LTCC A KEY TECHNOLOGY FOR MESO-SYSTEMS

MÁRIO RICARDO GÓNGORA-RUBIO,
IPT, SÃO PAULO, BRAZIL

BUENOS AIRES, 2002

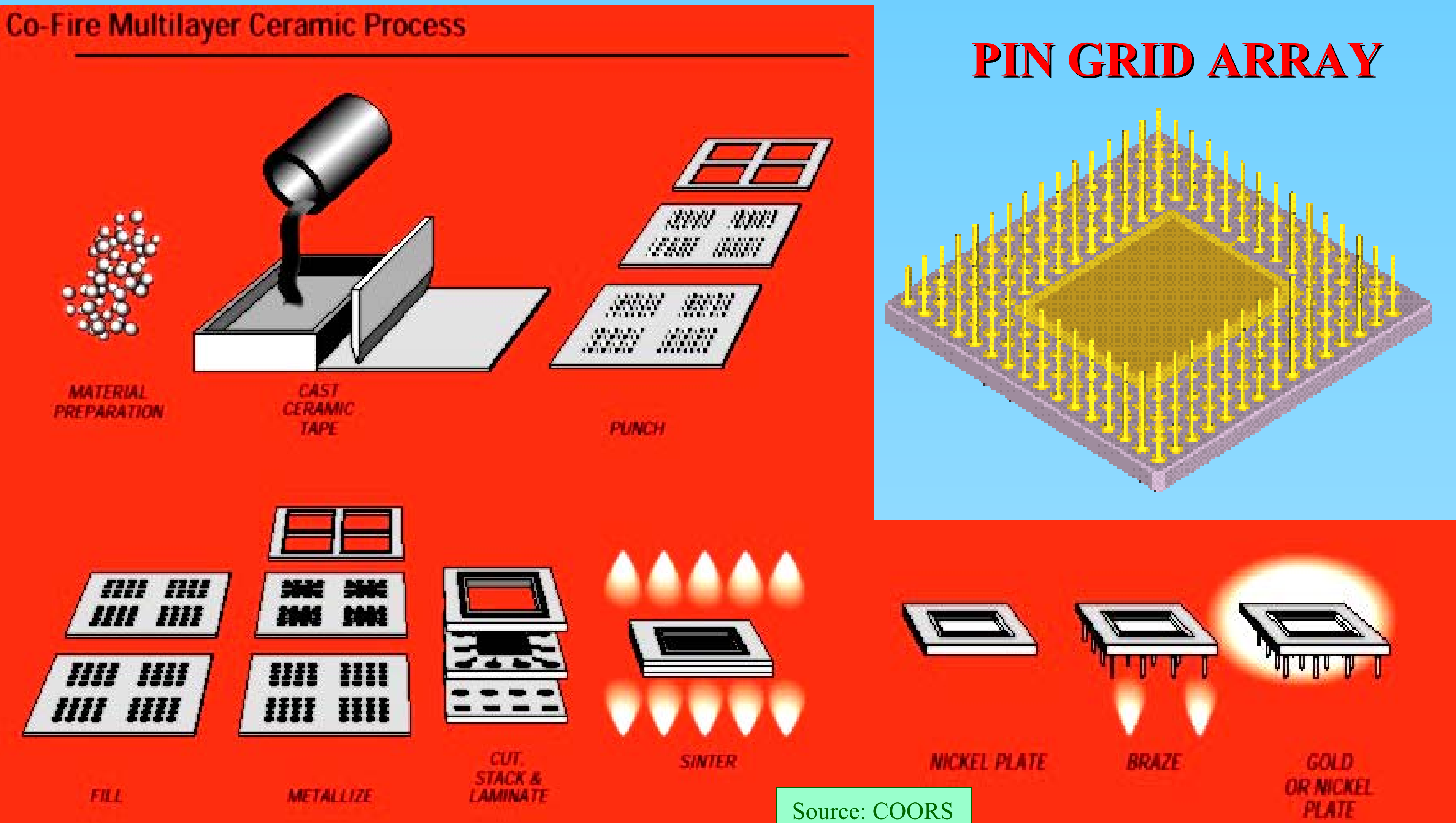
PRESENTATION OUTLINE

1. Advanced Packaging Techniques
   - **2D Packaging techniques**
   - **Flip-chip & BGA packaging**
   - **3D Packaging Techniques**
   - **Modular 3D Packaging**
2. LTCC Applications for Microelectronics
   - **MCM Applications**
   - **Embedded Passives**
   - **HF & Microwave Devices**
3. LTCC for MEMS/MST
   - **MST Introduction**
   - **LTCC for MST**
4. Meso Systems Devices and Applications
   - **Sensors**
   - **Actuators**
   - **Microfluidic devices**
   - **Meso-Systems**
5. Conclusions

1. ADVANCED PACKAGING TECHNIQUES

- 2D Packaging techniques
- Flip-chip & BGA packaging
- 3D Packaging Techniques
- Modular 3D Packaging

MULTILAYER LTCC (2D) CERAMIC PACKAGES



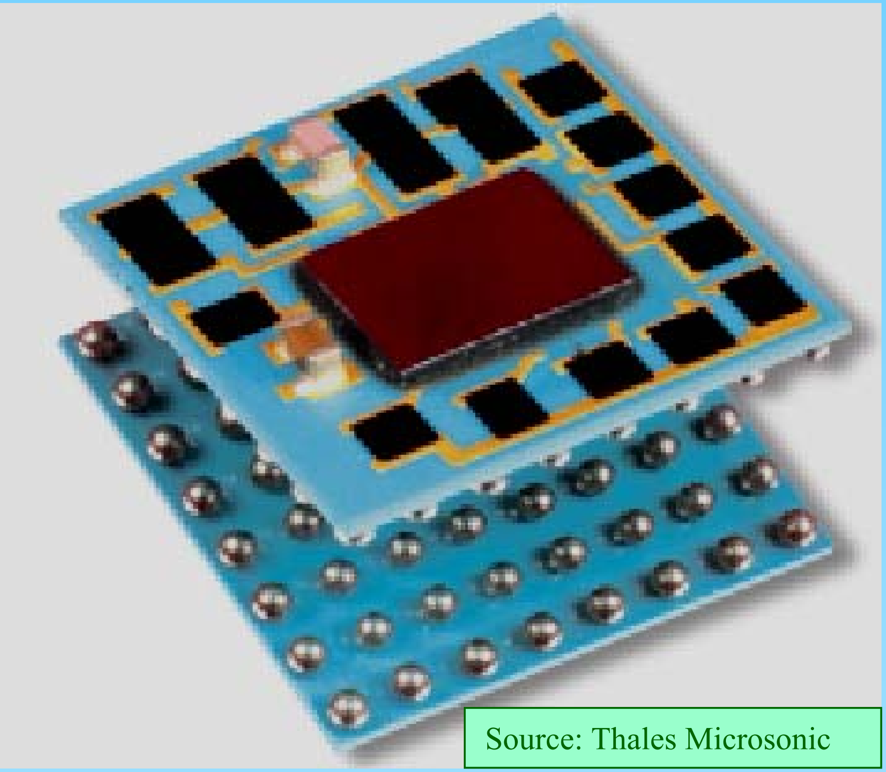
PIN GRID ARRAY

Source: COORS

LTCC ADVANCED PACKAGING TECHNIQUES

- Low Temperature Cofired Ceramic technology (LTCC) is adapted to high performance assembly and packaging techniques like flip-chip and BGA.
- The combination of this 3 technologies allow the design and fabrication of very high density and cost effective Single Chip and Multi Chip Modules.

- Flip Chip BGA CSP



Source: Thales Microsonic

FLIP-CHIP ON LTCC

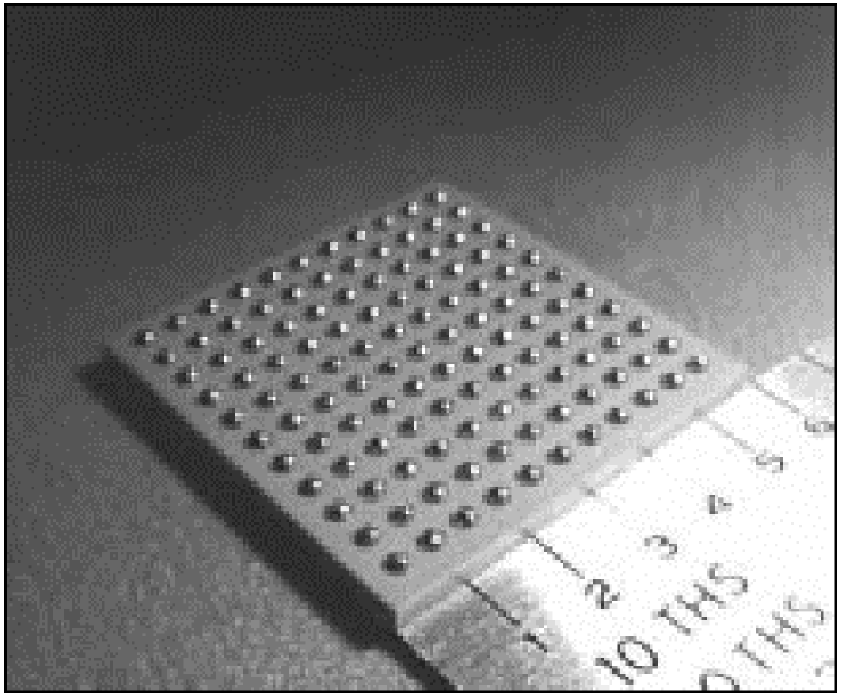
- Characteristics of flip-chip on LTCC
  - Peripheral and area I/O pad distribution
  - I/O pitch down to 250 µm (125 µm bump)
  - Three possible bonding techniques
    - SnPb solder reflow
    - thermocompression
    - conductive adhesive
- Advantages of flip-chip on LTCC
  - Direct bonding on top vias (no additional metallization required)
  - LTCC CTE very close to silicon CTE
  - High routing capability of the LTCC technology thanks to:
    - buried via structures (diameter down to 100 µm)
    - line pitch down to 200 µm
    - high number of layers

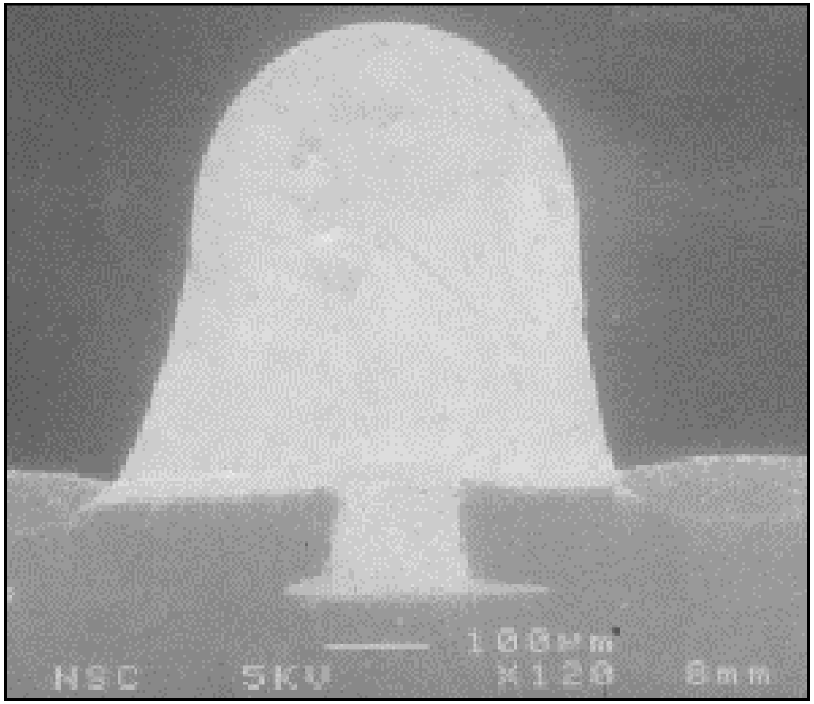
BALL GRID ARRAY WITH LTCC

- Characteristics of BGA with LTCC
  - **Ball pitch from 0.75 mm to 1.5 mm**
  - **Body size from 5 x 5 mm^2 to 40 x 40 mm^2**
  - **Number of I/Os up to 961**
  - **High temperature solder balls**
  - **Adapted to single and multi-chip module design**
  - **Large range of techniques for die protection**
    - **Glued metallic or ceramic lid**
    - **Epoxy overmolding or glob top**
    - **Brazed hermetic Kovar ring**
- Advantages of BGA with LTCC
  - **High design flexibility**
  - **Very high number of I/Os at reasonable pitch**
  - **High routing capability of the LTCC**

LTCC-BGA

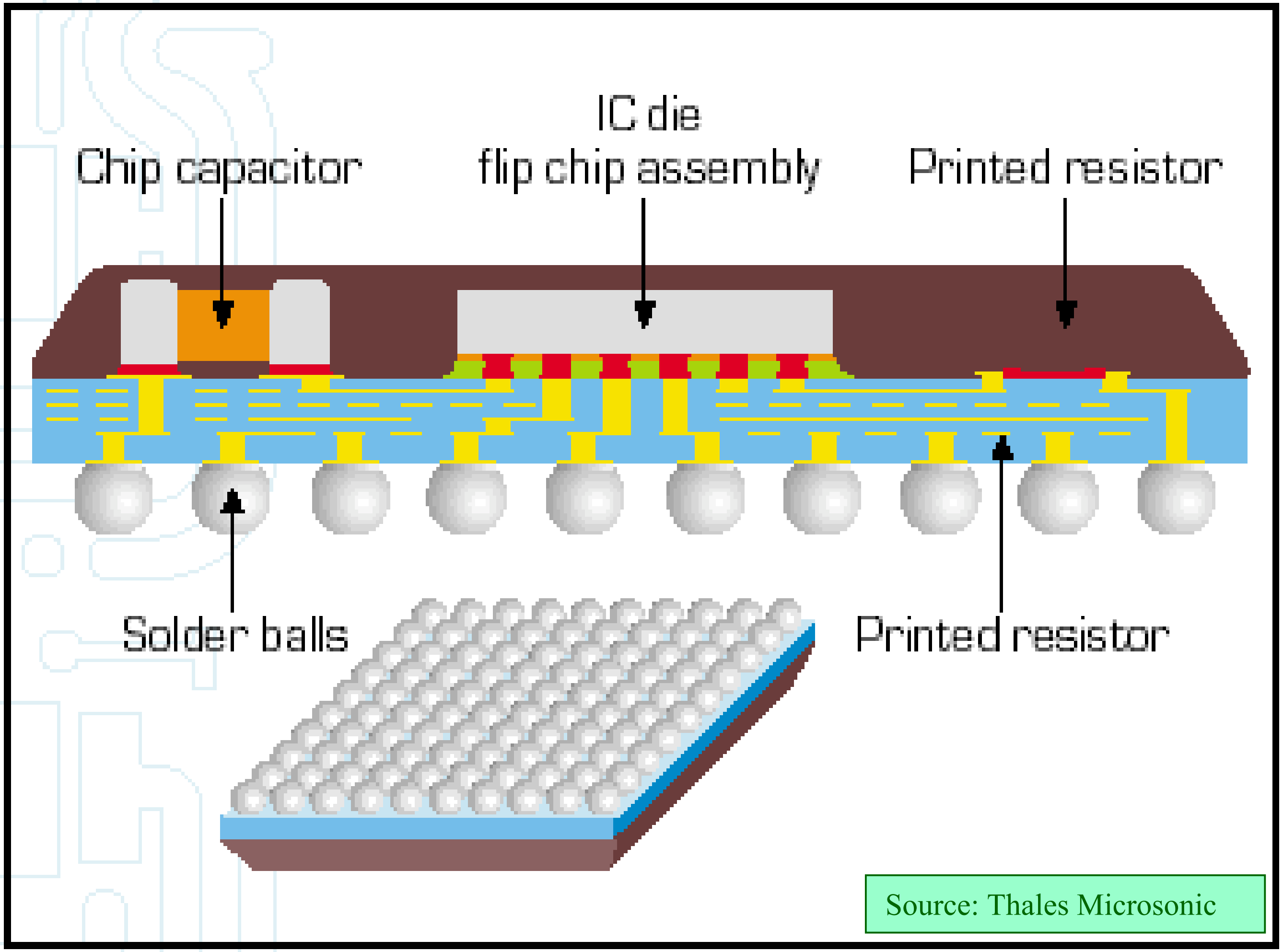
Part and Cross Section – 30 mil ball





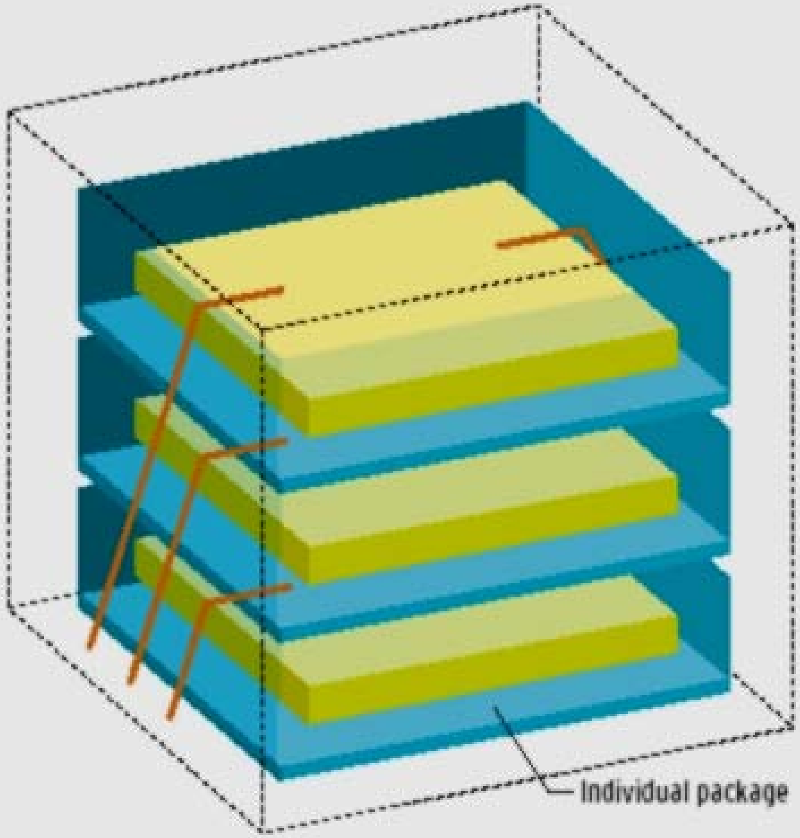
Source: National Semiconductors

COMBINATION OF BGA, FLIP CHIP AND LTCC TECHNOLOGIES



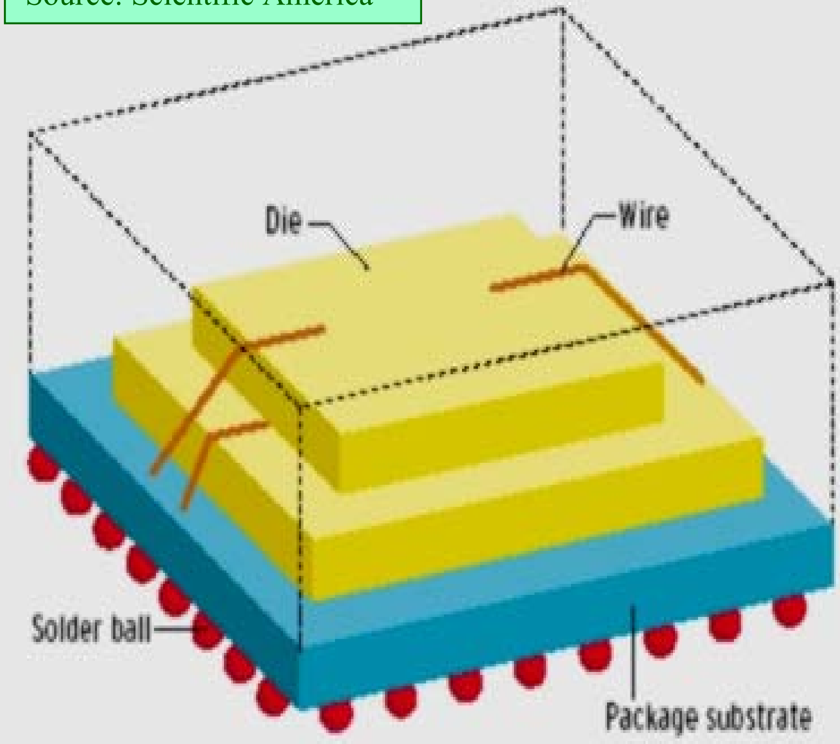
3D PACKAGING

Source: Scientific America



Stacked Packages

Packaged memory chips are commonly stacked on top of each other to supercharge memory in equipment ranging from cell phones up to high-end computers.

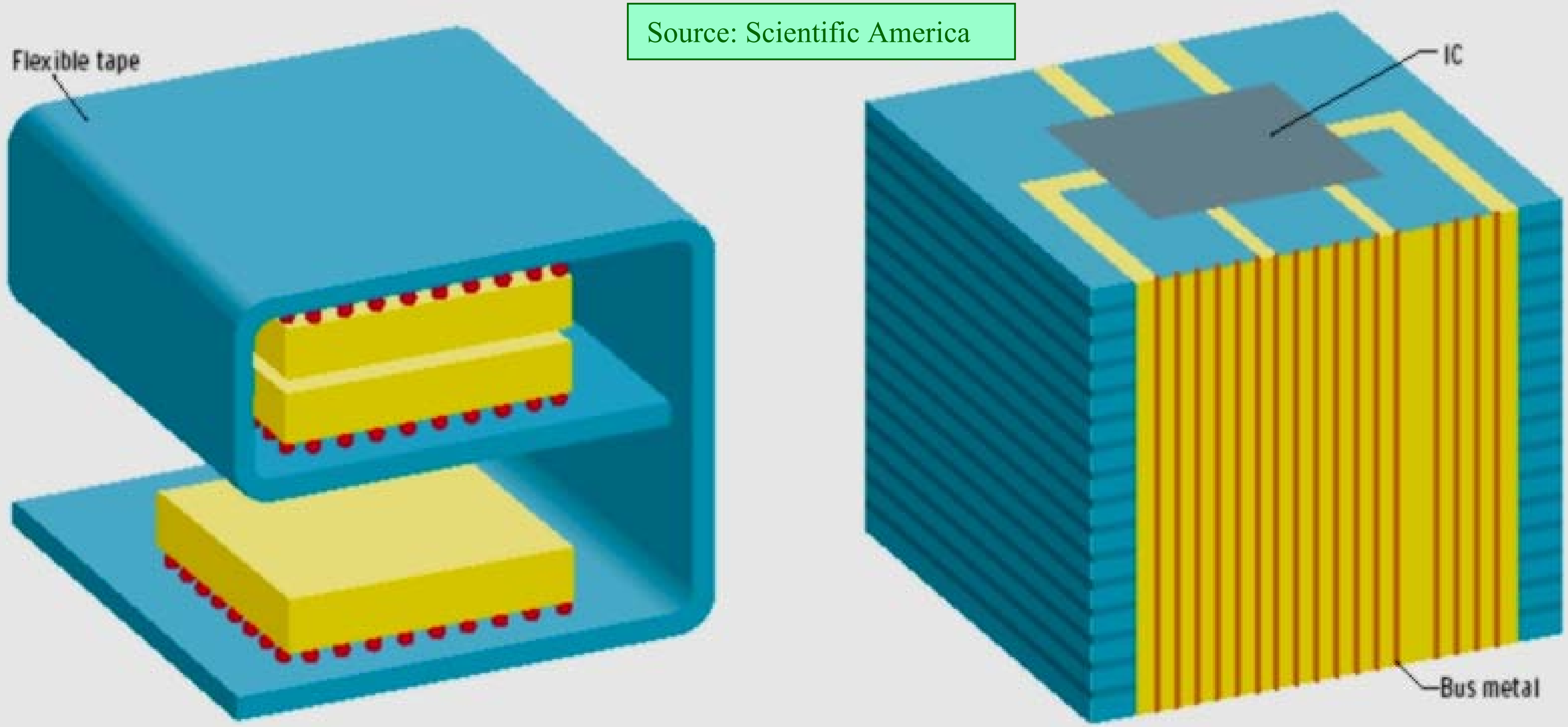


Stacked Chip-Scale Package

More compact are packages that stack bare die and wire-bond them to pads that connect to the solder balls leads on the substrate. The package is connected to a circuit board via the solder balls.

3D PACKAGING (CONT.)

Source: Scientific America



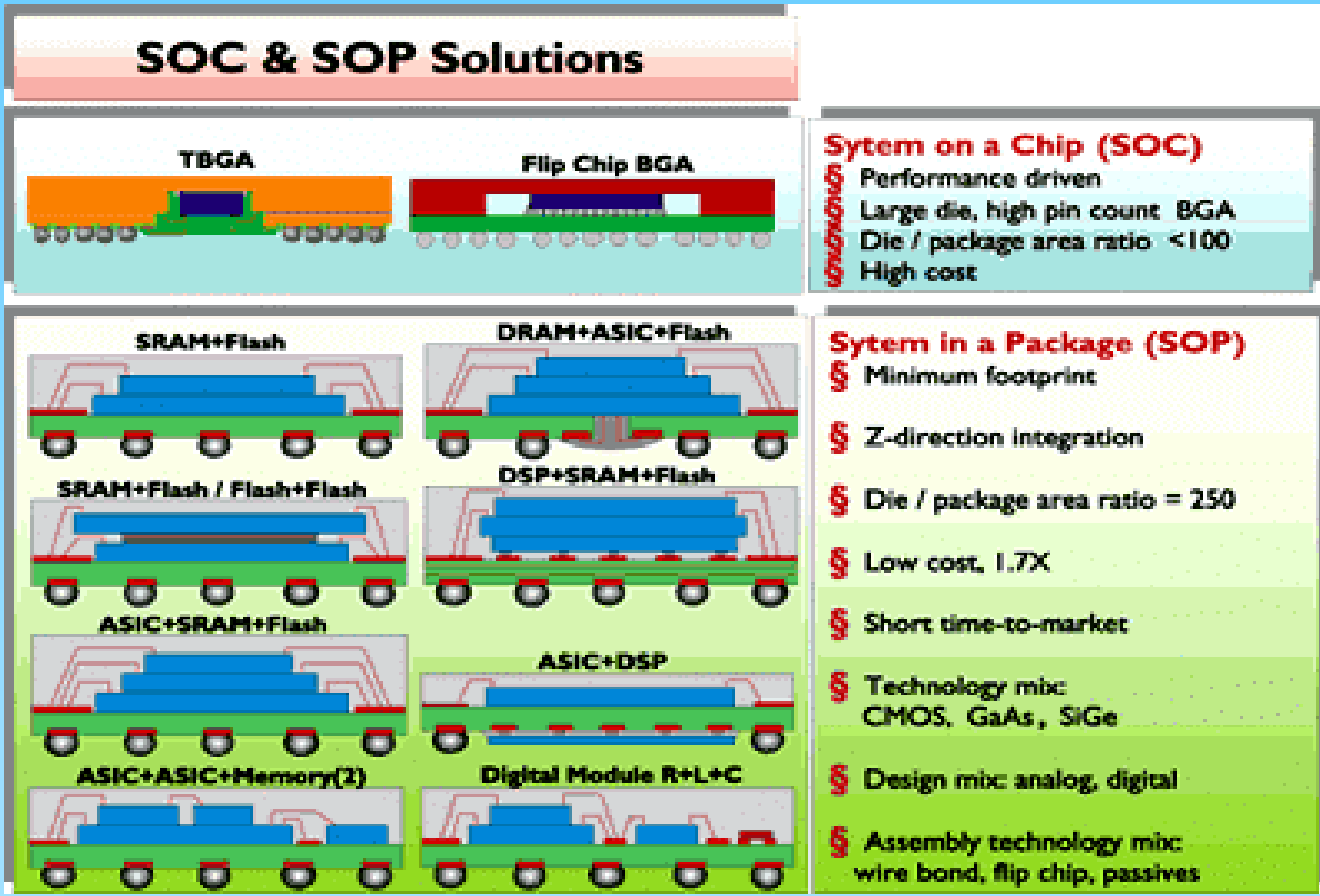
Folded Package

One of the newer ways for cramming capability into a small package starts with packaged chips on a flat polyimide tape. The flexible tape is then folded to yield a small footprint.

System-in-a-Cube

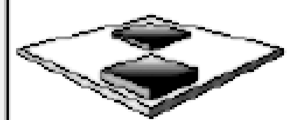
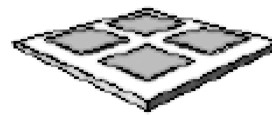
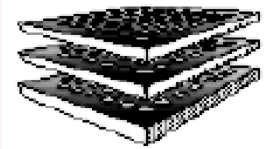
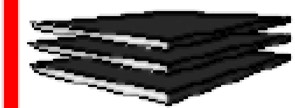
The densest package so far relies on a stack of epoxy layers in which are embedded different kinds of chips. Metal interconnects to the layers run along the sides of the stack.

SYSTEM ON A CHIP



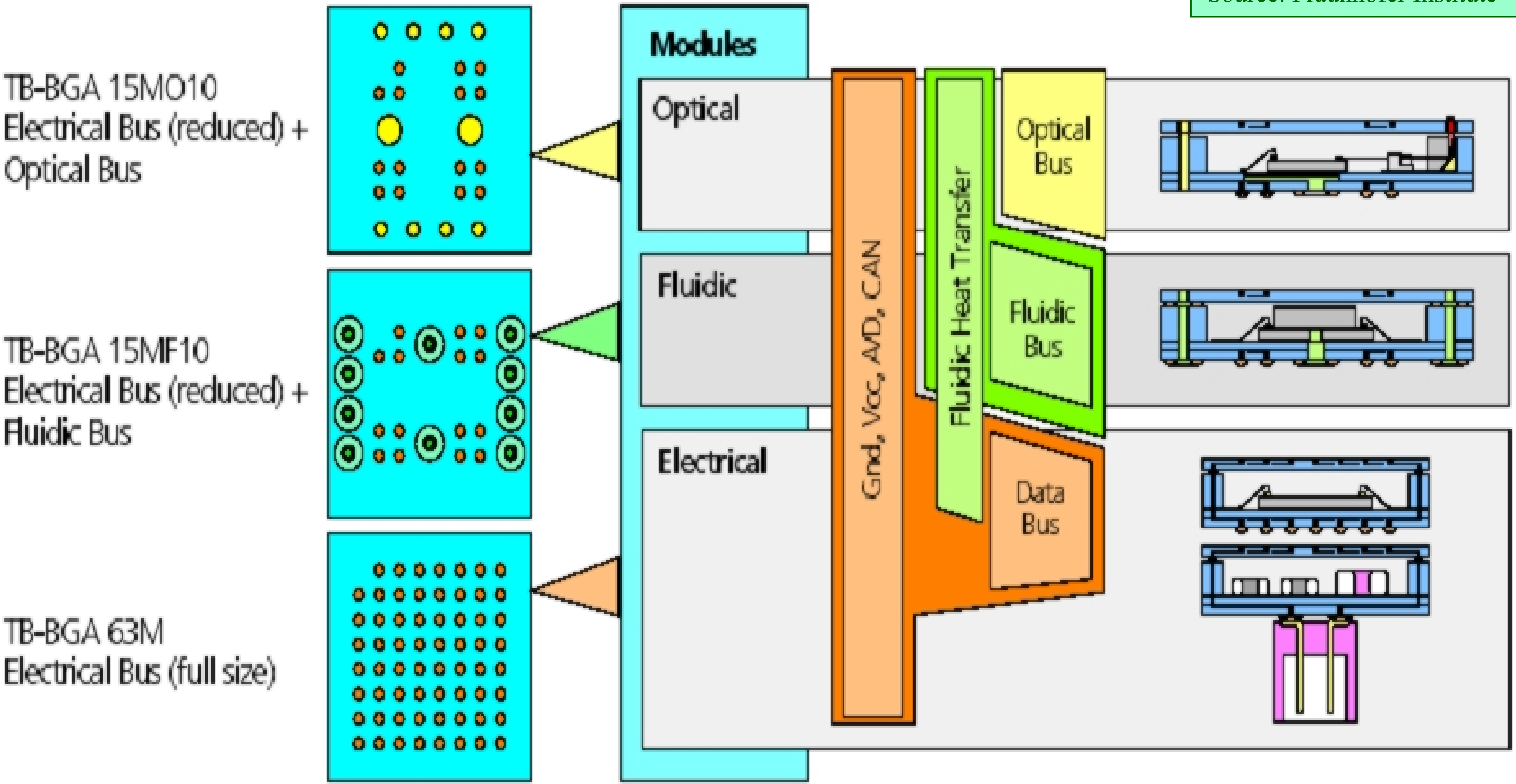
MODULAR PACKAGING CONCEPTS COMPARISON

Source: Fraunhofer Institute

	2D Integration		3D Integration	
	packaged	unpackaged	packaged	unpackaged
				
Size and weight	high	higher than 3D	lower than 2D	low
Silicon efficiency	very good	good	very good	low
Power consumption (parasitic C's)	high	rather high	rather low	low
Noise	not optimal	not optimal	good	very good
Flexibility / universality	restricted	restricted	high	restricted
Use of market-available MEMS	feasible	difficult	feasible	difficult
Standardization of interfaces	feasible	difficult	feasible	difficult
Additional packaging steps	necessary	not necessary	necessary	not necessary
Protection against environment	high	almost none	high	almost none
Need for cleanroom environment	no	yes	no	yes

MODULAR SYSTEM INTERFACES

Source: Fraunhofer Institute



LTCC-TB-BGA (TOP-BOTTOM- BGA)

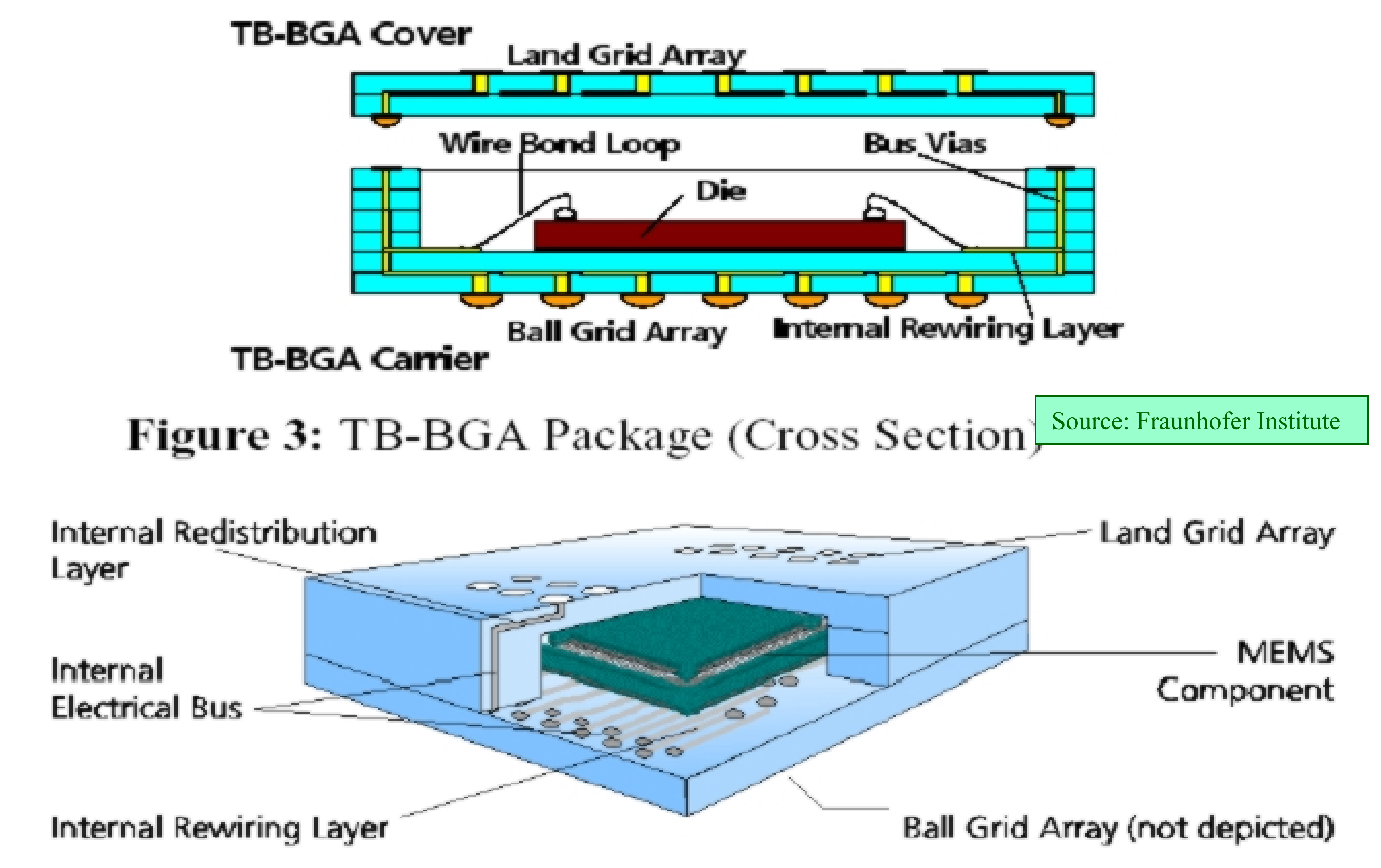
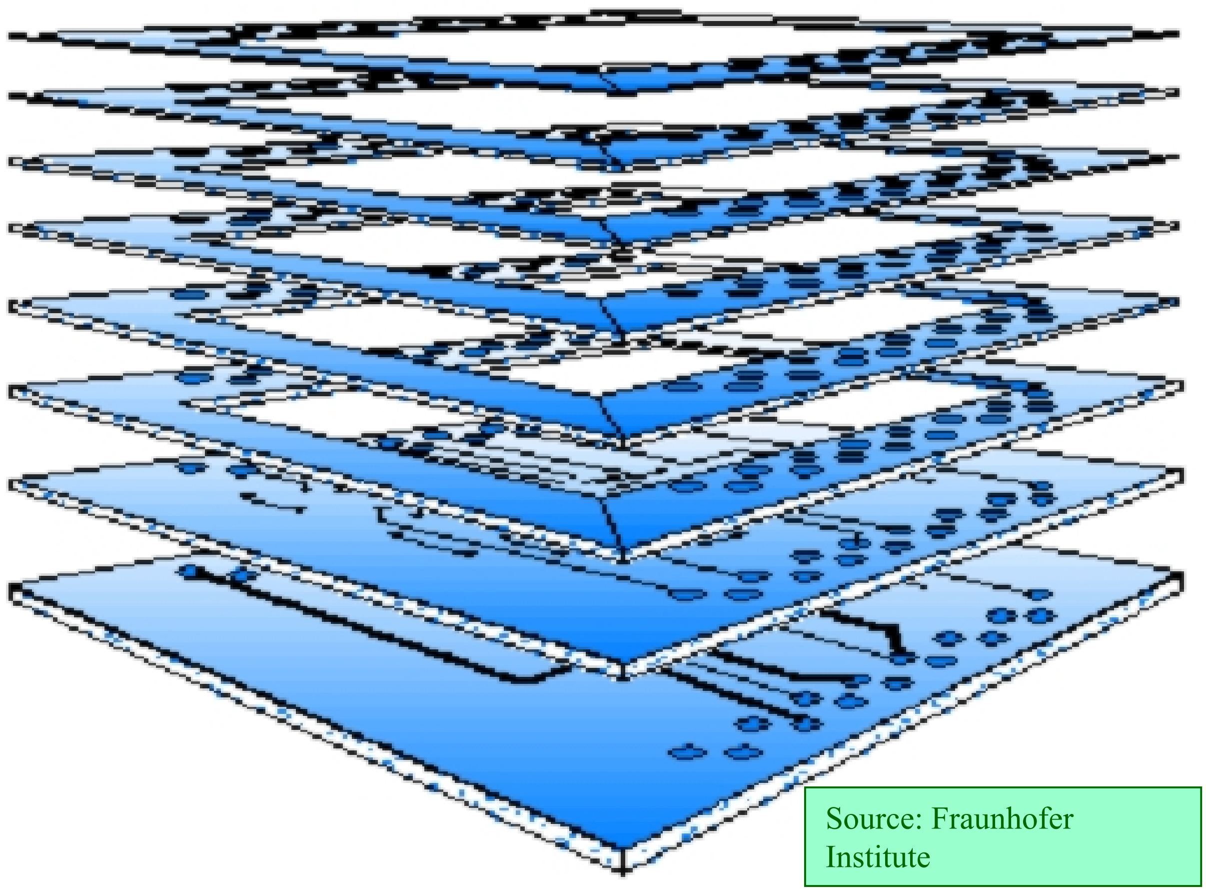


Figure 3: TB-BGA Package (Cross Section)

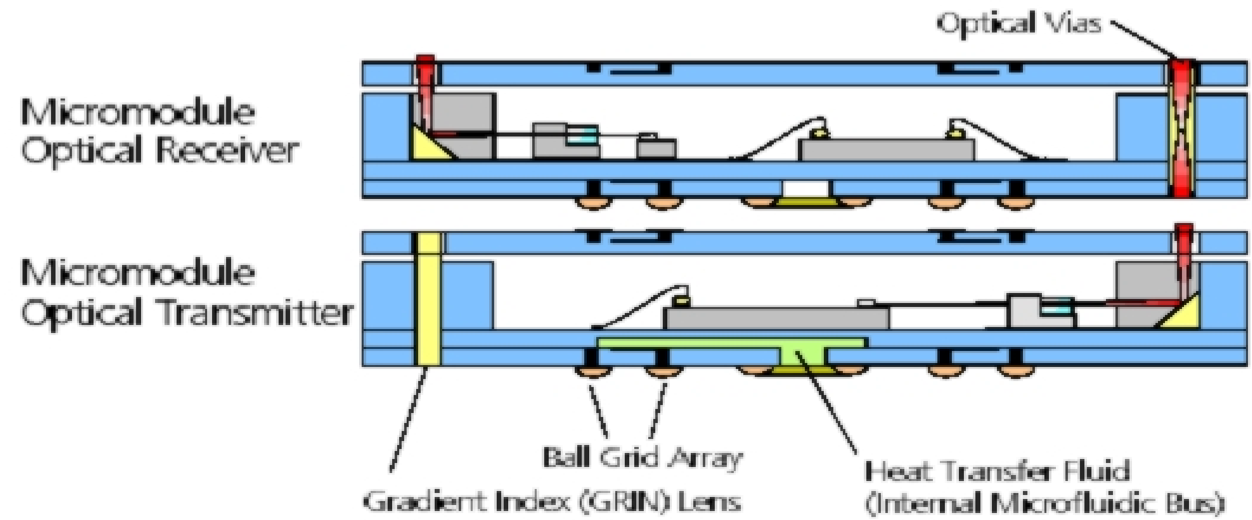
Source: Fraunhofer Institute

ASSEMBLY OF A LTCC CARRIER

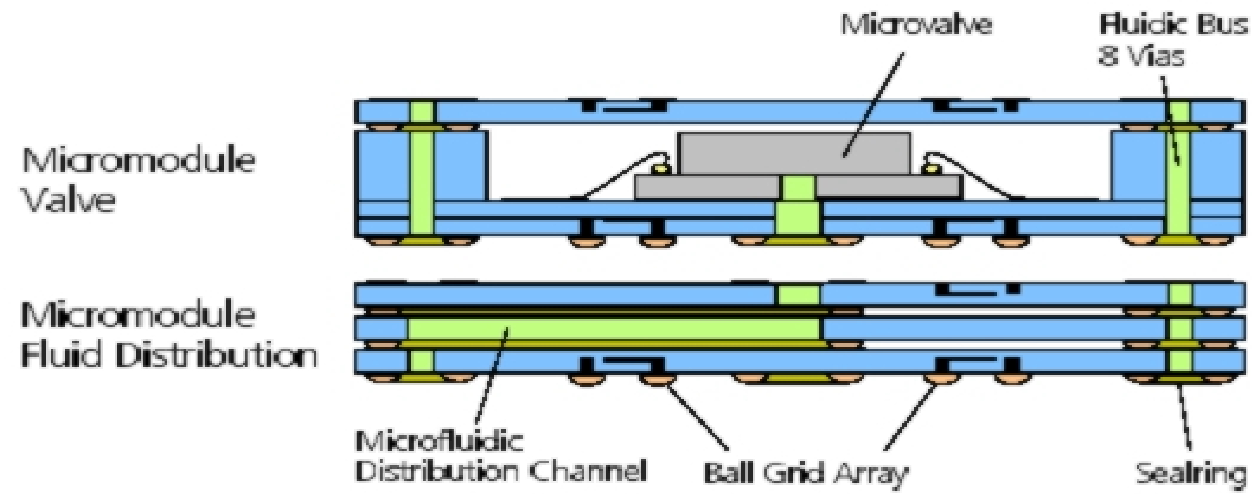


Source: Fraunhofer Institute

OPTICAL & FLUIDIC INTERFACES

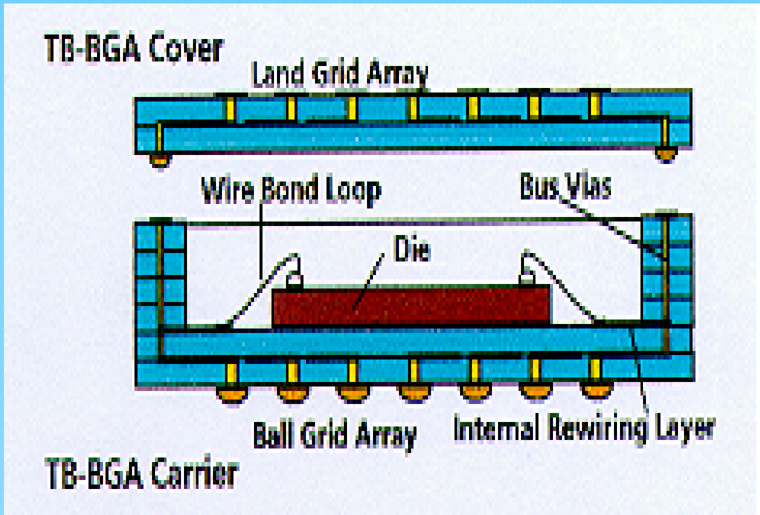


Source: Fraunhofer Institute



SOME 3D LTCC MODULES

- 16 Bits Microcontroller   Flow Sensor



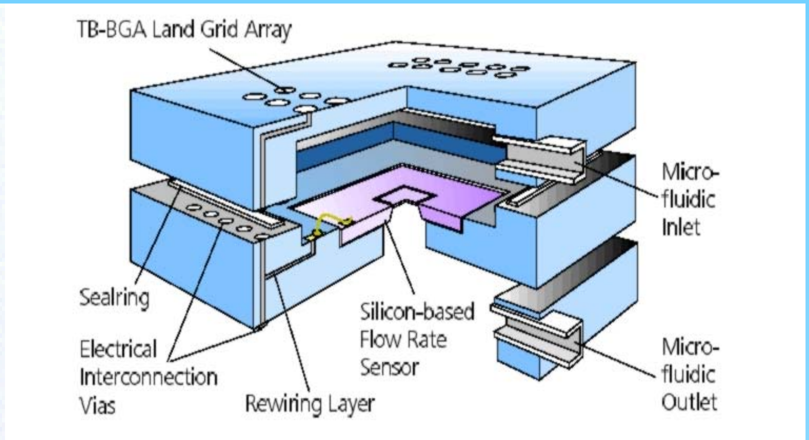
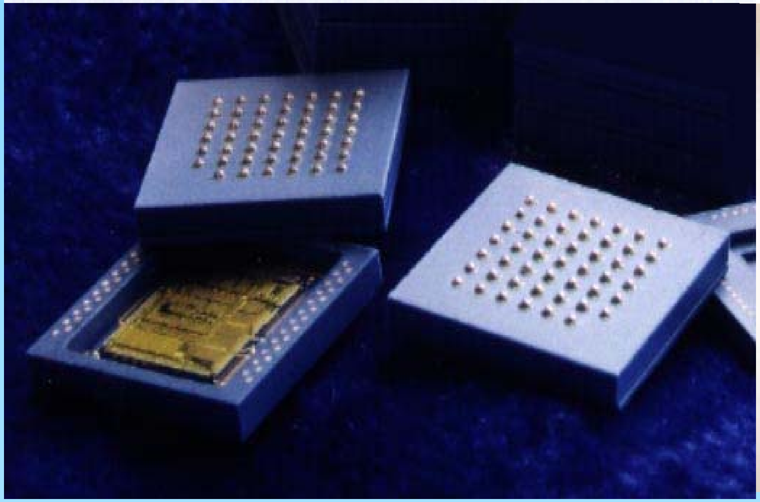
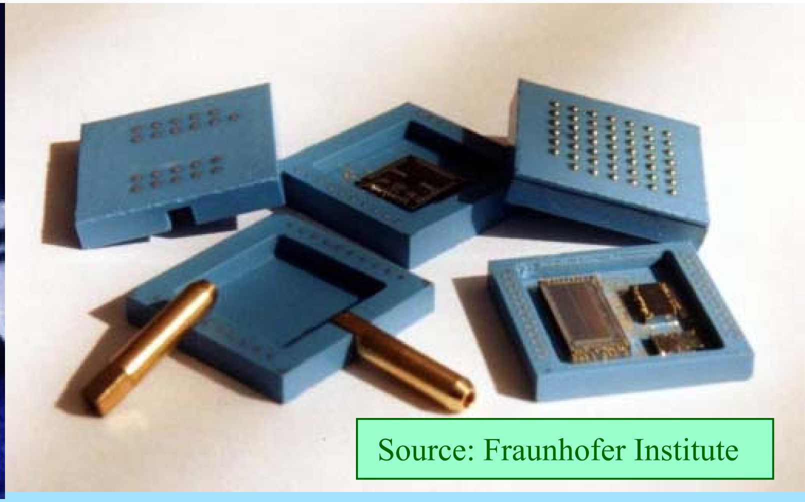


Figure 17: Design of a Flow Rate Sensor Module (LTCC)



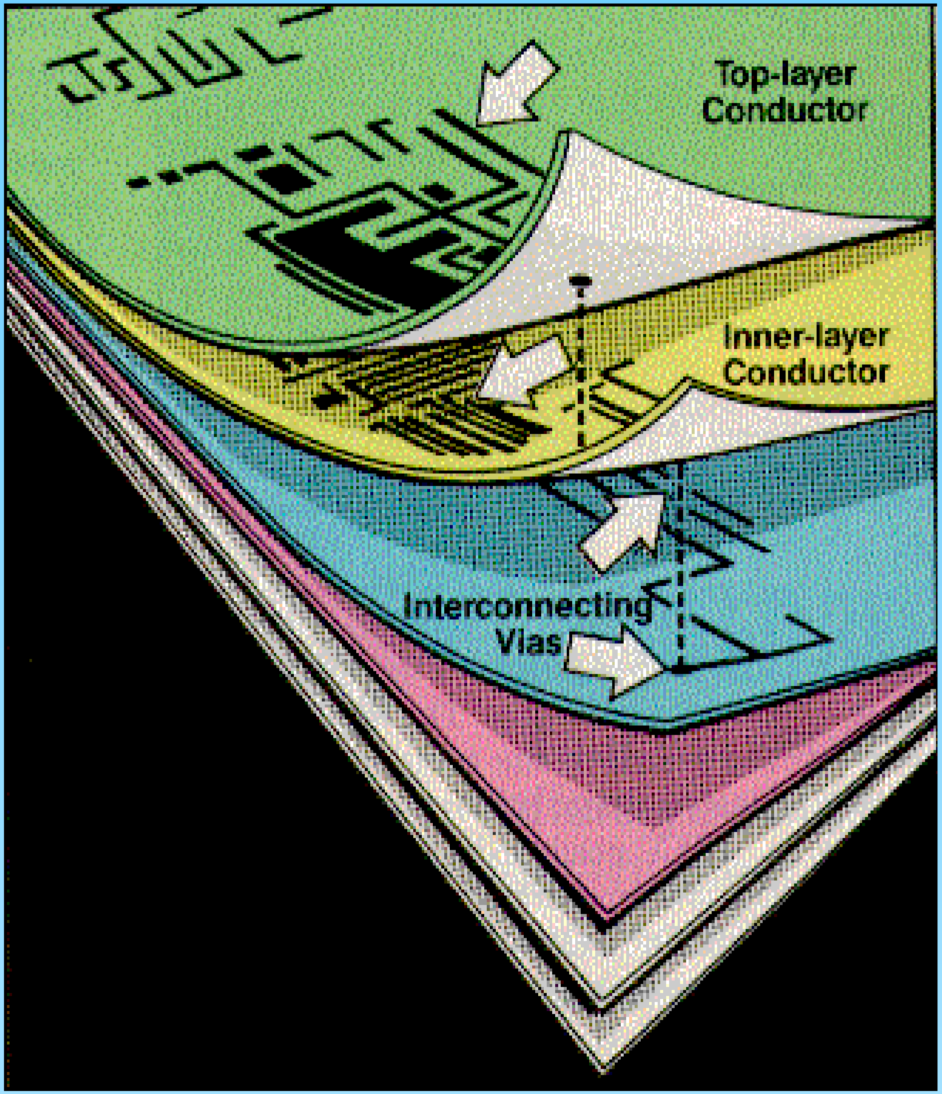


Source: Fraunhofer Institute

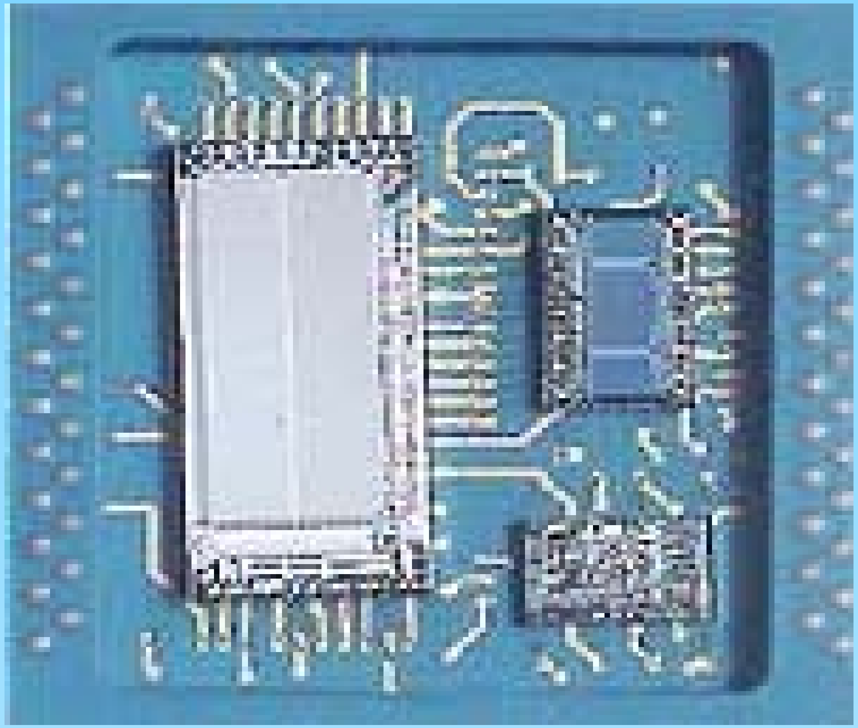
2. LTCC APPLICATIONS FOR MICROELECTRONICS

- MCM Applications
- Embedded Passives
- HF & Microwave Devices

LTCC APPLICATIONS IN MCM



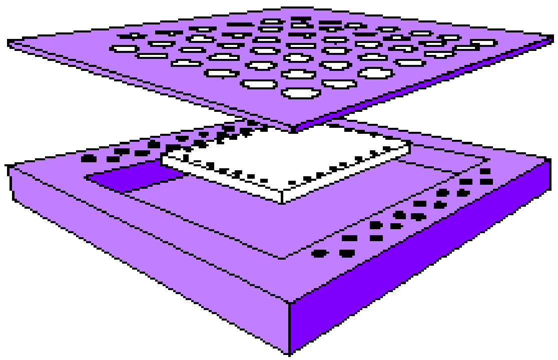
- LTCC is well adapted to high performance MCM applications using packaging techniques like flip-chip and BGA.

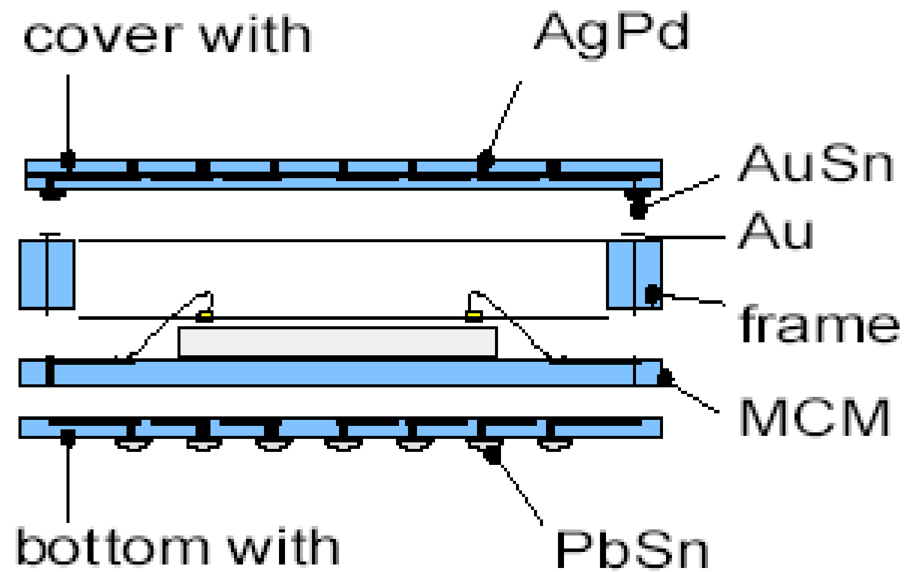


LTCC TB-BGA for MCM

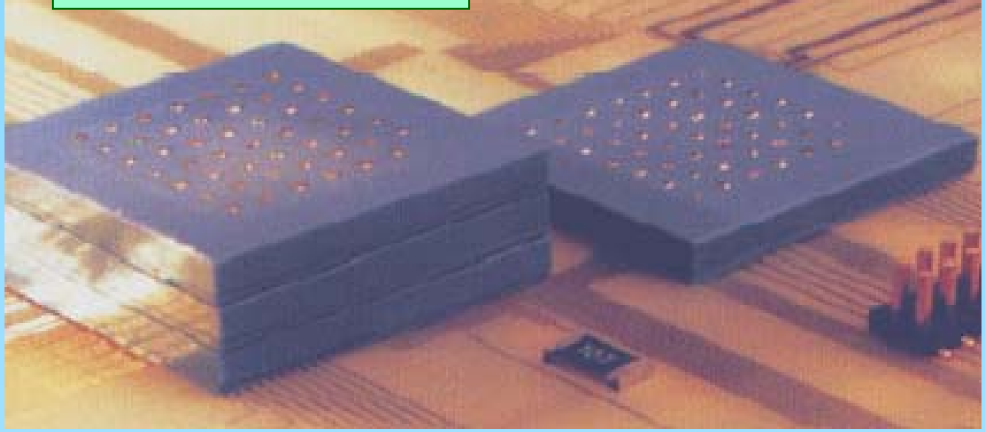
size	12,5 x 12,5
use	9,6 x 11,0
pin count	48
BGA pitch	1,27

units: mm





Source: Fraunhofer Institute



- TB-BGA can be used as MCM carrier for Harsh environments.

MCM SUBSTRATES COMPARISON

	Ceramic		Organic		
	LTCC	HTCC	FR-4	Advanced	PTFE
Electrical performance	++	+	-	-	++
Integral passives and functions	++	-	-	+	-
3-D structures	++	-	-	-	-
Interconnect density	+	+	-	-	-
Resistors	+	+	-	-	-
Thermal performance	+	++	-	-	-
Board/substrate size	-	-	++	+	+
Microelectronic process	+	+	-	-	-
Reliability	++	++	+	+	+

++ indicates signifigant advantage

HIGH VOLUME MANUFACTURING

- 100,000 Units/Week Multiple Sources
- Cost Effective Design and Process
- Silver Internal Conductors
- Multi-up Processing
- Single Cofire Process

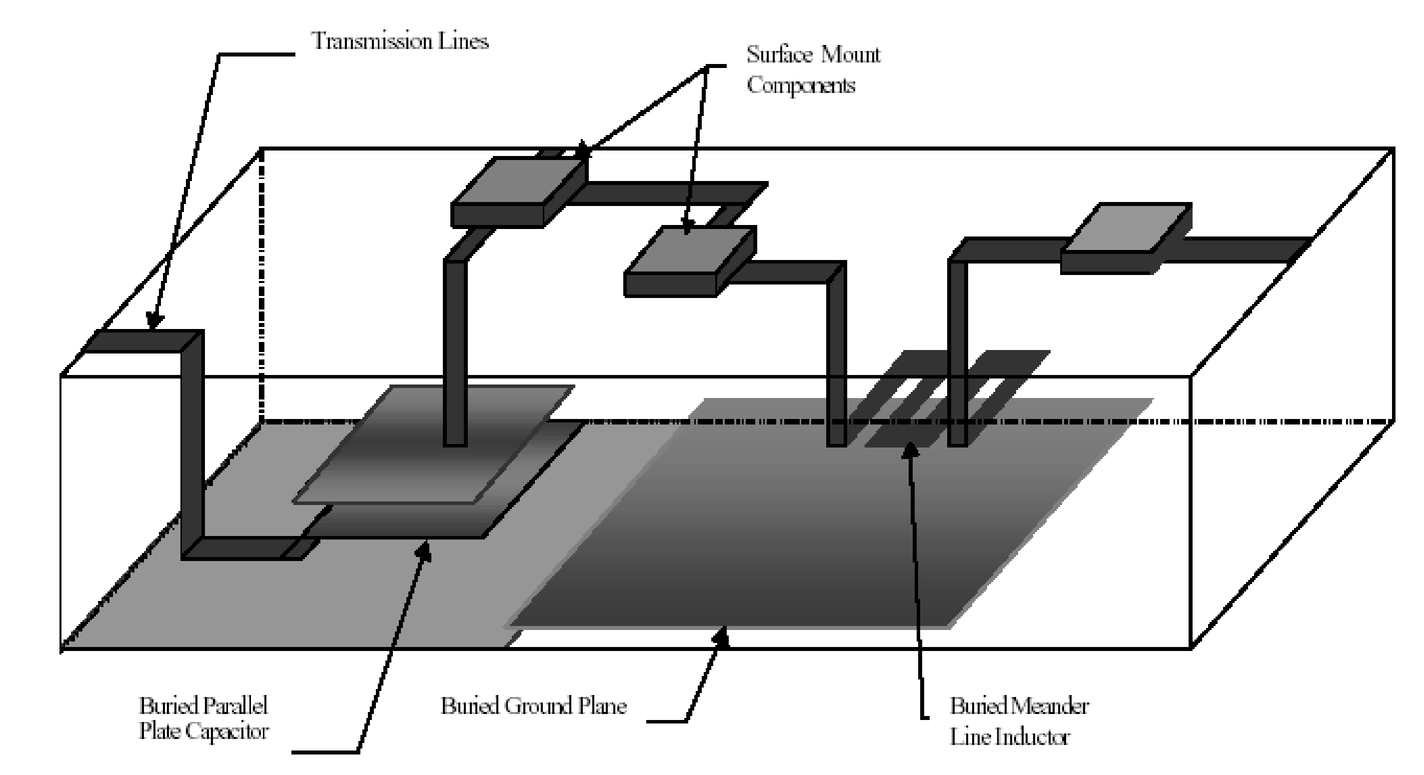
Source: DuPont

Read/Write Amplifier for disk drive

EMBEDDED PASSIVES

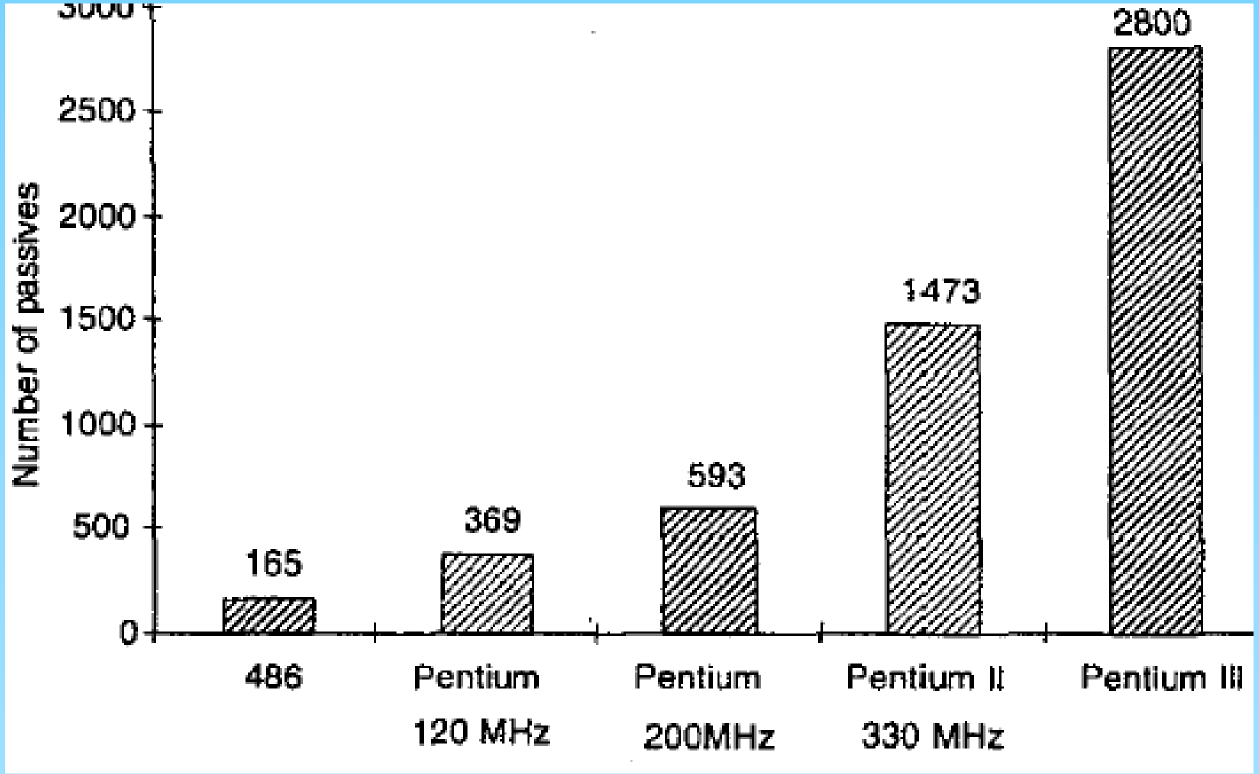
– **Integrated Passive Components, IPC's, generally fall into three (3) categories:**

- **Resistors: Generally comprised of ruthenium oxide (RuO_2) or tantalum oxide (Ta_2O_5)**
- **Capacitors: Generally comprised of silicates or titanates**
- **Inductors: Generally metallic conductors in some spiral shape to provide inductance**



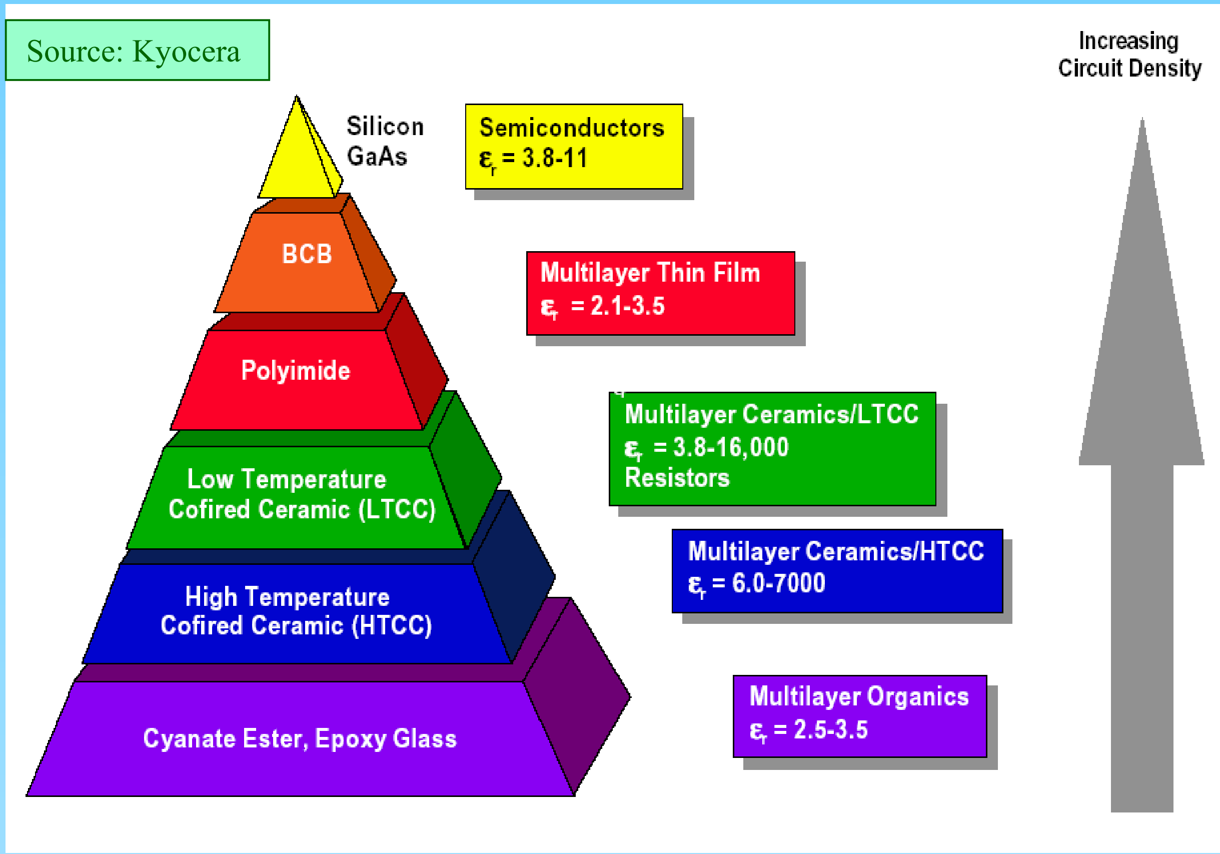
NUMBER OF PASSIVES IN PC BOARDS

– **Passives are very important part in Microelectronic devices, being 80% of total parts in hand held and computer applications.**



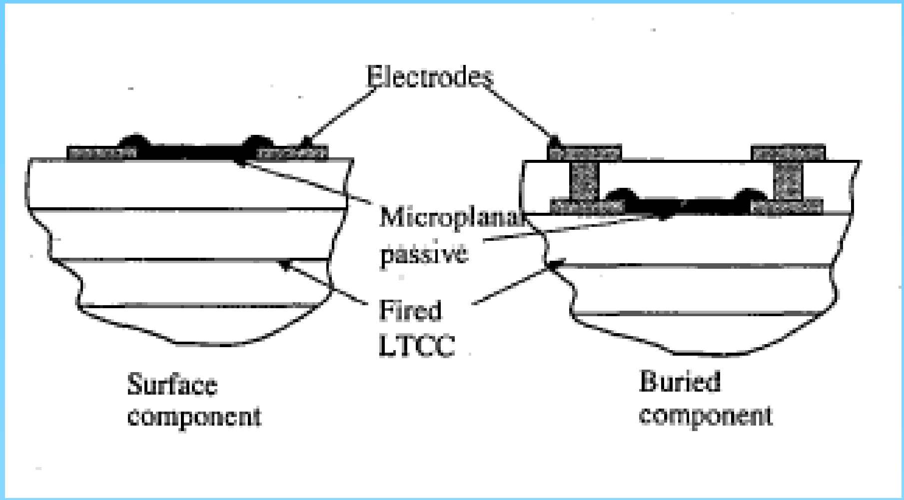
LTCC AND INTEGRATED PASSIVES TECHNIQUES

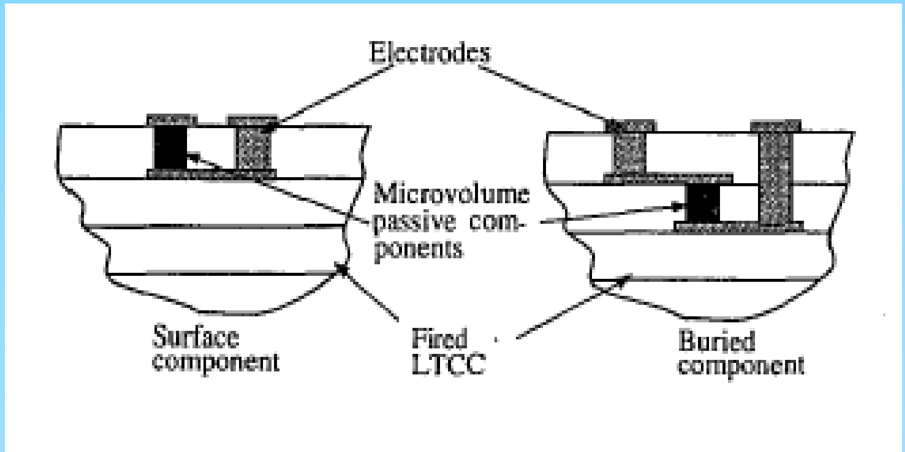
- LTCC displays the widest range of dielectric properties available for any packaging technology, enabling the incorporation of passive components.
- Furthermore, LTCC technology can incorporate resistive material thus enabling the integration of both resistors and capacitors within the substrate, as embedded passives



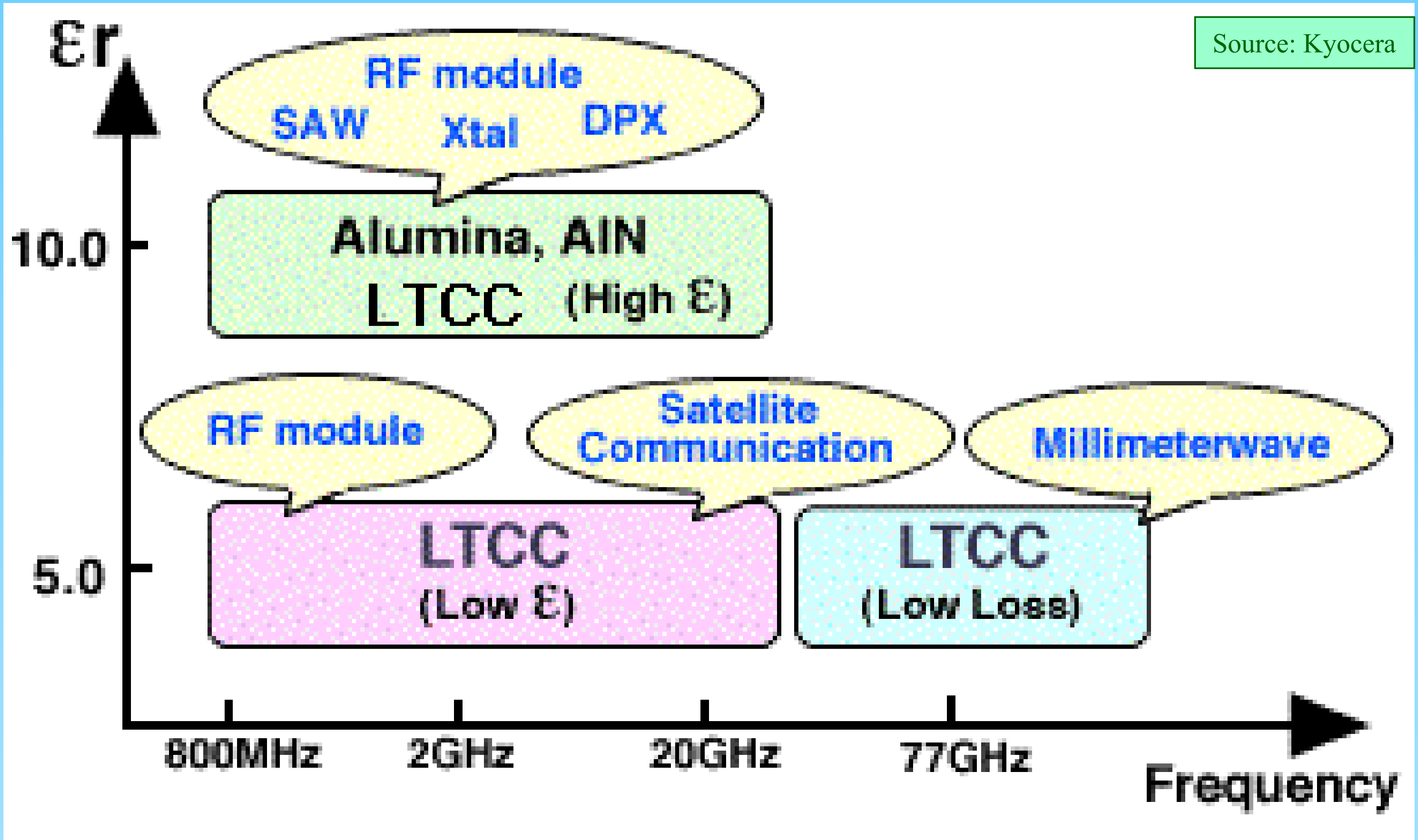
EMBEDDED RESISTORS

- Embedded Resistors can be fabricated from thick film or Photo thick film pastes.
- There two types of embedded resistors:
  - **Microplanar passive**
  - **Microvolume passive**
- High Voltage Pulse trimming can be used to modify resitor value

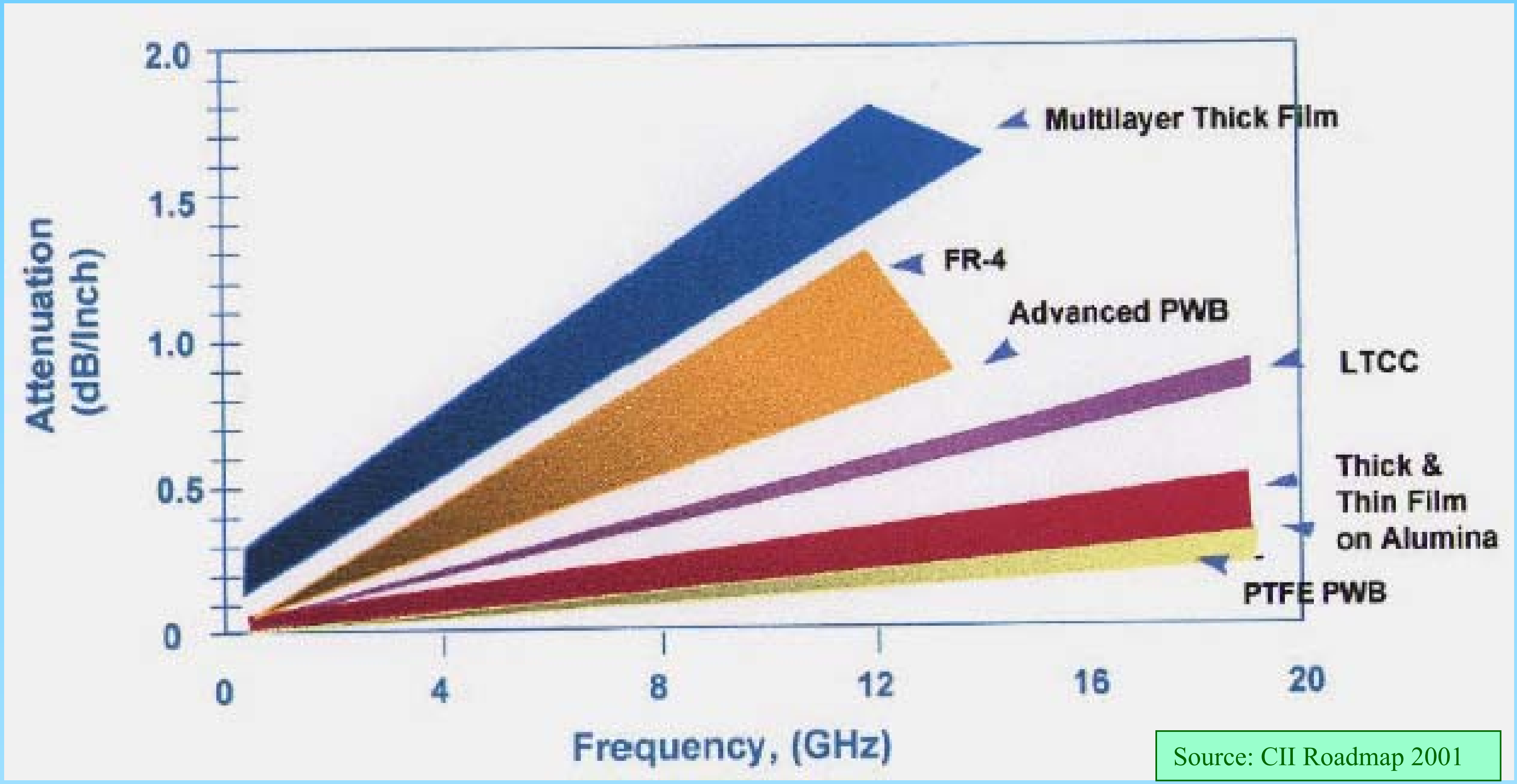




LTCC COVERAGE OF HF, RF & MW

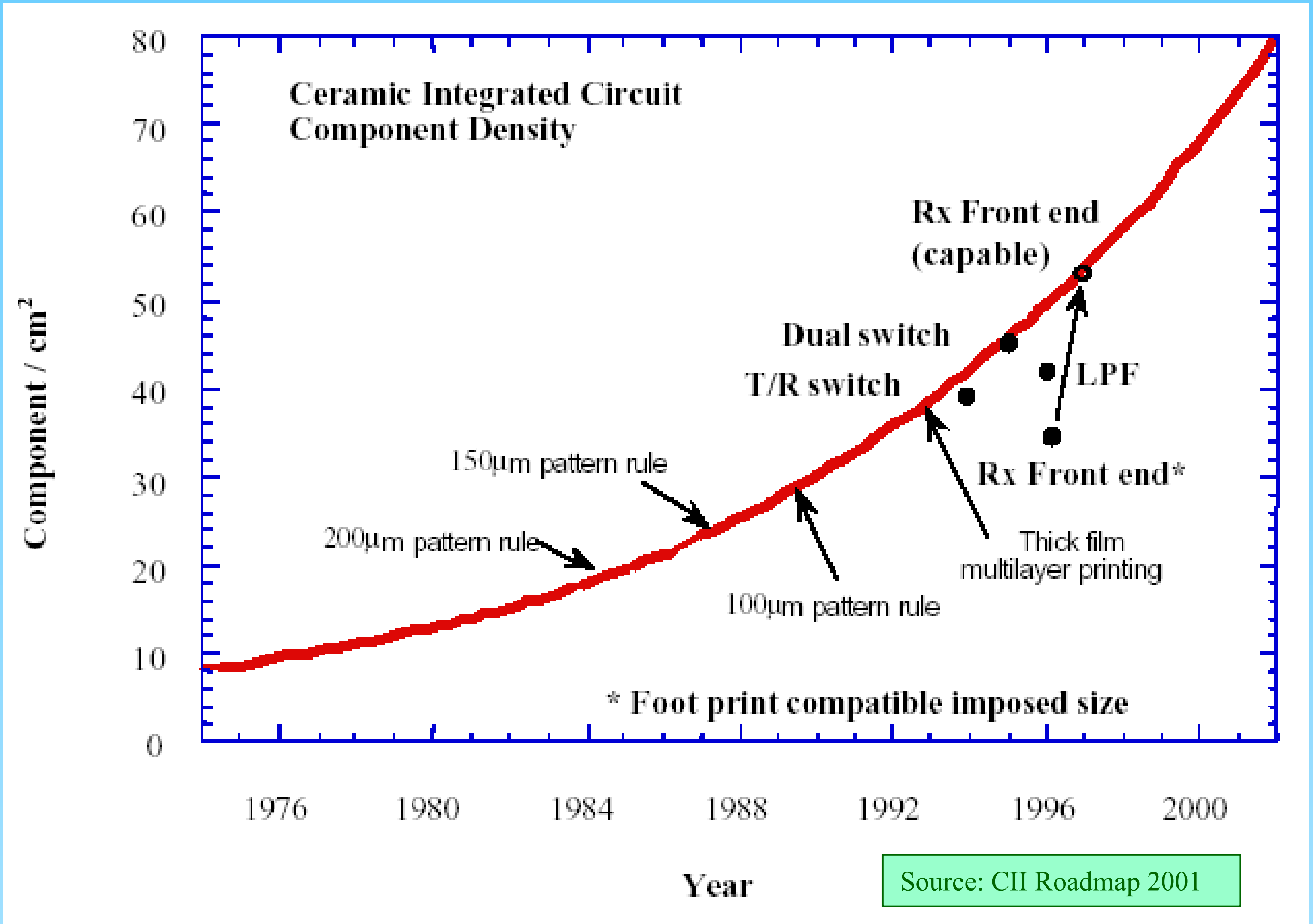


50 Ω Attenuation Summary

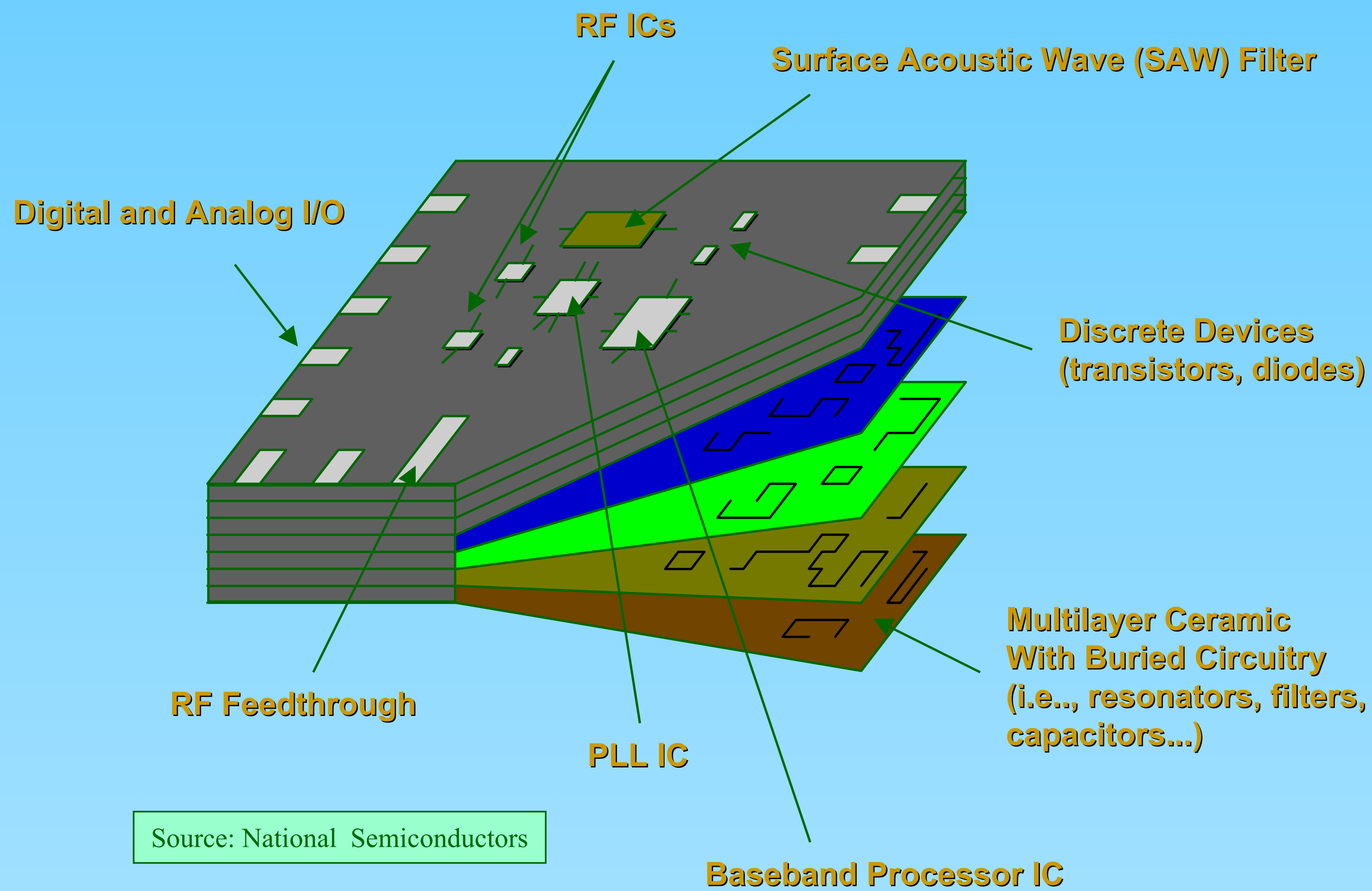


Source: CII Roadmap 2001

CERAMIC IC COMPONENT DENSITY



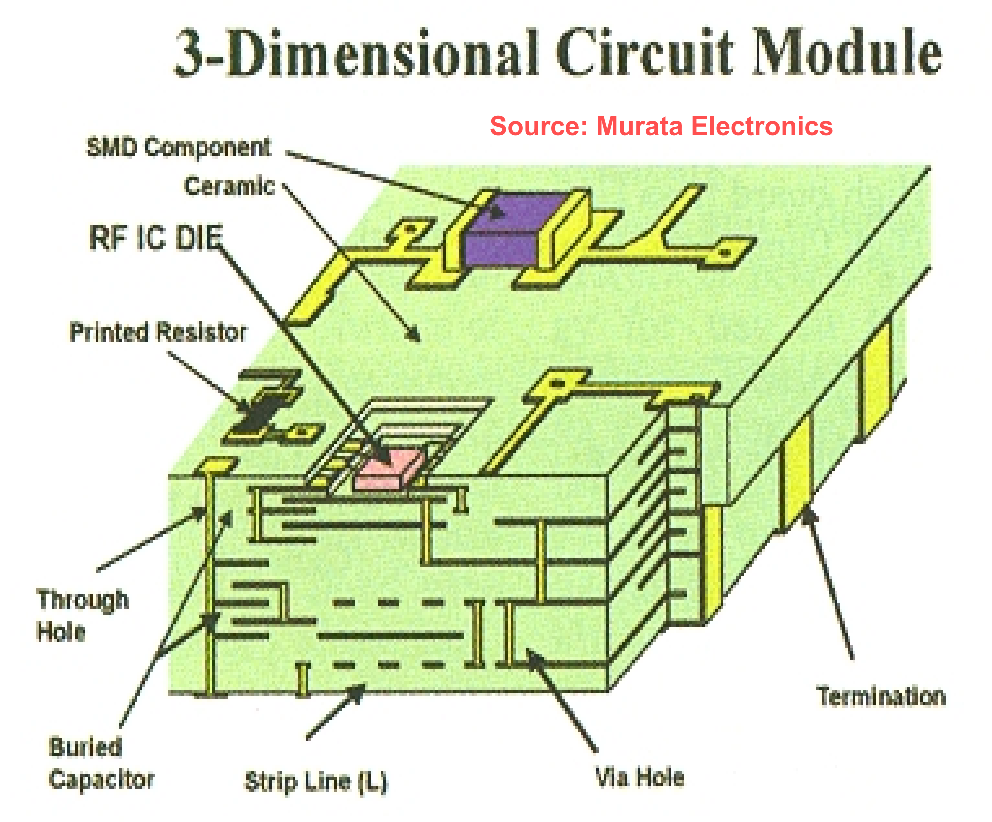
LTCC WIRELESS MODULE



Source: National Semiconductors

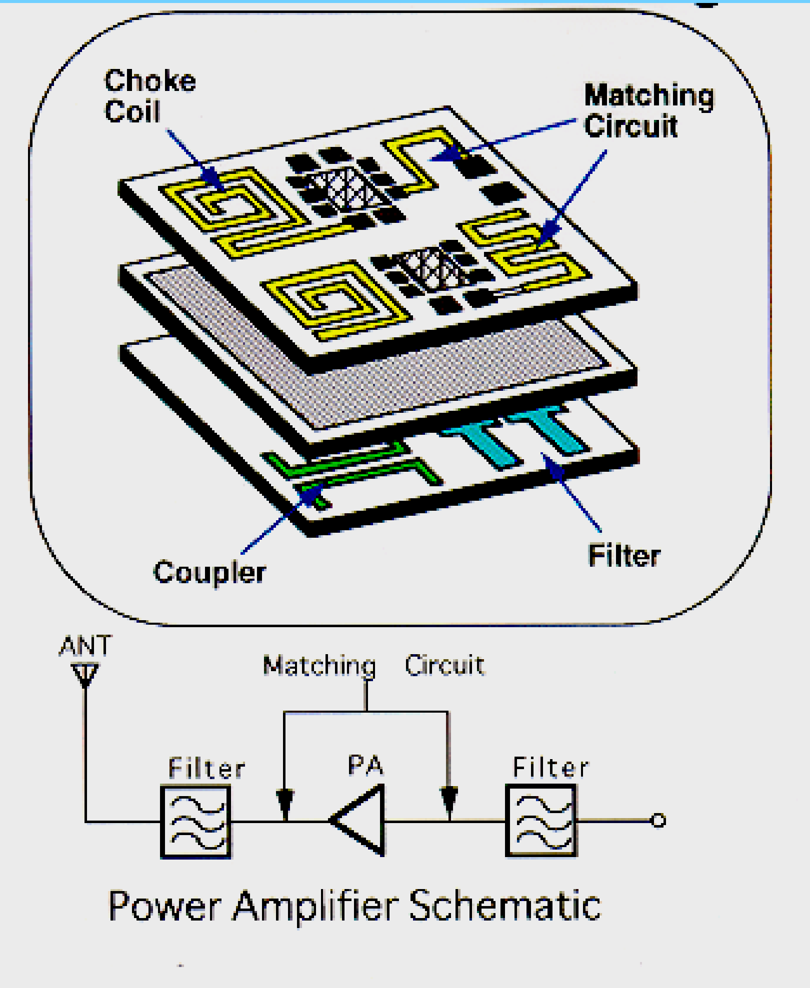
INTEGRATED RF MODULE

- LTCC
- Integrated Passives
- 3-D designs
- Controlled Impedance
- Hi Q
- Size reduction
- Direct Chip Attach
- Rapid Prototypes

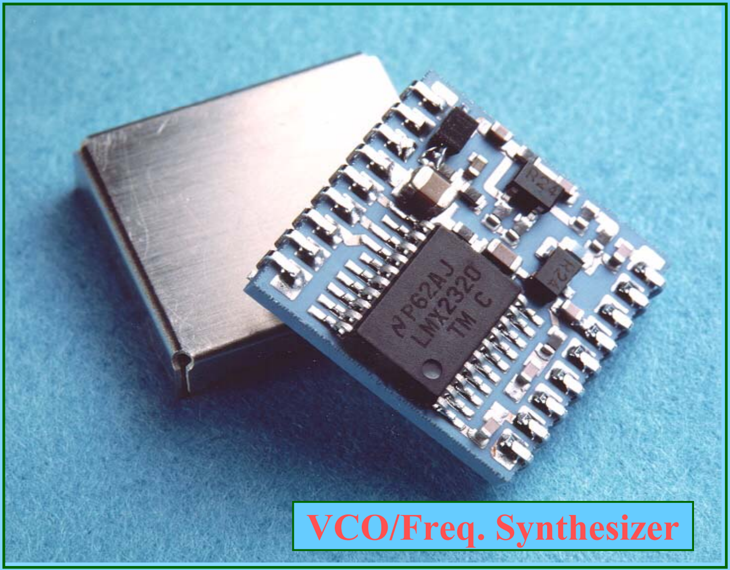


VERTICAL INTEGRATION IN PACKAGING

- A Paradigm Shift
  - # of Passives: 200
- Assumptions:
  - Comp. Value: 20pF/20nH
  - Comp Size: 3 mm Sq
  - Q Value: 30 - 100
  - # Layer: 8
  - Area: 25 X 25 mm
  - Approx. Cost:$3.60
  - Cost Savings: >$4.00

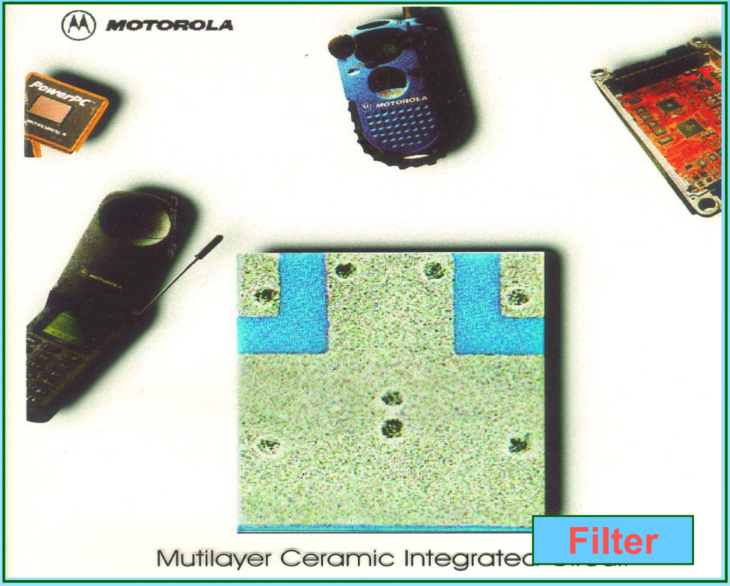


LTCC RF Applications

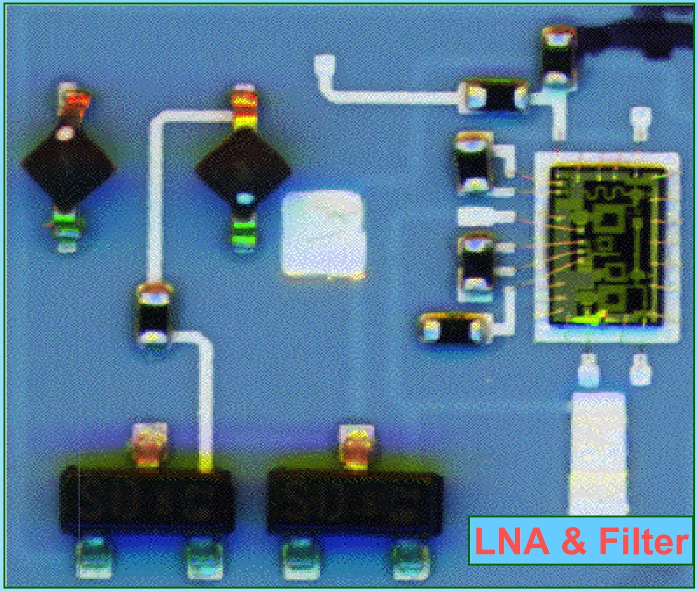


VCO/Freq. Synthesizer

Antenna



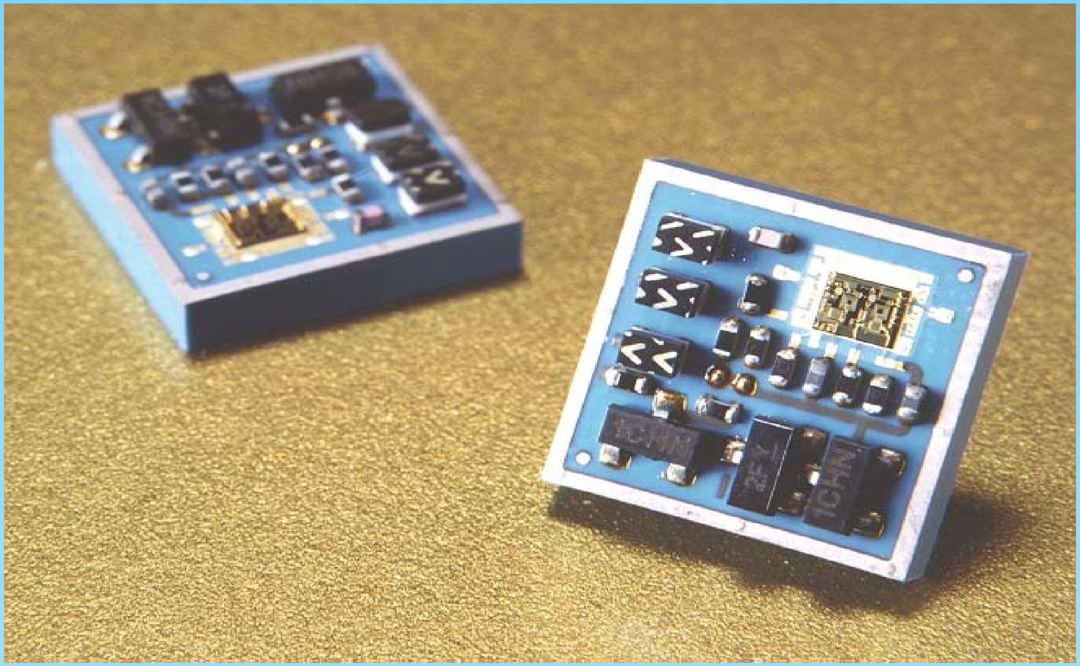
Filter



LNA & Filter

INTEGRATED RECEIVER FOR SATELLITE HANDSET

Wireless Module with Integrated Passives



26 Embedded Components
- 9 Thick Film Capacitors
- 8 Multilayer Capacitors
- 9 Transmission Lines / Coils

16 Mounted Components
- 7 Resistors
- 2 PIN Diodes
- 2 Ferrite Beads
- 2 MOSFETs
- 1 Limiter Diode
- 1 Capacitor
- 1 LNA

Source:Motorola

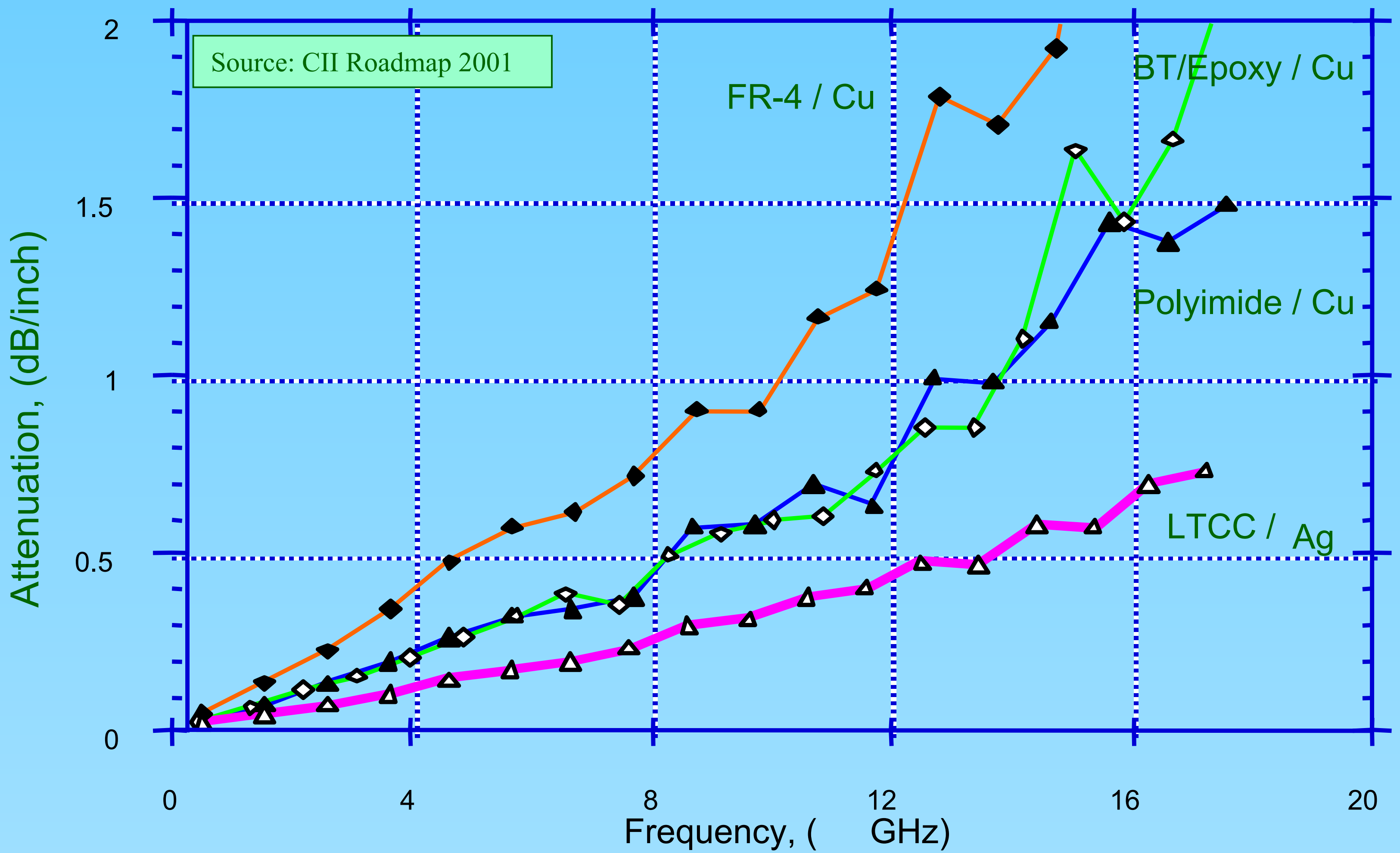
MICROWAVE REQUIREMENTS

- Compact structures
- High volume production capability
- Parallel processing - LTCC
- Integrated components
- Excellent electrical performance – low loss
- Precise parameters – right first time design
- Environmental stability

LTCC KEY POINTS FOR MW

- Parallel processing:-
  - High yield
  - Quick turnaround
  - Volume manufacture
- High layer count readily available
- Integrated components:-
  - Microwave circuit structures
  - L, C & R

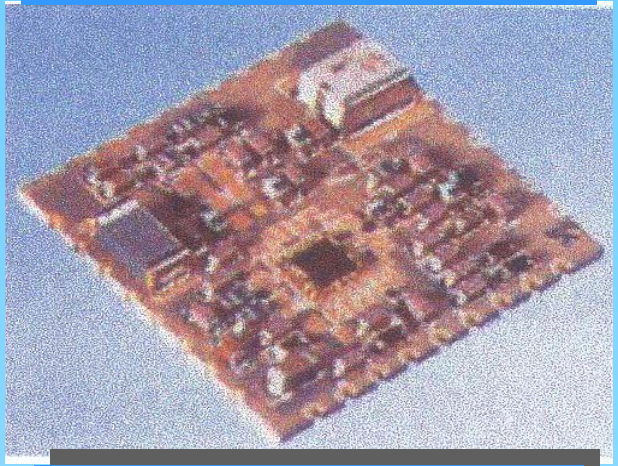
FR-4 VS. POLYIMIDE VS. BT EPOXY VS. LTCC



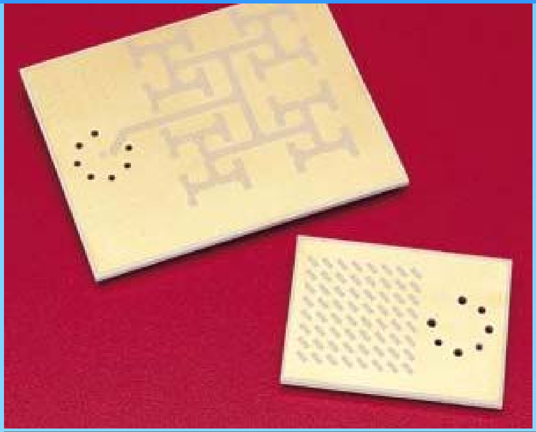
50 Ω Microstrip Attenuation Organic Substrates - wide lines

LTCC MW APPLICATIONS

Bluetooth modules



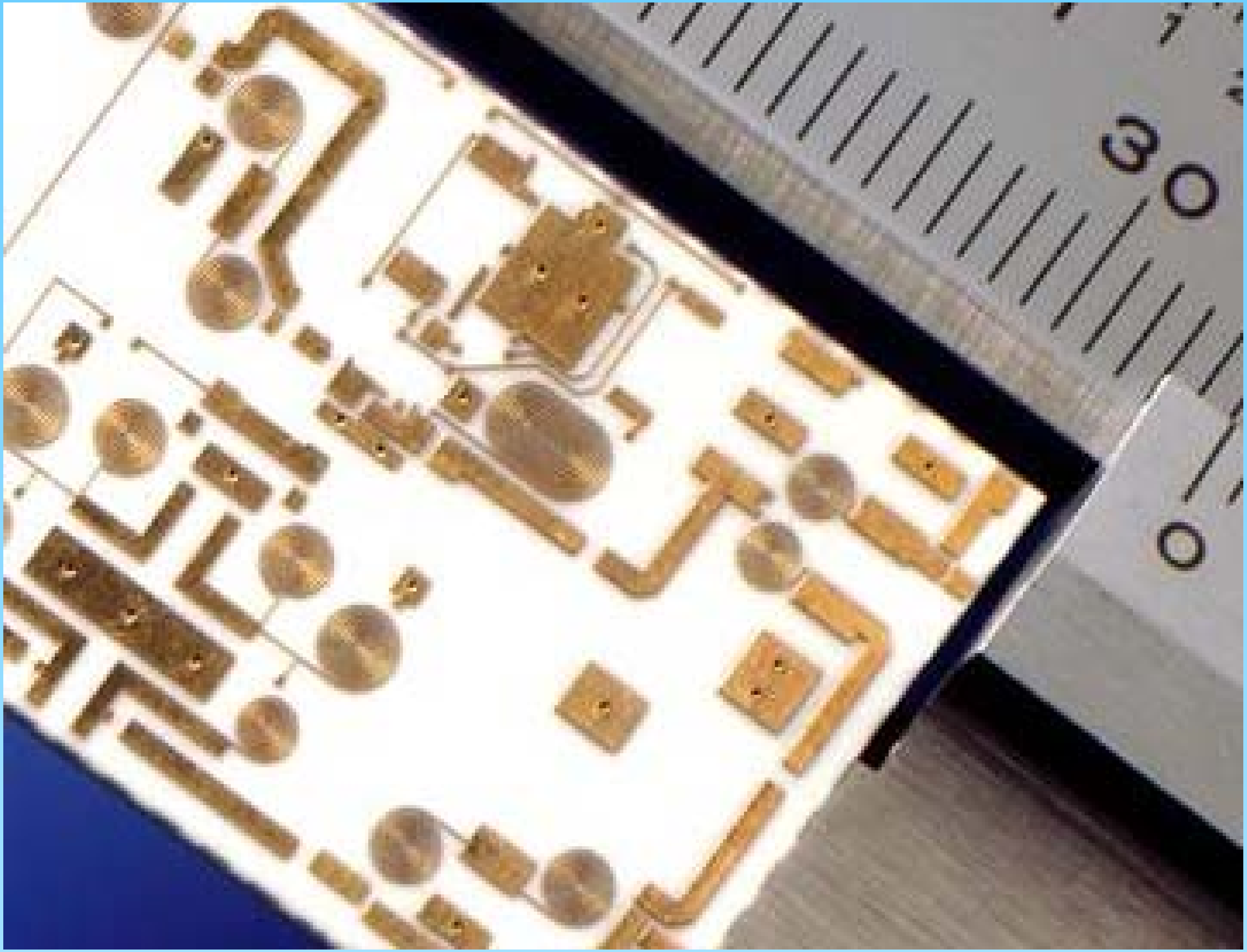
77 GHz planar antenna



Transceiver Modules

Spiral Antenna

MICROWAVE CIRCUIT



TECHNOLOGY NEEDS

– Finer Lines / Smaller Vias:

- Combine photo patterning with tape and paste to allow patterning of line pitches below 100 µm and via pitches below 150 µm.

– Embedded Passive Components:

- Adopt thick film resistor and hi-K capacitor technology for compatibility with LTCC Tapes.
- For inductors apply photo patterning to create high-density spiral patterns

– Lower K Dielectric:

- Lower dielectric constant from current levels to further improve the performance
- of high-speed digital signal applications.

– Process:

- Advanced via formation techniques including mechanical, laser and photo via tool sets will provide the means to allow vias to achieve smaller sizes.
- For thick film printing, advances are needed in mask tolerances and controls, thick film paste rheology control, optical alignment of mask to pattern and improved thick film printing, mask release controls.
- To achieve finer line widths (<25-50 µm), metal mask technology is required to extend the tolerance control beyond what is currently achievable using conventional wire mesh (emulsion) screens.

LTCC FORECAST TO 2011

Driver	Enabling Attribute	2001	2003	2005	2011
Size Reduction	Via Size	50µm	50µm	40µm	25µm
Increased Density	Via Pitch	200µm	150µm	120µm	75µm
Size Reduction	Line Width	30µm	25µm	20µm	15µm
Increased Density	Line Pitch	60µm	50µm	40µm	30µm
Cost Reduction	Panel Size	165cm^2	250cm^2	360cm^2	645cm^2
Connectivity	Line Size and Spacing	40cm/cm^2	133cm/cm^2	200cm/cm^2	267cm/cm^2
Time-to-Market Commercial Prototype	Cycle Time	30 days	20 days	15 days	5 days
Time-to-Market Commercial Production	Cycle Time	15 days	10 days	10 days	5 days
Time-to-Market Hi-Rel Prototype	Cycle Time	130 days	100 days	90 days	50 days
Time-to-Market Hi-Rel Production	Cycle Time	75 days	50 days	40 days	20 days
Clock/Frequency Increases	Frequency Performance	40Ghz	94GHz	Improved Values	
Intimate Elect./Mech. Interface	Hi-Temp Performance	+150°C	+160°C	+175°C	+200°C
Size and Cost Reduction	Integrated Passives	Resistors 100Ω - 100KΩ±10% TCR ±250ppm/°C	Wider Range and Improved Tolerances		
		Capacitors 1000pF/.25mcm^2 ±10% TCC X7R	Wider Range and Improved Frequency Characteristics & Tolerances		
		Inductors Function of trace features and Materials Employed	Wider Range and Improved Frequency Characteristics & Tolerances		

3. LTCC FOR MEMS/MST

- MST Introduction
- LTCC for MST

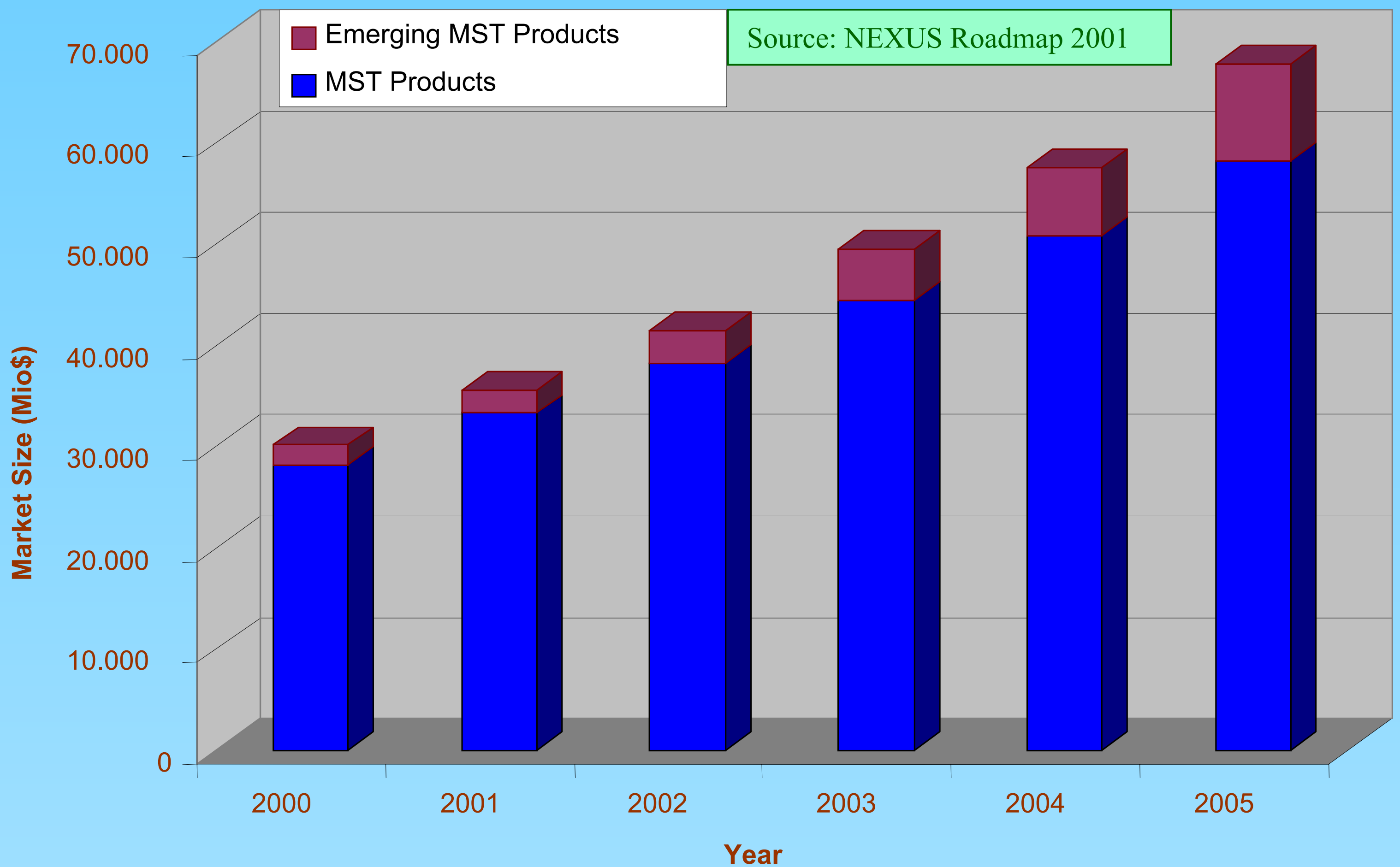
MST APPLICATION FIELDS

- Automotive /Transportation
- Information Technology, Peripherals
- Telecommunications
- Medical / Biomedical
- Environment / Industrial Processes
- Household Appliances/ Entertainment
- Other Applications (Defense, Aerospace)

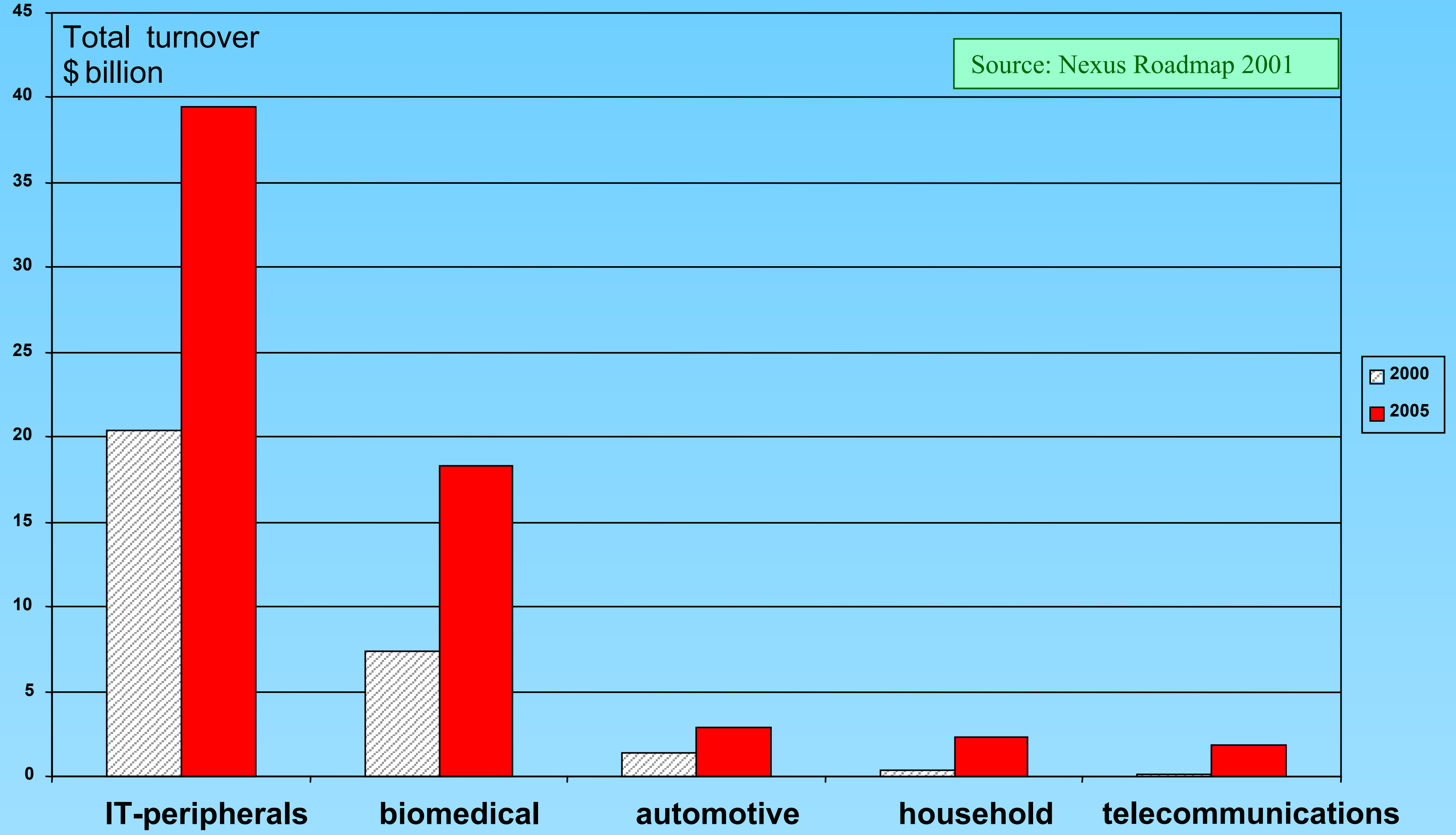
MST PRODUCTS

- Read-Write Heads
- Ink jet Heads
- Heart Pacemeakers
- Biomedical diagnostics
- Hearing Aids
- Pressure Sensors
- Acceleration Sensors
- Gyroscopes
- Infrared Sensors,thermopiles
- Flow Sensors
- Microdisplays
- Drug Delivery Systems
- MST devices for Chemical Analysis
- Optical Mouse
- Inclinometers
- Microspectrometers
- Optical MEMS
- RF-MEMS
- Fingerprint biometric Sensors
- Micromotors
- Microoptical Scanners
- Electronic Paper

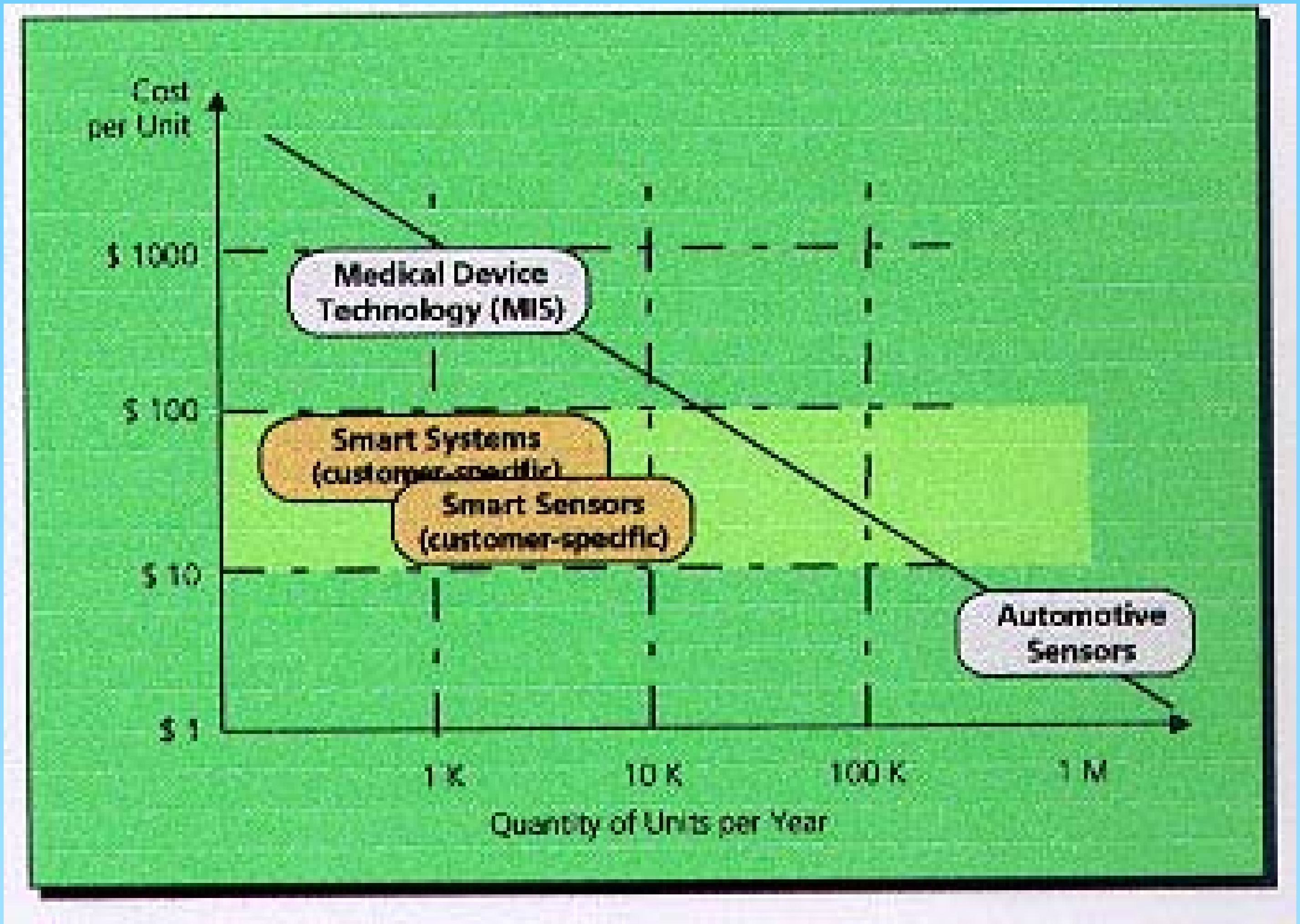
MST WORLD MARKET



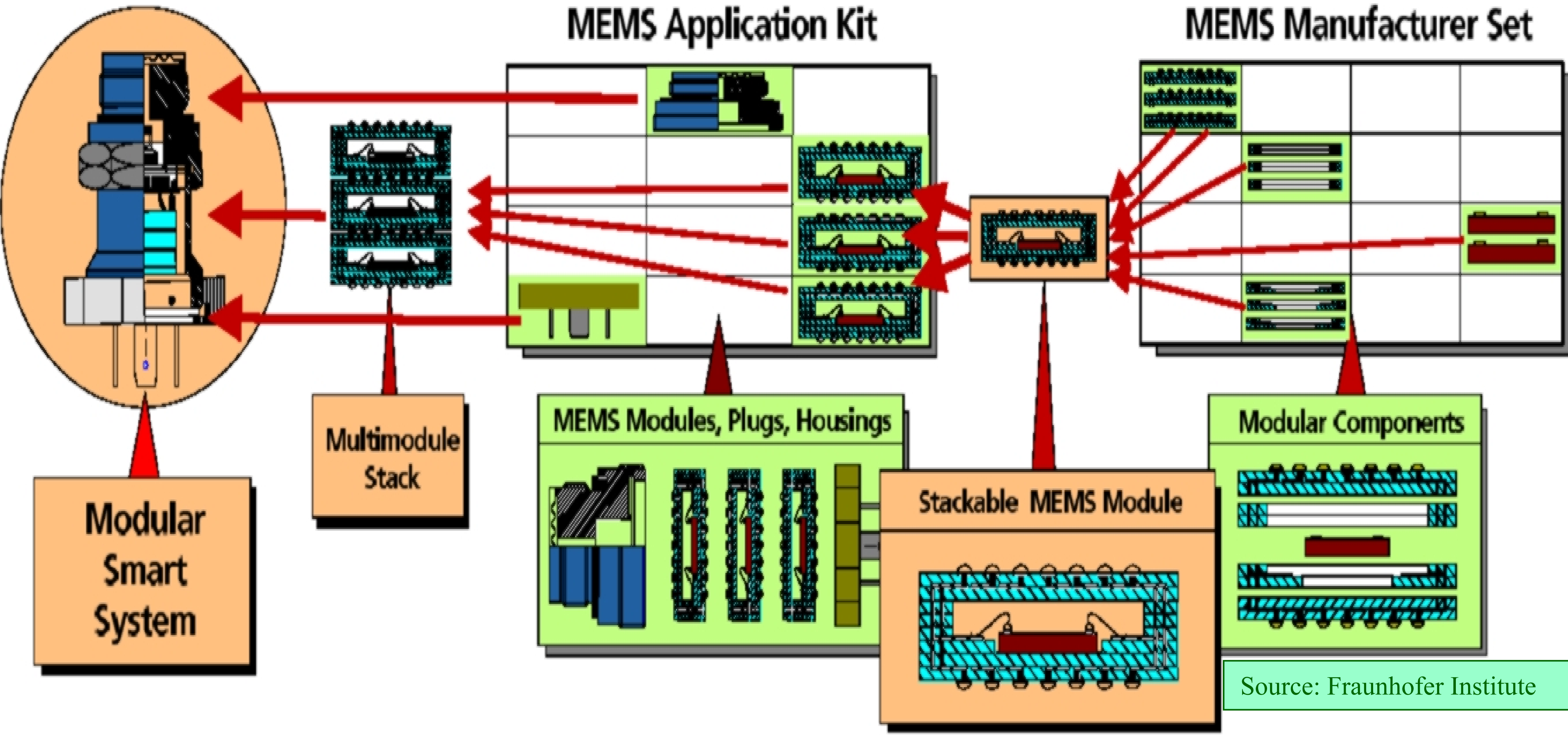
MST APPLICATION FIELDS (2000-2005)



EXPECTED COST FOR SMART SYSTEMS

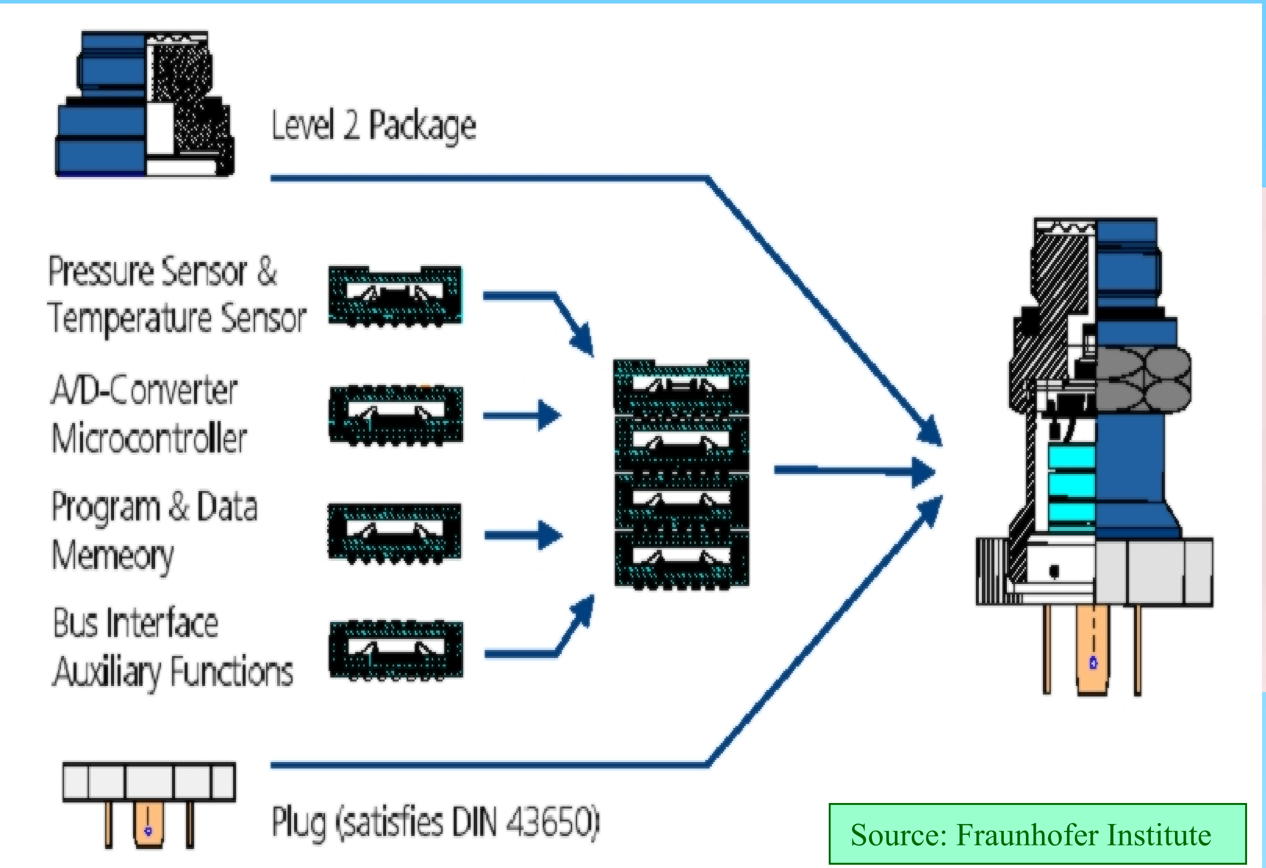


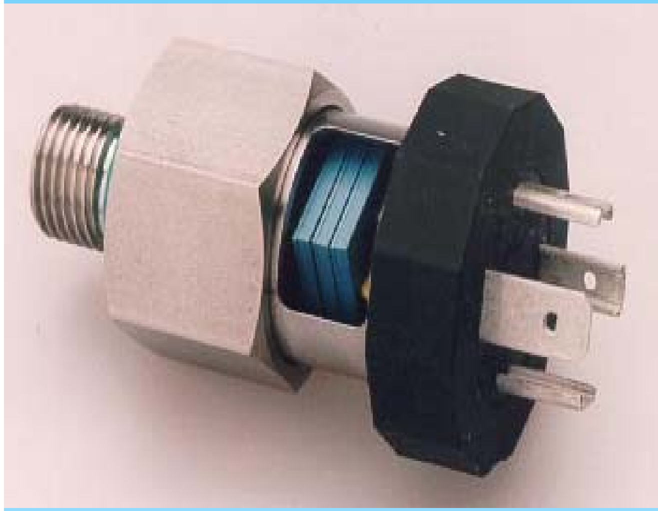
MODULAR MICRO-SYSTEMS



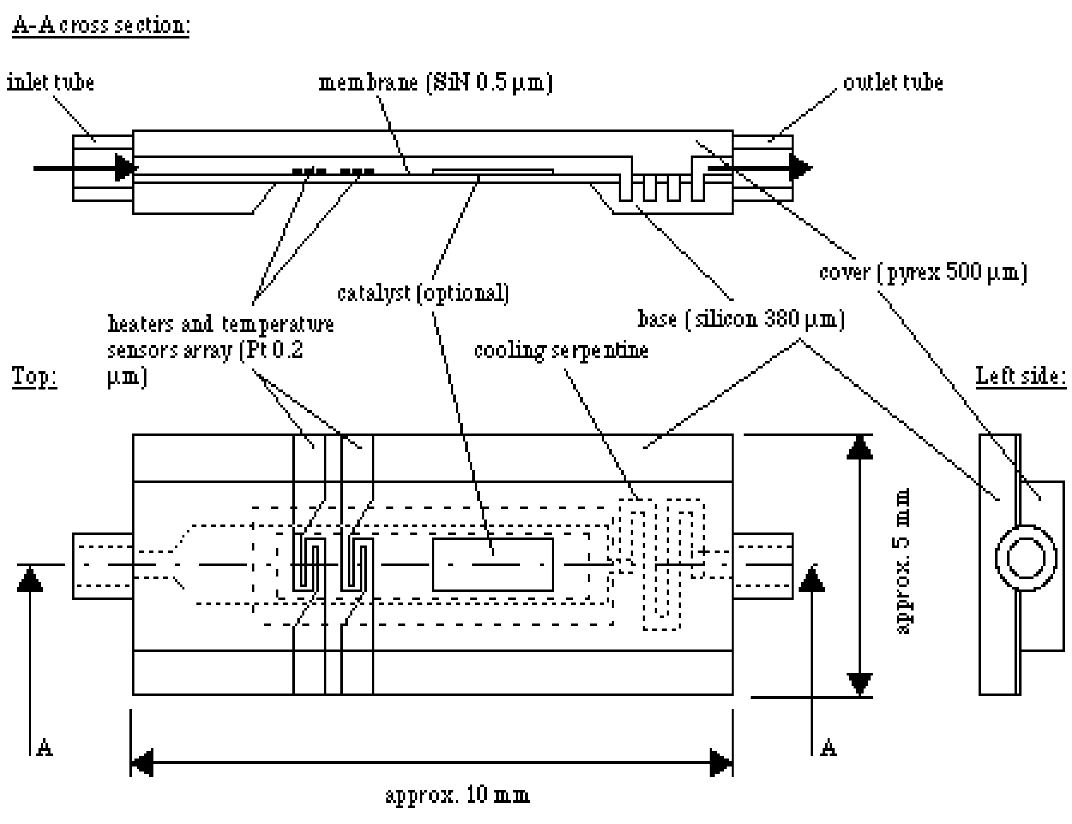
Source: Fraunhofer Institute

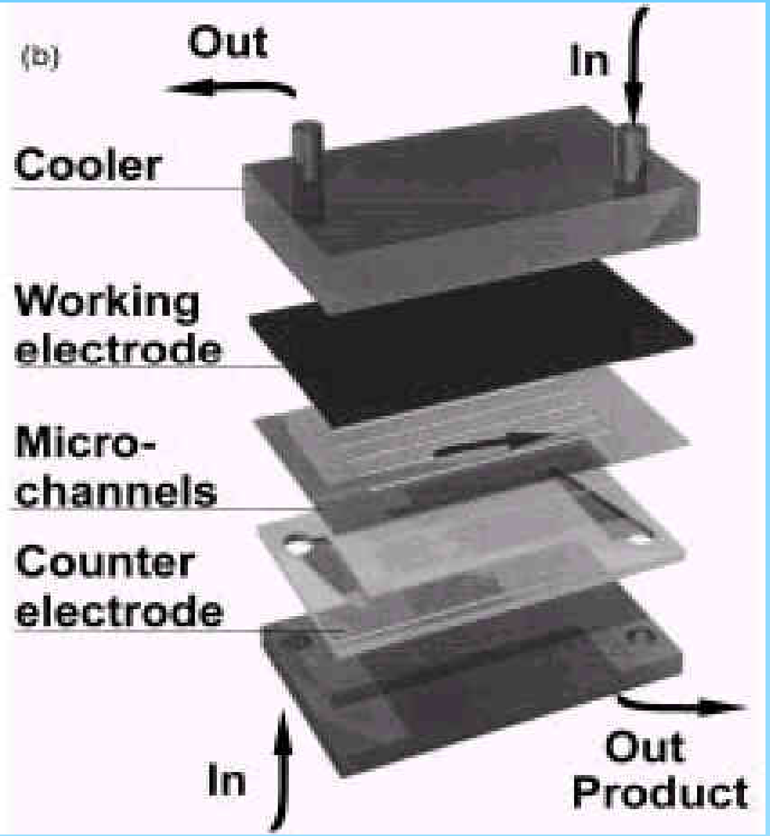
SMART PRESSURE CONTROL SYSTEM



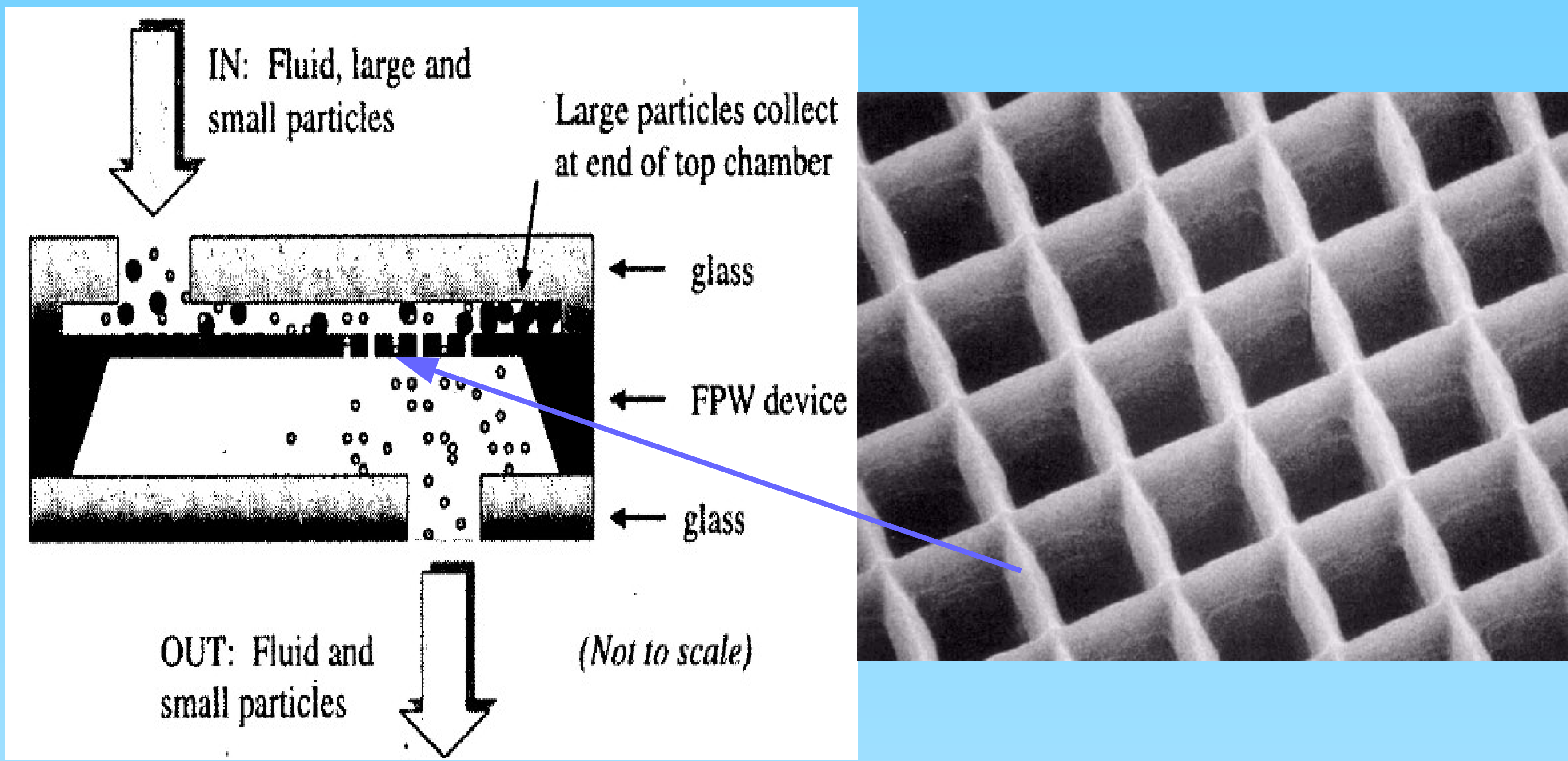


MST APPLICATIONS ON MICROREACTORS

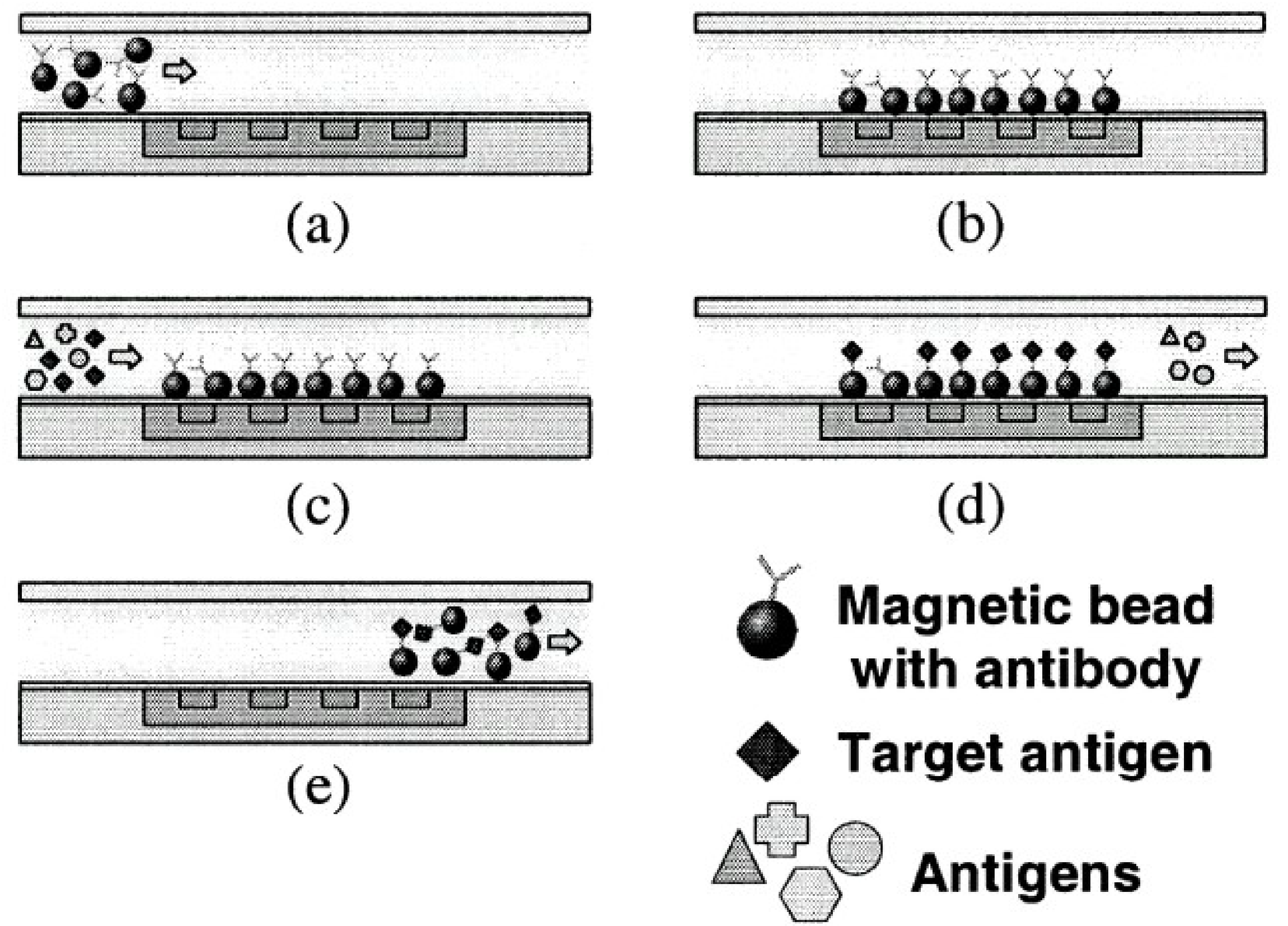




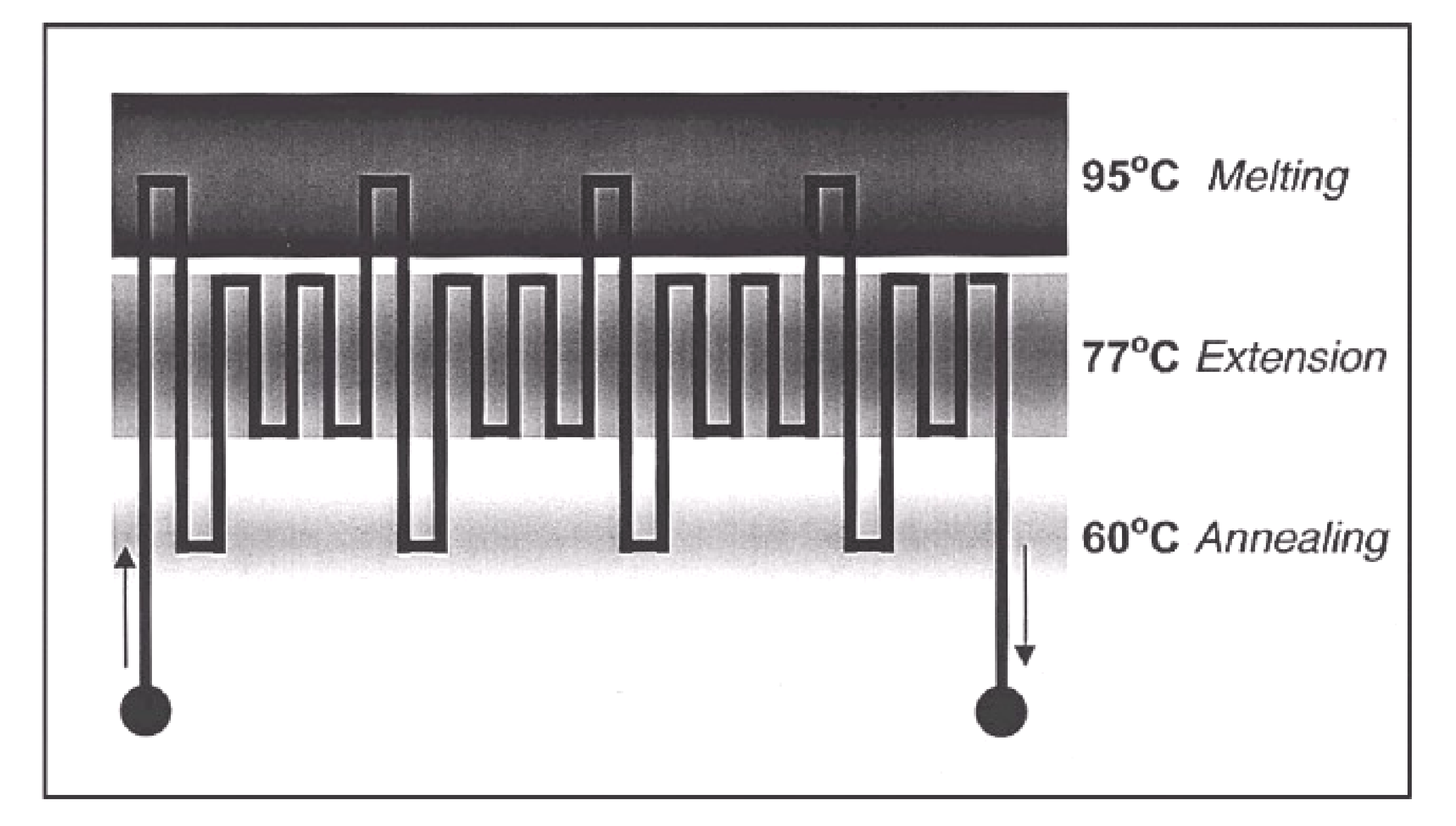
MST APPLICATIONS (MICROFILTERING)



MST APPLICATIONS (BIO-SEPARATION)



MST APPLICATIONS
(PCR IN CONTINUOUS FLOW)



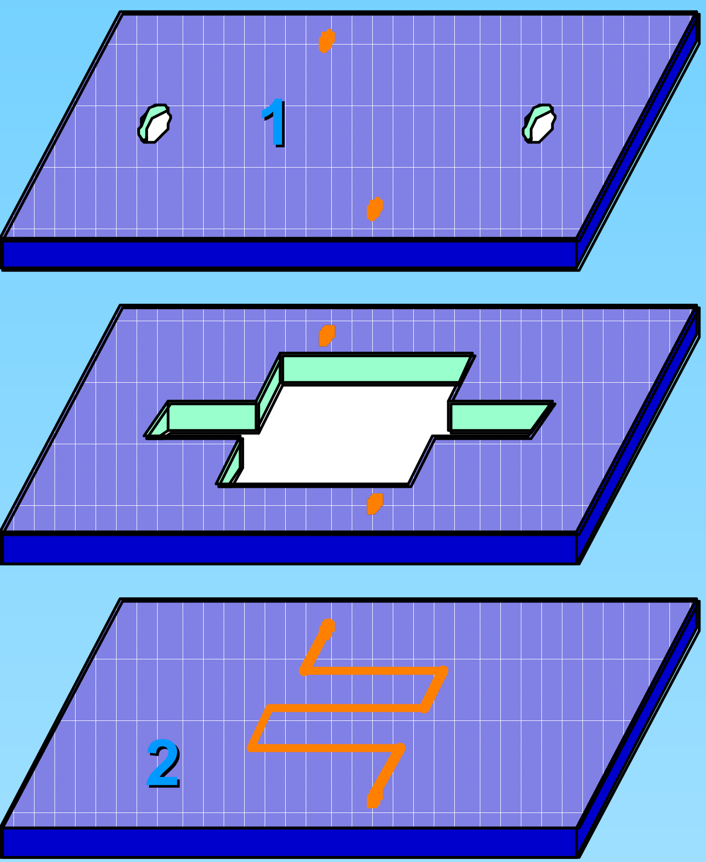
4. MESO SYSTEMS, DEVICES AND APPLICATIONS

- Sensors
- Actuators
- Microfluidic devices
- Meso-Systems

LTCC TECHNOLOGY WORK-PLAN FOR MESO-SYSTEM IMPLEMENTATION

- Allow ceramic MCM/LTCC technology compatibility with other micro-system technologies available;
- Study of different Green Ceramic Tapes machining techniques;
- Measurement and control of sagging during lamination and sintering;
- Development of suitable lamination methods for micro-structures;
- Fabrication of cavities, channels, bridges and other structures for S&A;
- Design and Fabrication of fluidic devices using LTCC Technology
- Design and implementation of sensors using hybrid LTCC technology;
- Design and implementation of actuators using hybrid LTCC technology ;
- Design and Implementation of Fluid handling devices using hybrid LTCC technology;
- Design and Implementation of Meso-systems, for Analytic Chemistry, Biomedical Engineering or Bio-Technology using LTCC technology;

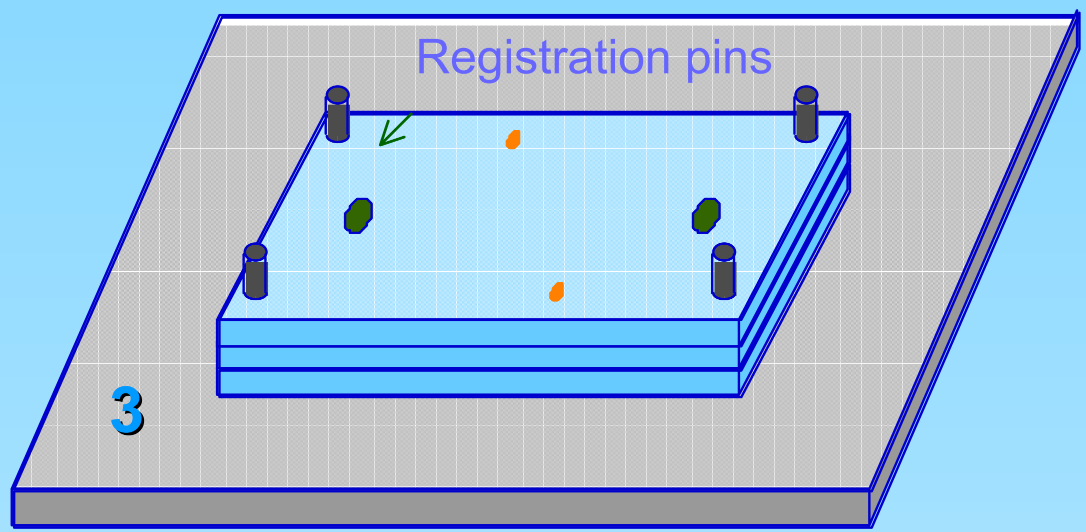
FLEXIBLE LAYERED MANUFACTURING OF MESO-SCALE SYSTEMS USING CERAMIC TAPES



1. Machining each layer to create desired patterns

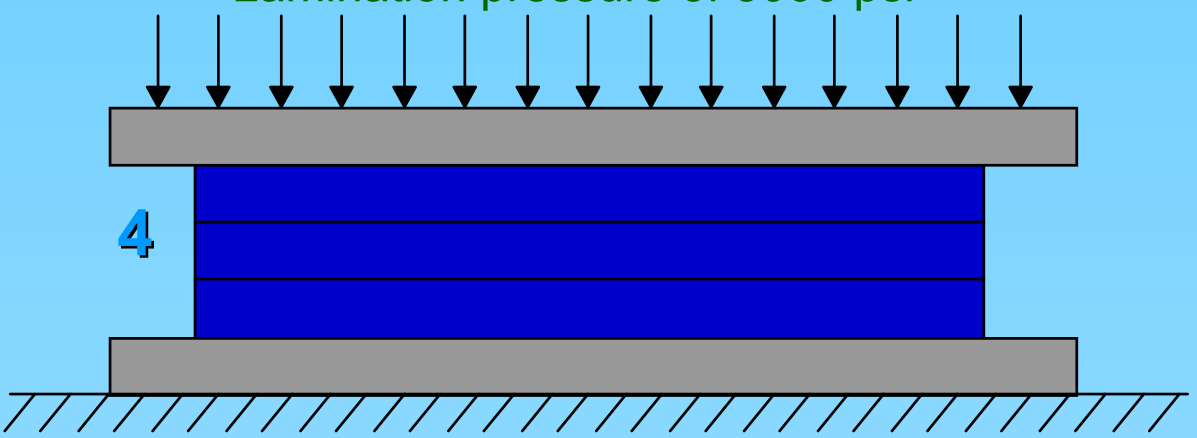
2. Screen printing and via filling or thin film deposition through a mask

3. Alignment and Stacking



Flexible Layered Manufacturing of Meso-scale Systems Using Ceramic Tapes

4. Lamination



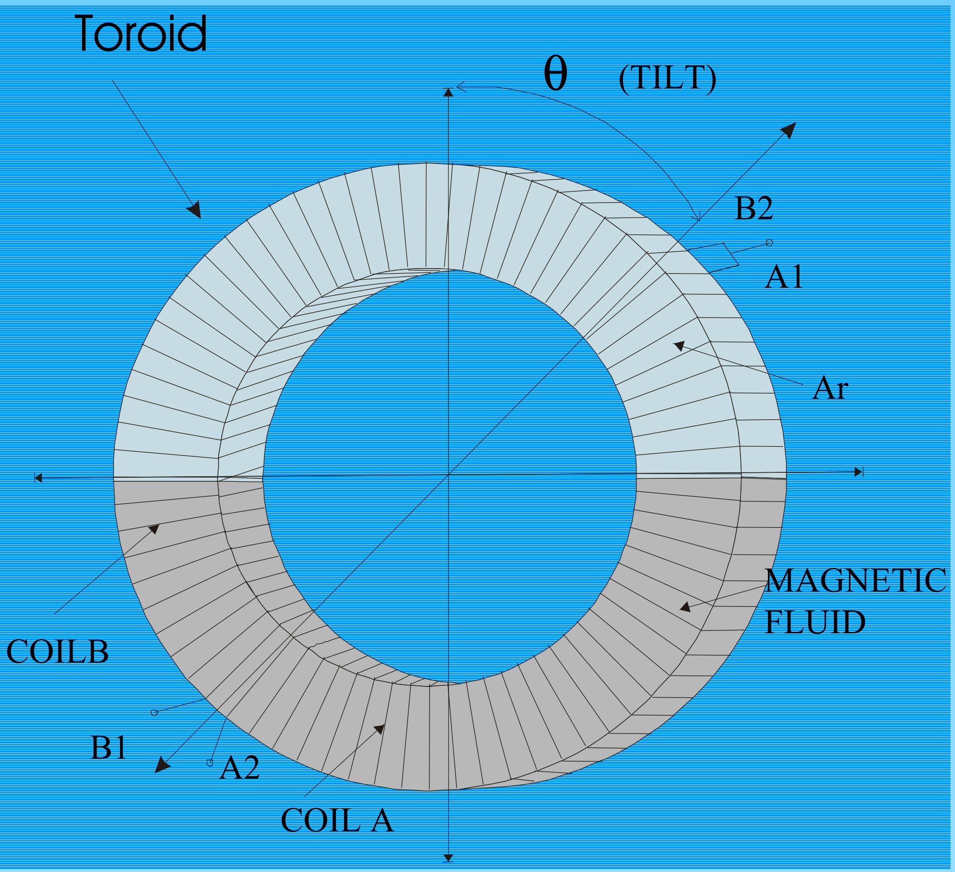
5. Co-firing

Cross-section after firing

SENSORS USING GREEN CERAMIC TAPES

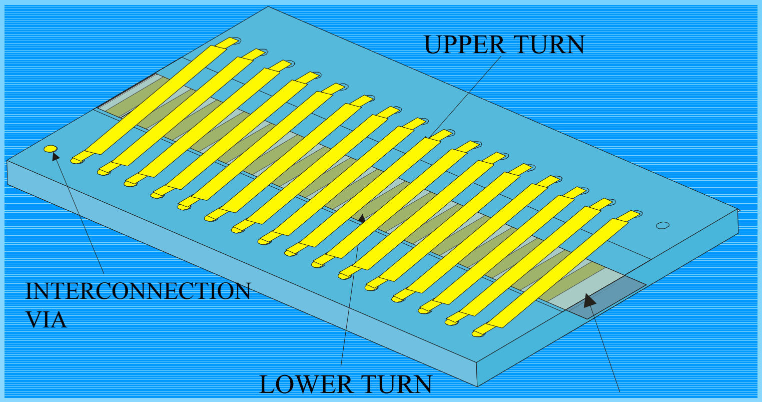
- Displacement and attitude sensors
  - LVDT type displacement sensor
  - Attitude sensor using ferrofluids
  - Eddy current proximity sensor
- Pressure Sensors
  - Load Cells
  - Differential pressure sensors
  - High temperature pressure sensor using exfoliated membrane
- Basic Micro-Fluidic Devices
  - Micro-channels
  - Critical orifices
  - Mixers
  - Hot Plates
  - Liquid Cooling devices
- Thermal Flow Sensor
  - Flow sensor using thermal loss measurement
- Chemical Sensors
  - SNO_2 Gas Sensor
  - PH Sensor
  - Electrochemical Electrodes

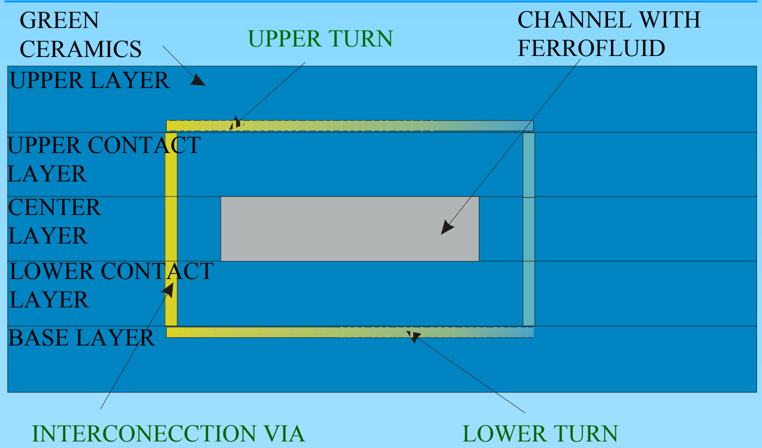
ATTITUDE SENSORS USING FERRO-FLUIDS



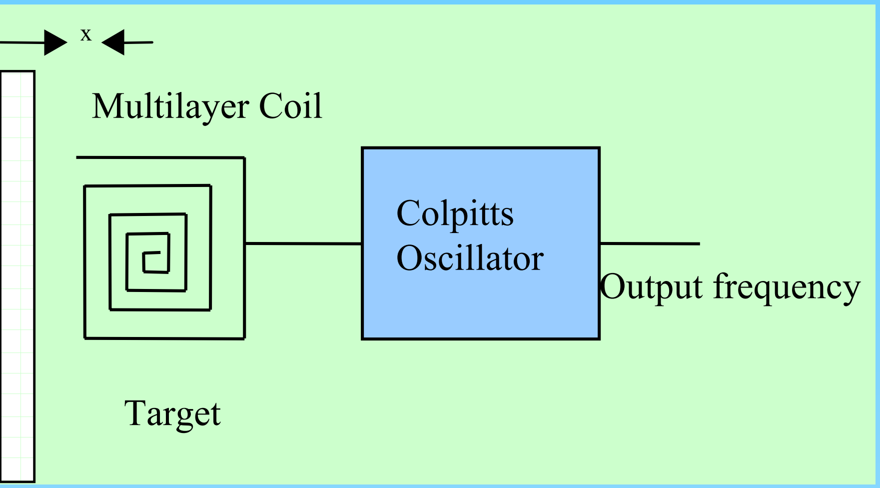
$$|v_1 - v_2| = cte \cdot \theta$$

Toroidal planar coil conception

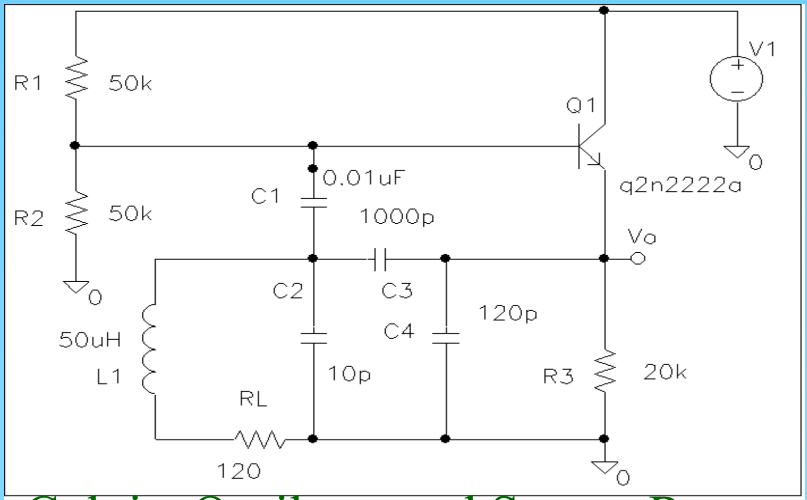




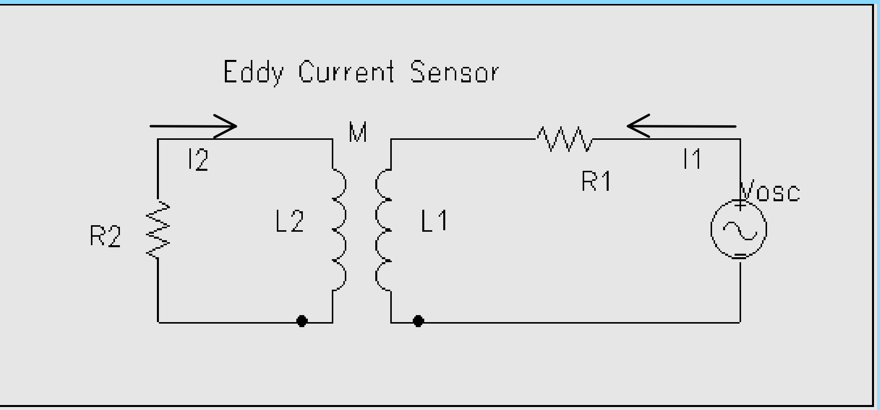
EDDY CURRENT PROXIMITY SENSOR



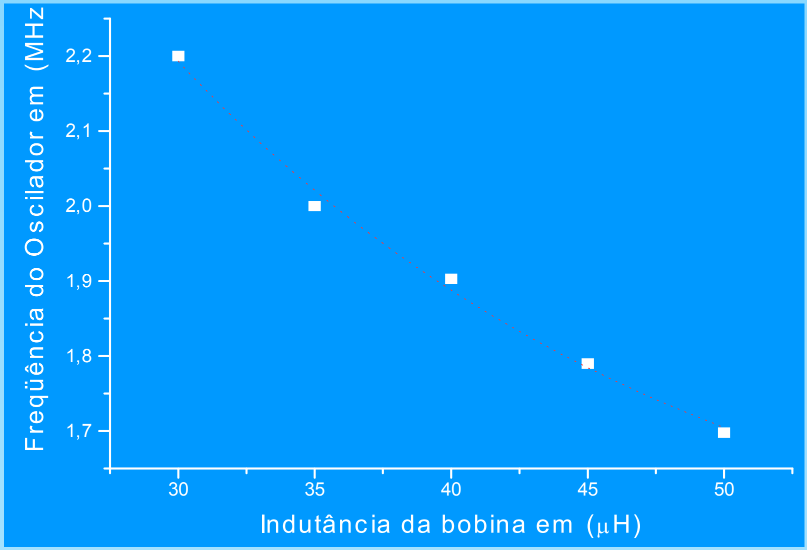
Block diagram of proximity sensor



Colpits Oscilator and Sensor Response

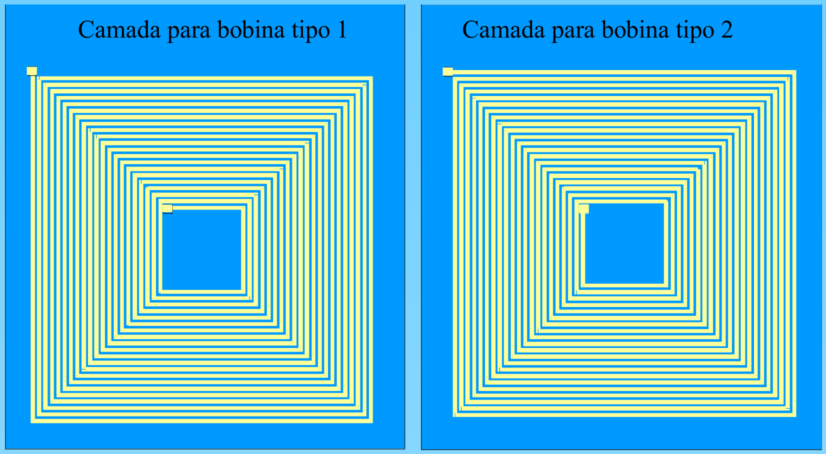


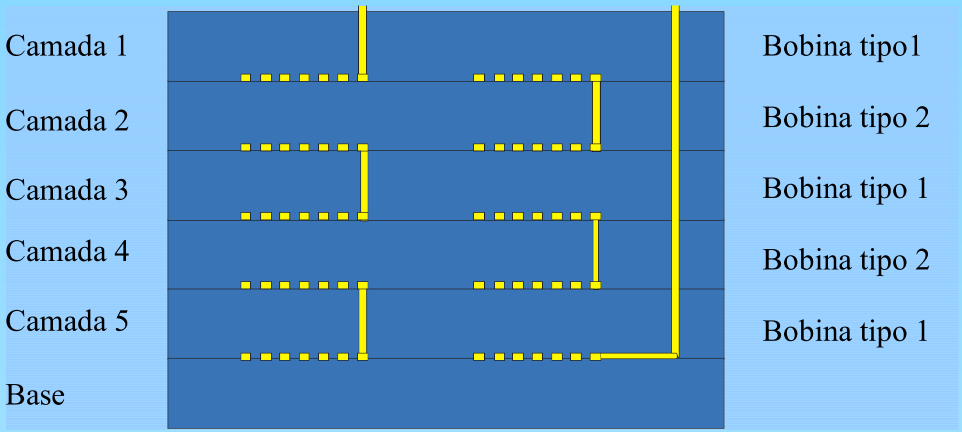
Equivalent circuit of proximity sensor



SENSOR IMPLEMENTATION USING MULTILAYER LTCC COIL

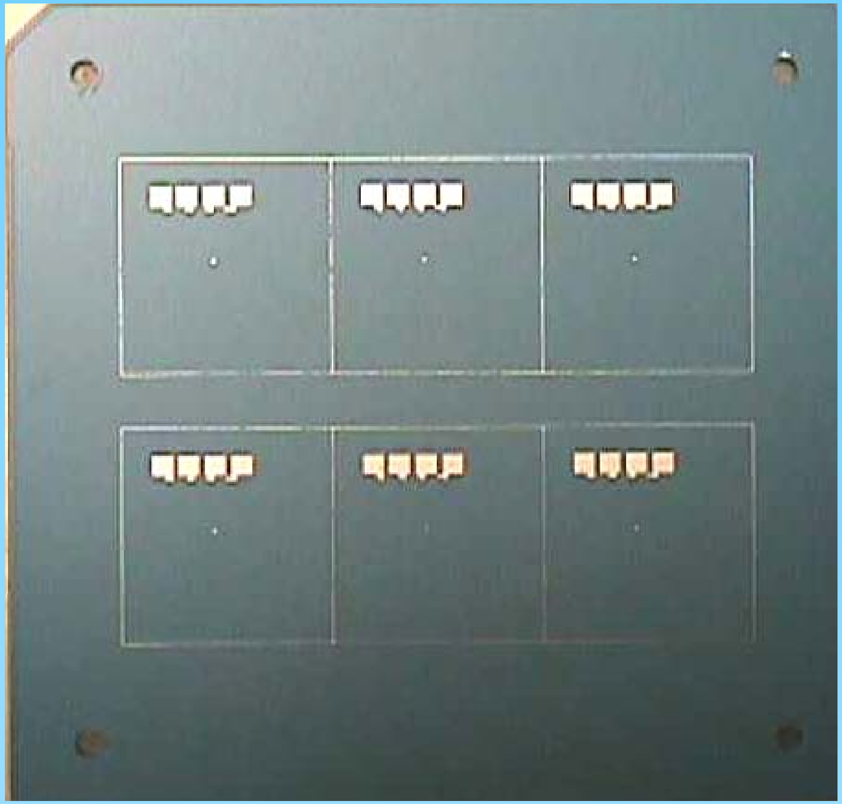
- Coil was fabricated using DuPont 6142D silver conductor paste, screen printed onto the ceramic tape.
- Film thickness of 10 µm, lines and spaces of 80 µm were achieved .
- Layers were connected with 250 µm in diameter screen printed silver vias of DuPont 6141D paste.





FABRICATED DEVICES

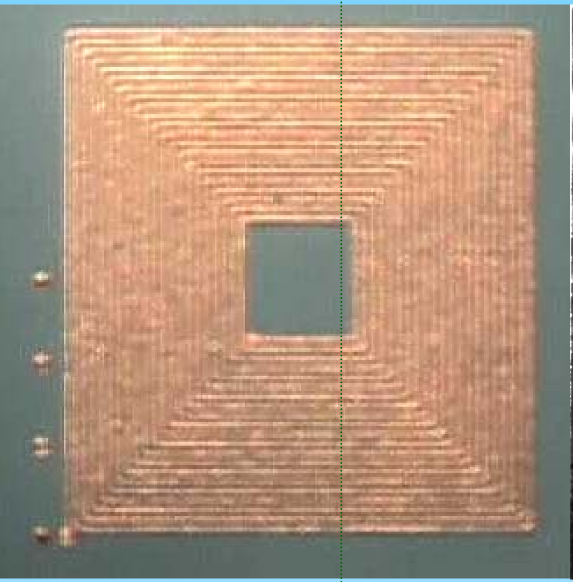
- A multilayer green tape coil was implemented adding encapsulating layers and top contact pads.
- A set of six coils was fabricated using 3” x 3” DuPont 951 green ceramic tapes

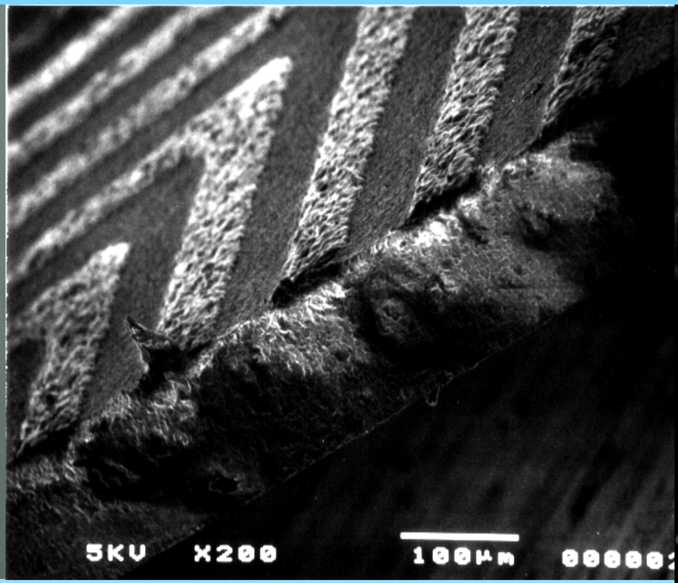


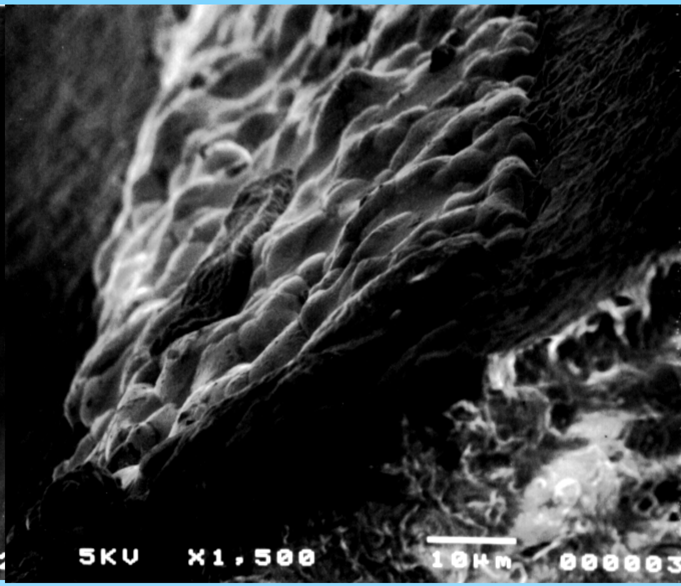
TYPICAL LAYER AND CONDUCTOR DETAILS

Single coil layer

Silver conductor details





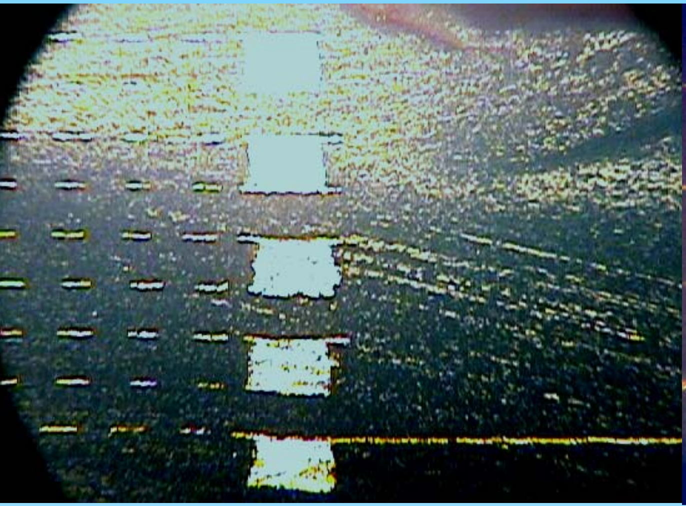


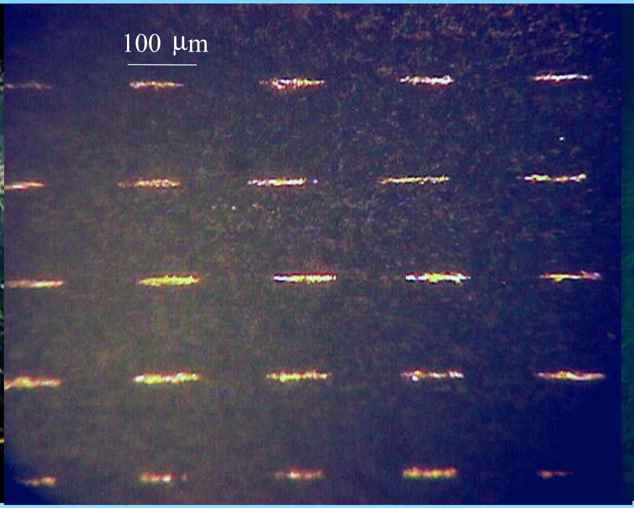
Cross Section A-A

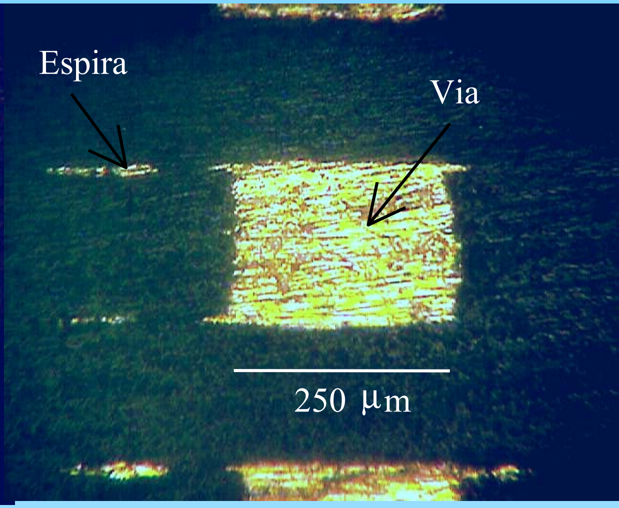
MULTILAYER COIL CROSS SECTION, TURNS AND VIA DETAILS

(A-A) Central cross section of coil

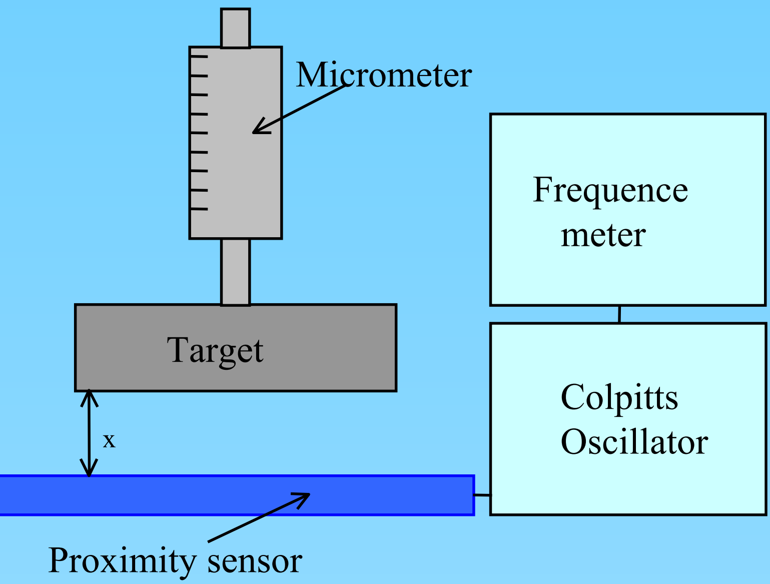
Turns and via details



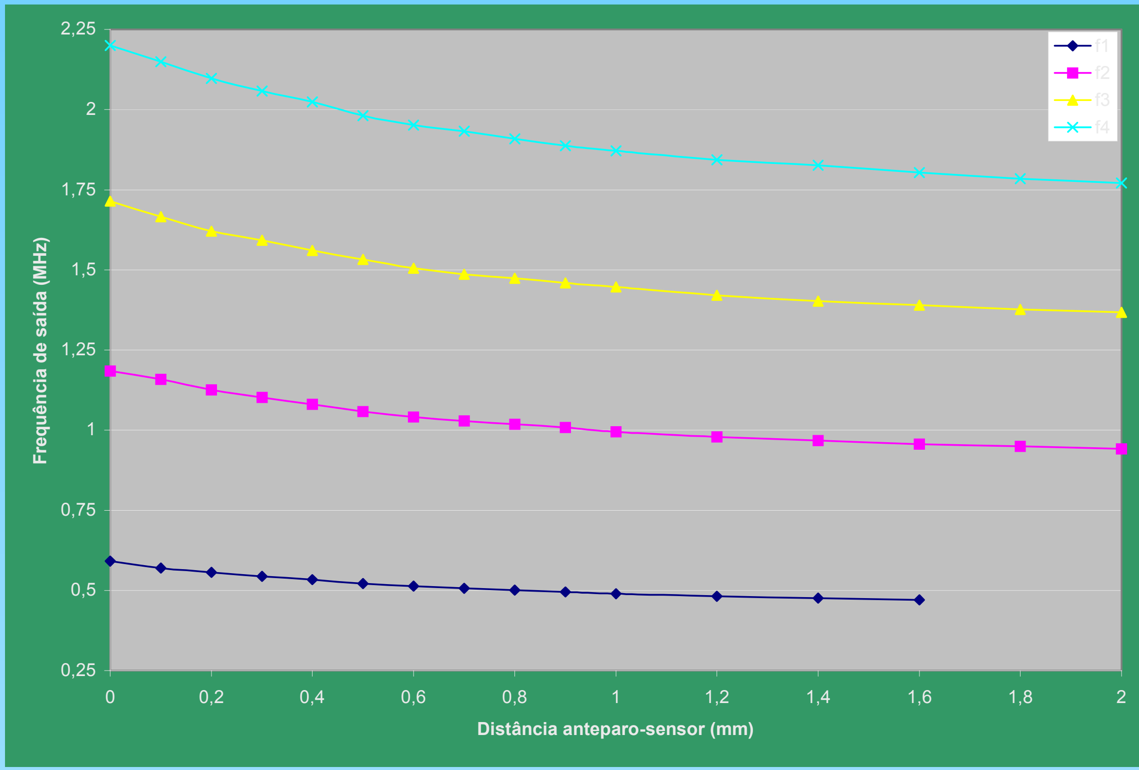




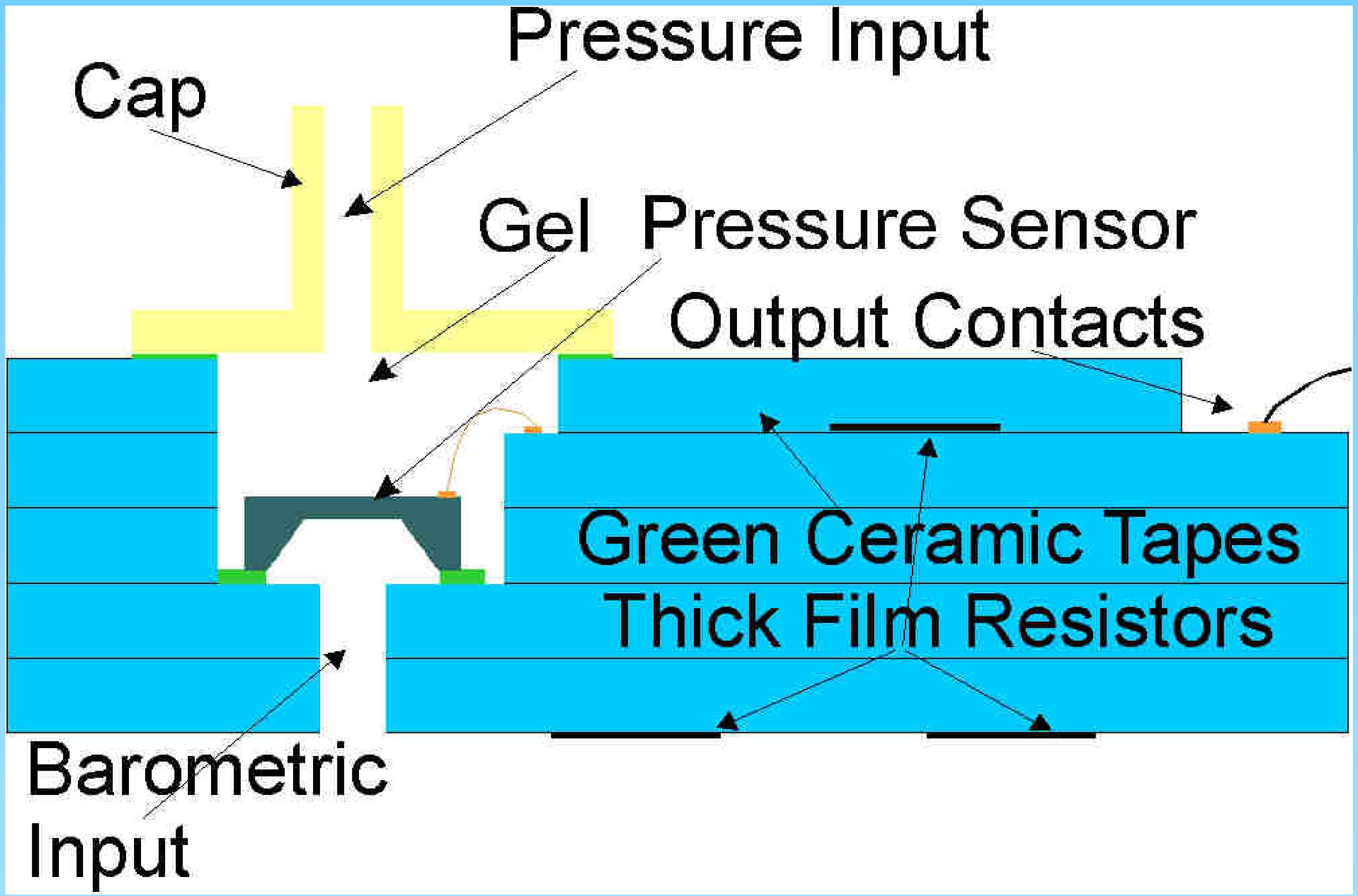
PROXIMITY SENSOR MECHANICAL CHARACTERIZATION



Experimental Set-up



LTCC HYBRID PRESSURE SENSOR

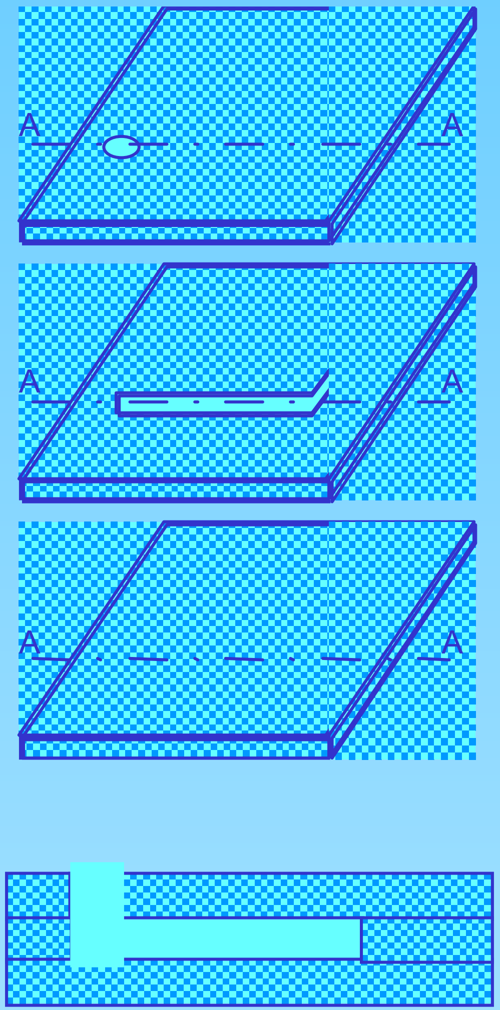


BASIC MICROFLUIDIC DEVICES

- Micro-channels;
- Critical Orifices, for passive flow control;
- Mixers;
- Hot plates;
- Liquid Cooling Devices.

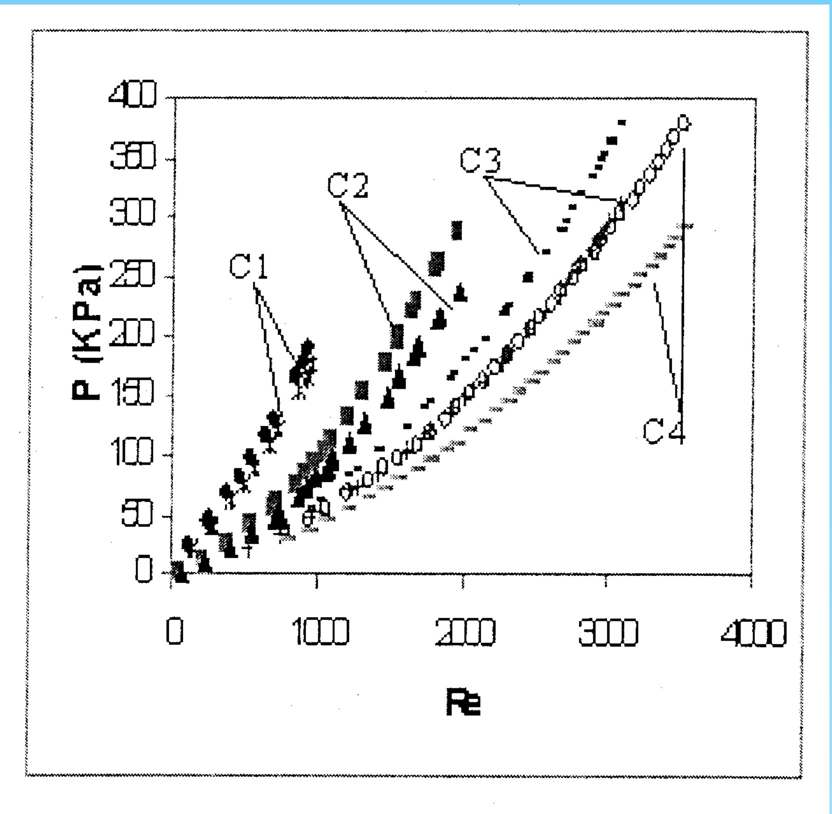
MICRO-CHANNELS

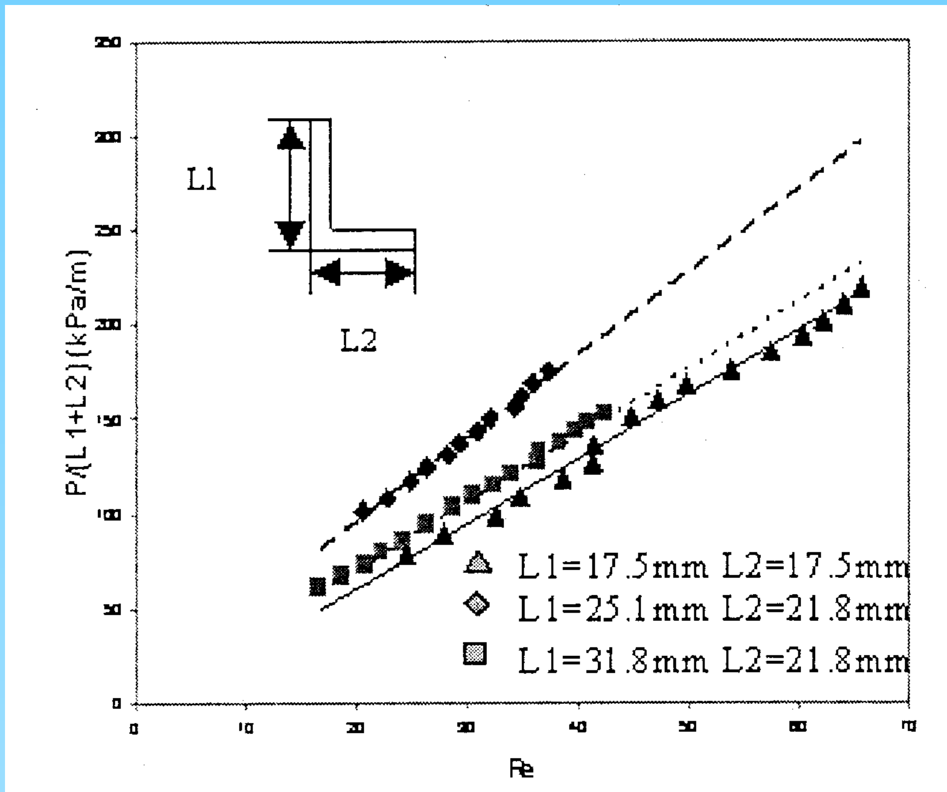
- Poiseuille equation relates linearly pressure drop with flow in reduced geometry channels.



Corte A-A

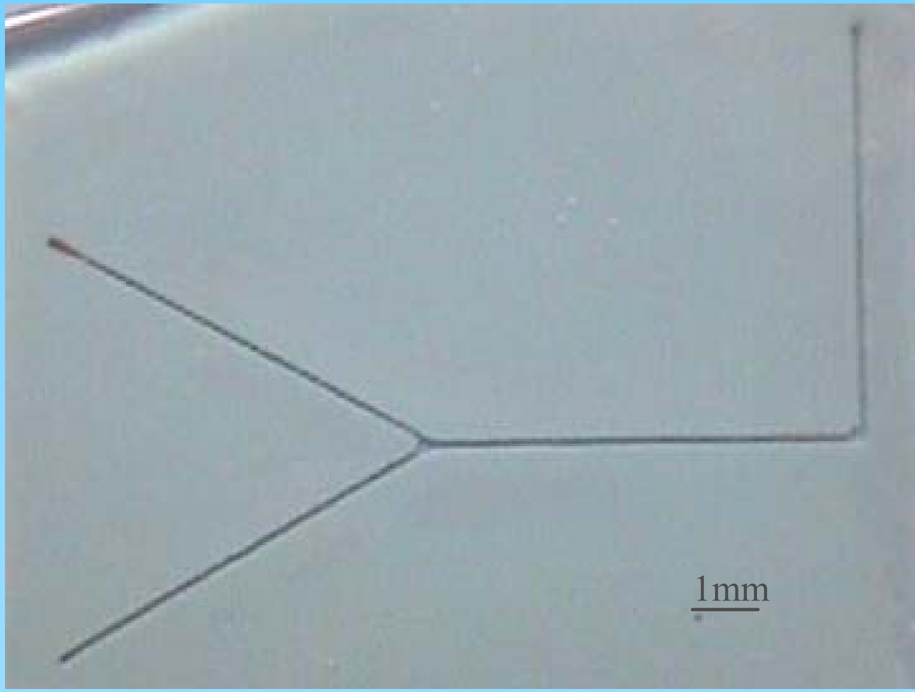
PRESSURE DROP VS. REYNOLDS NUMBER FOR STRAIGTH AND L CHANNELS



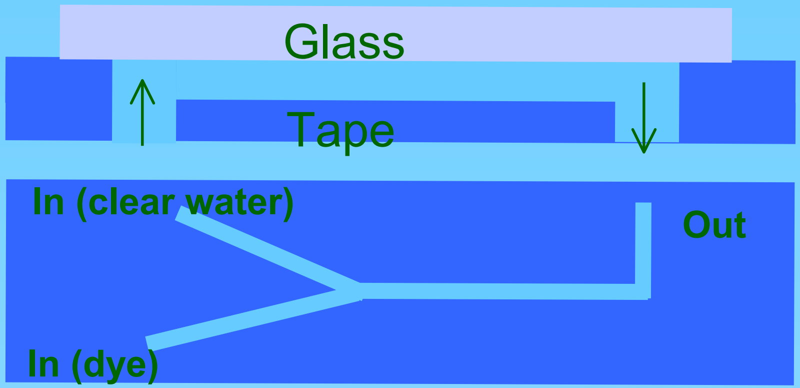


Y MICROCHANNEL FABRICATED USING GREEN TAPES AND GLASS.

- In Microchannels of minute dimensions Reynolds Number are very low, making difficult liquid mixing.
- Microchannel corners can be used as mixers



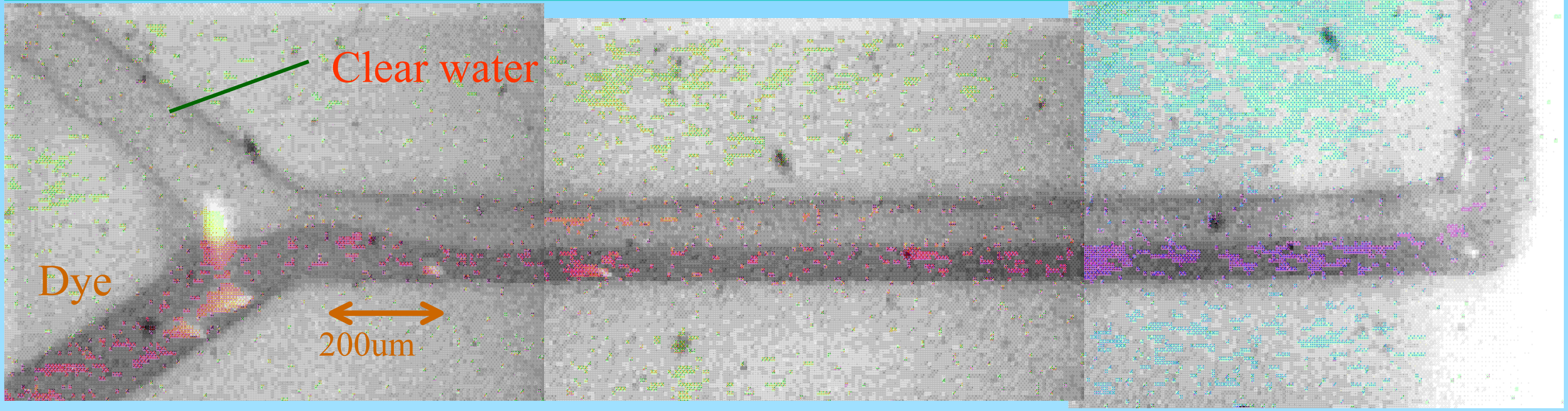
Visualization of the flow in Micro-channels Fabricated in Ceramic Tapes



Schematic (side view)

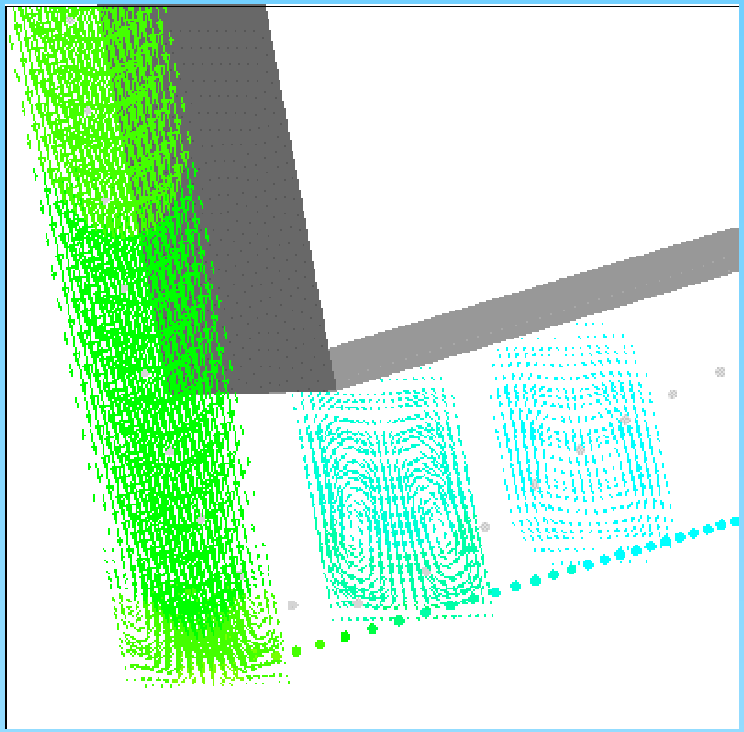
Schematic (top view)

Channel cross-section: 200µm×200µm   Re≈30



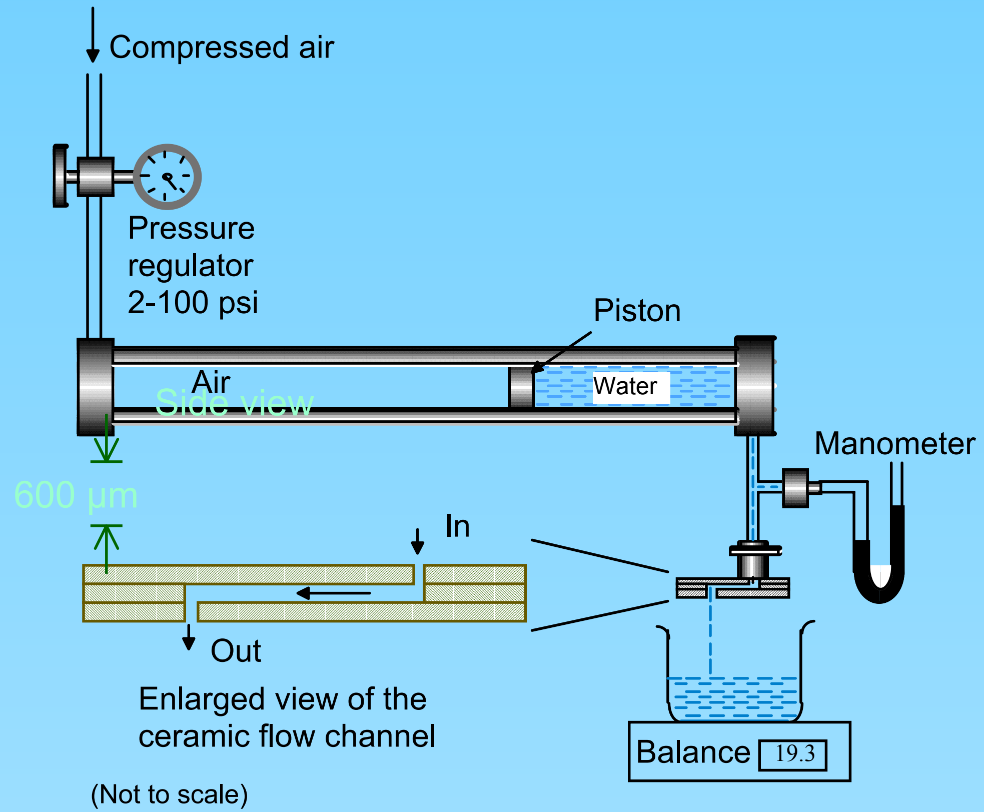
Flow Modeling and Measurements

in Micro Channels made in Ceramic Tapes



Velocity field of the flow around a corner
Re = 80; square cross section.

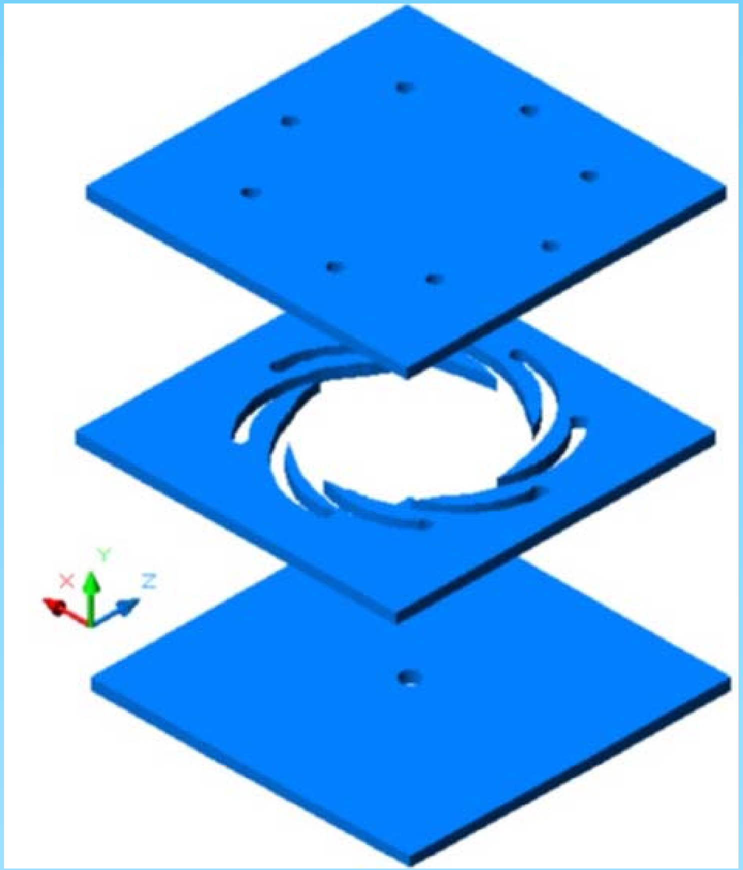
Flow in a L-shaped channel



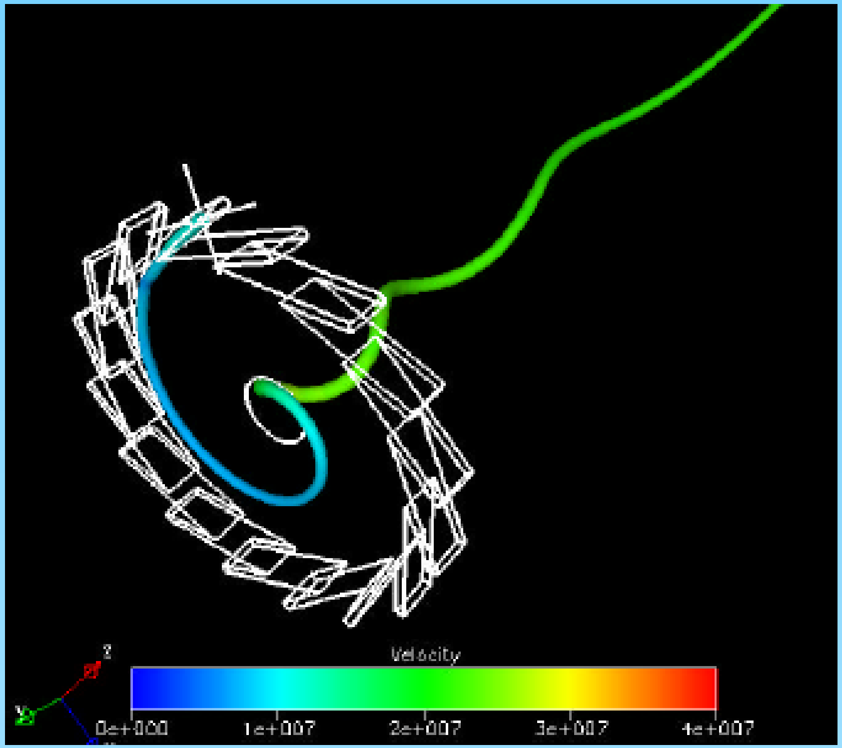
The experimental setup

LTCC VORTEX MIXER

LTCC Layer



Streamline Simulation

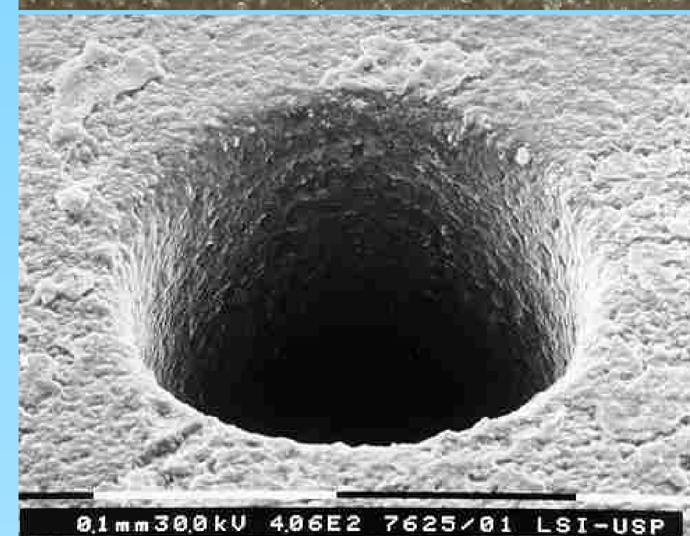


CRITICAL ORIFICES FABRICATED

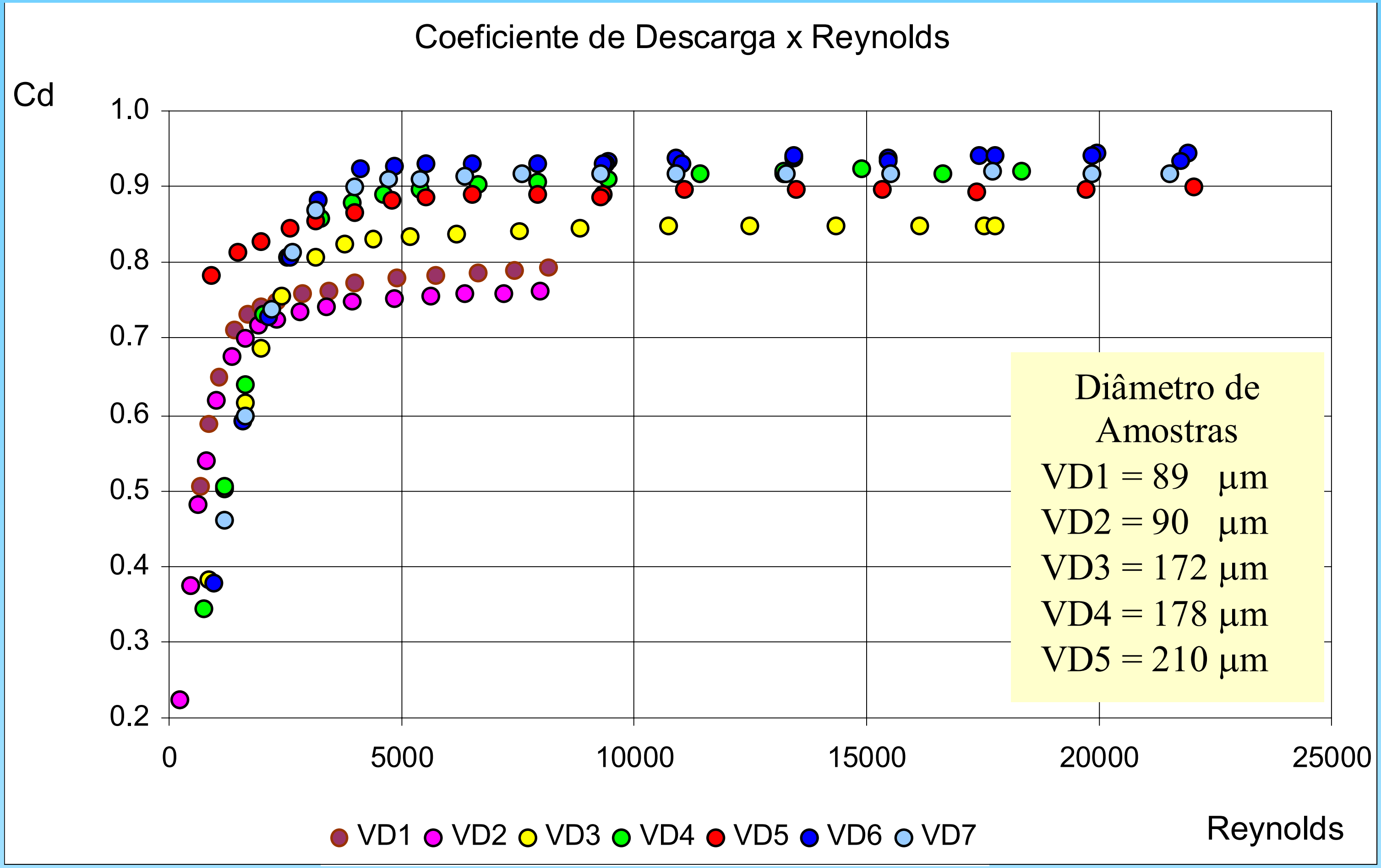
- Mass flow $\dot{m}$ in practical conditions can be expressed by:

$$\dot{m} = C_d \dot{m}_{ideal} = C_d C_* A_* \frac{P_o}{\sqrt{R_g T_o}}$$

- A*=Cross section
- To= Stagnation Temperature
- Po=Stagnation Pressure
- Rg=Gas Constant
- C*=Critical flow function
- Cd= Discharge coefficient

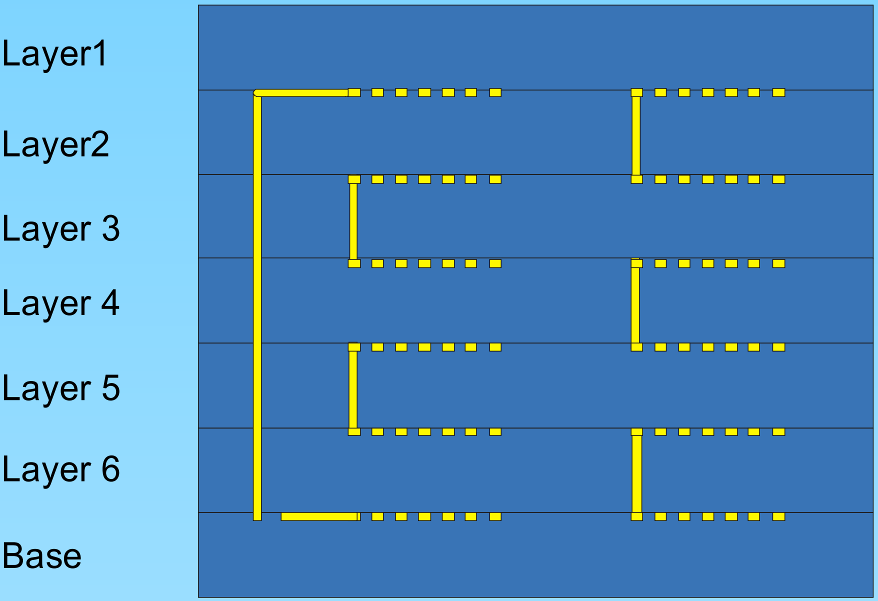


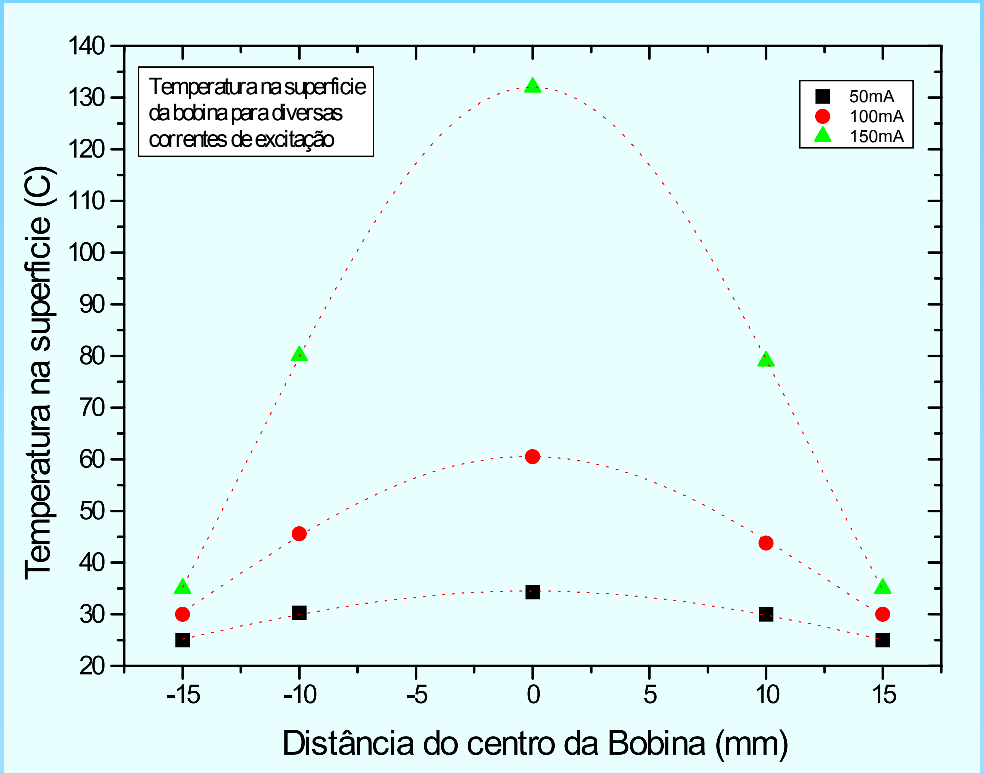
DISCHARGE COEFFICIENT VS. REYNOLDS NUMBER FOR CERAMIC CRITICAL ORIFICES



HOT PLATES

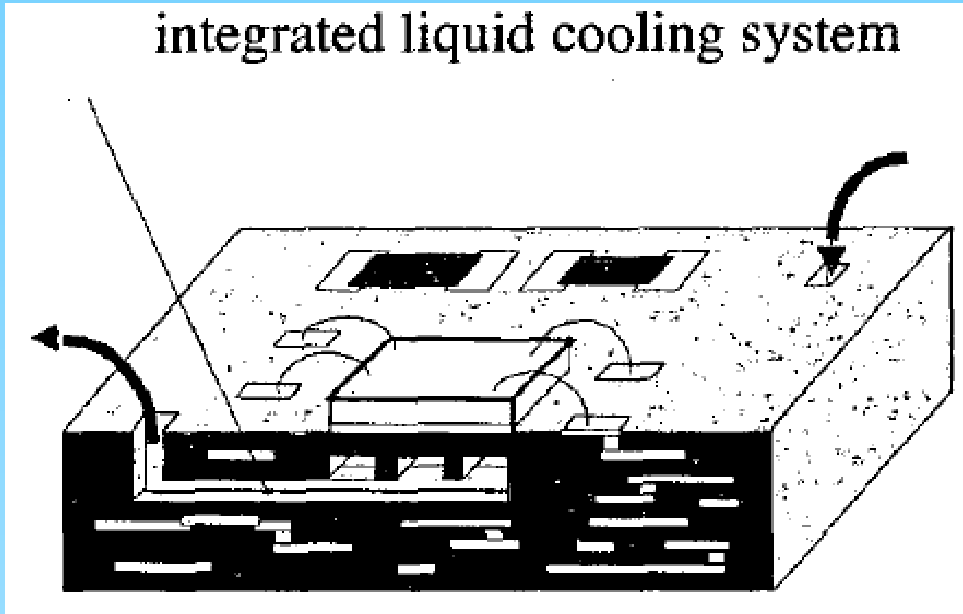
- With few layers it is possible to get a simple hot plate.
- Surface heating Vs. current in hot plate





LIQUID COOLING SYSTEMS

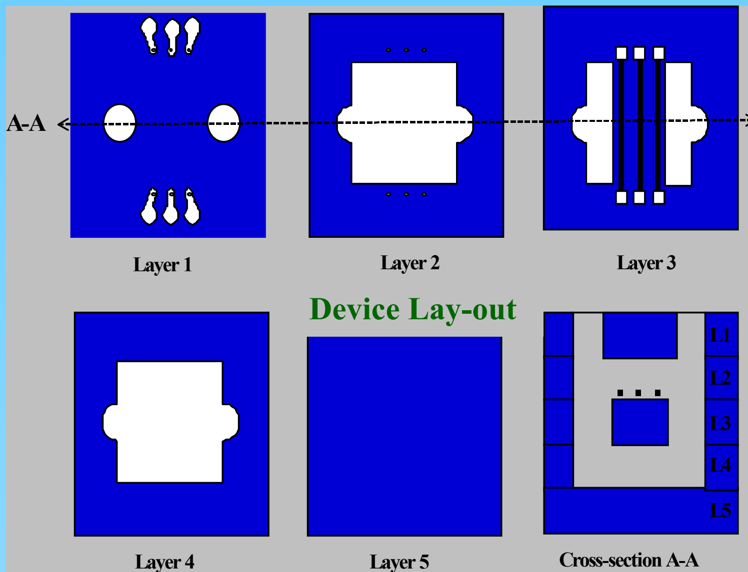
- Thermal management is an important problem in electronic packaging.
- LTCC thermal vias and microchannels can deliver liquid cooling systems with thermal dissipation of up to 50 W/cm^2



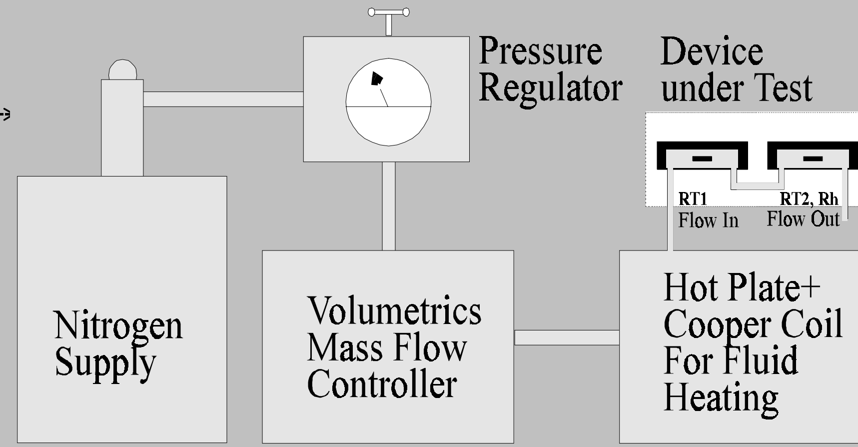
THERMAL FLOW SENSOR WITH GREEN CERAMIC TAPES

- Thermal methods display some advantages for implementing flow sensors as:
  - **Thermal isolation between structure and support;**
  - **Low thermal capacity improving response times;**
  - **Small dimension devices;**
  - **Integration in a micro-system or MEMS scheme.**

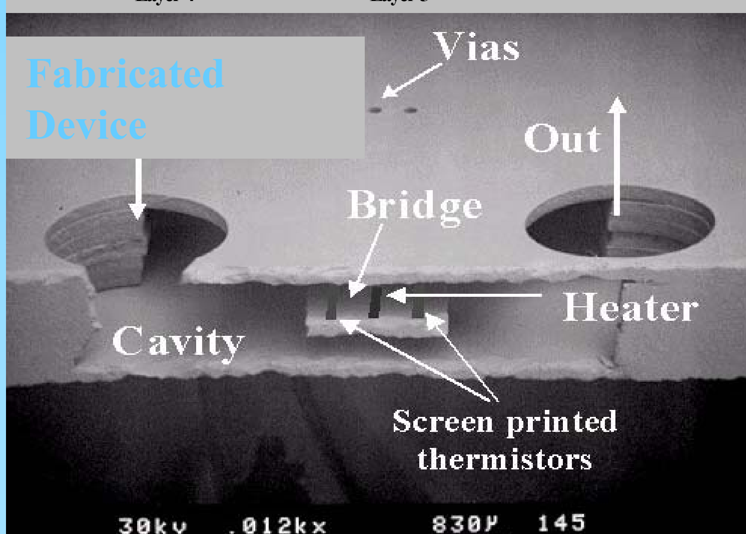
LTCC FLOW SENSORS

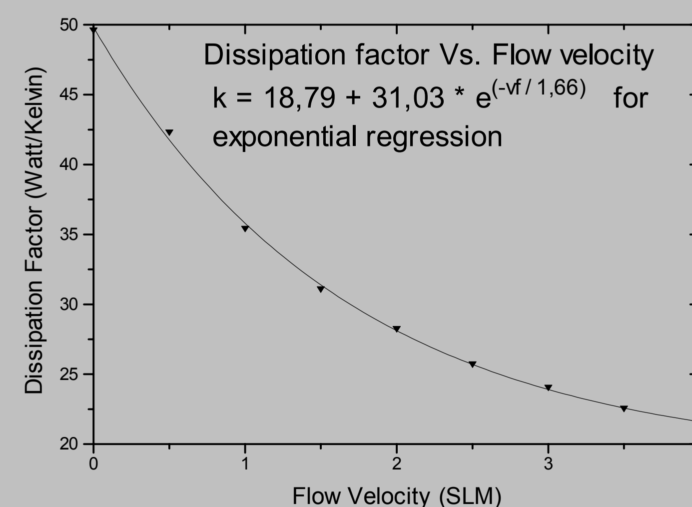


Device Lay-out

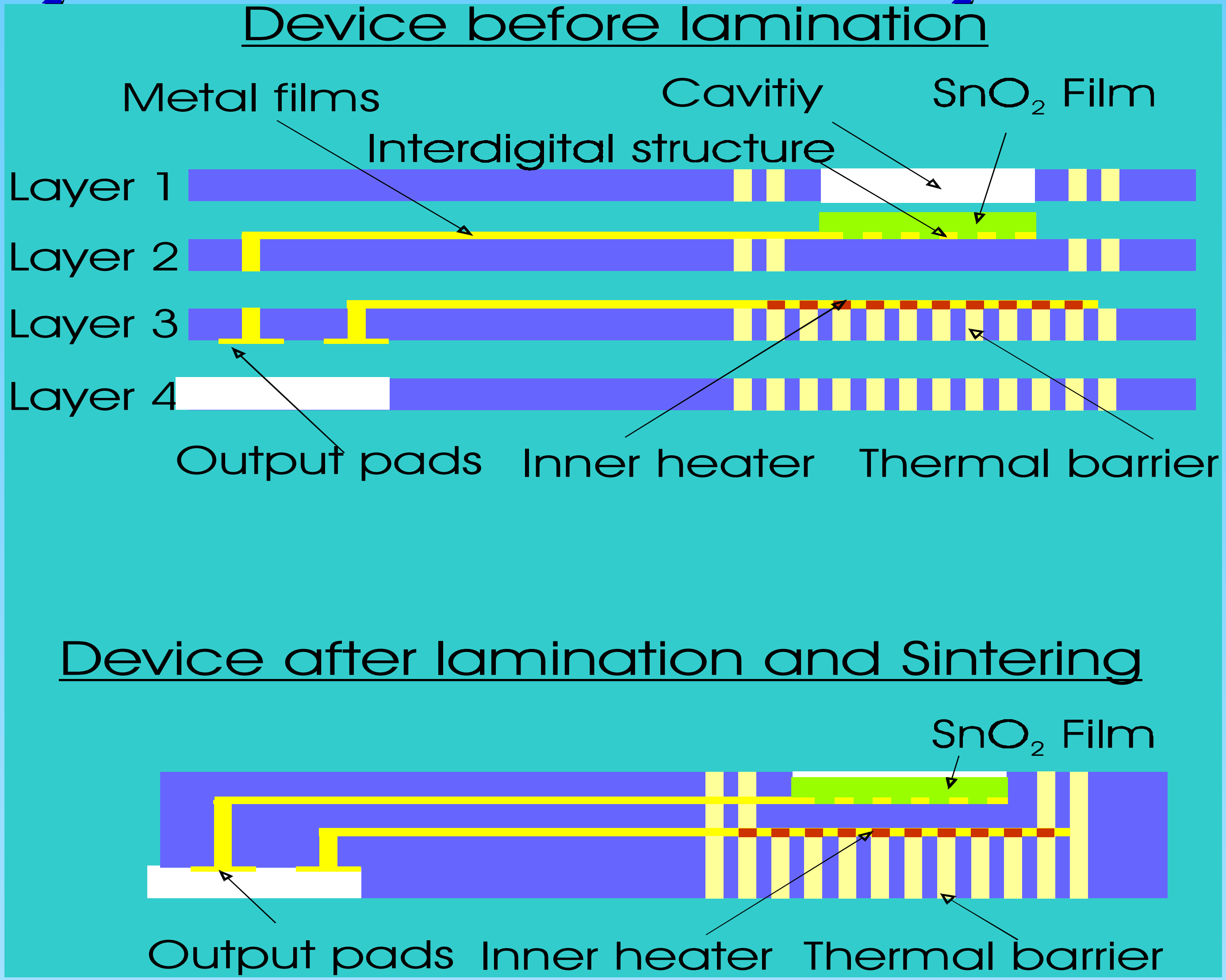


Experimental Set-Up



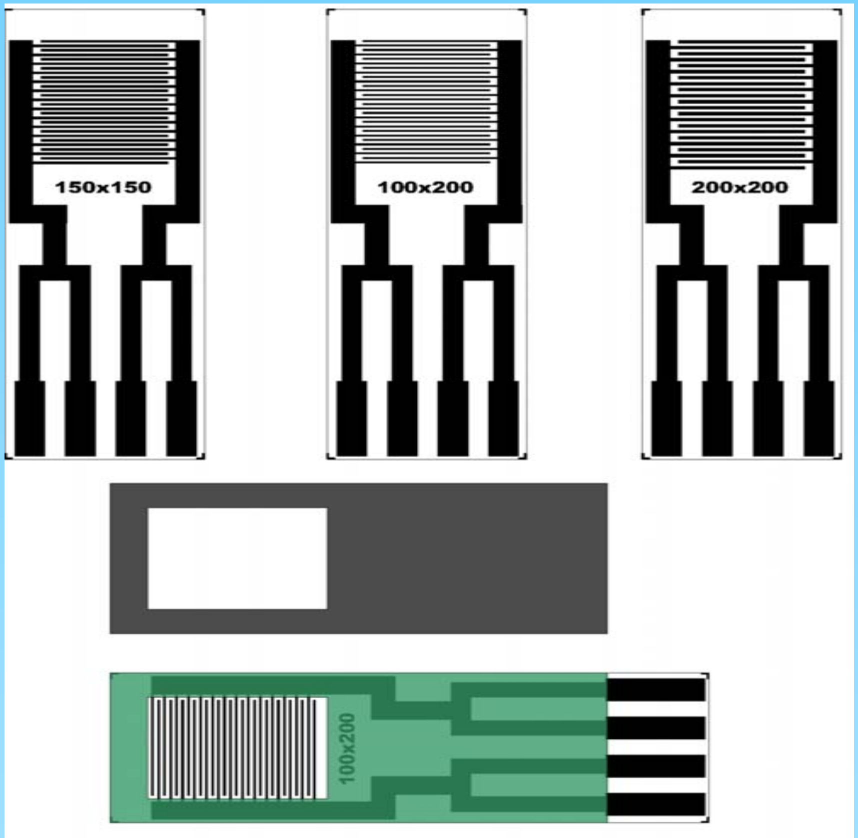


SNO_2 SENSORS FOR CO AND CO_2 DETECTION

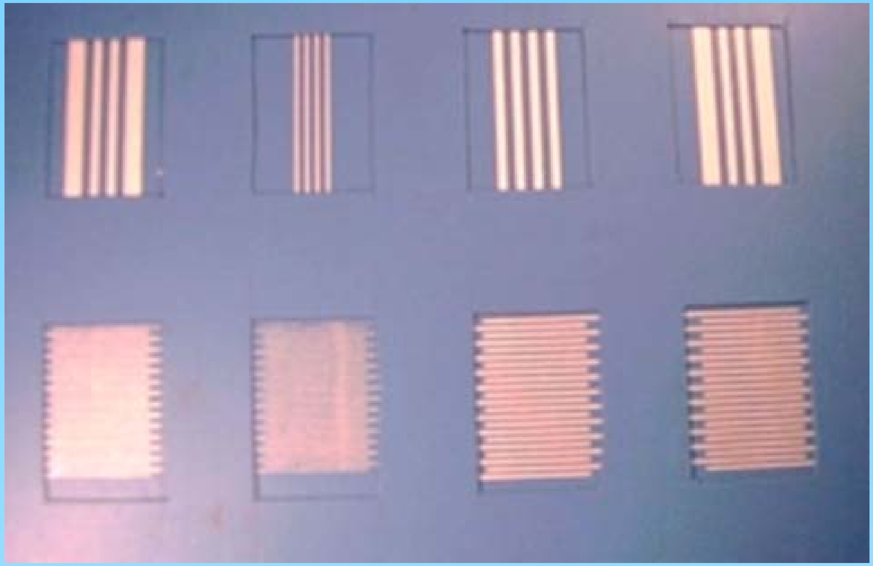


CONDUCTIVITY SENSORS

INTERDIGITAL ELECTRODES

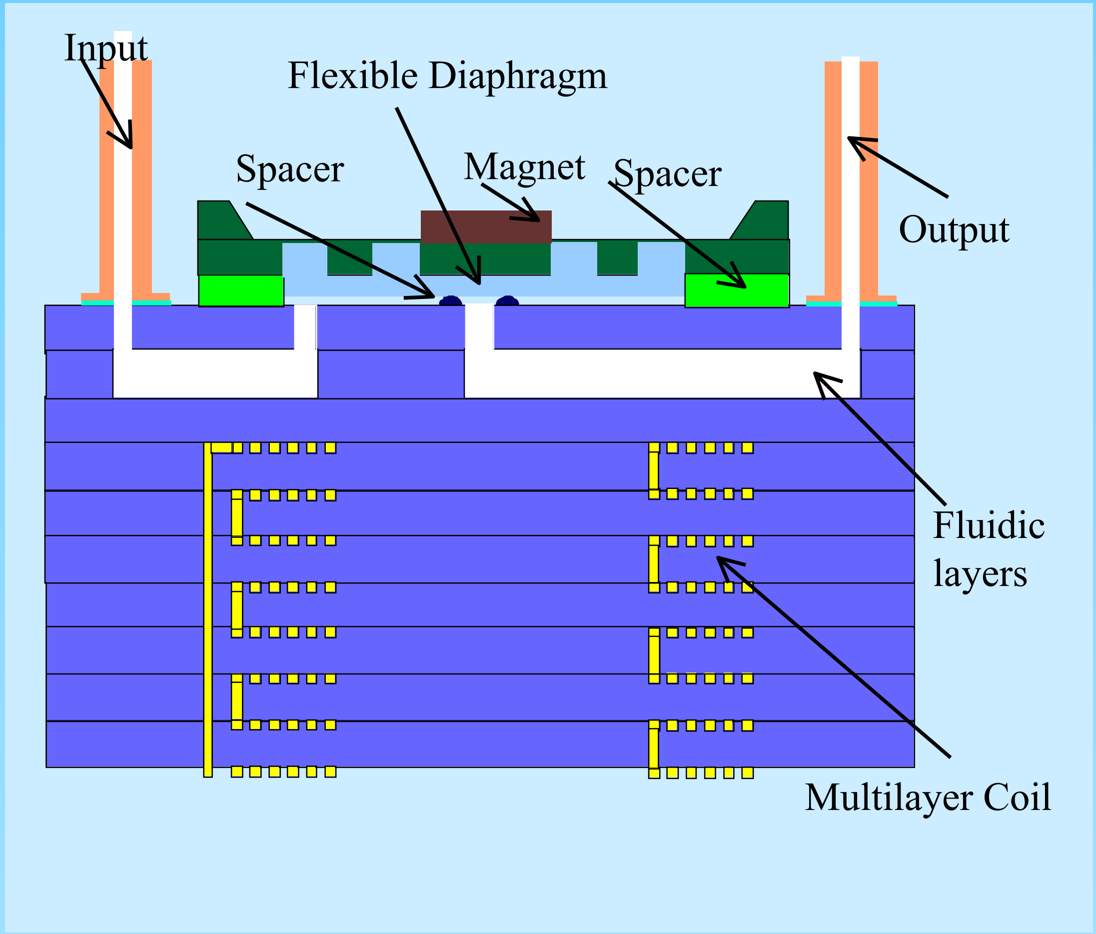


FABRICATED DEVICES



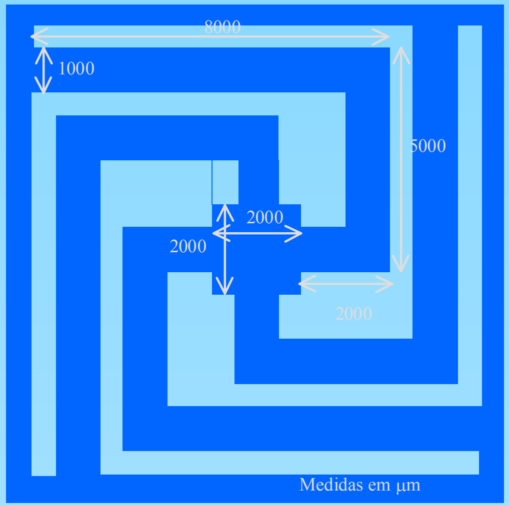
ELECTROMAGNETIC MICROVALVE

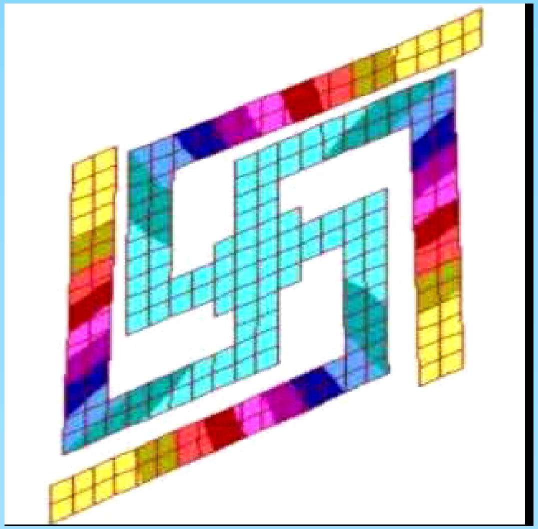
- The device was implemented using the fabricated coil laminated together with a fluidic subsystem and adding (bond or laminate) a Flexible Diaphragm with a permanent magnet.

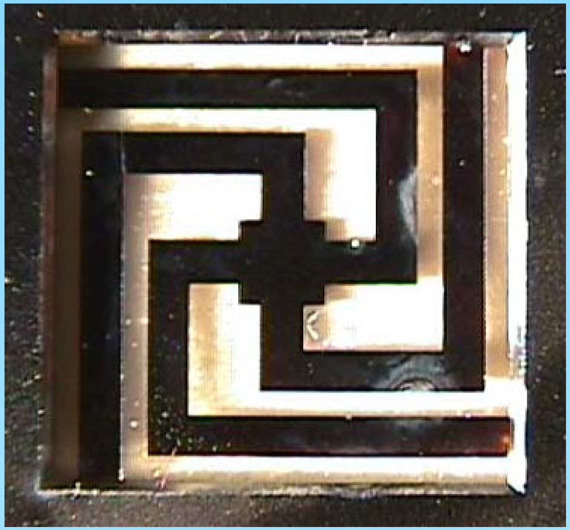


MICROVALVE ELASTIC ELEMENT

- Square Spiral Spring adopted for a Silicon implementation .
- Using other materials as Green Tapes and photo-formable tapes allow us to use other geometries (circular spiral or labyrinth)
- COSMOS output for square spiral spring deflection, for forces of 0,1 kgF applied at spring center, for a 8000 µm leg width and 100 µm thickness.
- View of fabricated Si/Siloxane flexible diaphragm using modified process

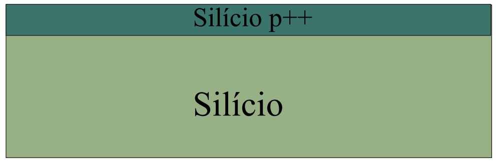




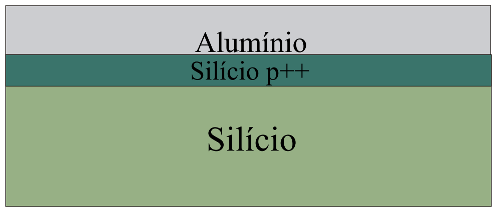


FLEXIBLE DIAPHRAGM FABRICATION METHOD

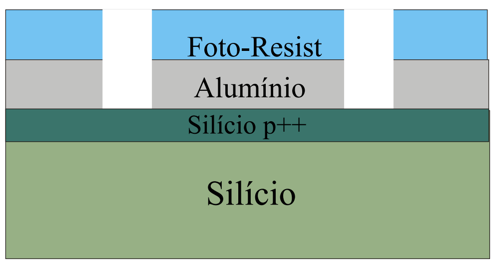
Spring Thickness definition



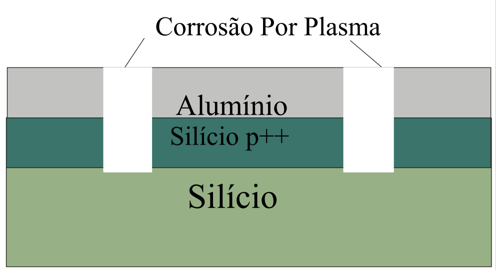
Al Masking



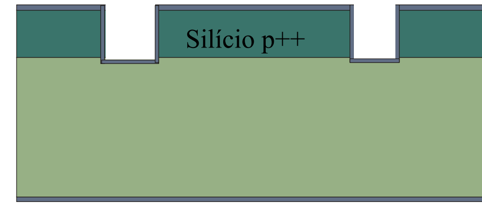
Spring geometry definition



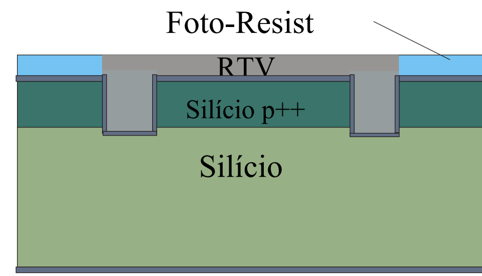
Plasma etching



Silicon nitride deposition

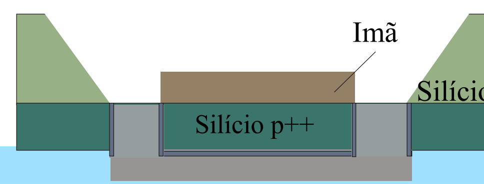


Definition of area for RTV dipping



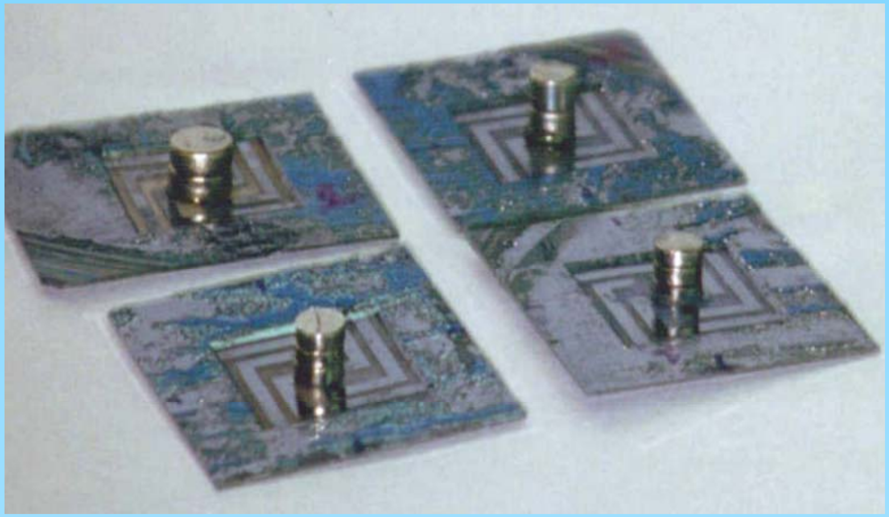
Anisotropic etching for diaphragm release

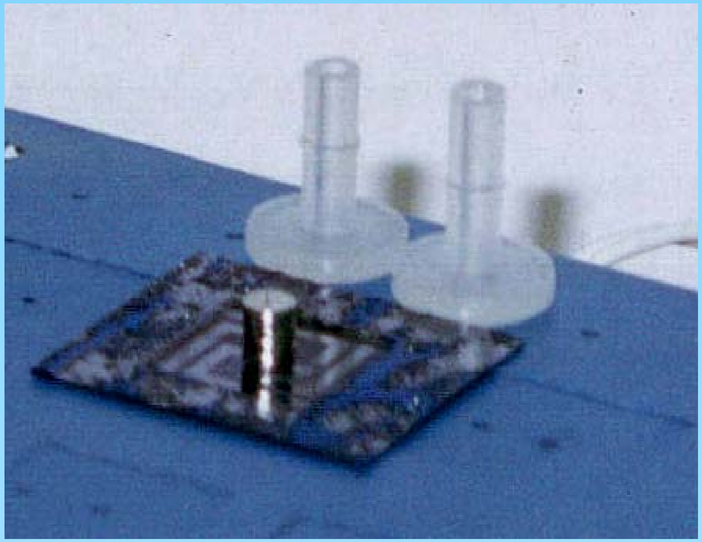
Magnet bonding



Normally Closed Microvalve

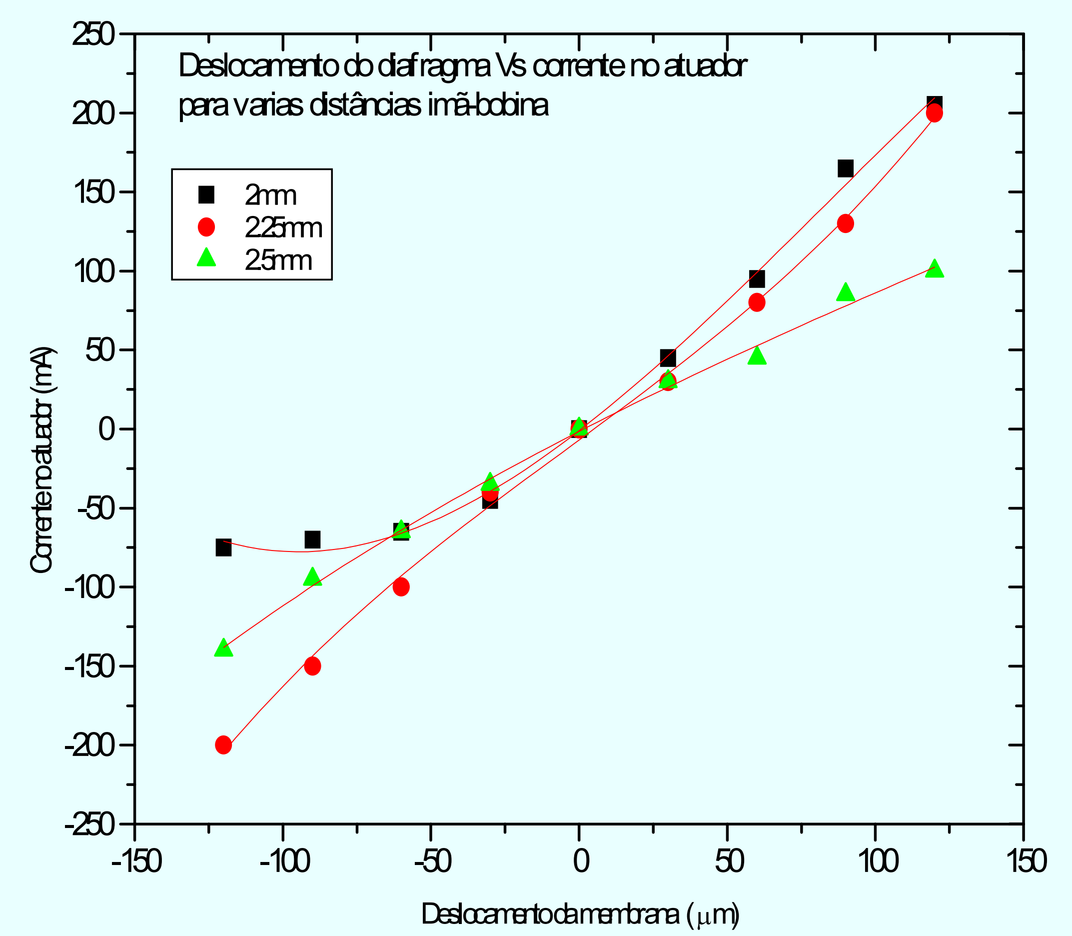
- Flexible Silicon/Siloxane flexible diaphragms with magnets and Microvalve after fabrication steps.
- Several devices can be acomplished in the same substrate.





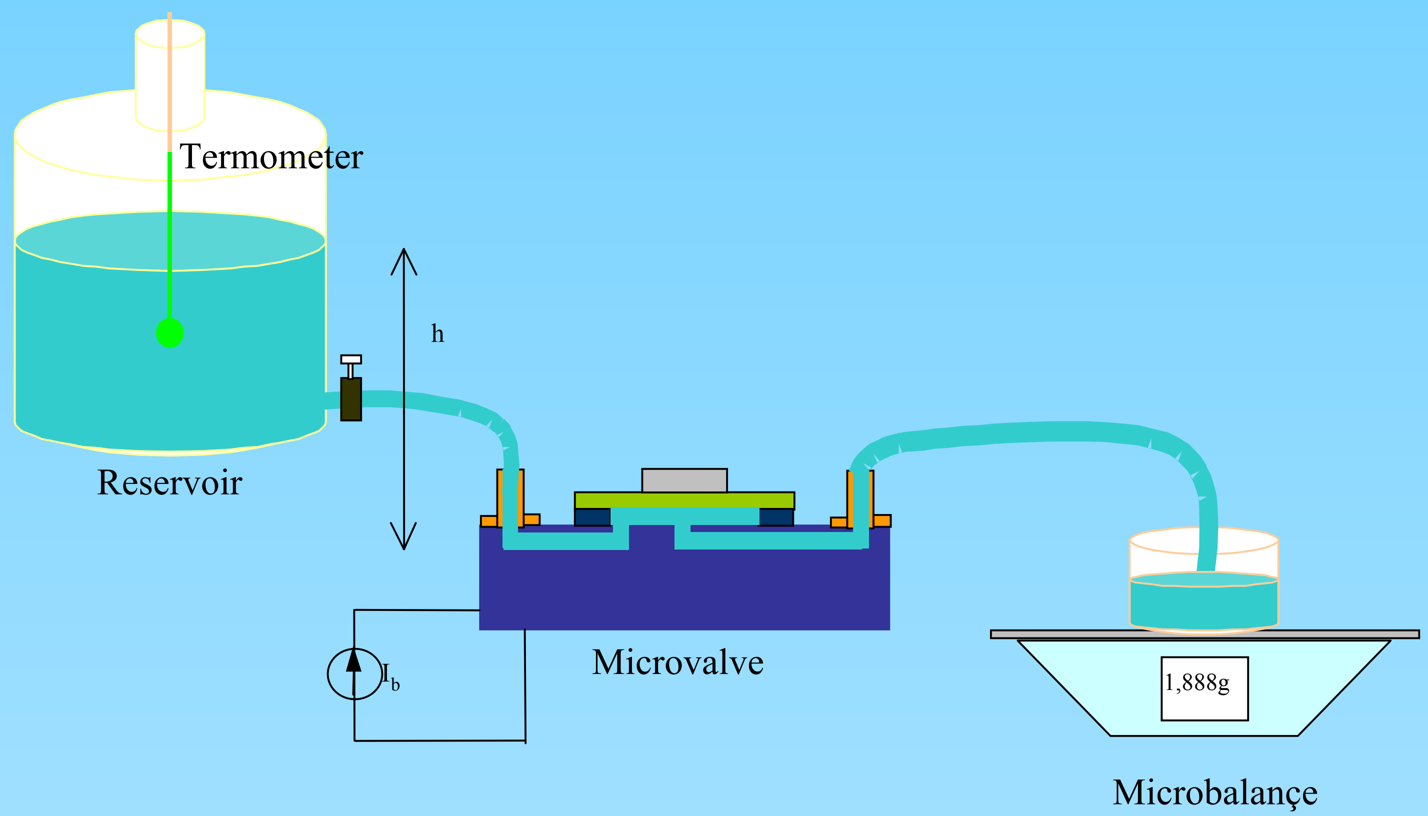
Diaphragm displacement

- Displacement of diaphragm Vs. Coil current for a magnet of 870 Gauss.



MICROVALVE FLOW EXPERIMENTAL SET-UP

- Experimental set-up for Flow Vs. Pressure input in microvalve



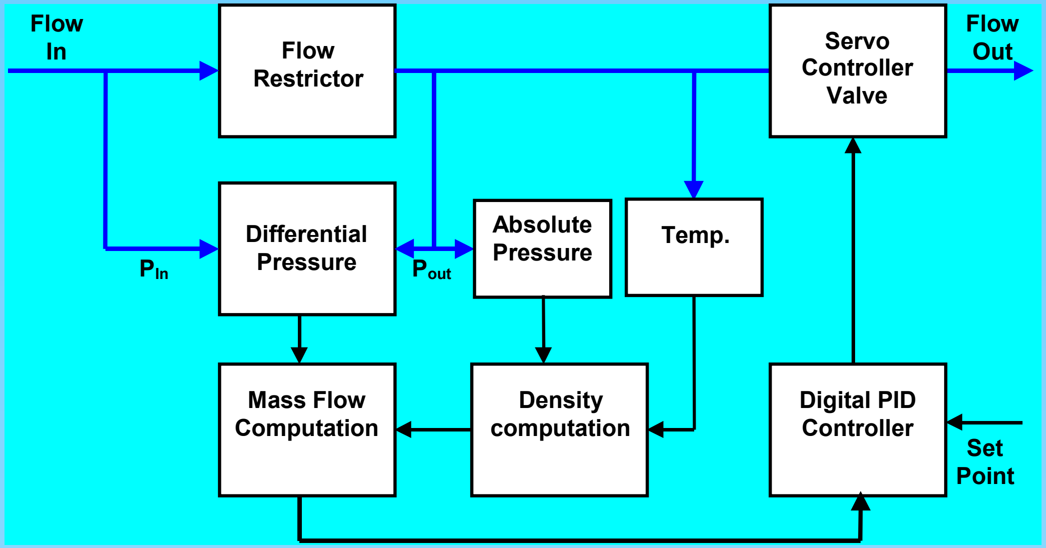
LTCC APPLICATIONS ON MESO-SYSTEMS

- One of the important features of green tape technology is the possibility of fabricating three-dimensional structures using multiple layers.
- Several devices were demonstrated using LTCC technology :
    - **PROXIMITY SENSORS;**
    - **PRESSURE SENSORS**
    - **FLOW SENSORS;**
    - **PASSIVE FLOW CONTROL DEVICES;**
    - **FLUIDIC DEVICES;**
    - **E.M. MICROVALVE.**

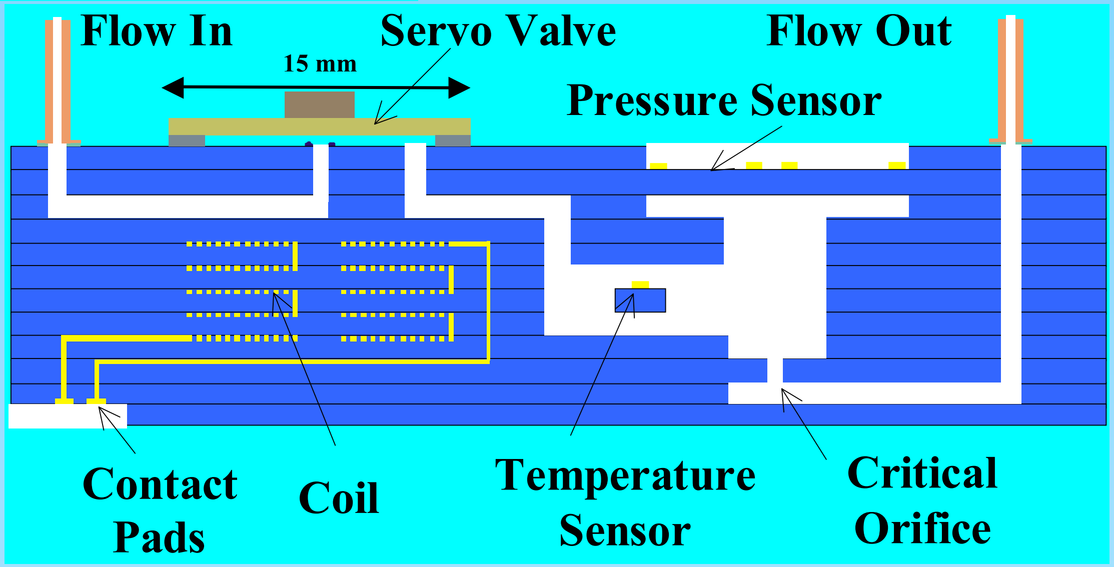
SOME PROPOSED MESO-SYSTEMS

- Using LTCC hybrid technology we can immediately implement several key meso-systems:
  - **Drug delivery meso- system;**
  - **Mass Flow control meso-system;**
  - **Fluid Injection Analysis meso-system.**

LTCC MASS FLOW CONTROLLER



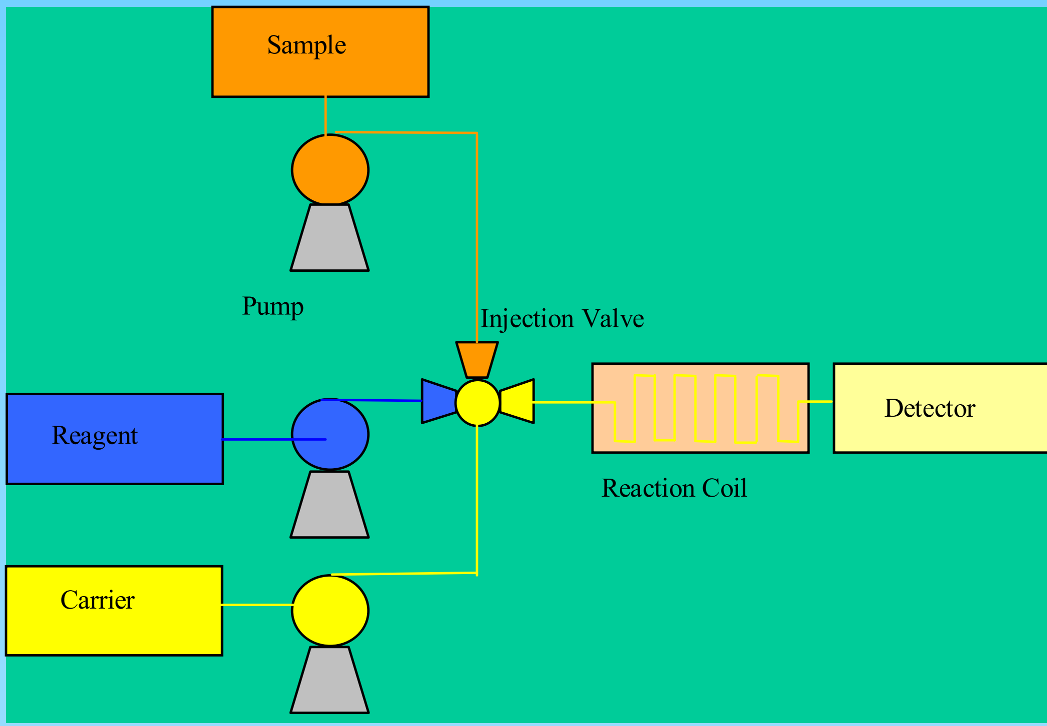
Typical Mass Flow Controller Block Diagram



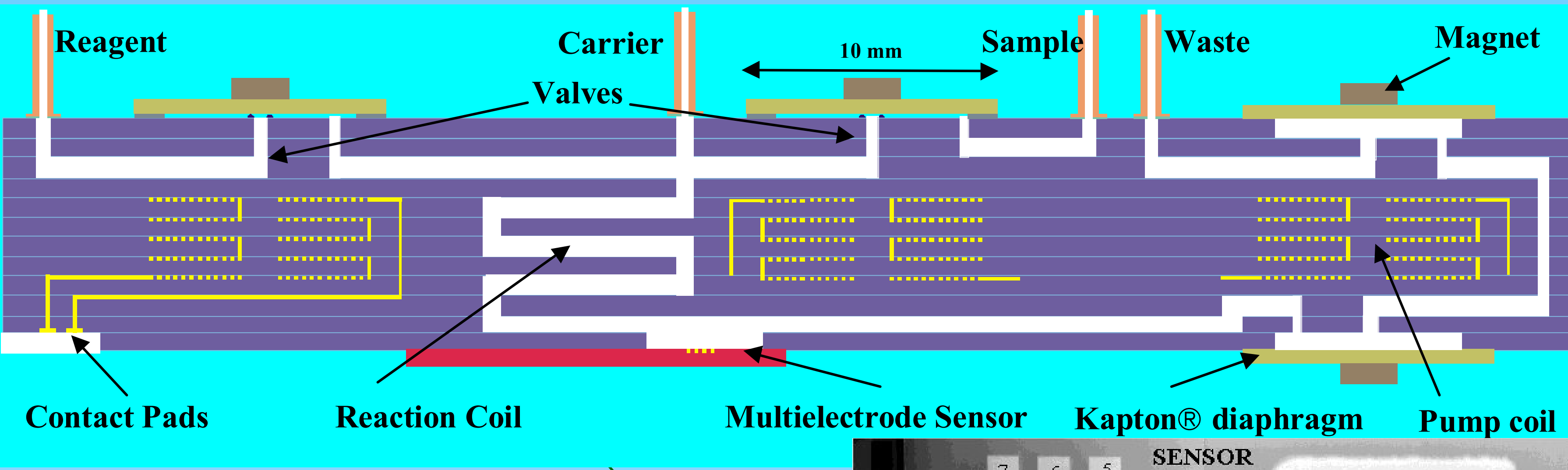
LTCC Mass Flow Controller Conception

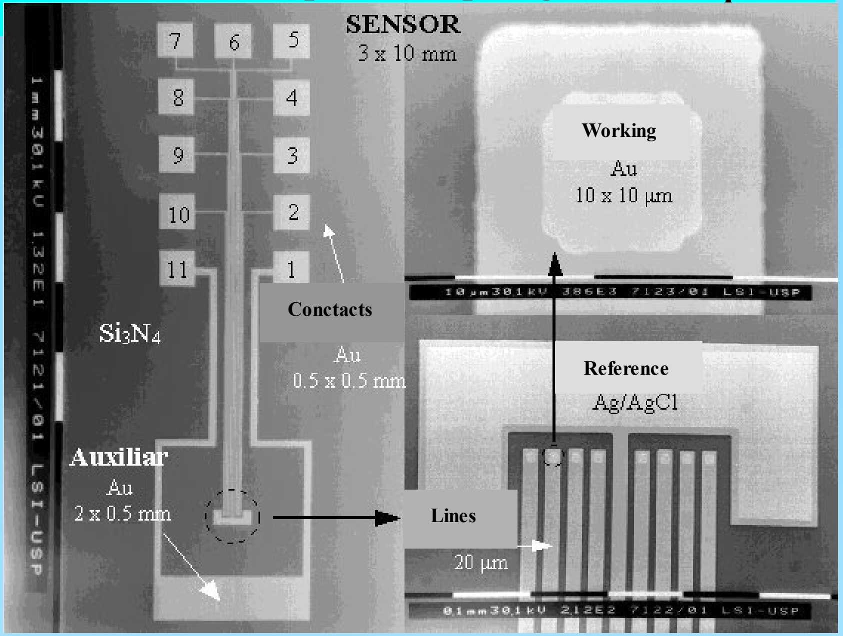
BASIC FIA SCHEME

- FIA miniaturization is interesting due to several advantages:
  - **Sensor can have its sensibility and selectivity optimized;**
  - **Time for analysis is 10 to100 s, allowing up to 300 analysis/hour;**
  - **Waste and sample size are minimized;**
  - **System performance is enhanced.**



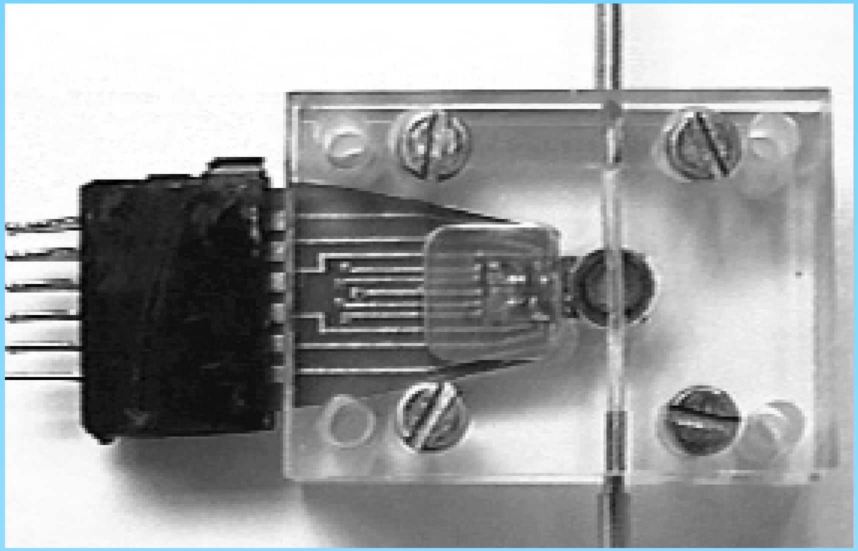
PROPOSED FIA HYBRID LTCC MESO-SYSTEM

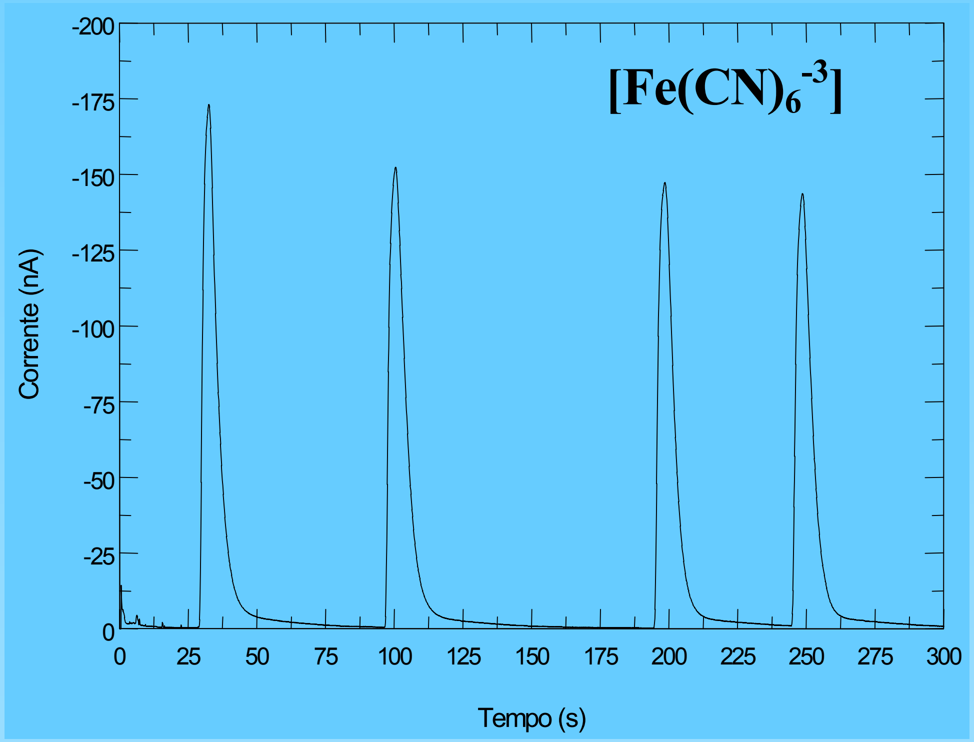




Silicon multi-electrode sensor

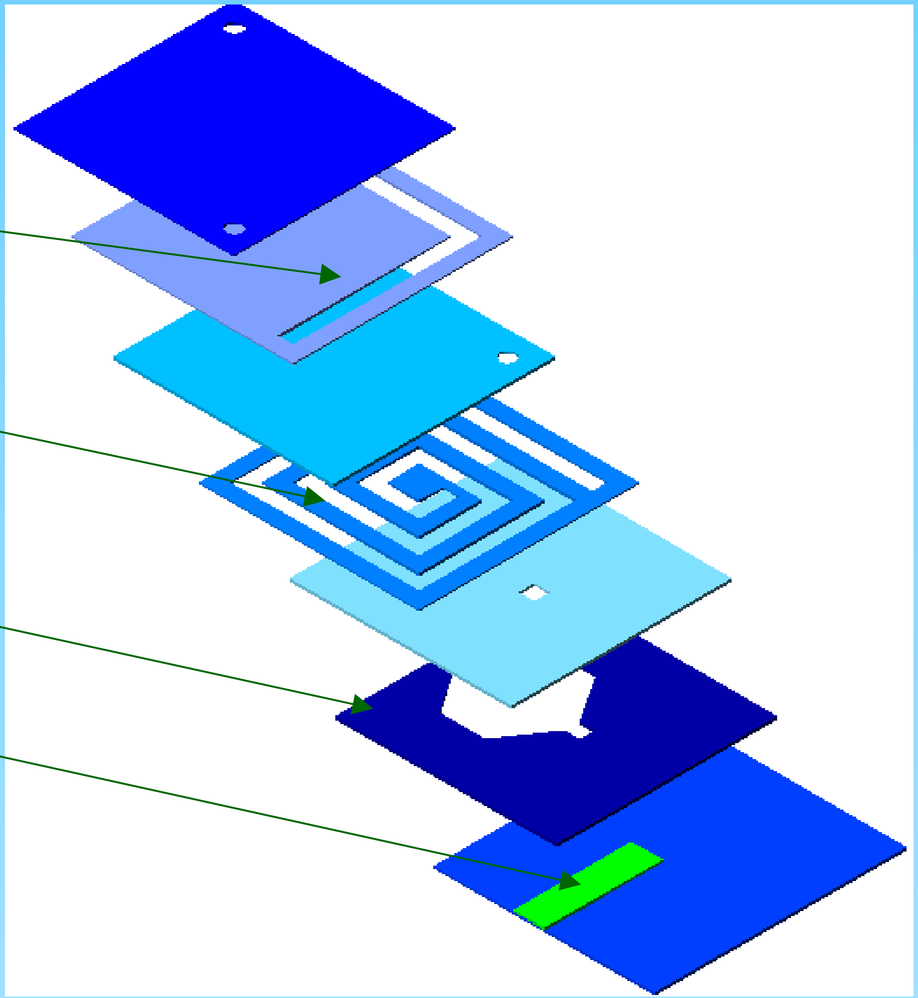
Actual FIA tests





LTCC FIA Manifold

- Manifold Layers
  - Input Layer
  - Merging Layer
  - Fluid Via
  - Spiral Mixer
  - Fluid Via
  - Sensing Cavity
  - Sensor
  - Base



CONCLUSIONS

–The brief description given here demonstrates how LTCC technology is a suitable material for the fabrication of Meso systems.

–One of the important features of LTCC technology is the possibility of fabricating three-dimensional structures using multiple layers of LTCC tapes.

Thanks for
your attention