THINFILM PASSIVE COMPONENTS

Presented by
Prof. Rao Tummala

Georgia Institute of Technology
3D-Systems Packaging Research Center

Atlanta, Georgia

TPC Consortium

- Objectives
- Strategy and Scope
- Team
- Current and Future Industry Memberships
- Membership Options and Costs

Consortium Objectives

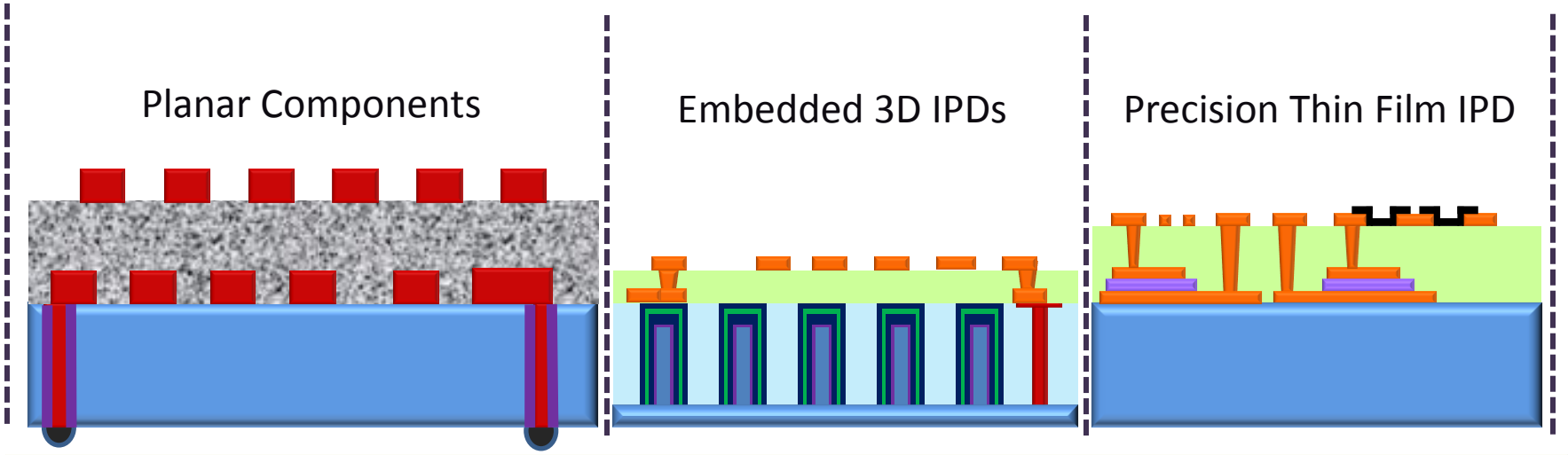
- Leading-edge research to nanoscale-based thin film components
- Educate the students to provide to industry
- Technical objectives consistent with industry need
- Supply chain involvement for manufacturing
- Technology transfer by means of industry assignee or mentor

Thin Film Passive Components

Magnetics

High-Density Capacitors

Supercapacitors



Passive Components for Power – RF – Digital – Analog Functions

Thin Power Components

Integrated Power Sources

RF Components

RF Components

EMI Isolation

Thin Film Batteries

Proposed Technical Scope

TPC Technology	***State-of-the-Art***	***Proposed Research Objectives***
Power Supply Capacitors	• 40-100 μF/cm^2; 250 microns • Self-healing only with high ESR	• 100-200 μF/cm^2 • 50-100 microns • Self-healing with low ESR
Power supply Inductors	• 100 nH/cm^2; 300-500 microns • High losses at high current and frequency	• 100-1000 nH /cm^2; 100 microns • Lower losses
Decoupling capacitors	• Substrate compatibility • Yield and manufacturing issues	• Organic or glass compatible • Defect-free processes for yield and manufacturability
RF Components	• Permittivity of 8-10 • Non-magnetic • Tolerance with discrete processes	• Permittivity of 20-80 • Permeability of 10-20 • Tolerance and tunability when integrated
Supercapacitors	• Discrete bulky devices • Frequency: 1-100 Hz	• Planar integrated components • 100-1000 Hz
Thin Film Batteries	• 0.5 mAhr/cm^2 for 1 micron	• 1 mAhr /cm^2 for 1 micron

Proposed Research and Team

- Program Manager: Dr. P. Markondeya Raj
- Design and Modeling: Prof. Madhavan Swaminathan
- Materials and Processes
  - Dr. Meilin Liu (Batteries)
  - Dr. Gleb Yushin (Supercapacitors)
  - Dr. P. Markondeya Raj (Inductors)
  - Dr. Himani Sharma (Capacitors)
  - Dr Venky Sundaram (Substrate Integration)
- Industry Liaison and Contracts: Mr. Dean Sutter
- Program Director Prof Rao Tummala

Technical Interest of Companies

- Maxim
- Kemet
- Texas Instruments
- Fairchild
- ON Semi
- National Semi.
- Thin film Corporation

Supply Chain:

- EVG
- Inframat
- Tango Systems
- Cabot Corp.
- Mag-Inc

Membership Options and Costs

- Full Member:$100K /year
  - Each company can select a project to focus on
  - Each full member company to get royalty free, no cost, non-exclusive license to technology
  -
- Supply Chain Member: $ 25K

TPC Consortium Workshop
May 25. 2011, 1- 5 PM

1:00 PM	TPC Consortium Launch (Dr. P. M. Raj)
1: 30PM	High-Density Capacitors & Inductors (Dr. P M Raj)
2:00 PM	RF, Digital & Mixed-signal Components (Prof. Swaminathan)
2:30 PM	Thin & Planar Supercapacitors (Prof. Gleb Yushin)
3:00 PM	**Break**
3.15 PM	Thin Film Batteries and Integration (Prof. Meilin Liu)
3.45 PM	Organic, Silicon & Glass substrates with components,(Dr. V Sundaram)
4:15PM	Industry Survey and Fedback, IP-Legal

http://www.prc.gatech.edu/events/SpringIAB2011/index.shtml

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Outline

- GT-PRC's TPC Focus and Vision:
- TPC Challenges
- GT - TPC Strategy
- TPC Research Focus:
    - Power supply
    - Digital and RF
    - Power Sources
- PRC's industry survey
- Program Launch Plans and Membership details

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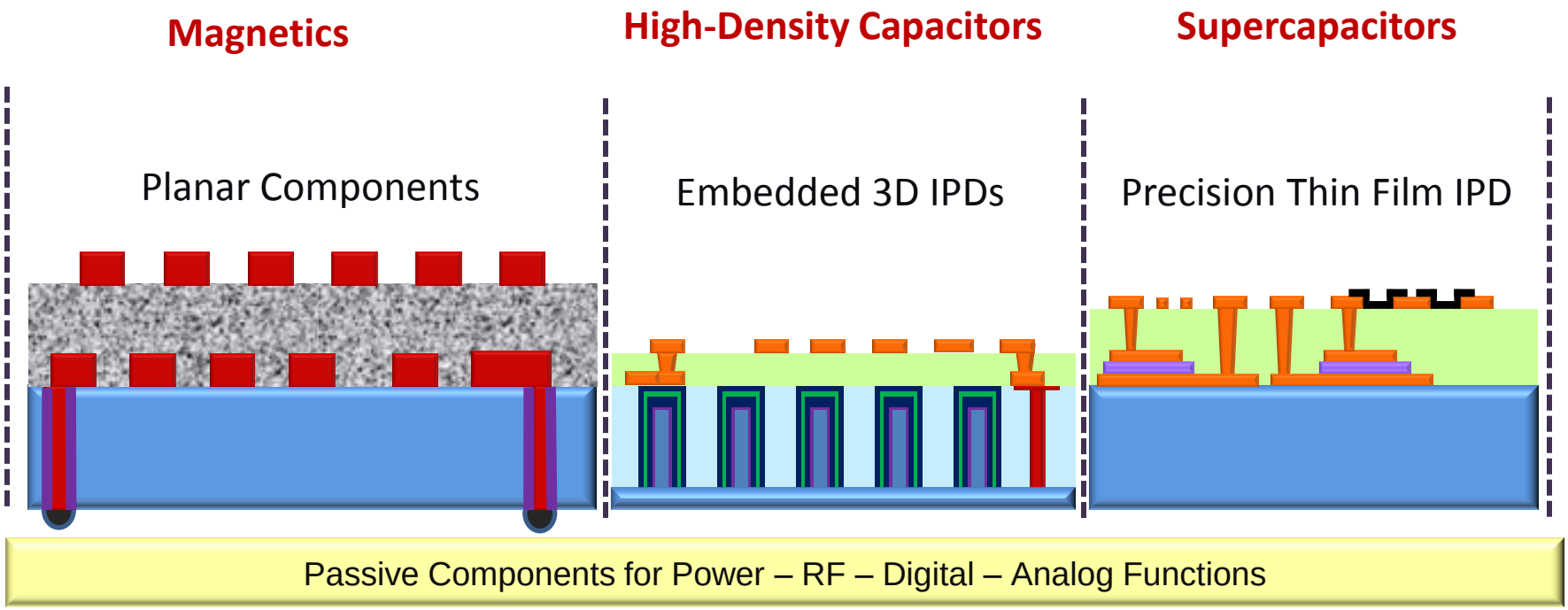
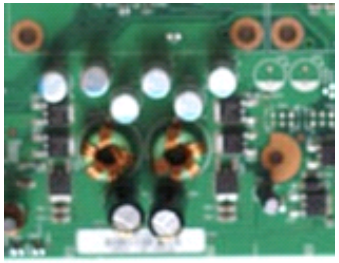
Thin Film Passive Components

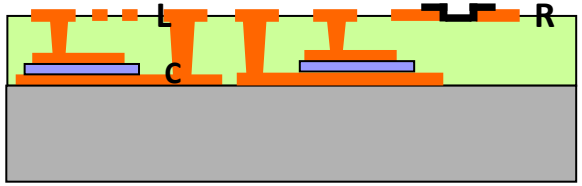


Thin Film Passive Components – Vision

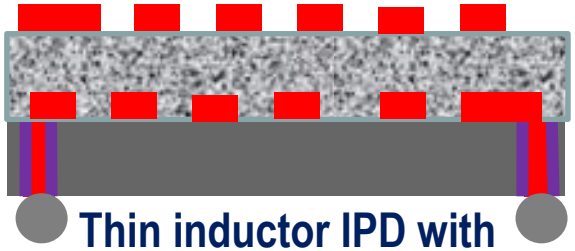


Bulky Components and Systems

1. Thin IPDs
2. Enhanced properties
3. Self-healing reliability
4. Embedded
5. Manufacturability, reparability, tunability
6. Testability



Thin IPDs with passive array



Thin inductor IPD with TPV Connection

Thin capacitor IPD with TPV Connection

TPC Strategy

- Improved component performance:
  - Novel materials with superior properties for higher volumetric density;
  - Process tolerance and tunability for certain needs;
  - Reliability by self-healing;

- Package integration with organics, silicon and glass substrates:
  - Thin film integration options for bulky discrete components

- Manufacturability
  - Self-healing
  - Ability to rework and re-assemble with embedded components
  - Avoid individual component pick-and-place wherever possible

- Low-cost
  - Processes that are cheaper compared to those used in traditional discretes
  - Reduce the required number of components

TPC Challenges

- Property challenges:
  - Existing materials for passive components are reaching fundamental limits . No dramatic enhancements are possible in:
    - Volumetric storage density
    - Permeability and permittivity
    - Efficiency
- Process Challenges:
  - Materials and processes with enhanced performance are not easily compatible with package substrates
  - Usually 100s of microns thick; difficult to embed in the package;
- Manufacturing Challenges:
  - Testability and reparability
  - Yield

Proposed Technical Scope

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Uniqueness of GT-PRC for TPC Consortium?

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

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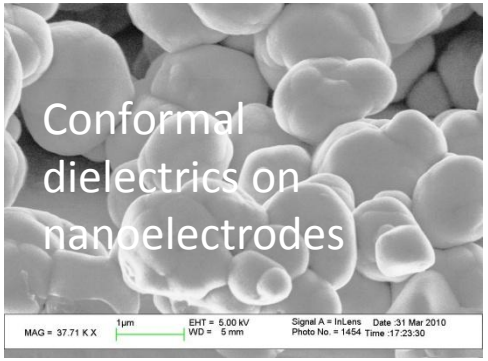
  - Dr. Gleb Yushin (Supercapacitors)
  - Dr. P. Markondeya Raj (Inductors)
  - Dr. Himani Sharma (Capacitors)
  - Dr Venky Sundaram (Substrate Integration)
- Industry Liaison and Contracts: Mr. Dean Sutter
- Program Director Prof Rao Tummala

I. High-Density Capacitors

Objectives:

- 100-200 μF/cm^2
- 20 V
- 0.1-1 μA/μF leakage
- Integration in organic or silicon packages



Component Thickness:

50 microns;

Volumetric efficiency:

10,000 – 100,000 μF/cc

Challenges:

- Conformal high K dielectrics
- Self-healing with Low ESR conformal electrodes
- Silicon or package integration

Proposed R&D:

- Solution crystallization of high K films on nanoelectrodes
- Self-healing with metal electrodes
- Package-compatible processes

II. High-Density Inductors

Objectives:

- 100-1000 nH/mm^2
- 50-100 micron device
- 100 MHz

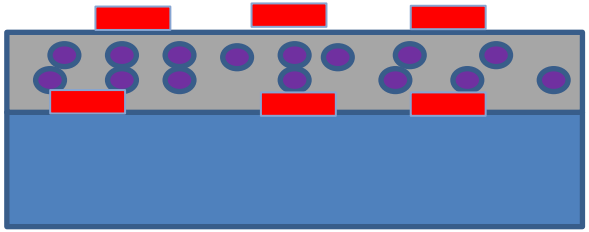
Challenges:

- Inferior properties with ferrites
- Process incompatibility with ferrites;
- High losses with metal nanocomposites
- Thicker films with nanomagnetic films

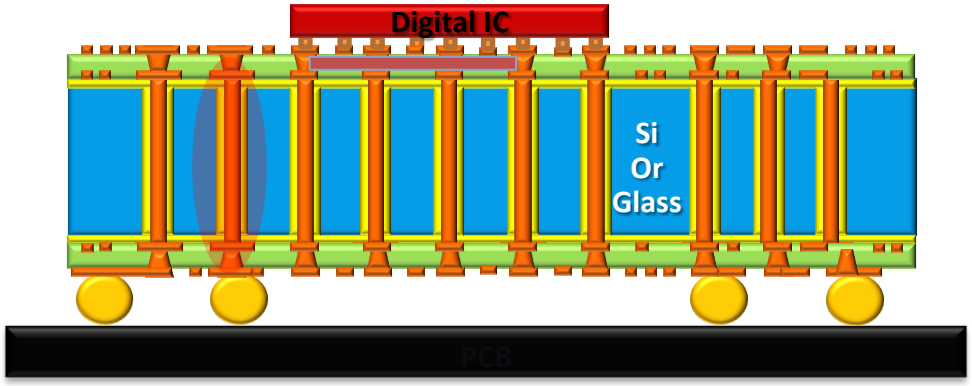
Proposed R&D:

Embedded inductors using nanomagnetic materials and structures with high frequency stability and high quality factor,

- Low-cost process for integrating nanomagnetic films with the right geomtry and properties



III. Thin Film Decoupling Capacitors



Decoupling in High-Speed Processors

Targets:
▪ Thin film: 2-100 μF/cm^2
▪ TPV: 2-3 μF/cm^2
▪ Silicon, organic and glass substrate compatible
▪ Low-cost tools:
▪ Allow testability and reparability

Material and Process R&D:

- Package-compatible High K films
  - Solution-derived inorganic thin films on large-area panels
  - Self-healed thin film capacitors
  - Conformal coatings inside TSV or TPV
  - Low-cost High K thin film on TPV

Design R&D

- Design of a high impedance power delivery network with low power with embedded inductors and capacitors that demonstrates reduced layer counts
- Demonstrate significant capacitor reduction
- Demonstrate 30% or more improvement in jitter and eye height as compared to current practice

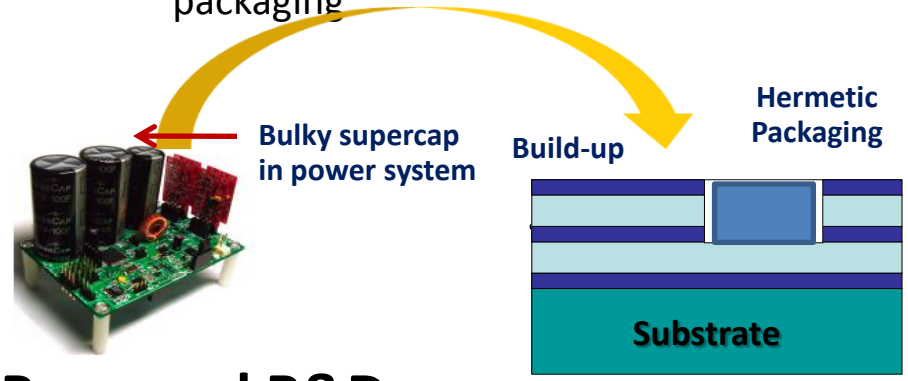
IV. Supercapacitors

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 packaging

Challenges:

- High Energy Density / High Frequency (100-1000 Hz) operation has never been demonstrated
- Intergated Supercaps never demonstrated
- Solid Electrolyte operating at high frequency – a challenge



Proposed R&D:

- Patterned deposition of either CNT (or metal nanowires) on Si wafer surface via CVD
- Surface coating with metal oxide layer (via ALD or CVD)
- Developing successful process flows for the formation of integrated devices based on the proposed architecture
- Studying effects of film thickness, porosity, architecture and metal oxide microstructure on the frequency response, capacitance and power characteristics
- Developing new routes for infiltration of electrodes with polymer electrolyte and investigate the effects of electrolyte (polymer, solvent, salt) on frequency response

V. Thin Film Batteries

Objectives:

- 10X enhancement in energy density compared to state-of-the-art

  (1 mA hr/cm^2 for 1 micron thickness)

- 10 X enhancement in power density with thinner electrolytes

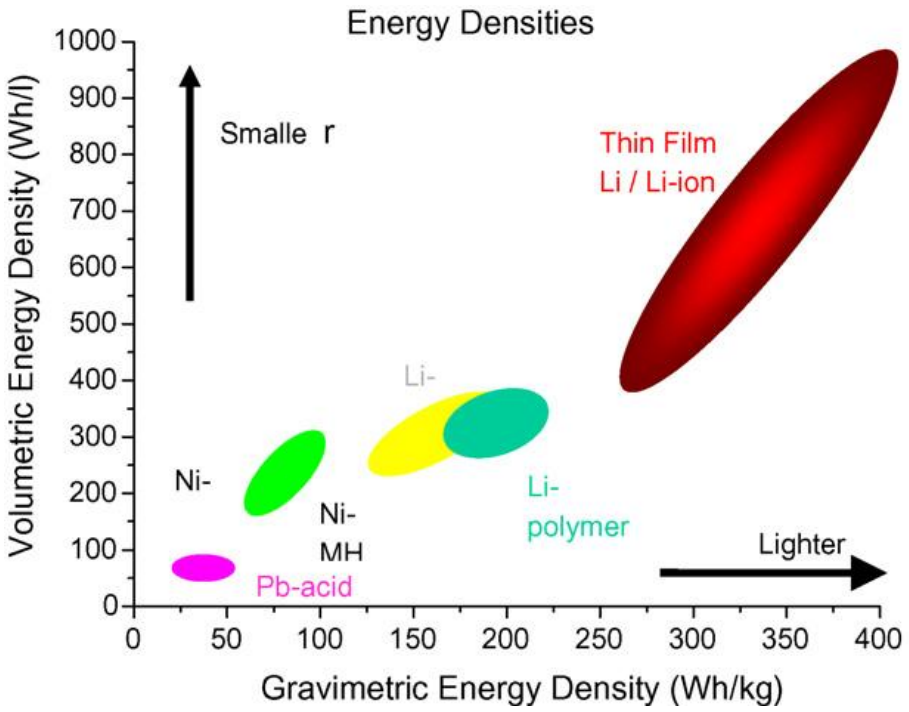
- Integration on silicon

Challenges:

- Substrate process compatibility with thin film nanoelectrodes
- Defect-free processes with conformal electrolytes

Proposed R&D:

- High surface area nanoelectrodes and conformal electrolytes to integrate power sources as planar components



VI. RF and Analog Components

Objectives:

Novel high K dielectrics:

Permittivity: 10-80
Permeability: 10-100
Dielectric Loss tangent: < 0.005
TCC <30 ppm/C
Tolerance of 5%

Precision R, L and C

Design of RF and mixed signal components

Challenges:

•Existing RF dielectrics are expensive and not scalable (LTCC) and have limited permittivity of ~8 (polymer composites)

•Higher permittivity leads to thermal and frequency instability, and high loss;

•Tolerance from processing and material variations;

Proposed R&D:

Design:

•Demonstrate highly miniaturized TSV enabled filters with high performance
•Polymer and glass matrix composites or thin film capacitors with engineered properties
•Compare with organic and ceramic solutions in terms of size and performance

•Tolerance without trimming from:
- •Thickness control
- •Lateral dimension control

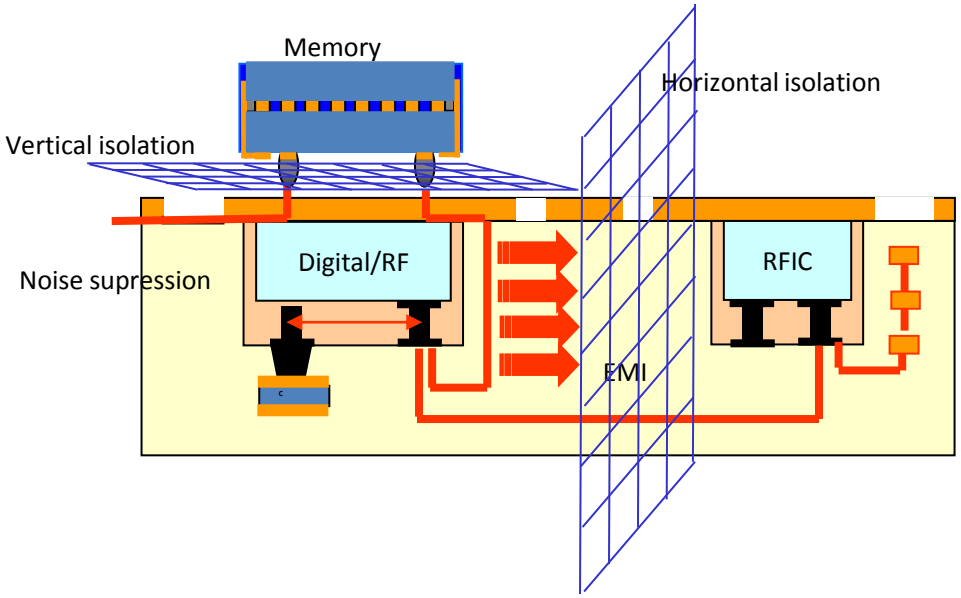
VII. Components for EMI Isolation

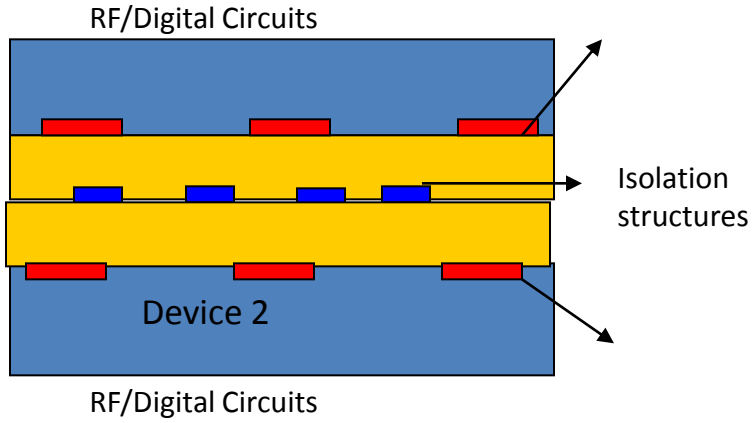
Objectives:

- Horizontal and vertical isolation in mixed-signal 3D modules and packages

Proposed R&D:

- Miniaturized EBGs with high permittivity and permeability materials
- Vertical isolation with nanomagnetic films





Proposed TPC Plan

	July-Sept 2010	Oct- Dec 2010	Jan-March 2011	Apr-June 2011	July-Sept 2011	Oct-Dec
Webinars and workshops	x	x				
White paper on power components						
Initial program launch				X		
Discussion with Companies						
Contracts, Membership Agreements						
Full Program Launch on passive components						X

Membership Options and Costs

- Full Member:$100K /year
  - Each company can select a project to focus on
  - Each full member company to get royalty free, no cost, non-exclusive license to technology
  -
- Supply Chain Member: $ 25K

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 TPC surveys from 45 companies

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

Company Response Request

Are you interested in ETPC

- 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*

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3.45 PM	Substrate Integration Approaches (Dr. V Sundaram)
4:15PM	TPC Consortium Development – IP (Mr. Dean Sutter) Membership options and costs (Mr. Dean Sutter) Industry Feedback (Prof. Rao Tummala) Future Plans (Dr. Raj Pulugurtha)