

Embedded Thin Film Components Packaging Consortium (ETCP)

presented by

Georgia Institute of Technology
3D-Systems Packaging Research
Center

Atlanta, Georgia
July 21, 2010

Webinar Outline

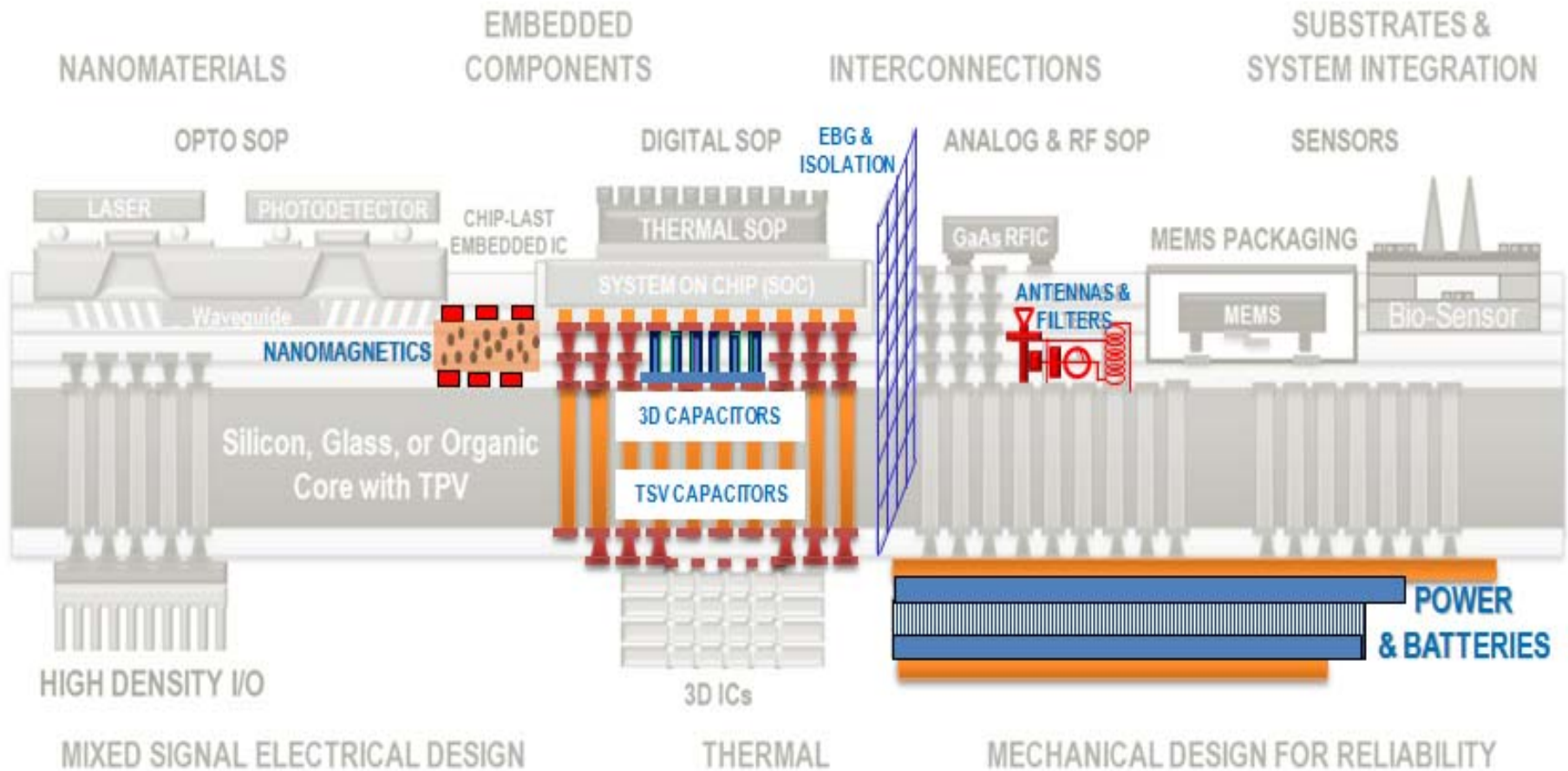
- Introduction – Prof. Rao Tummala
 - Purpose of Webinar
 - Why ETCP?
 - Why Georgia Tech ?
 - Research Focus and Targets
 - ETCP Team
- Phase 1 Program Details – Dr. P. M. Raj
 - Objectives
 - Research Focus
 - Research targets, tasks and team
 - Industry Survey Response
 - Companies interested, membership options and costs
 - Next step for Companies and for Georgia Tech



Purpose of Webinar

- Invite Global Electronic Companies to Join GT PRC Consortium either as “Full Member” with IP rights or as “Supply Chain Member” to supply thin film passive component materials, processes, tools, packages or modules:
 - For strategic technology
 - To leverage company funding by 10X
 - Utilize Industry-centric and proven team

ETCP Focus



Why ETCP Consortium ?

- Replace bulky system components on board with embedded thin film components in the package for
 - Miniaturization
 - Cost
 - Performance



ETCP Rationale

- Better miniaturization
 - Replace bulky discrettes with thin films; Enhance volumetric efficiency by 10-100X with advanced materials and structures
 - Eliminate individual component packaging
 - Allows efficient designs to reduce the required number of components and also lowers the component values.
- Better cost
 - Use lower cost and scalable processes that are cheaper than those used for discrete component manufacturing
 - Eliminate discrete assembly steps
 - Miniaturize with better volumetric efficiency to further lower the costs
- Better performance:
 - Integrating components lowers the parasitics from traces and interconnections
 - Improve process tolerance for high performance applications from 15% to 5-10% with advanced lithography processes



Why the Georgia Tech PRC?

- I. Expertise in advanced materials, processes and integration for embedded thin components
- II. 15 years systems packaging research experience
 - 6 core areas: design, materials & processes, components, thermal, interconnections and reliability, and systems integration
 - \$242 million knowledge base
- III. Comprehensive cleanroom systems research facilities
 - \$50 million IC and systems packaging research
- IV. Experience in collaborating with over 150 global companies
 - Consortia
 - One-on-one programs
 - Supply chain engagement
 - Industry-centric team
 - Deliverables at industry pace



ETCP Tasks and Team

- Faculty Director: Prof. Rao R. Tummala
- Research Director: Dr. Venky Sundaram
- Program Director: Dr. P. Markondeya Raj
- Design and Modeling: Prof. Madhavan Swaminathan
- Materials and Processes Dr. Himani Sharma
- Industry Liaison and Contracts: Mr. Dean Sutter



ETCP Focus & Targets

Component Type	Components	Research Targets
A. POWER Components	A1 High density inductors	<ul style="list-style-type: none"> ▪ 1000 nH/mm²/layer ▪ Q > 50 @ 0.1-1 GHz
	A2 High density capacitors and supercapacitors	<ul style="list-style-type: none"> ▪ 100-1000 μF/cm²
	A3 Thin film batteries	<ul style="list-style-type: none"> ▪ 1 mAhr/cm². μm
B. DIGITAL Components	B1 TSV Capacitance density	<ul style="list-style-type: none"> ▪ 10-50X increase from oxide TSV
	B2 High density planar and trench capacitors	<ul style="list-style-type: none"> ▪ 1-10 μF/cm² at above 100 MHz
C. RF Components	C1 Dielectrics	<ul style="list-style-type: none"> ▪ 10-20X enhancement in permittivity with low loss and TCC
	C2 Magnetodielectrics	<ul style="list-style-type: none"> ▪ High permeability and permittivity; ▪ Low Loss
	C3 Tunable components	<ul style="list-style-type: none"> ▪ Low voltage tuning; ▪ Tunability with low loss and TCC
	C4 EMI isolation	<ul style="list-style-type: none"> ▪ 1-10 GHz; -50 dB



Technical Barriers

- High density capacitors for power supply:
 - High yielding materials and thin film processes for nanostructures
- High density inductors
 - Metallic magnetic cores have limited frequency of operation.
 - Integration of ferrites in packages
- RF components
 - High Q and stable properties with high permittivity and permeability
 - Process tolerance
- EMI isolation
 - Ferrite beads are bulky for package integration
 - Design complexity for noise isolation



A. Power Components

A1. High Density Inductors

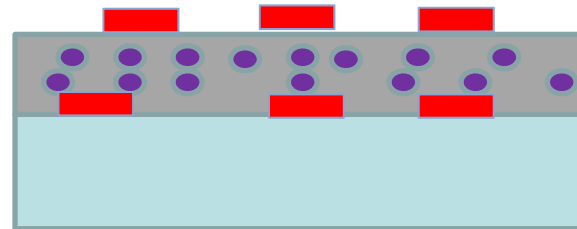
- Systems components operate at different voltage levels;
- Shift from larger system power supplies to smaller fast-switching power supply to sub-systems.
- Inductor-based power regulators are critical to convert battery voltage to the required voltage levels.
- Inductor volumetric energy storage and efficiency are the biggest bottlenecks for energy conversion.
- Integrating efficient power supply modules in planar format inside a 3D package will become a major focus for electronic system integration.



High Density Inductors Targets

Embedded power inductors using nanomagnetic materials and structures with high frequency stability and high quality factor, and improved EMI shielding.

- Inductance to :
 - 1 $\mu\text{H}/\text{mm}^2$
 - 50-100 micron device
 - 0.1-1 GHz
- Low-cost process for easier integration and high density



A2. High Density Capacitors

Applications:

- Voltage conversion:
 - Charge pumps
 - Linear regulators
- Filtering power supply noise
- DC blocking

Objectives:

50-100 $\mu\text{F}/\text{cm}^2$

20 V

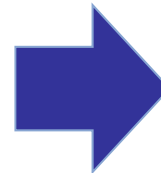
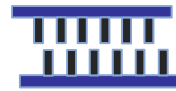
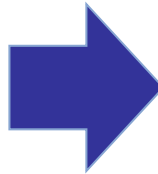
1 $\mu\text{A}/\mu\text{F}$ leakage

Integration in organic or silicon packages

A2. Supercapacitors

- Objectives:
 - Thin film or planar components to enhance the energy and power densities for efficient power supply, conversion and regulation.
 - Planar supercapacitor components for easier integration in the package

- High Surface Area Electrodes
- Electrolyte
- Hermetic Packaging of supercapacitors



Integrate them in the package

A3. Thin Film Batteries

Objective:

- High density using nanomaterials and nanostructures to integrate power sources as planar components

Rechargeable power sources for:

- Wireless sensor networks
 - RF IDs
 - Subsystem modules
 - Medical Implants
- 10X enhancement in energy density compared to state-of-the-art (1 mA hr/cm² for 1 micron thickness)
 - 10 X enhancement in power density with thinner electrolytes
 - Integration on silicon



B. Digital Components



B. Digital Components

- Power supply to core circuits in high-speed processors
 - Low impedance power supply in GHz frequencies
 - Eliminate surface mount capacitors on package
 - Minimize the need for on-chip decoupling

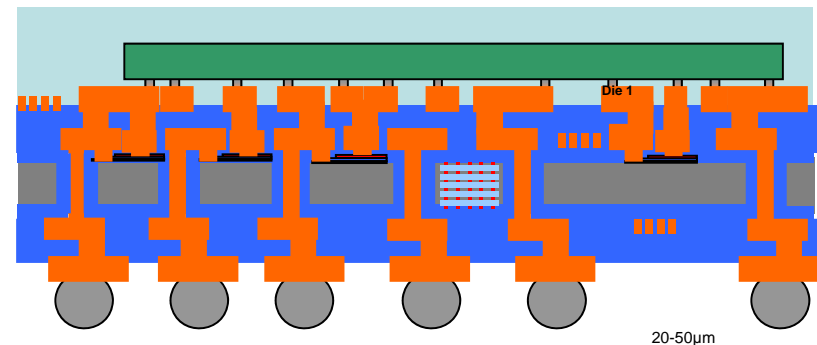
- Support 1 TB/s bandwidth in 3D Memory-Core Packages
 - Suppress power-ground noise coupling to high-speed I/Os



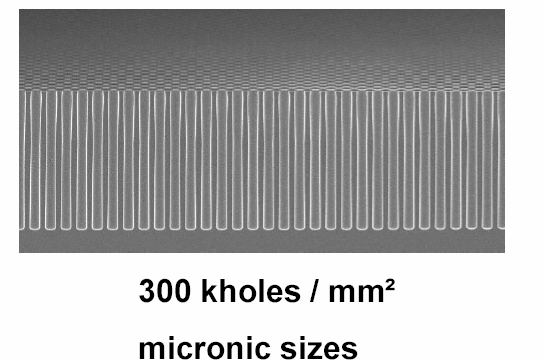
Decoupling Capacitors

- Thin film decoupling capacitors:
 - High permittivity thin films on silicon
 - Low-temperature silicon compatible processes
 - Stability in GHz frequencies

- Capacitors integration in 3D ICs:
 - Novel capacitor design and integration in 3D ICs



Decoupling Capacitors

State-of-the-art	PRC Focus
<p>Capacitance density of 15-40 $\mu\text{F}/\text{cm}^2$ Low voltage of $< 10\text{ V}$ Trench capacitors</p>  <p>300 kholes / mm^2 micronic sizes</p>	<p>5X higher than the state-of-the-art; Low-cost capacitors in 3D systems for terabits/sec bandwidth;</p>
<p>Deep trenches with high aspect ratio of 50-100</p>	<p>100-1000 enhancement in area</p>
<p>Moderate permittivity dielectrics: ALD and thermal oxidation Permittivity of 5-20</p>	<p>Low Cost processes for permittivity of 100-1000</p>

C. RF Components

- Capacitance density of 1-10 nF/cm² with
 - Low loss
 - Low TCC of 30-50 ppm/C
 - High tolerance with uniform film thickness and precision lithography
- High density RF inductors
 - 10 nH/mm² at 1-5 GHz
 - Q of above 100
 - Thin nanomagnetic films with 5-10 microns

Application	Capacitance Range	Q Factor	Tol.	Characteristics
RF Filter Cap.	1-100pF	>200	<5%	High Self Resonance Freq. Large Q Values
Bypass Cap.	0.01-0.1 μ F	>50	<15%	Low Impedance
Oscillators	10-100 pF	>200	<5%	Tunable High Q Low TCC
Matching networks	1-100 pF	>200	<5%	Tight Tolerance

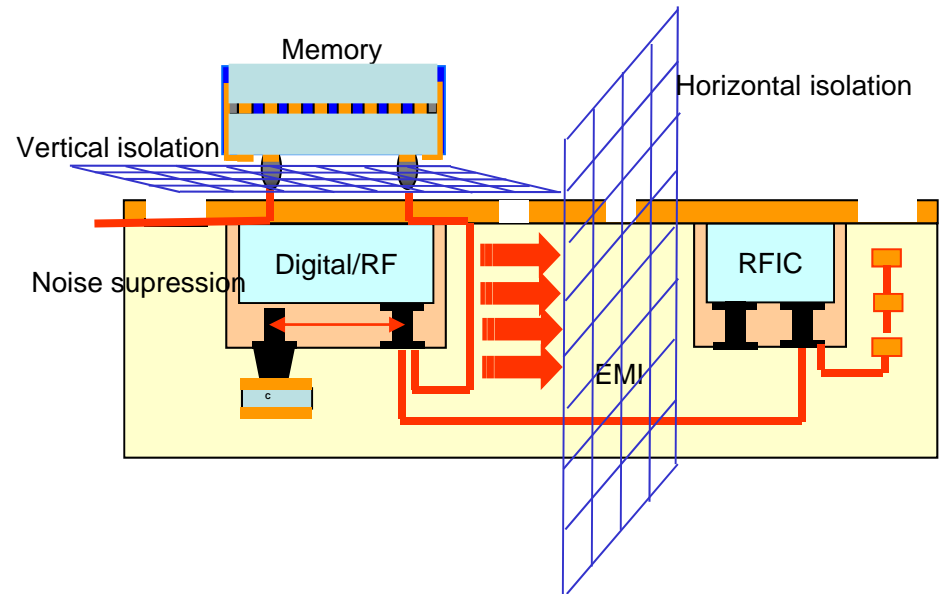
Embedded RF Capacitor Approach

- Organic substrates or organic build-up layer process compatible
- Polymer composites or thin film capacitors with engineered:
 - Permittivity: 10-80
 - Loss tangent: < 0.005
 - Temperature coefficient of capacitance: < 30 ppm/C
- Tolerance of 5% from:
 - Thickness control (10-15 microns with submicron accuracy)
 - Lateral dimension control (100s-1000s of microns with 2-3 micron accuracy)

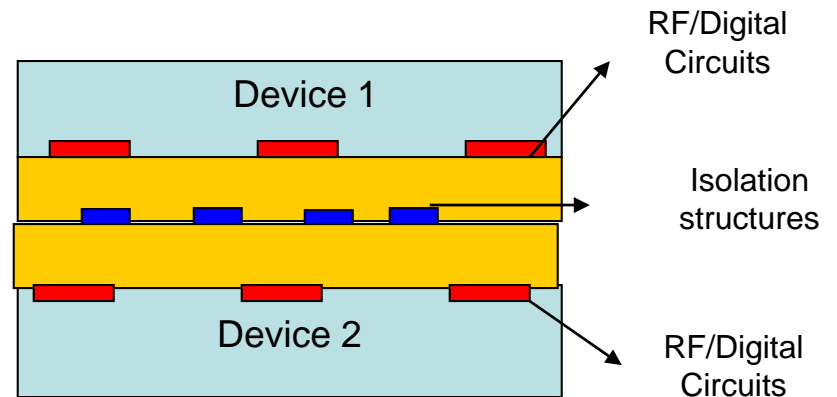
C3. EMI Isolation

NOISE ISOLATION of -50 dB
AT 1-10 GHz

- Horizontal isolation between adjacent ICs



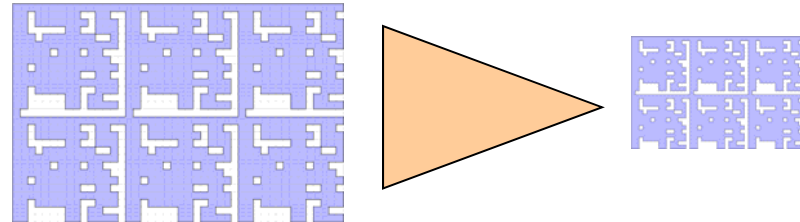
- Vertical Isolation in Stacked ICs



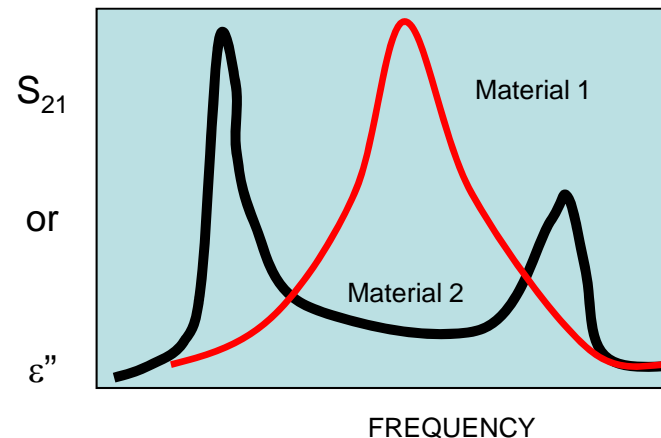
C3. EMI Isolation

- Horizontal isolation with miniaturized Electromagnetic Band Gap Structures

EBGs are large in size
Size scaled down with permittivity and permeability
Miniaturize with advanced materials



- Vertical Isolation with noise-absorbing layers



ETCP Two-Year Research Targets

Component type	Components	Research Targets
A. POWER Components	A1. High density inductors	<ul style="list-style-type: none"> • 1000 nH/mm²/layer • Q > 50 @ 0.1-1 GHz
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PRC Experience in Thin Film Components: Examples



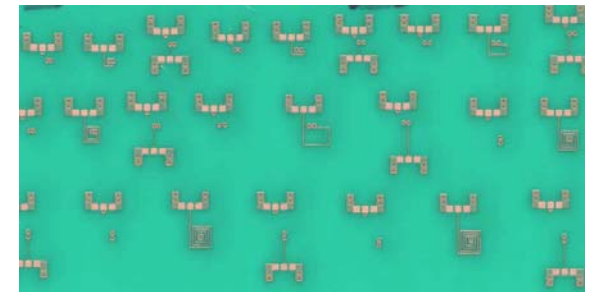
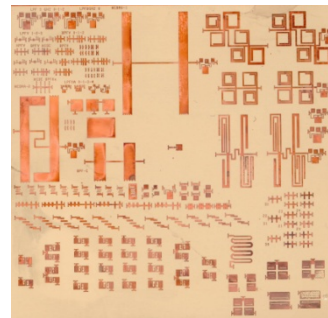
Polymer-based RF Capacitor

- Laminate type packaging substrate
- Low loss (< 0.002) stable with freq. (~ 100 GHz)
- Moderate dielectric const. (~ 2.95)
- Large processing area ($18'' \times 12''$)
- Low temperature process ($\sim 200^\circ \text{C}$)
- Low moisture absorption (0.04%)
- Can be the final PWB



Thermal stability

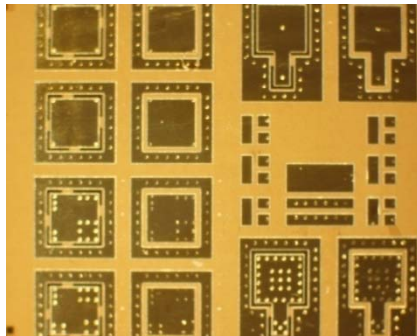
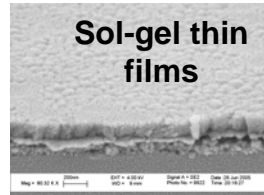
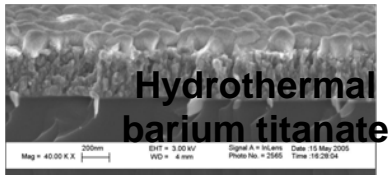
RF materials: LCP, PTFE composites



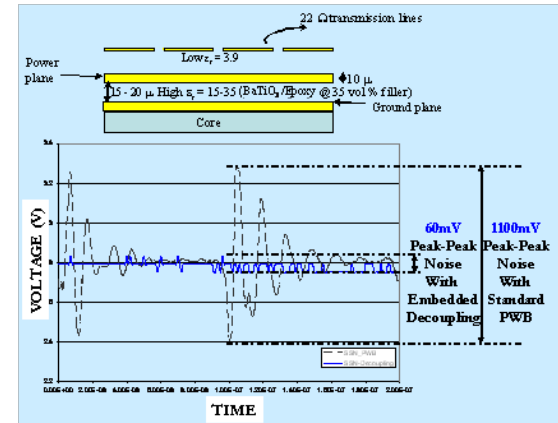
RF passives on LCP, FR4 (PRC)

Embedded Decoupling Capacitors

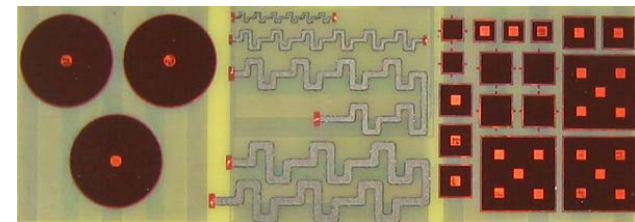
- Embedded Thin Film Decoupling Capacitors



Large area demonstration of embedded thin film capacitors on organic board;



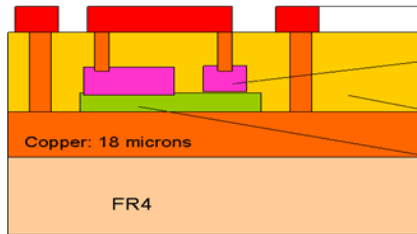
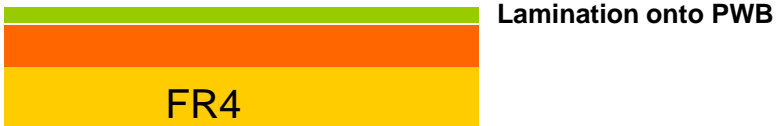
System-Level Function Enhancement



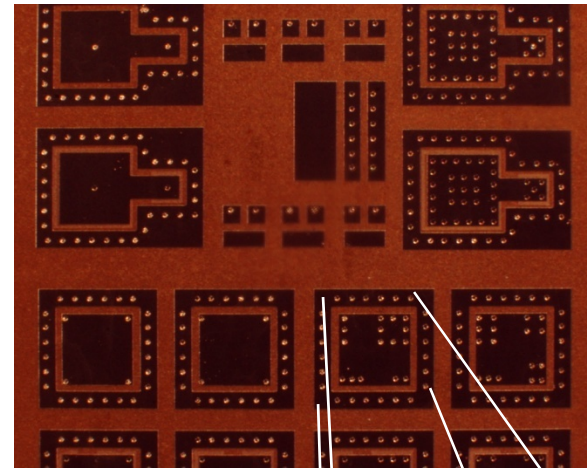
Nano-Composites & Nano-scale Thin Film High K Materials

Industry Prototypes

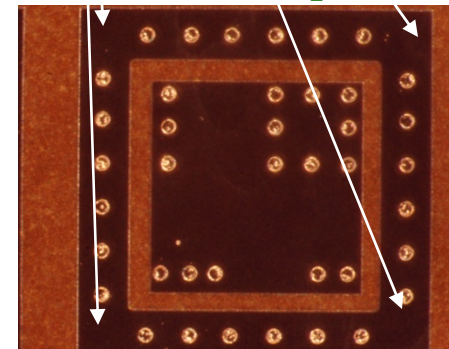
Embedded Capacitors



Cross section of Testbed with embedded capacitor



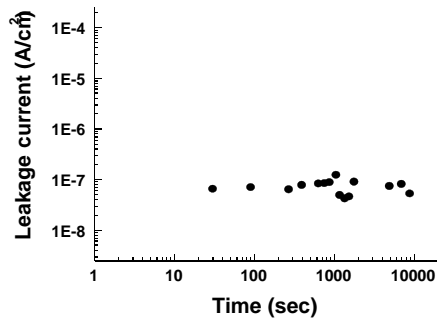
Fabricated Testbed with integrated barium titanate thin film capacitor



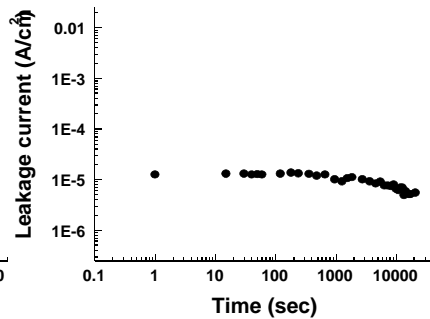
3 uF/cm² 15 V BDV ; 3 uA/cm² leakage at 3 V

Electrical Reliability Characterization of Thin Film Components:

HALT –Highly Accelerated Load Test:



115°C, 50 Kv/cm



115°C, 60 Kv/cm

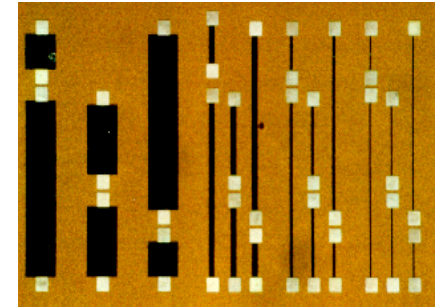
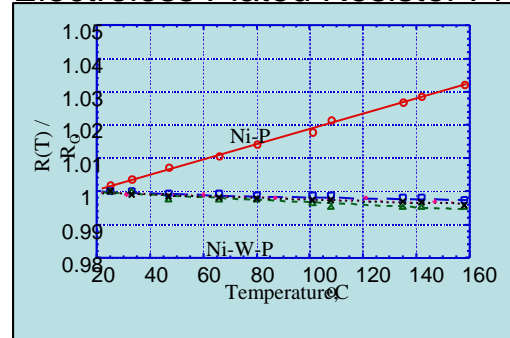


No failures from electrical reliability test

No failures from thermal shock test (Air-Air, -40 to 125°C)

Thin Film Resistor Examples

Electroless Plated Resistor Process



Electroless Ni alloy resistors

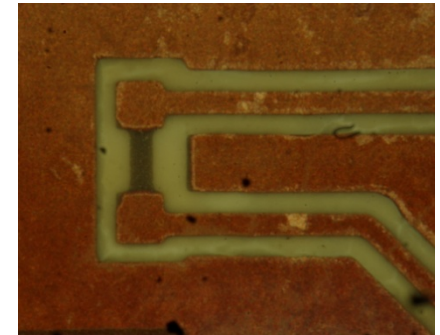
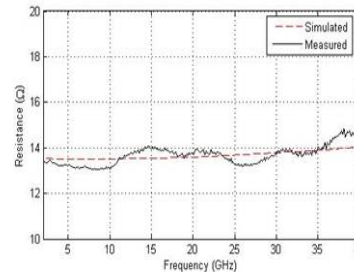
50-100 ohms/square

Foil transfer process

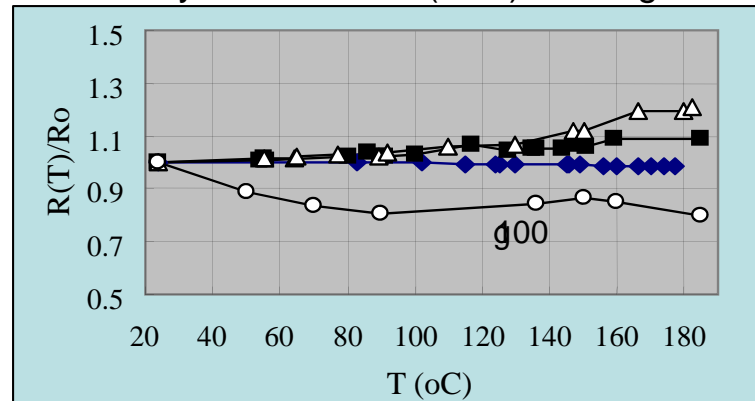
1-10 k Ohms/square

TCR 100 ppm/C

Foil Transfer Process



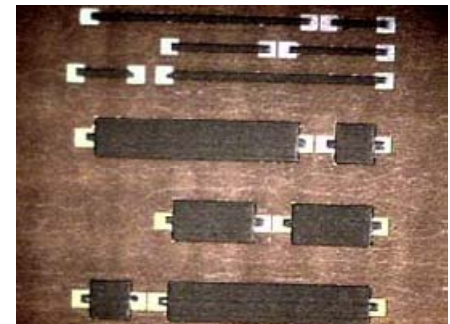
Polymer thick film (PTF) Printing Process



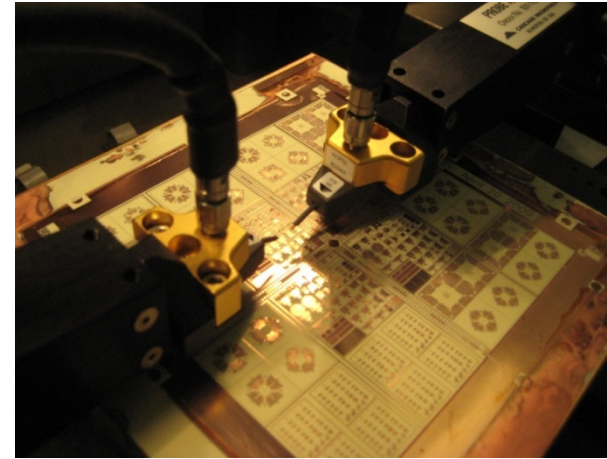
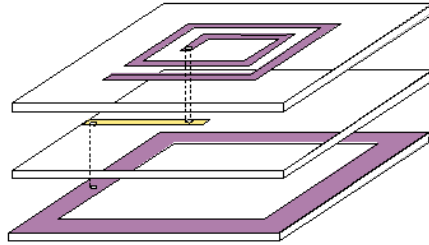
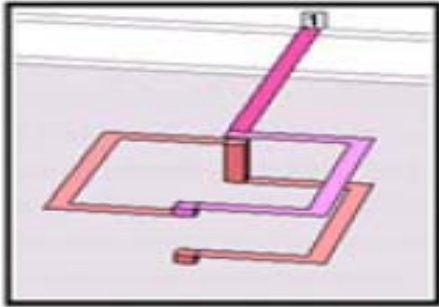
Printed polymer thick film resistors

500 – 10K ohms

TCR 300 ppm/C

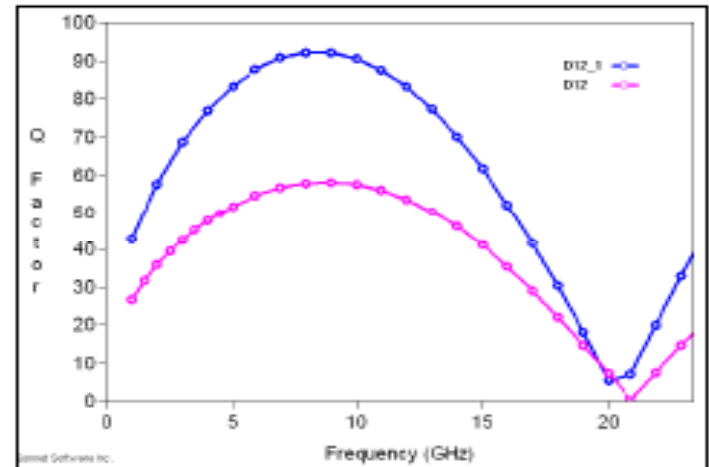


Thin Film Inductors



- Major innovations in:
 - Multilayered design with high inductance density (5 nH/mm^2) and high Q (70-200)
 - Materials: Low loss dielectrics
 - Low-Cost Multilayered Processes:
 - Low-cost drilling, wet metallization
 - Thin Form Factors

Quality Factor



Membership Benefits

Benefit	Full Member	Supply Chain
• Annual Membership Cost	\$100KUS	\$25KUS
• Program/Project Mentor	Yes	No
• Program/Project Steering	Yes	No
• I/P Rights – N.E.R.F License	Yes	No
• Test Vehicle Rights/Info	Yes/Yes	No/Yes
• Meeting Participation	Yes	Yes
• Reports	Yes	Limited
• Materials/Equipment in Program	Yes	Yes
• Engineer-on-Campus	Yes	Yes, “In kind” Related
• Leveraging of GT Know How	Yes	Yes
• Leveraging of Membership \$	Yes	Yes



Summary of the ETPC surveys from 45 companies

	Interest
High Density Capacitors	81%
High Density Inductors	52%
RF Components	51%
EMI Isolation	39%

ETC Program Launch: Next steps

- Industry feedback Oct. 2010
- White paper Dec 31,2010
- Launch date March 2011



Company Response Request

Are you interested in ETCP



As a full member?



As supply chain?

What changes do you like to see in the program focus?

Next Steps

- *Companies can identify their level of interest via PRC follow-up survey*
- *Interested companies will receive White Paper*
- *Membership agreements executed*



ETPC Webinar

Thank you for joining us.