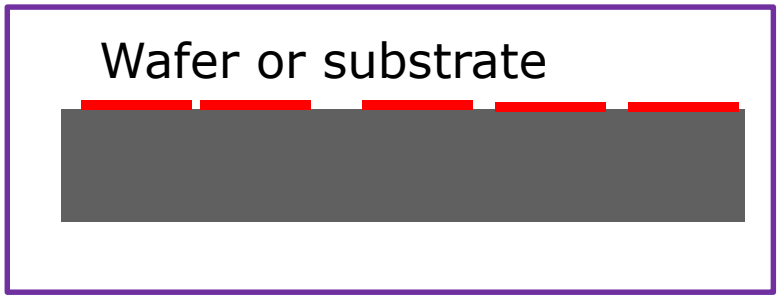
Heraeus

Power modules with passive-active integration

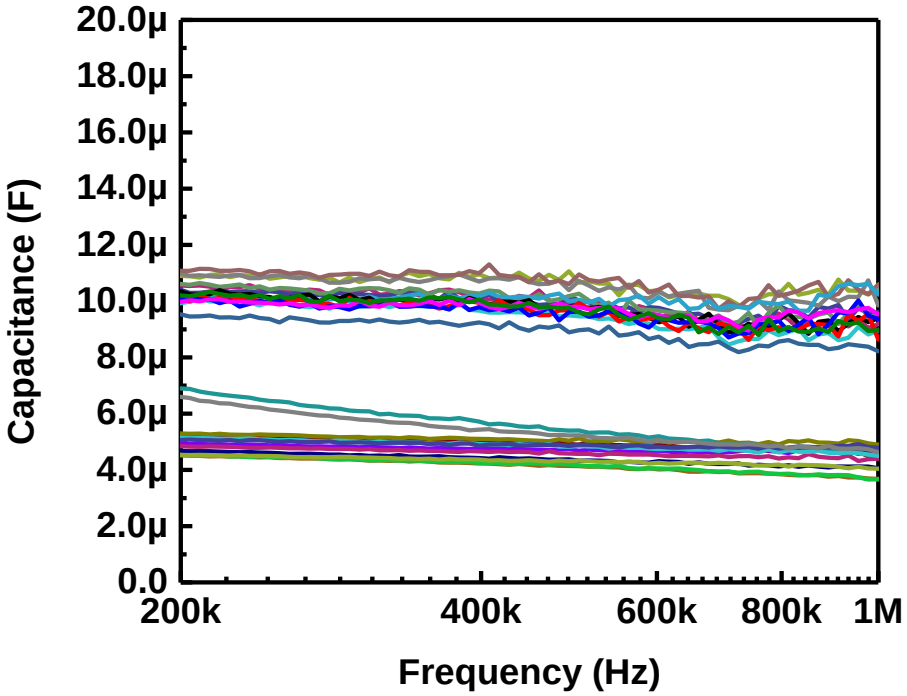


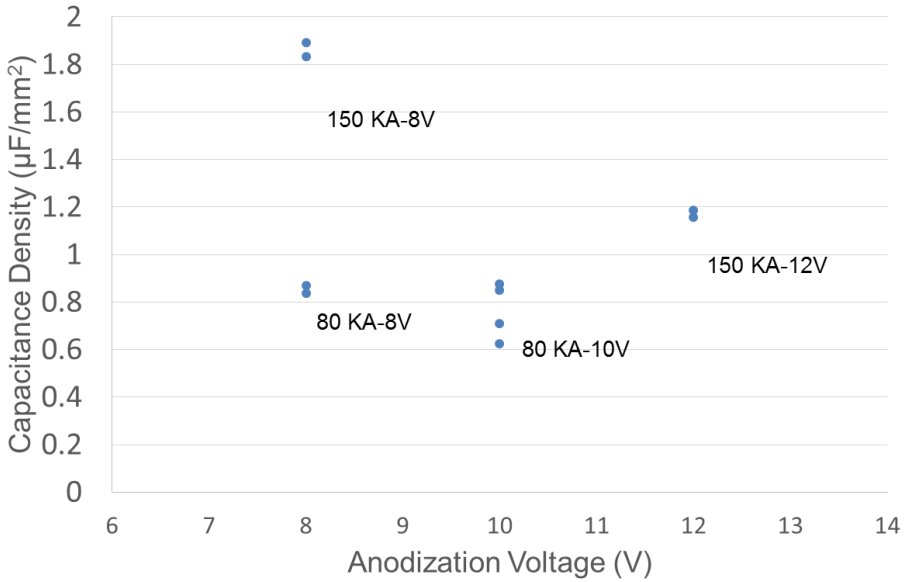
AVX





Capacitor Performance

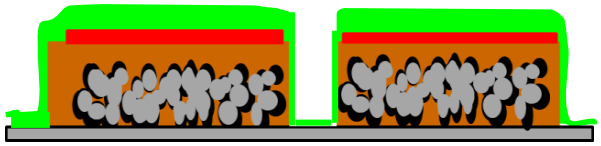




~1µF/mm^2 obtained wiuth:

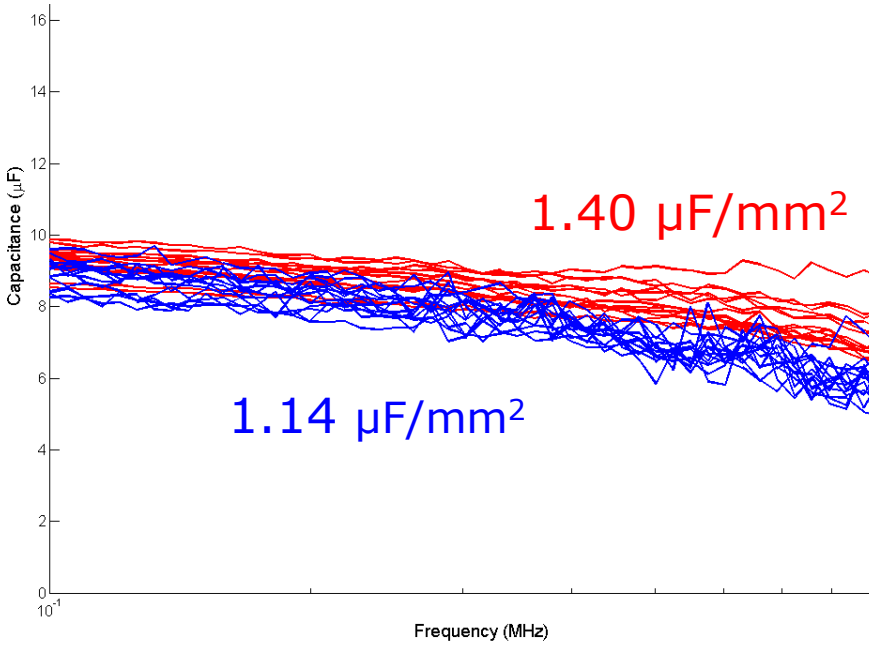
- 80 KA grade with thin dielectric thickness (8V/10V)
- 150 KA with thick dielectric thickness (12V)

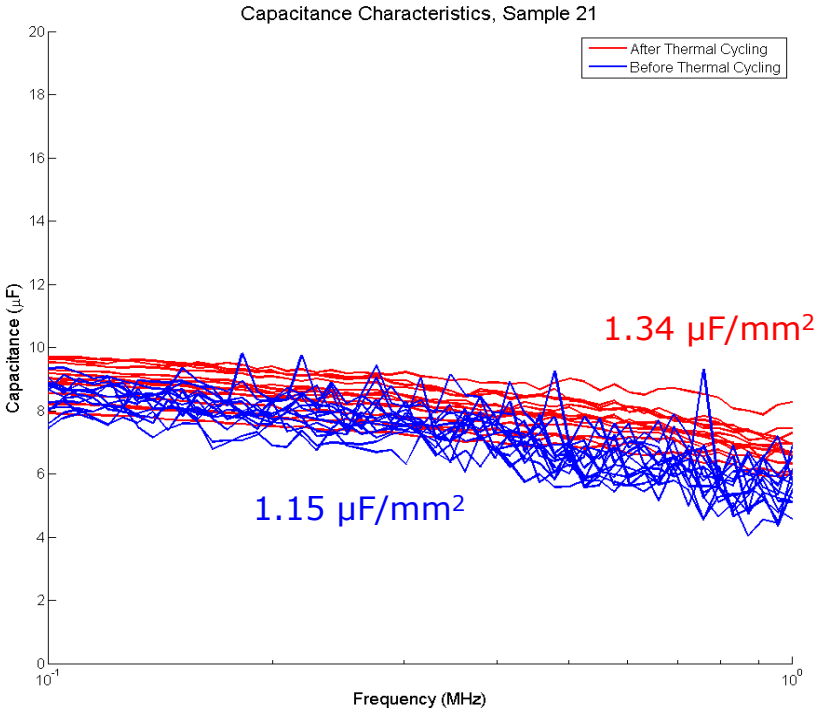
Reliability of passivated capacitors



TCT conditions → 65°C/95% RH, 500 hrs

Parlyene thickness- 200 nm

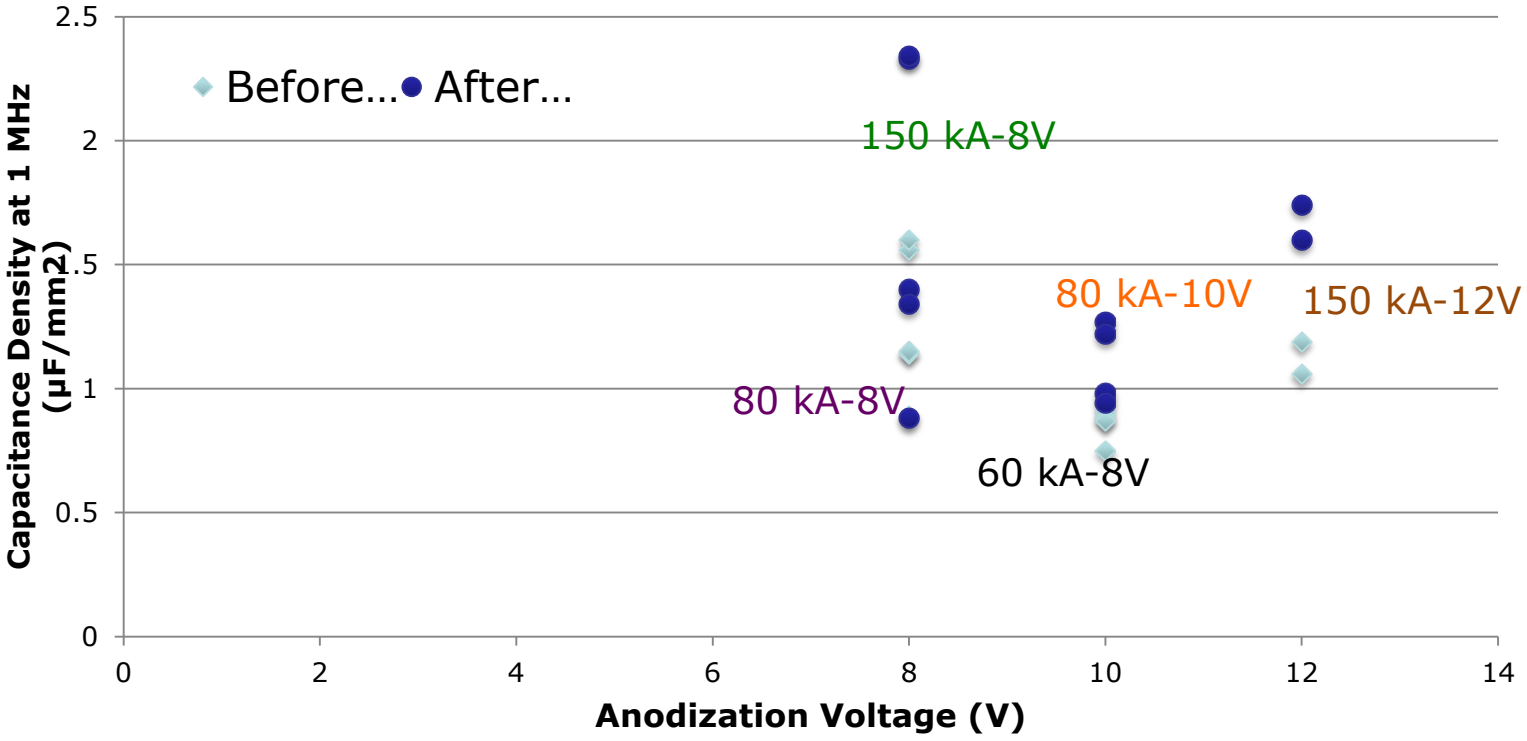




- Increase in capacitance observed post 500 hr of thermal cycling

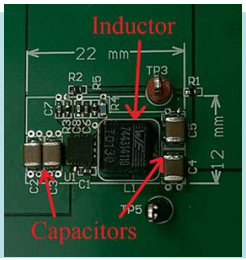
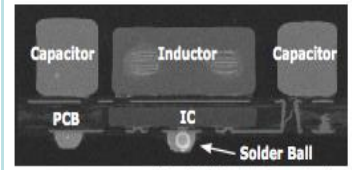
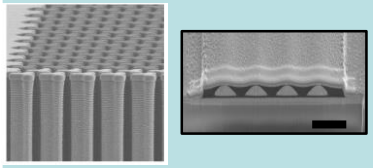
Reliability of Passivated Capacitors

65°C/95%RH 500 hours



- All foils passed 65/95 for 500 hours
- Capacitance comparable or higher after thermal and moisture test

Competitiveness of GT Approach with Embedding Si Integrated Ta Capacitors

		 MicroSiP™ Module Cross-Section (Courtesy of System Plus Consulting)		
	• Discretes	• Embedded ICs	• on-chip	• 3D Packages
Inductors	• Ferrites;	• Embedded or SMDs	• Thinfilm inductors	• Thinfilm inductors
Capacitors	• MLCCs	• MLCCs	• Trench capacitors	• Thinfilm capacitors
EFFICIENCY				
POWER HANDLING				
SIZE				
COST				
MANUF READINESS				

Summary

Pioneered a breakthrough capacitor integration technology on wafers and packages:

- Unlimited capacitance density on Silicon
- Low cost – cheaper than traditional discrete passives
- Extensible to high voltages
- Extensible to high frequencies

Created an ecosystem of supply chain involving:

- Material suppliers,
- Component manufacturers
- End-users

Extending this baseline technology to:

- High-voltage power modules: Ex. Automotive
- Automotive battery chargers
- Integrated voltage regulators