LTCC TECHNOLOGY FOR MESO-SYSTEMS

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WORKSHOP DE TECNOLOGIAS PARA MICROSSISTEMAS E SENSORES

IPT, SÃO PAULO, BRAZIL

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PRESENTATION OUTLINE

1. Introduction to LTCC Technology
   - –Ceramic Interconnections
   - –What is LTCC
   - –Technology Advantages
   - –Material Systems

2. LTCC Processing
   - –Processing steps
   - –Tape Machining
   - –Lamination
   - –Sintering
   - –Bonding to other materials
   - –Sagging Problem

3. Photo Patterned Processes
   - –Photo Definable Thick Films
   - –Photo Sensitive Thick films
   - –Fodel Compositions

4. New LTCC Systems
   - –Zero Shrinkage Tapes
   - –LTCC on Metal
   - –PI-LTCC

5. Advanced Packaging Techniques
   - –2D Packaging techniques
   - –Flip-chip & BGA packaging
   - –3D Packaging Techniques
   - –Modular 3D Packaging

PRESENTATION OUTLINE

6. LTCC Technology for Microelectronics
   - MCM devices
   - Buried Passives
   - HF & Microwave Devices

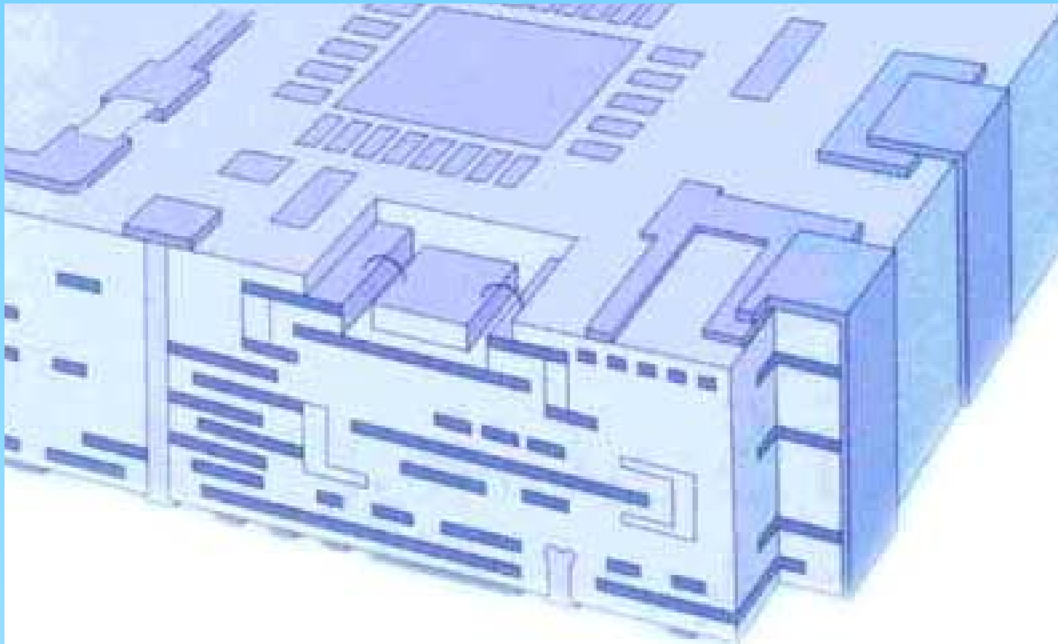
7. LTCC for MEMS/MST
   - MST Introduction
   - LTCC for MST

8. Meso Systems Devices and Applications
   - Sensors
   - Actuators
   - Microfluidic devices
   - Meso-Systems

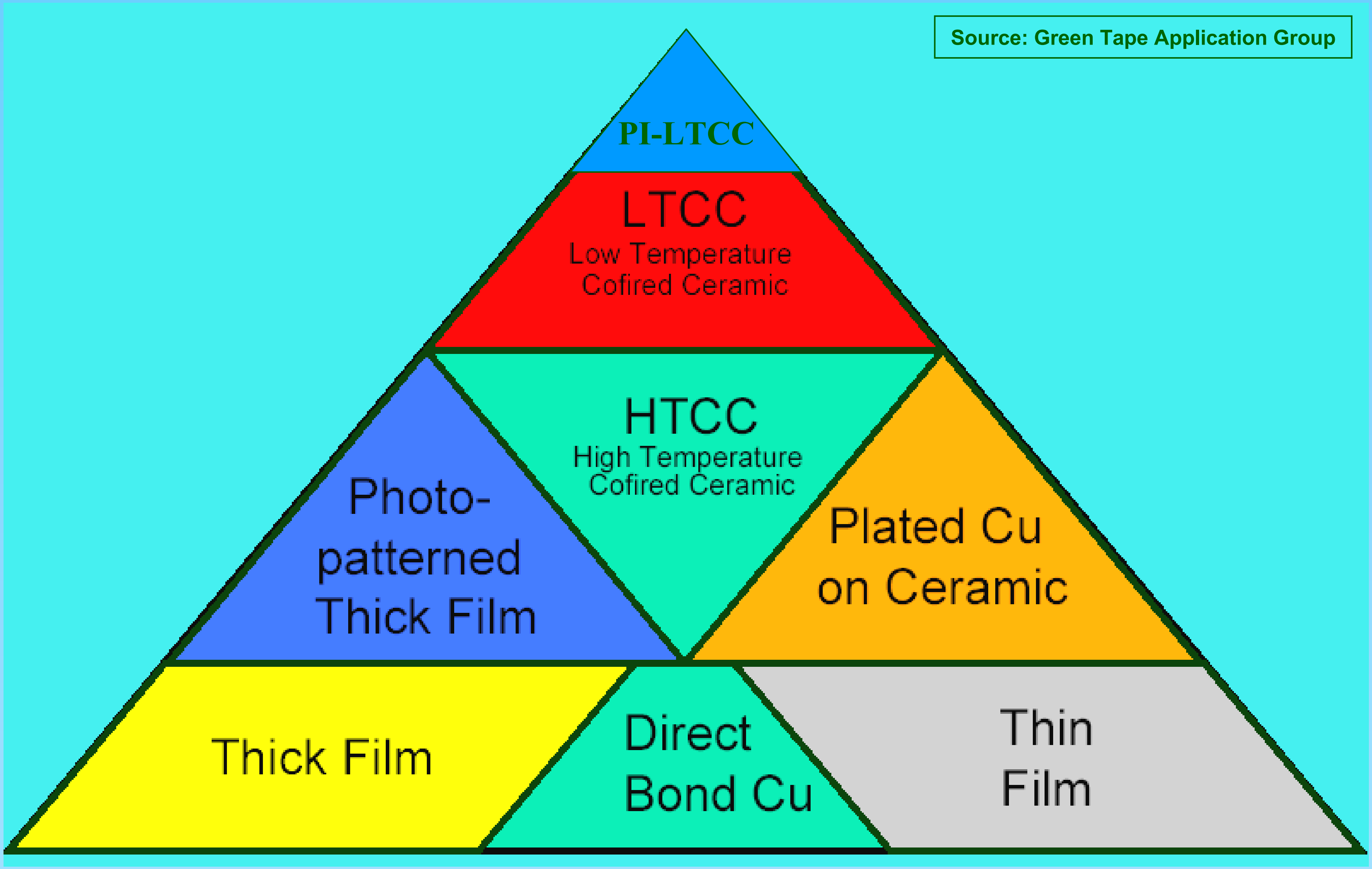
9. Conclusions

1. INTRODUCTION TO LTCC TECHNOLOGY

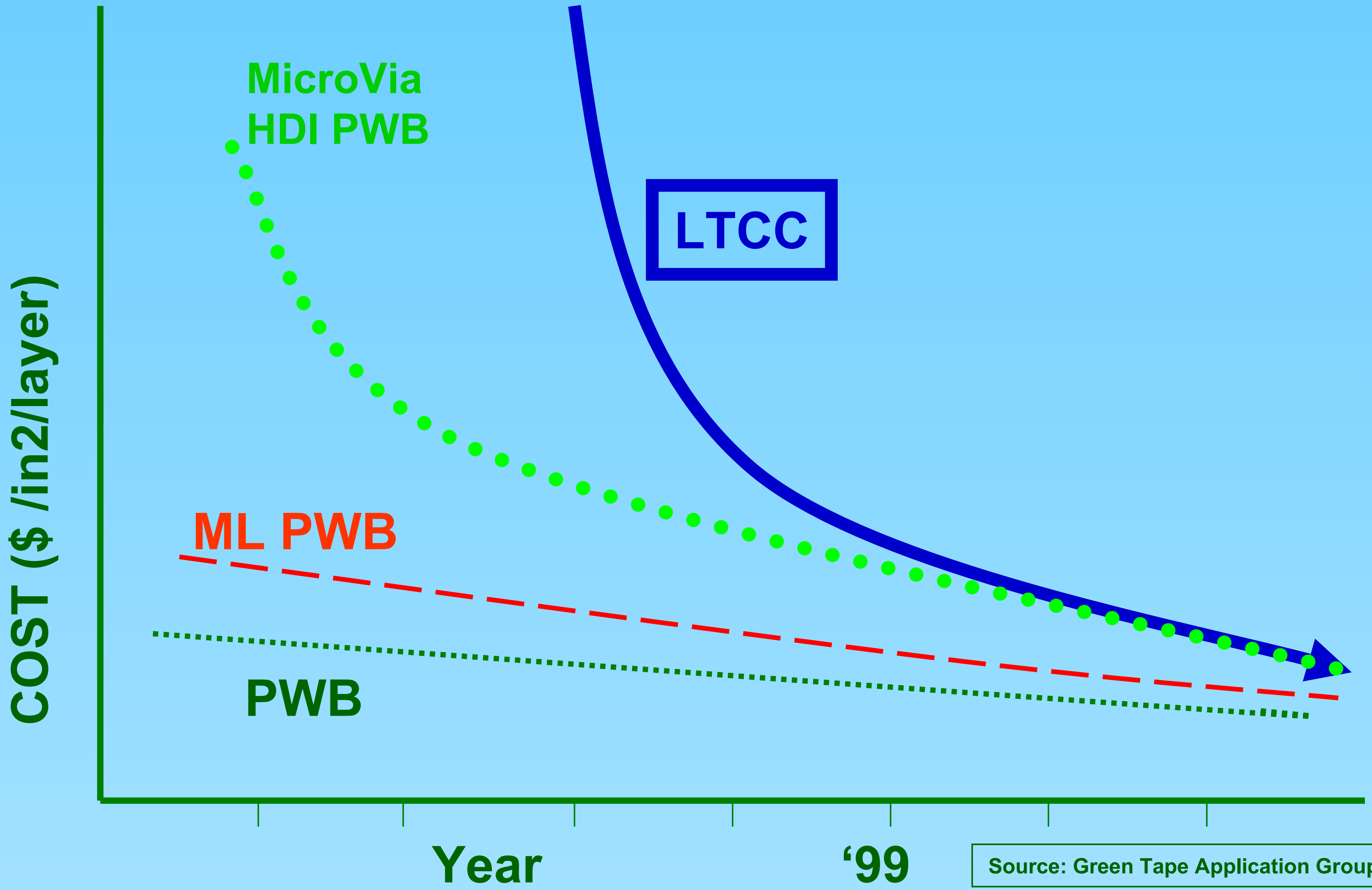
- Ceramic Interconnections
- What is LTCC
- Technology Advantages
- Material Systems



CERAMIC INTERCONNECT TECHNOLOGY

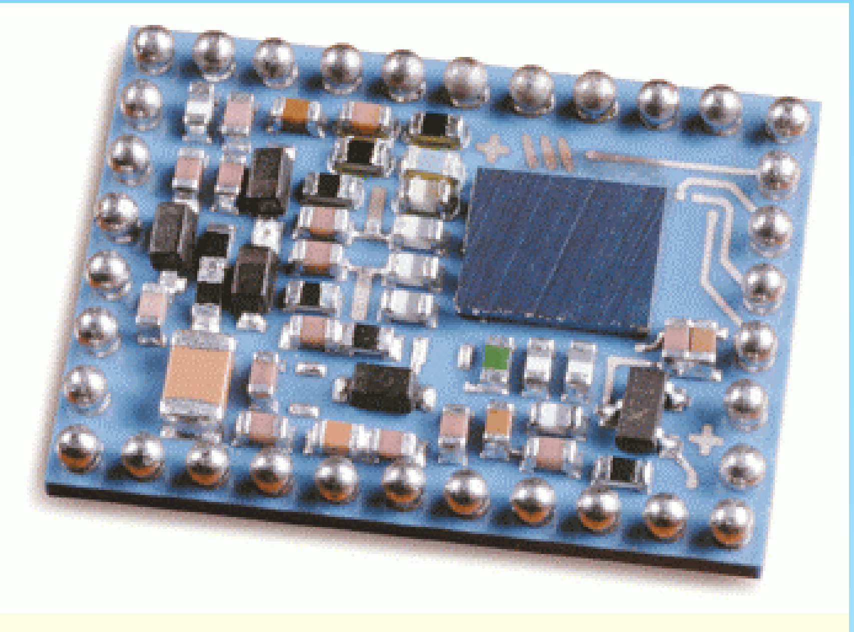


COST GAP NARROWS



WHAT IS LTCC ?

– LTCC was originally developed by Hughes and DuPont for Military Systems.
– The (LTCC) technology can be defined as a way to produce multilayer circuits with the help of single tapes, which are to be used to apply conductive, dielectric and / or resistive pastes on.
– These single sheets have to be laminated together and fired in one step all. This saves time, money and reduces circuits dimensions. An other great advantage is that every single layer can be inspected (and in the case of inaccuracy or damage) replaced before firing; this prevents the need of manufacturing a whole new circuit.
– Because of the low firing temperature of about 850°C it is possible to use the low resistive materials silver and gold .
– The size of the LTCC board can be reduced considerably because of the 3D structure and passive components such as capacitors, inductors and resistors can be embedded, which facilitates a high degree of integration.



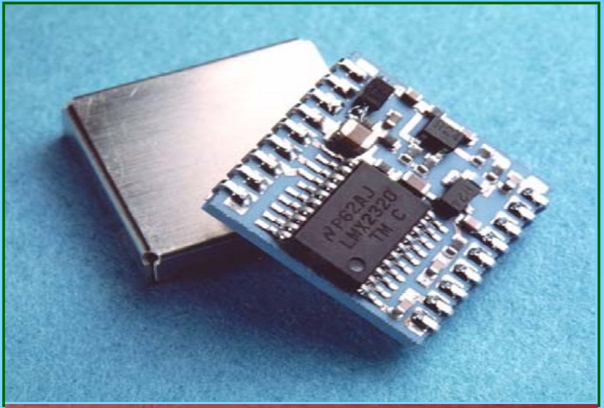
LTCC APPLICATIONS

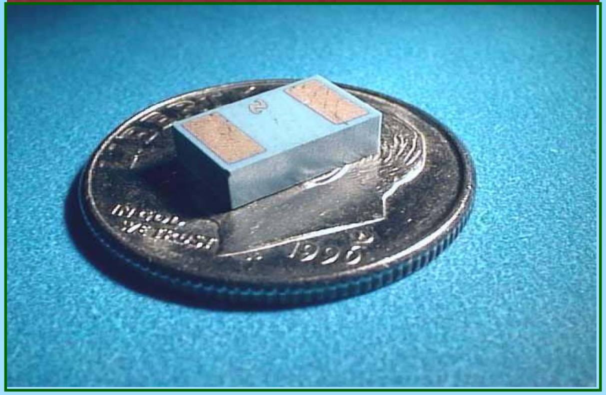
–LTCC technology provides low-cost, high passive elements (R, L, C) integration and good electrical properties with the possibility to use silver, gold, palladium, platinum as conductors.

–This is not achievable with HTCC technology, where the firing temperature exceeds 1000°C, which is only compatible with tungsten or molybdenum conductors.

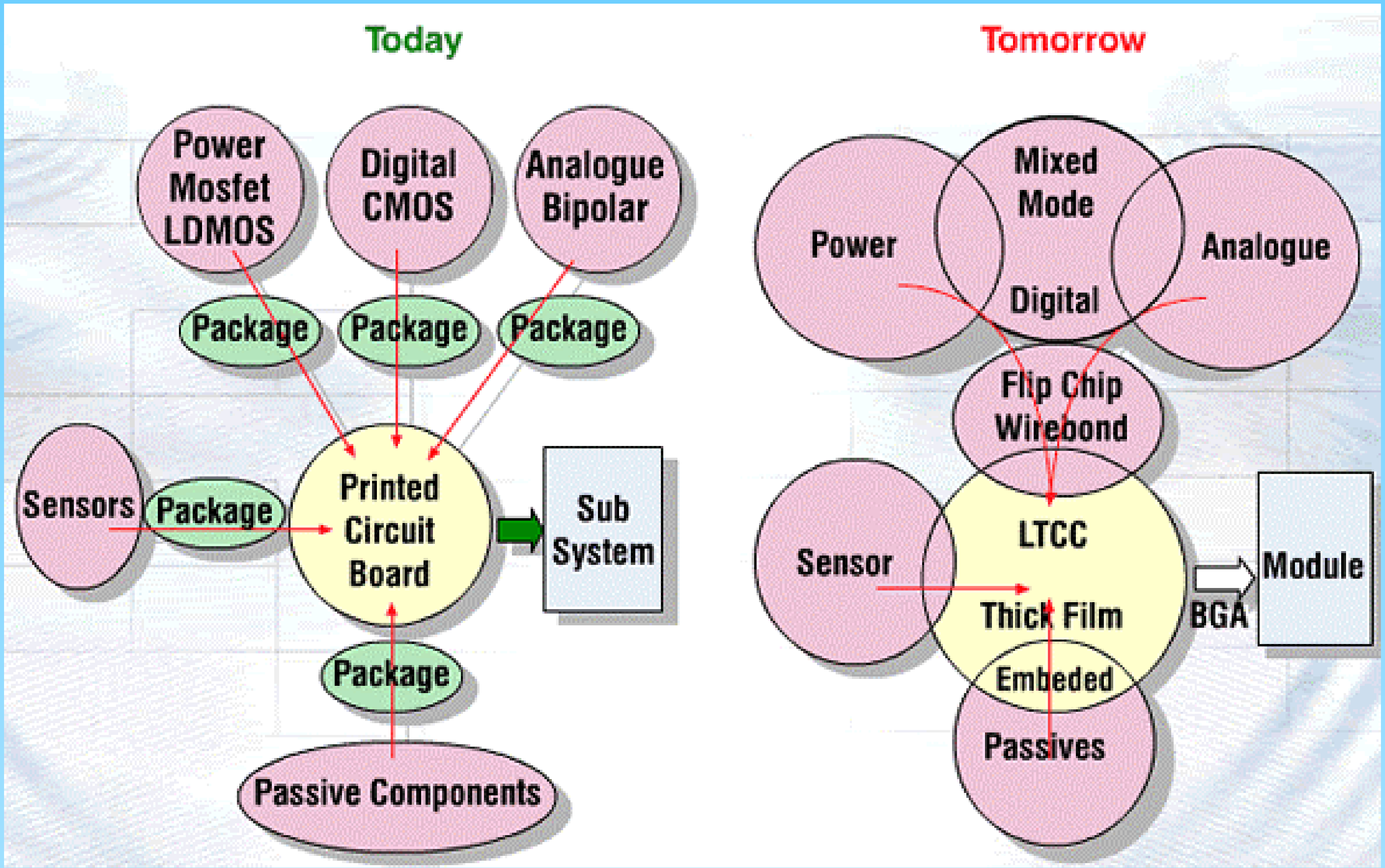
–The advantages of the LTCC technology make it suitable for a number of applications, i.e.:

- RF Modules
- Mobile phone
- Blue tooth
- Microwave & Opto-electronic modules
- Automotive, Medical & Military
- Sensor packaging
- Microsystems





TECHNOLOGY TRENDS



TECHNOLOGY ADVANTAGES (1)

- **Process**
  - –Parallel process (high yield)
  - –Single sinter step for all inner metallizations (cofiring)
- **Electrical**
  - –Low k compared to HTCC
  - –Low dielectric loss / no tremendous increase at microwave frequencies
  - –Higher conductivity compared to HTCC (factor 2..4)
  - –Number of signal layers almost unlimited
  - –High wiring density (vias 2 - 4 x smaller than Thick Film vias)
  - –Good control of dielectric layer thickness prerequisite for impedance control
  - –Passive integration possible
  - –Compatible to 7 decades of postfire resistors
- **Thermal**
  - –High resistance against ambient working temperatures (up to 350°C)
  - –Good thermal conductivity compared to PCBs (factor 10)
  - –Good match to semiconductor TCE's
- **Mechanical**
  - – Good ability to mechanical structuring (drilling, cutting, punching) in green state
  - –High mechanical strength of interconnecting structures
  - –Bare dice can be placed in cavities
  - –Very good hermeticity of the substrate (substrate can be part of the housing)

TECHNOLOGY ADVANTAGES (2)

- Low cost technology
  - –Collective process adapted to automated manufacturing equipment
  - –Only one firing step for all internal layers
  - –Silver based conductors
  - –Firing temperature below 1000°C
- High reliability
  - –Ceramic based materials
  - –Temperature range of [–55°C ,+150°C]
  - –Hermetic dielectric
  - –Low thermal coefficient of expansion
  - –Compatibility with bare dies
- High electrical performance
  - –Various tape thickness (35 to 210 µm): low parasitic line capacitance
  - – Low resistivity conductor (Ag or Au – 3 mΩ/square)
- High flexibility
  - –Compatibility with a wide range of assembly techniques
    - Bare dies: wire bonding, Flip chip,
    - Packaged devices: SMT
  - –Packaging capability (PGA, LGA, BGA, QFP)
  - –Complex shape of substrate
  - –Cavities
- High integration density
  - –Conductor linewidth down to 50 µm
  - –Buried via structures
  - –Via diameter down to 150 µm
  - –Via pitch down to 300 µm
  - –High number of conductive layers: up to 24
  - –Double sided substrate capability
  - –Printed resistors (top or bottom)
  - –Integrated packaging capability
  - –Buried passive components

LTCC TAPE MATERIAL SUPPLIERS

- The following companies offer LTCC tapes for various applications.
  - DuPont
    - 951
    - 943
    - ElectroScience Laboratories (ESL)
    - 41110-25C
    - 41010-25C
    - 41020-25C
    - 41110-70C
    - 41020-70C
    - Northrop Grumman
    - "Low K"
  - Ferro
    - A6M
    - A6S
  - Heraeus
    - CT2000
    - CT700
    - CT800
  - Kyocera
    - GL550
    - GL660
  - Nikko
    - Ag2
    - Ag3
  - Samsung
    - TCL-6A
    - TCL-7A

2. LTCC PROCESSING

– Processing steps

– Tape Machining

–Lamination

– Sintering

– Bonding to other materials

– Sagging Problem

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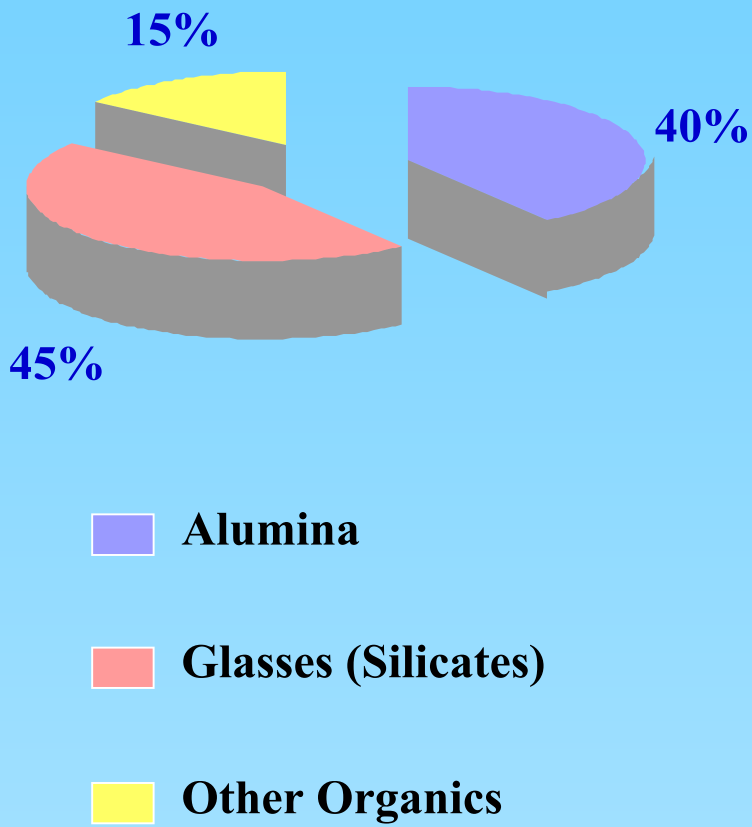
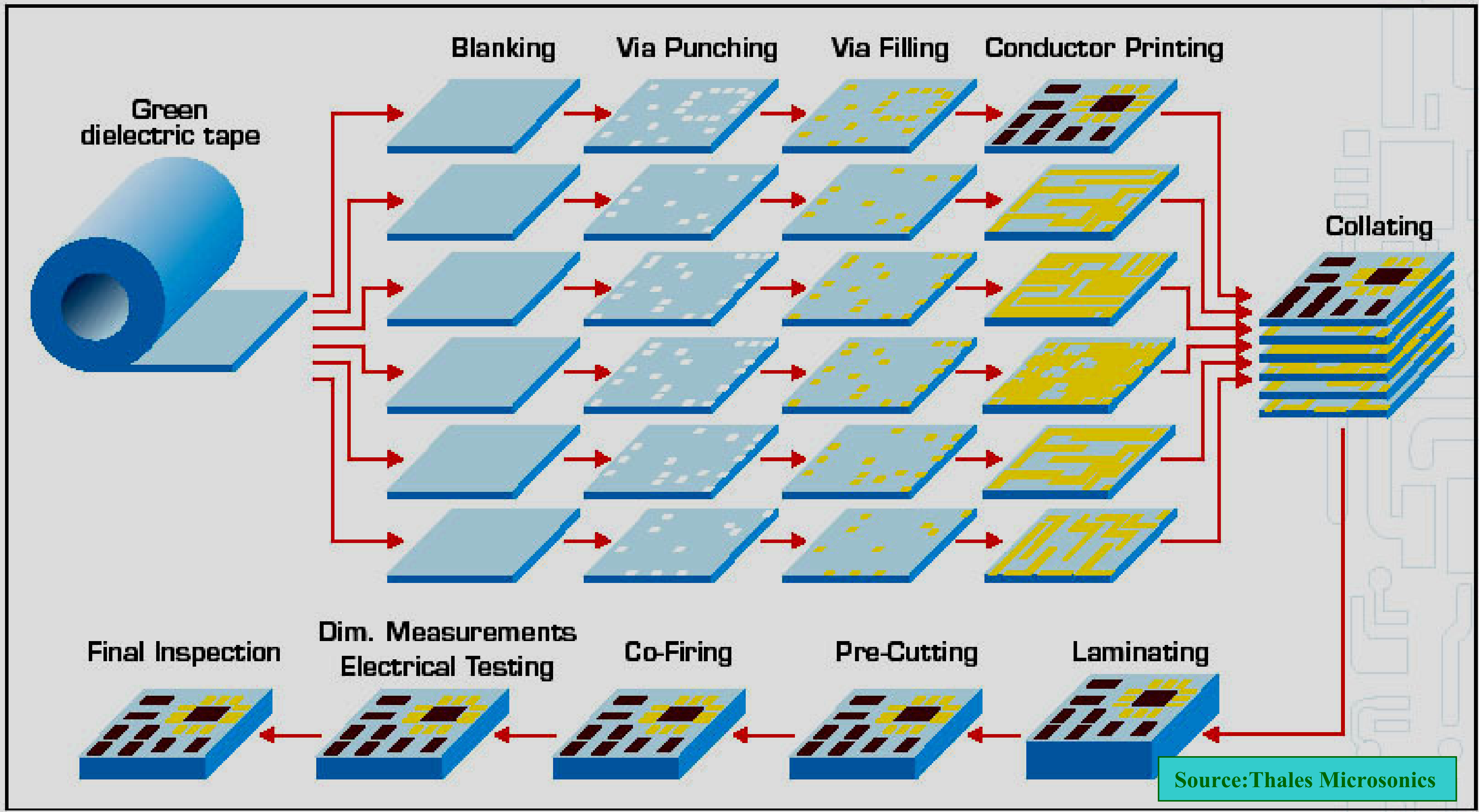
LOW TEMPERATURE CO-FIRED CERAMICS (LTCC)

LTCC-951 Composition



- Glass-ceramic composite materials
- The ceramic filler is usually alumina, Al_2O_3
- The usual composition also includes a glass frit and an organic binder (plasticizer and anti-flocculant)
- Called green tape before firing and sintering

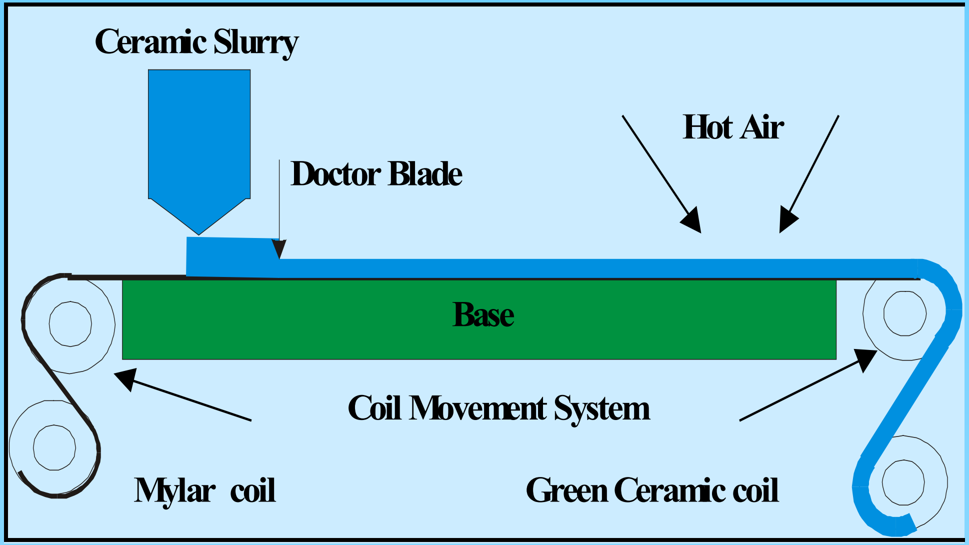
LTCC PROCESSING SCHEDULE

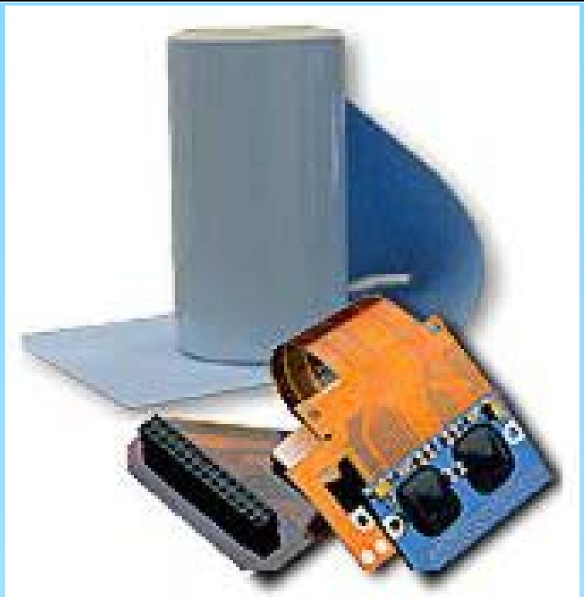


Source:Thales Microsonics

LTCC MANUFACTURING PROCESS (1)

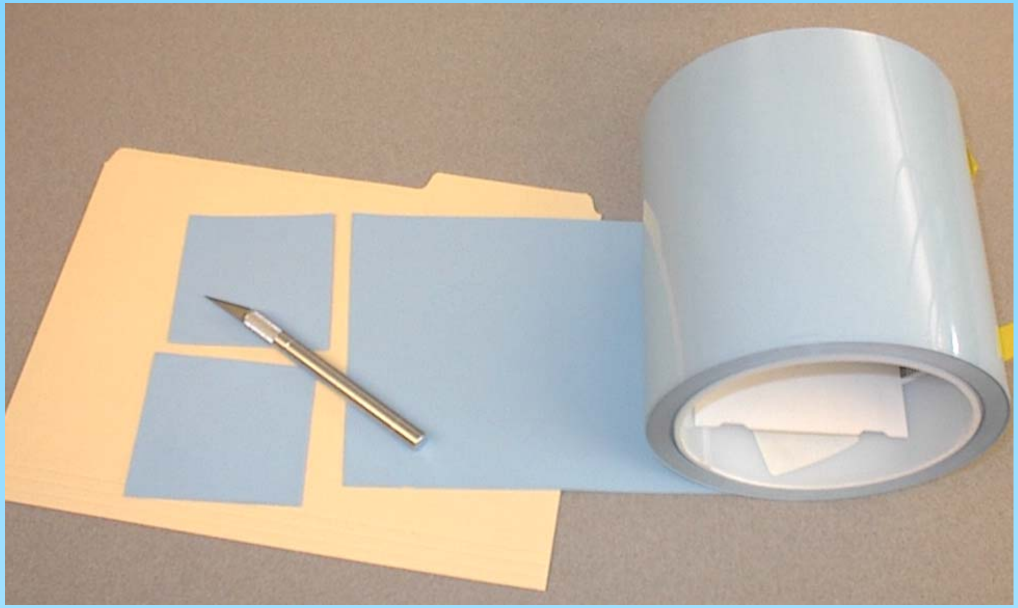
- Materials Preparation
  - –LTCC Ceramic tape materials are prepared by milling precise amounts of raw materials into a homogeneous slurry.
  - –This mixture is principally of ceramic/glass powders with controlled particle sizes with fluxes and small amounts of organic binders and solvents.
  - –This slurry is poured onto a carrier and then passed under a blade to produce a uniform strip of specific thickness.
  - –When dried, this strip becomes a ceramic-filled “Green ceramic tape” which is easily handled in rolls or sheets for unfired processing.

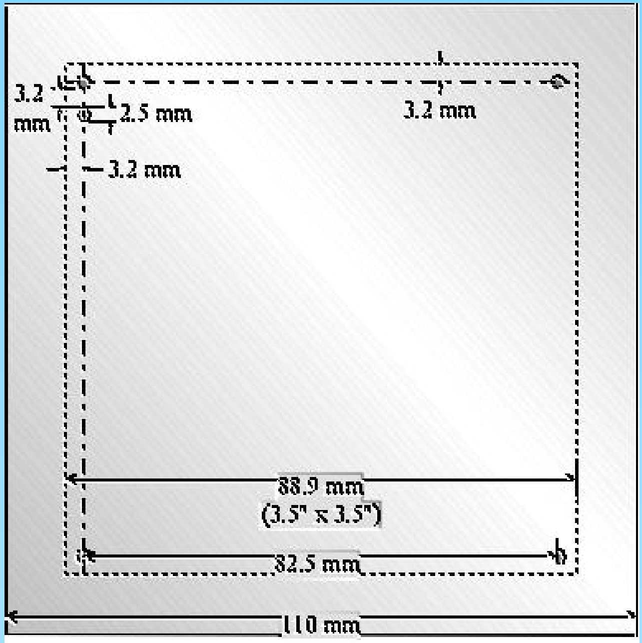




LTCC MANUFACTURING PROCESS (2)

- Tape Preparation
  - –Cutting tape
  - –Pre-Conditioning in the furnace
  - –Punching or burning registration holes
  - –Removing Mylar-tape
- Blanking
  - –A blanking die is used to create orientation marks and the final working dimension of the green sheets.

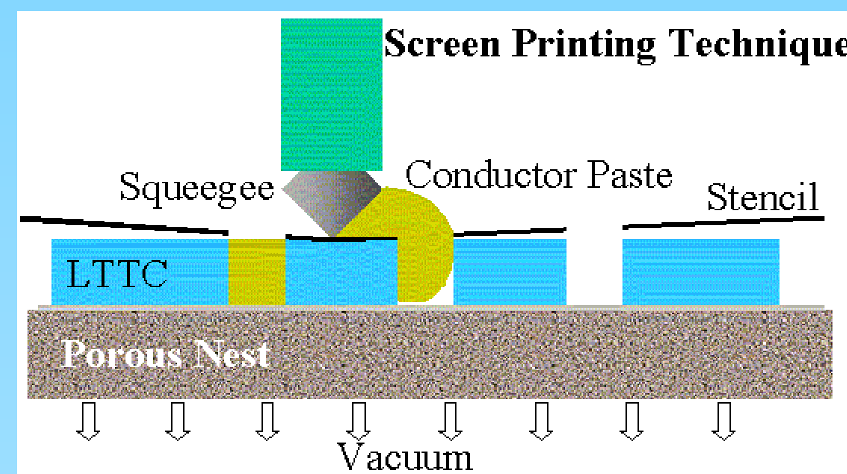




LTCC MANUFACTURING PROCESS (3)

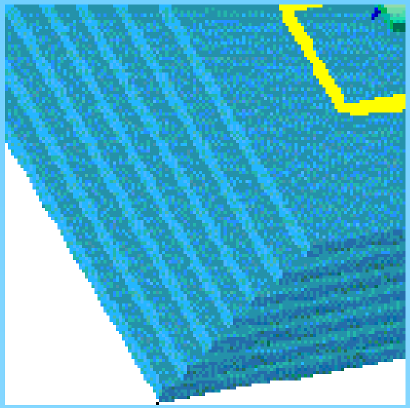
- **Via Machining**
  - Using high-speed mechanical punching with a matrix tool, Laser System, CNC or JVE.

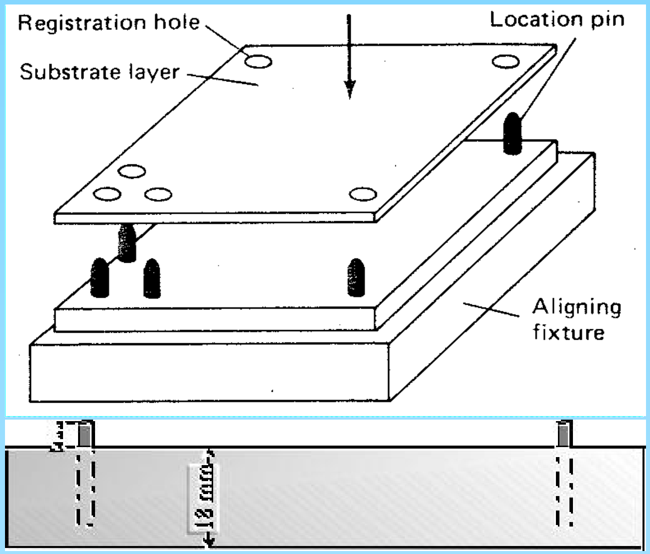
- **Via Filling**
  - Performed using an thick film screen printer with a stencil metal mask.
  - Registration is performed using a vision system.



LTCC MANUFACTURING PROCESS (4)

- Paste Printing
  - –Resistor, conductor and dielectrics deposits are performed using an automatic thick film screen printer with mesh screens.
- Collating
  - –All layers will be collated and stacked with a special tool and will be fixed together to avoid misalignment.
  - –Can be performed using a vision system for alignment.

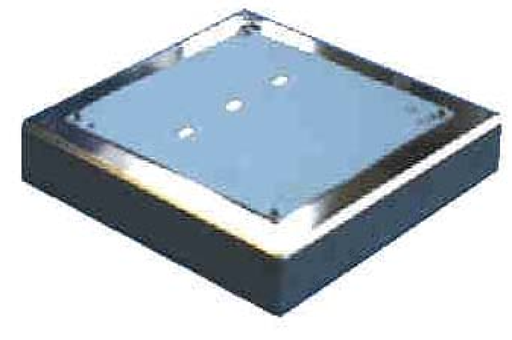




LTCC MANUFACTURING PROCESS (5)

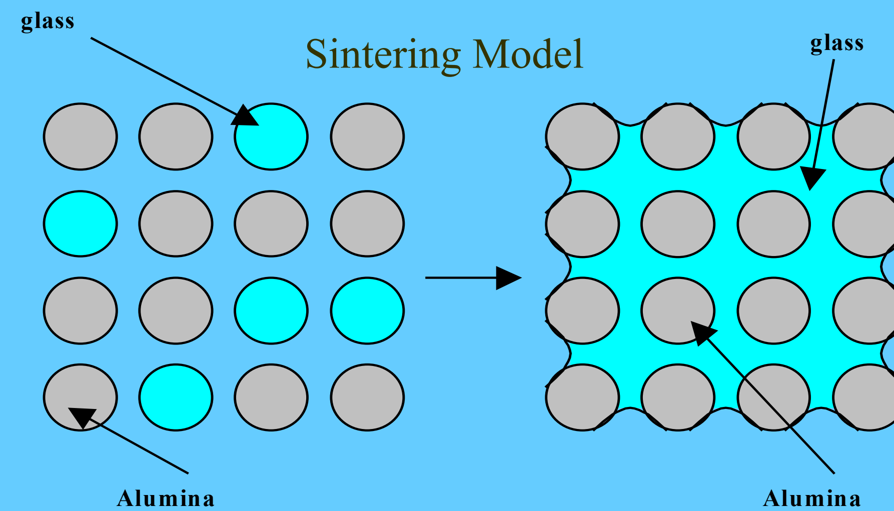
- Laminating
  - Accomplished using uniaxial or isostatic lamination in a specially designed thermal press
  - Temperature for lamination 100 °C
  - Laminating pressure is 3000 PSI
  - Typical cycle time is 10 minutes.

- Pre-Cutting
  - Laminates are pre-cut with a hot blade, meeting the panel drawing specifications.

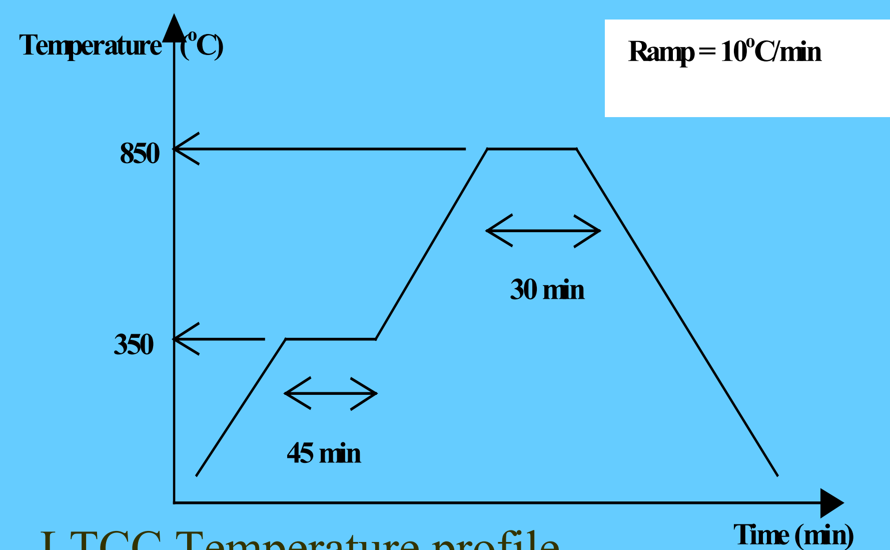


LTCC MANUFACTURING PROCESS (6)

- Co-Firing
  - –Made in a belt or special furnace at a peak temperature of 850°C and a dwell time of 30 minutes.
  - –The typical cycle time is 3 hours.



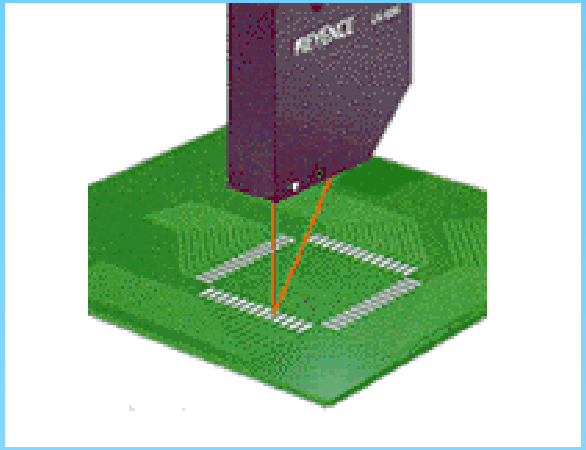
Sintering Model



LTCC Temperature profile


Sintering Furnace

LTCC MANUFACTURING PROCESS (7)

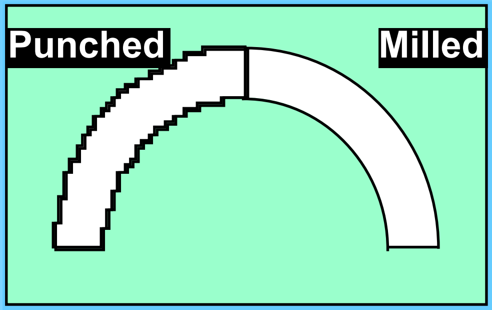


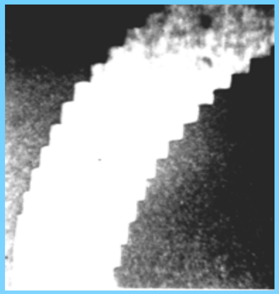
- Dimensional Measurements /Electrical Test:
  - –Panel and circuit size can be checked with automatic measurement vision system. Electrical resistance test is performed with an automatic system with probe card.

- Final Inspection:
  - –Optical, Laser and acoustic inspection techniques are performed on completed parts in accordance with the applicable standards.

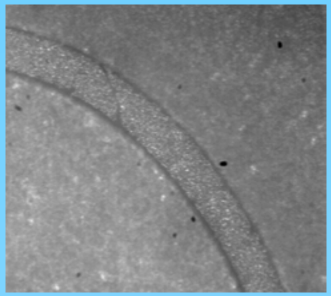
Mechanical Machining of Ceramic Tapes

Machined Samples





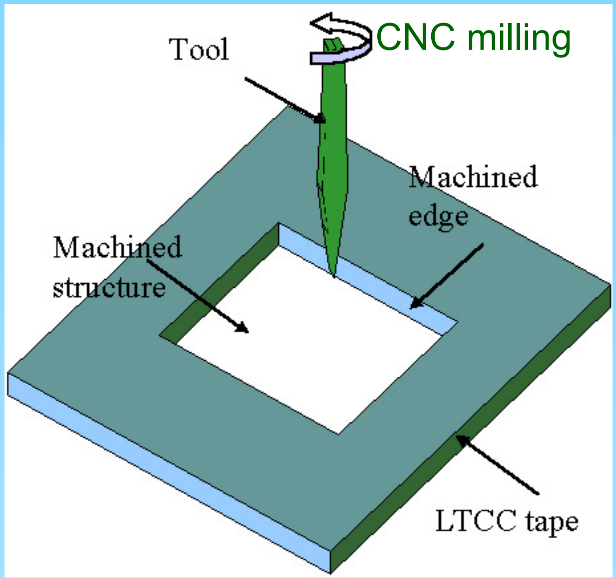
Punched curve



CNC milled curve

PUNCHING

- Circular or square shape
- Smallest size 0.004”(~100microns)
- Machining of curved features is difficult
- Partial depth machining cannot be done



CNC MILLING

- Smallest size (~150 microns)
- Machining of curved features is easy
- Partial depth penetration facilitating shallow channels and thin membranes
- Vacuum chuck holder or wet tape is used to fix tape

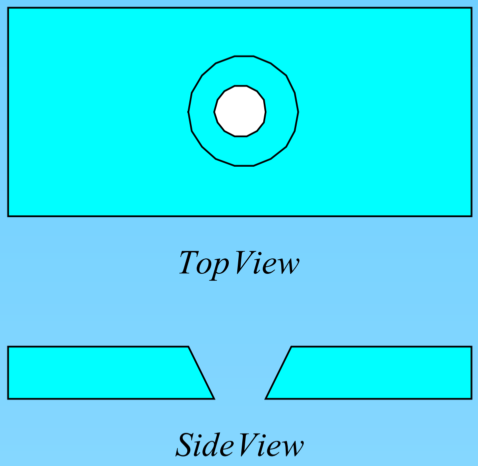
LASER MACHINING OF CERAMIC TAPES

Nd-Yag Laser

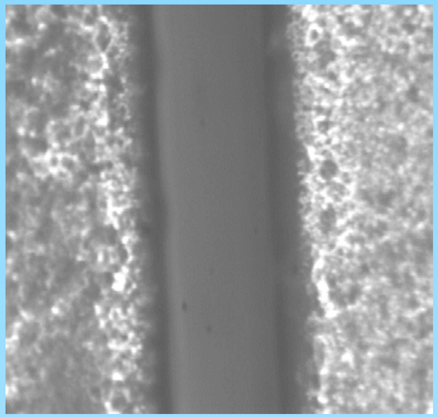
- **Thermal machining process**

Excimer Laser

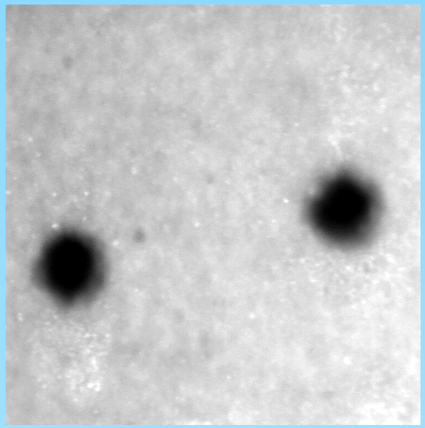
- **Smallest size: ~10 microns**
- **No thermal damage (adiabatic process)**
- **Machining of whole feature at once using mask**
- **Partial depth penetration facilitating shallow channels and thin membranes**



Schematic of the Laser machined hole



Nd-Yag Laser machined sample
(~150 micron wide channel, 20X)

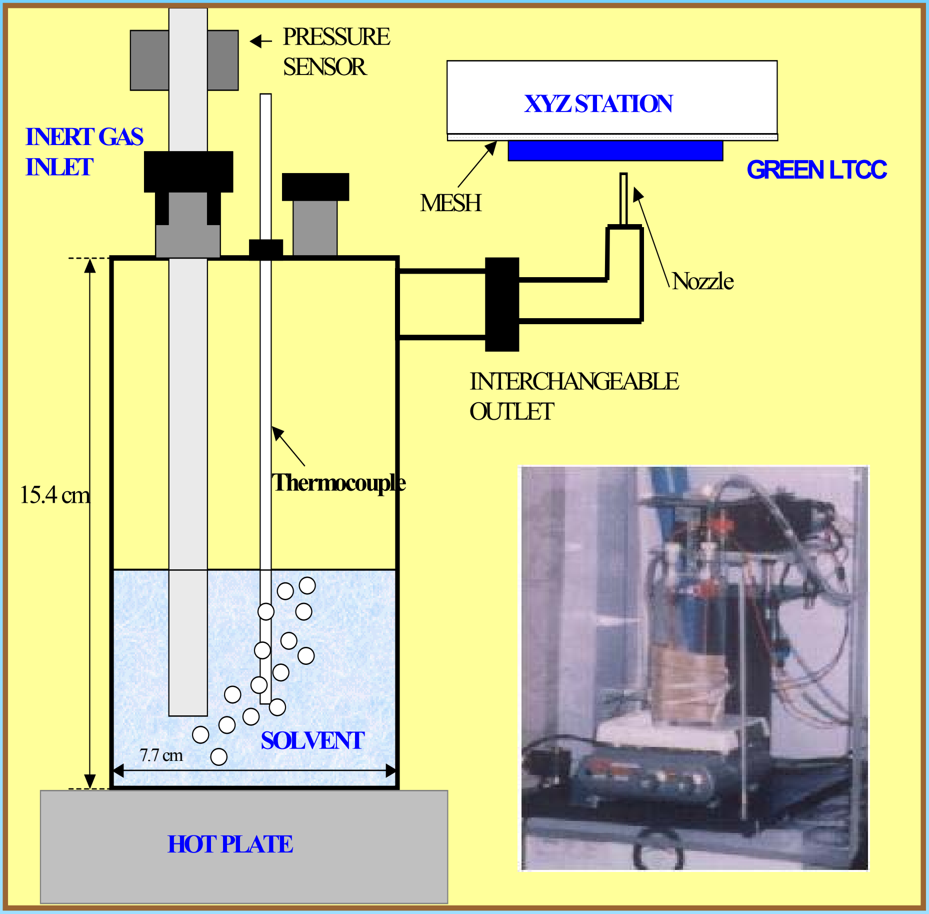


Excimer Laser machined sample
(~ 40 micron holes, 20X)

Yag Laser Machined Via

TAPE JET VAPOR ETCHING

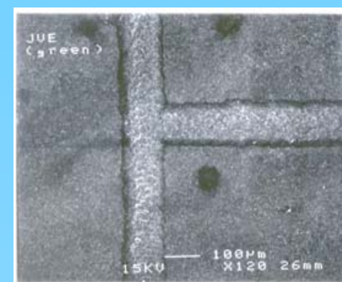
- A jet of acetone dissolves the organic binder
- The alumina grains are removed by momentum transfer
- Computer controlled xyz station and valves
- Morphology controlled by processing parameters: pressure, temperature, distance to sample, solvent, nozzle size and diameter

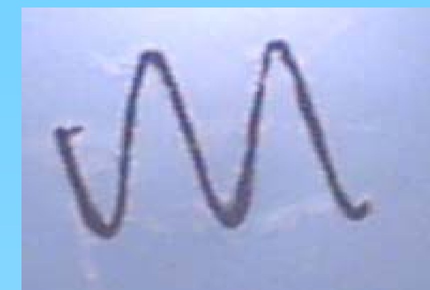


ADVANTAGES OF JET VAPOR ETCHING

- Rapid prototypes
  - **More flexible than traditional punching technique**
    - **One can do partial cavities and continuous borders when machining long channels**
  - **Processing and instrumentation costs are a fraction of conventional punch and die process**

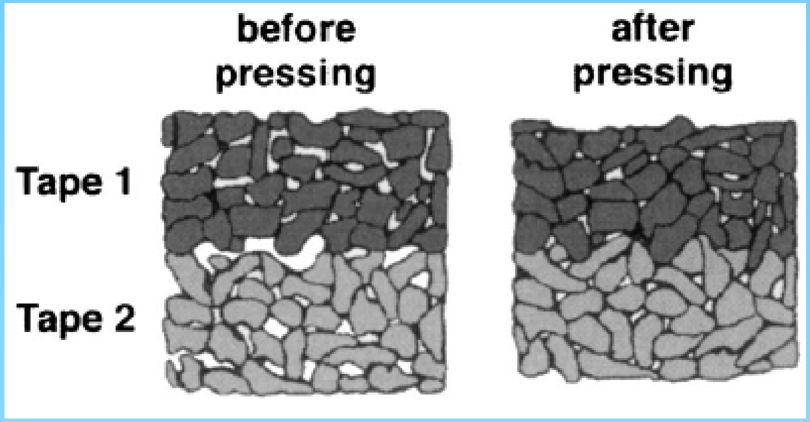
Features as small as 10µm has been obtained

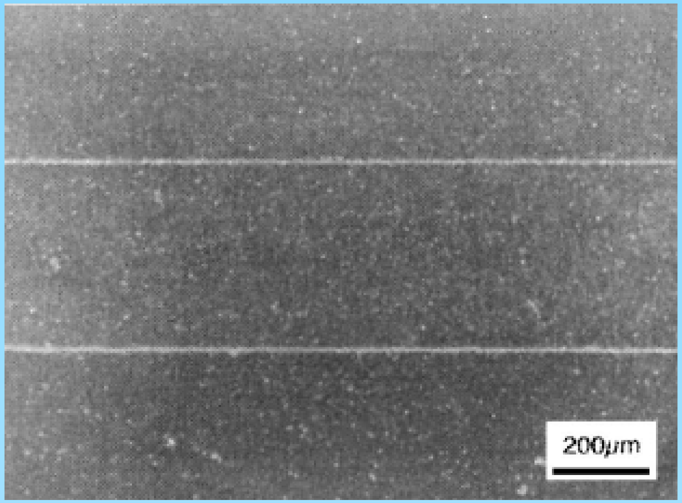




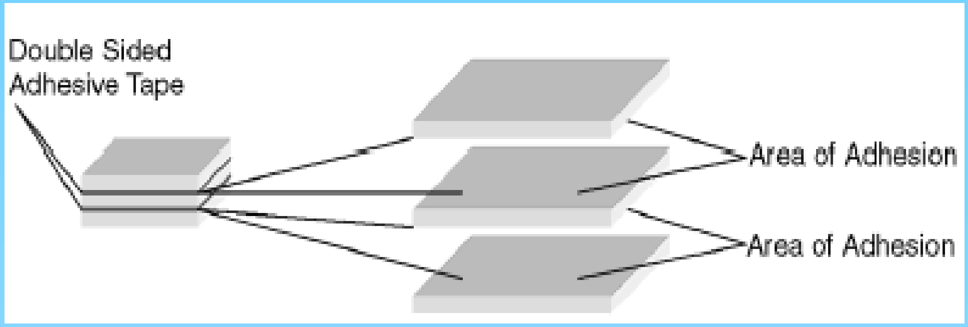
Lamination Process

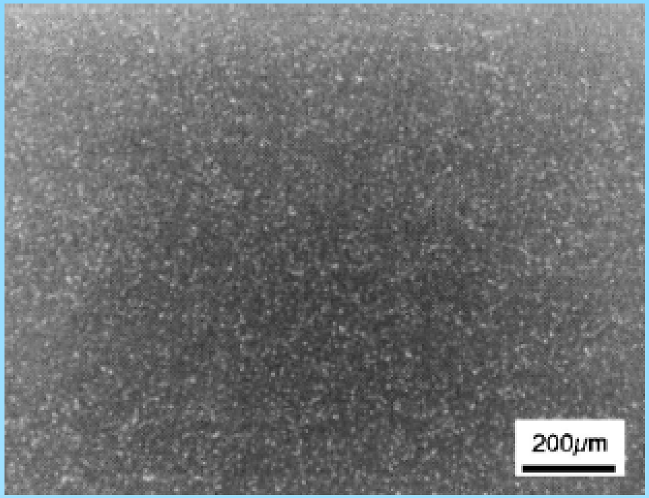
Thermocompression



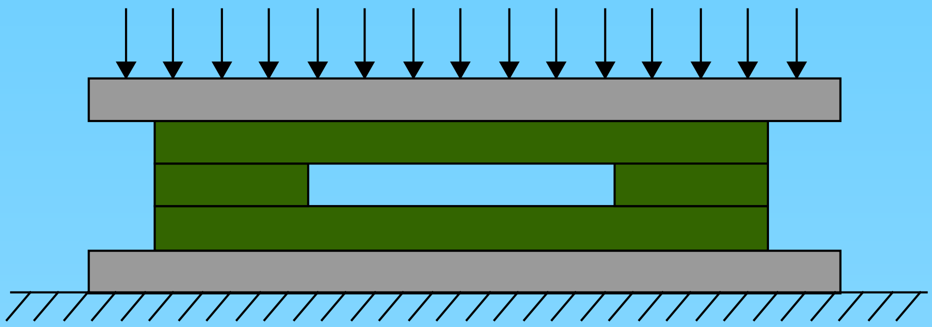


Cold Low Pressure

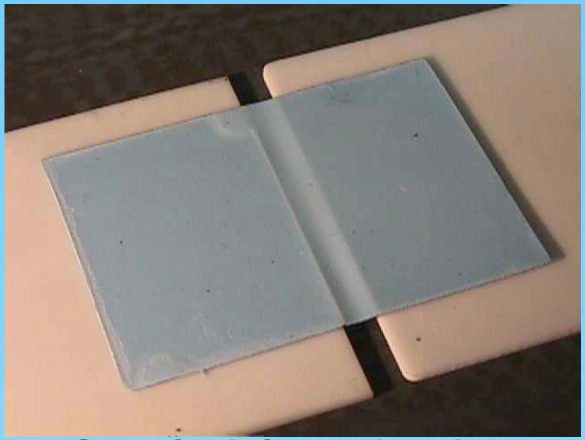




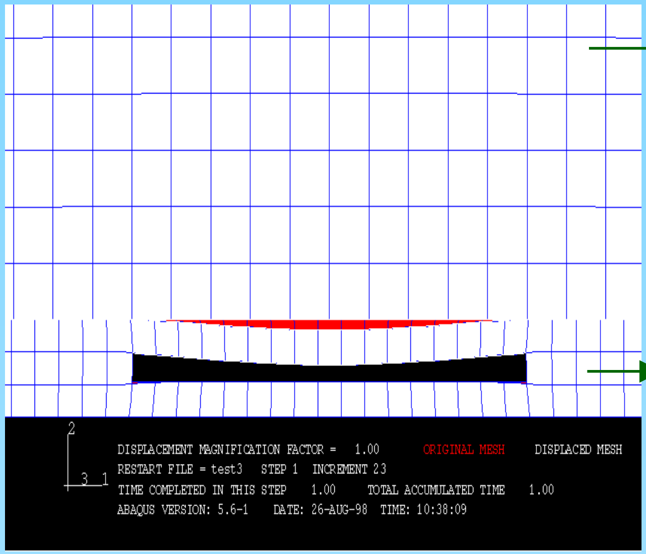
LAMINATION INDUCED DEFORMATION



Lamination pressure = 3000 psi



Sample deformed under pressure

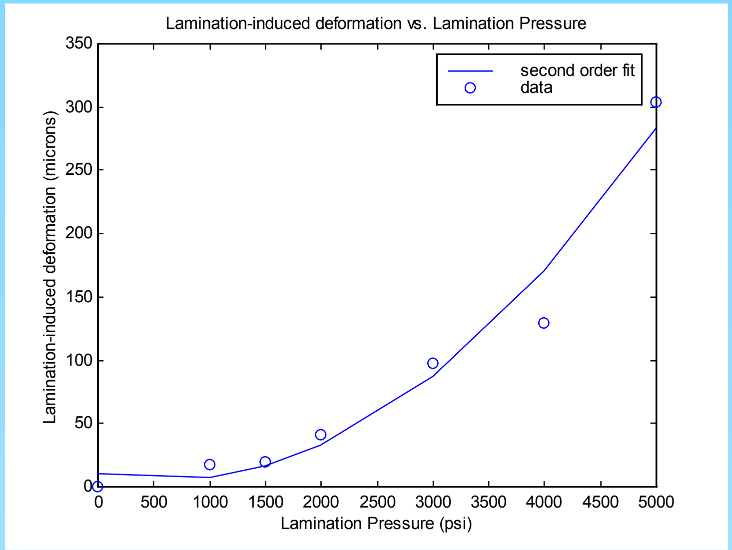


Press

Three-layered Ceramic Tape Laminate

ABAQUS FEA Simulation

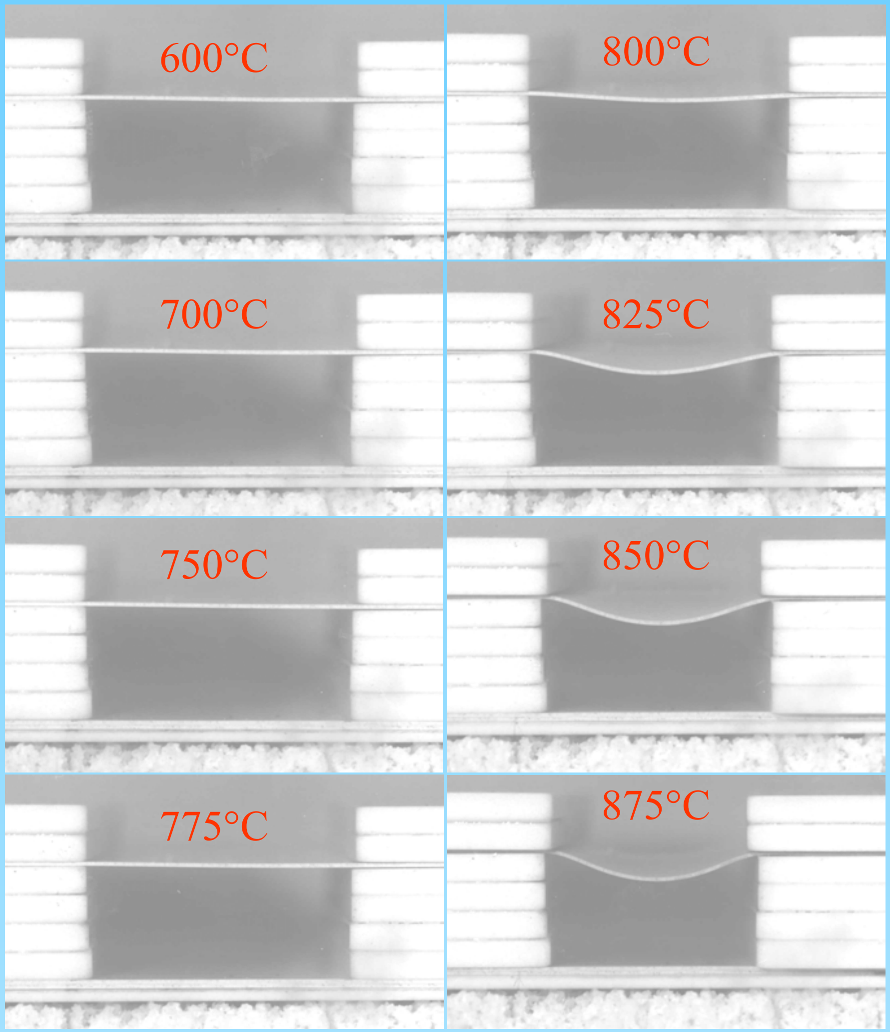
Maximum deformation (µm)



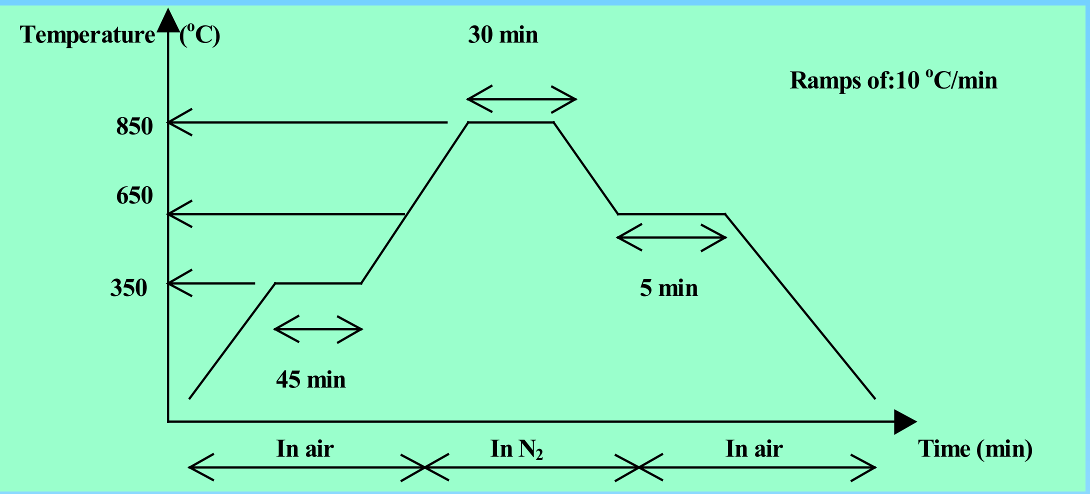
Lamination pressure (psi)

LTCC TAPES FIRING INDUCED DEFORMATION

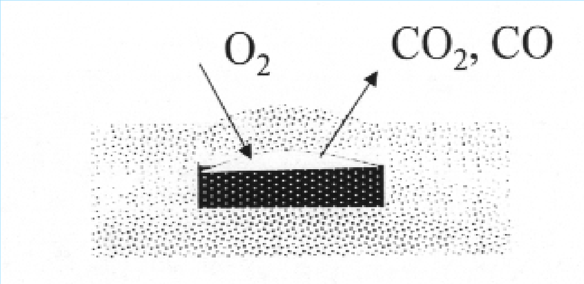
- Firing induced deformation as a function of temperature



COMPENSATION USING FUGITIVE PHASE MATERIALS (GRAPHITE PASTE)

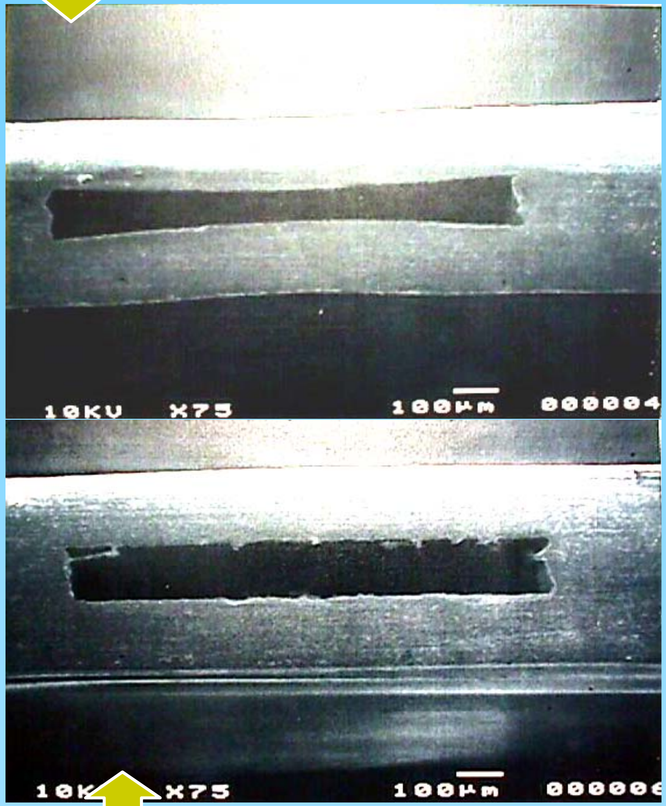


Sintering profile



Sintering Mechanism

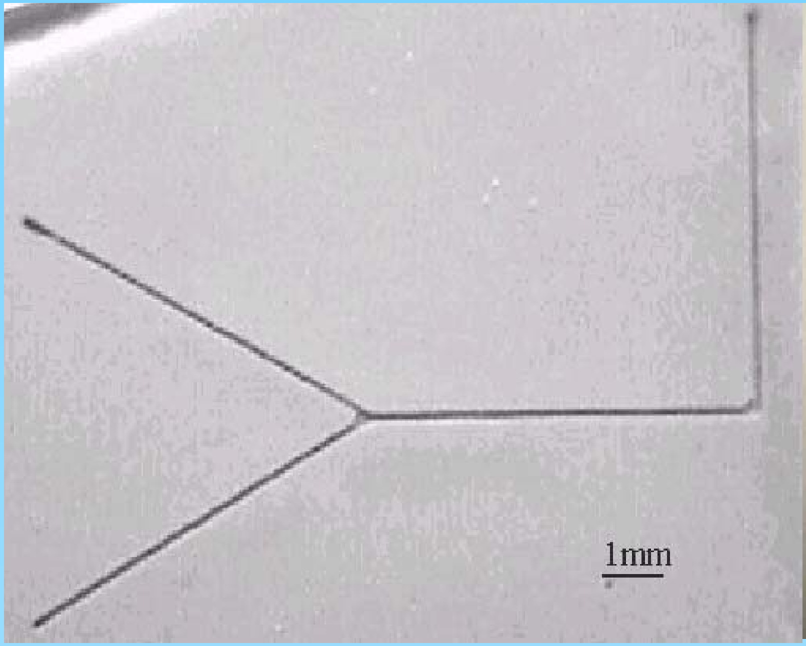
Without graphite



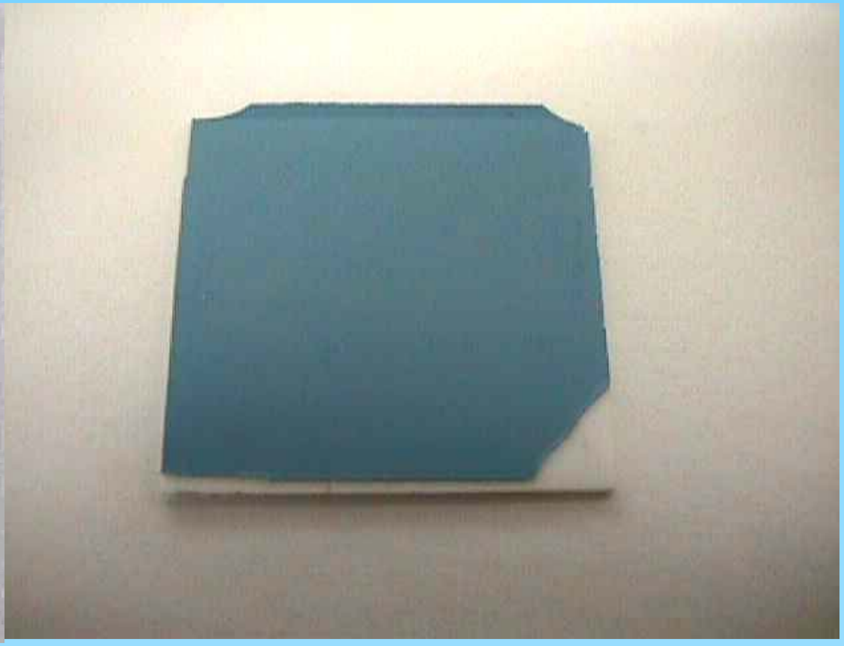
With graphite

BONDING OF LTCC TAPES TO OTHER MATERIALS

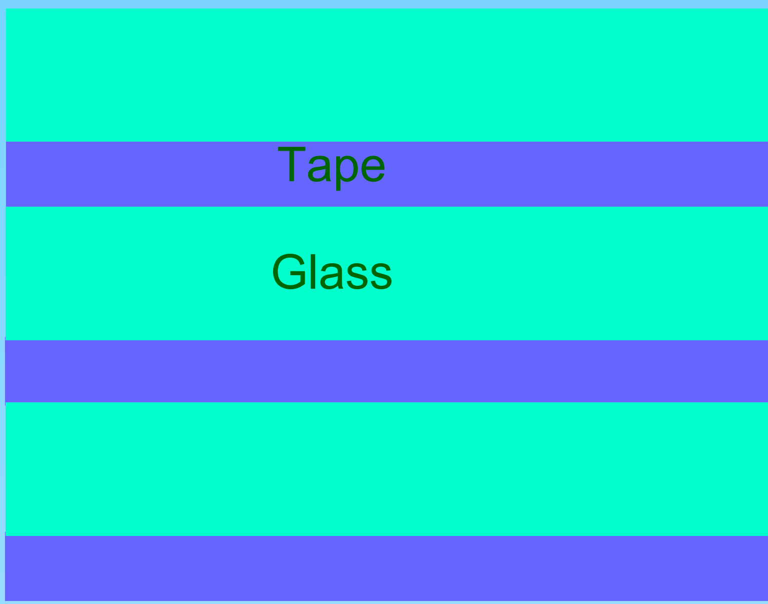
LTCC to Glass

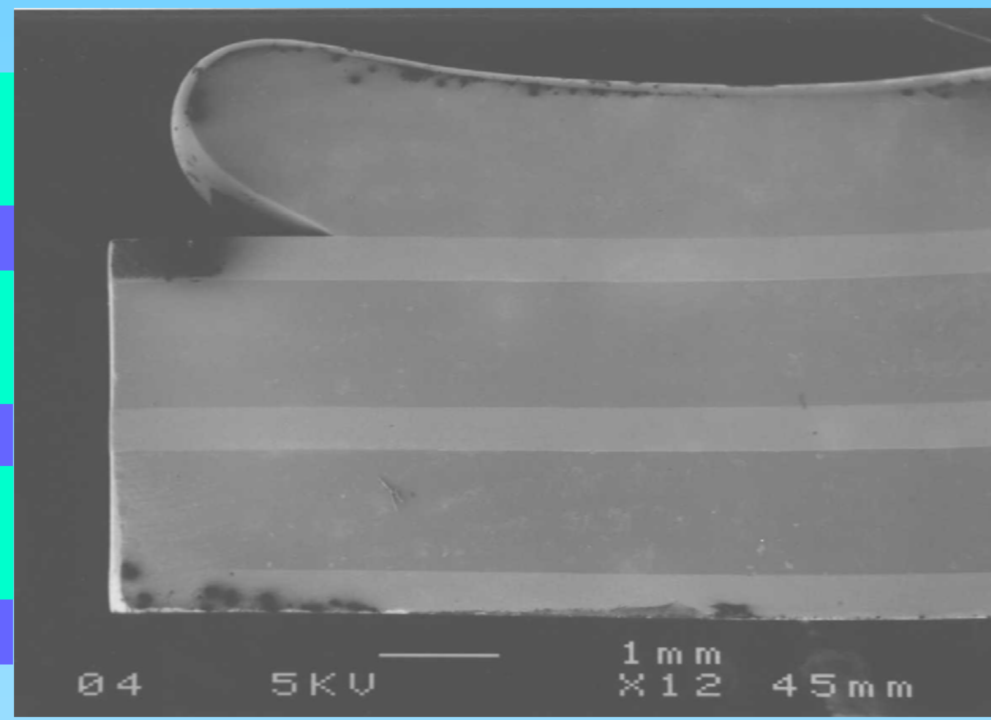


LTCC to Alumina



MULTI-LAYERED STRUCTURES WITH GLASS AND CERAMIC TAPES

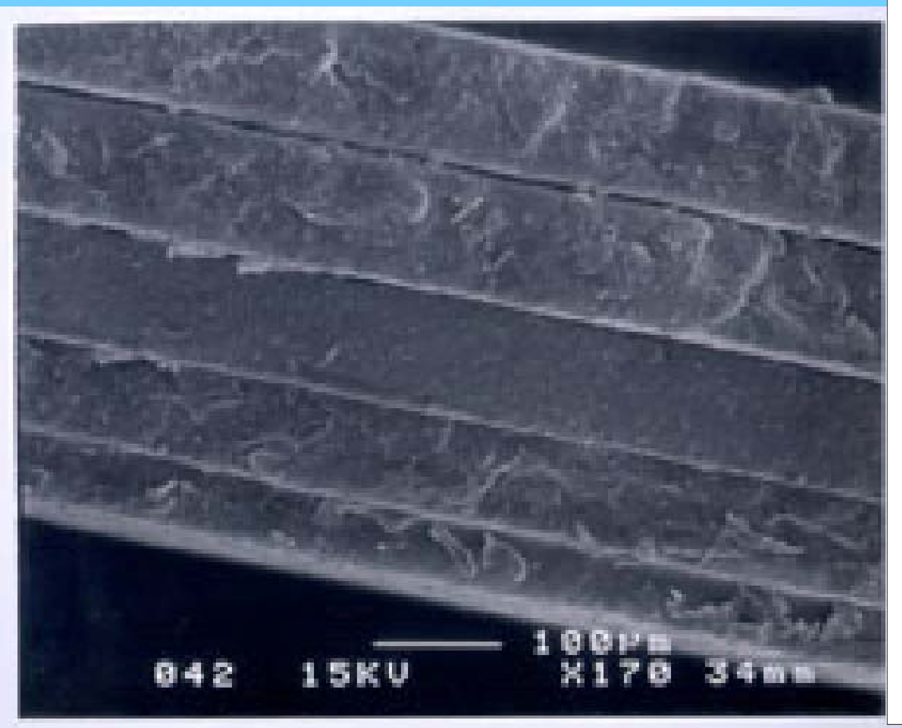


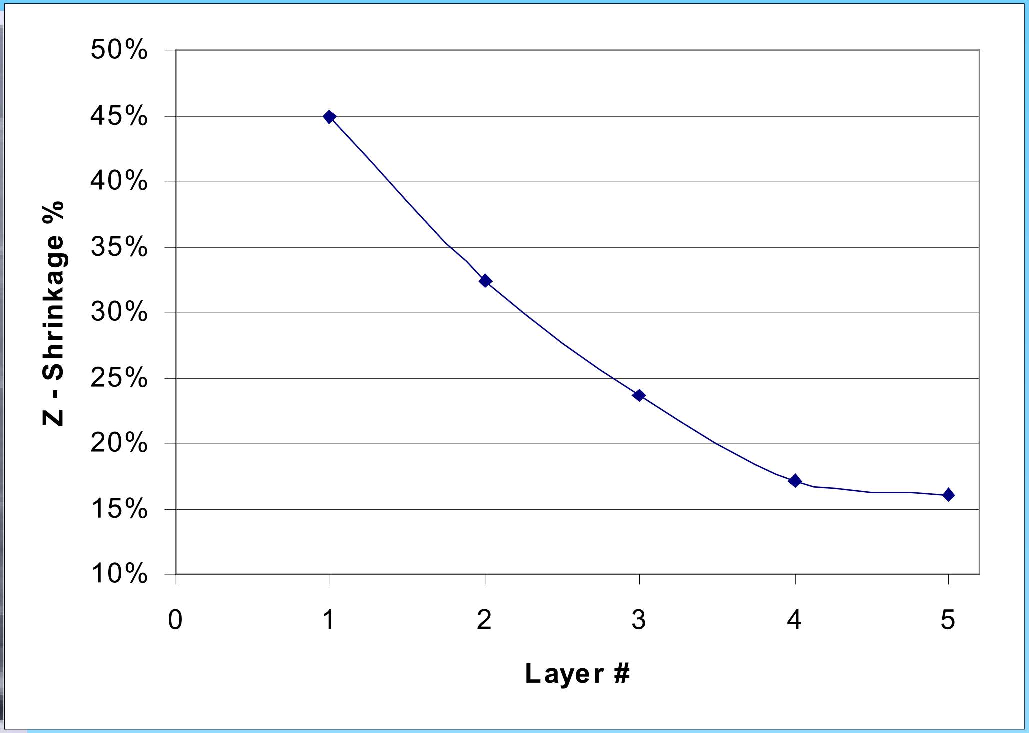


Schematic

SEM of the Sample

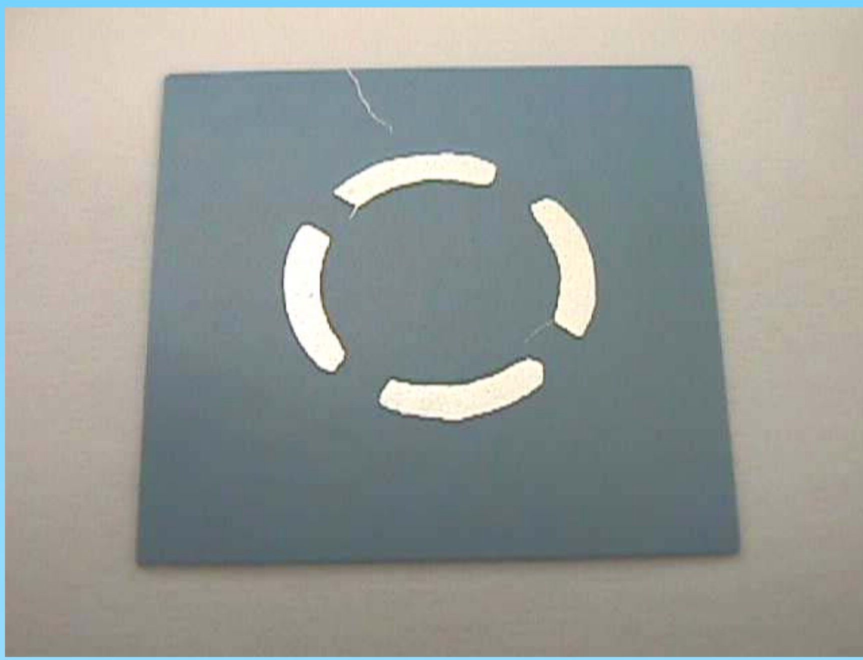
CONSTRAINED LAMINATION AND SINTERING





- Z - shrinkage behavior in a multilayer structure under constrained lamination and sintering.

THIN AND THICK FILM COMPATIBILITY WITH LTCC TAPES



100 nm Aluminum PVD deposited thin film

15 µm screen-printed piezo- resistor

3. PHOTO PATTERNED THICK FILM PROCESSES

- Photo Defined Thick Film
- Photo Sensitive Thick Film
- Fodel Compositions

PHOTO THICK FILM TECHNIQUES

–Photodefined Thick Film

- •Paste (normally conductor) is optimized for etching.
- •Patterned after firing, using a resist,then etched.

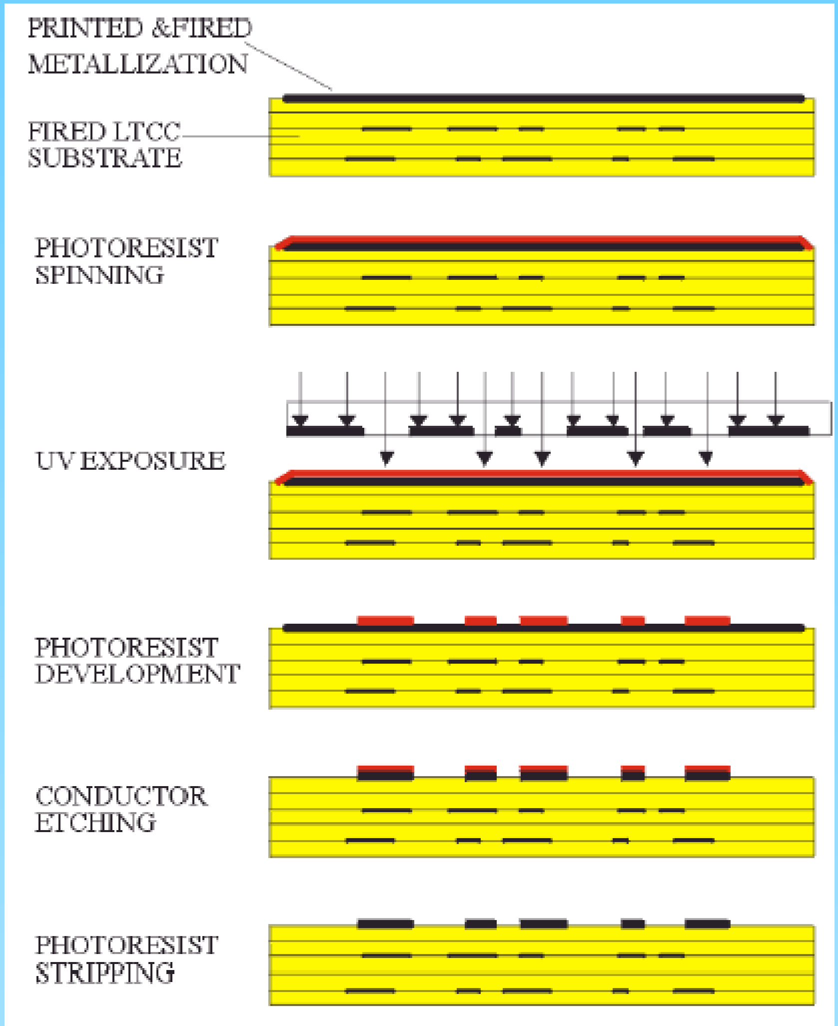


PHOTO DEFINED THICK FILM

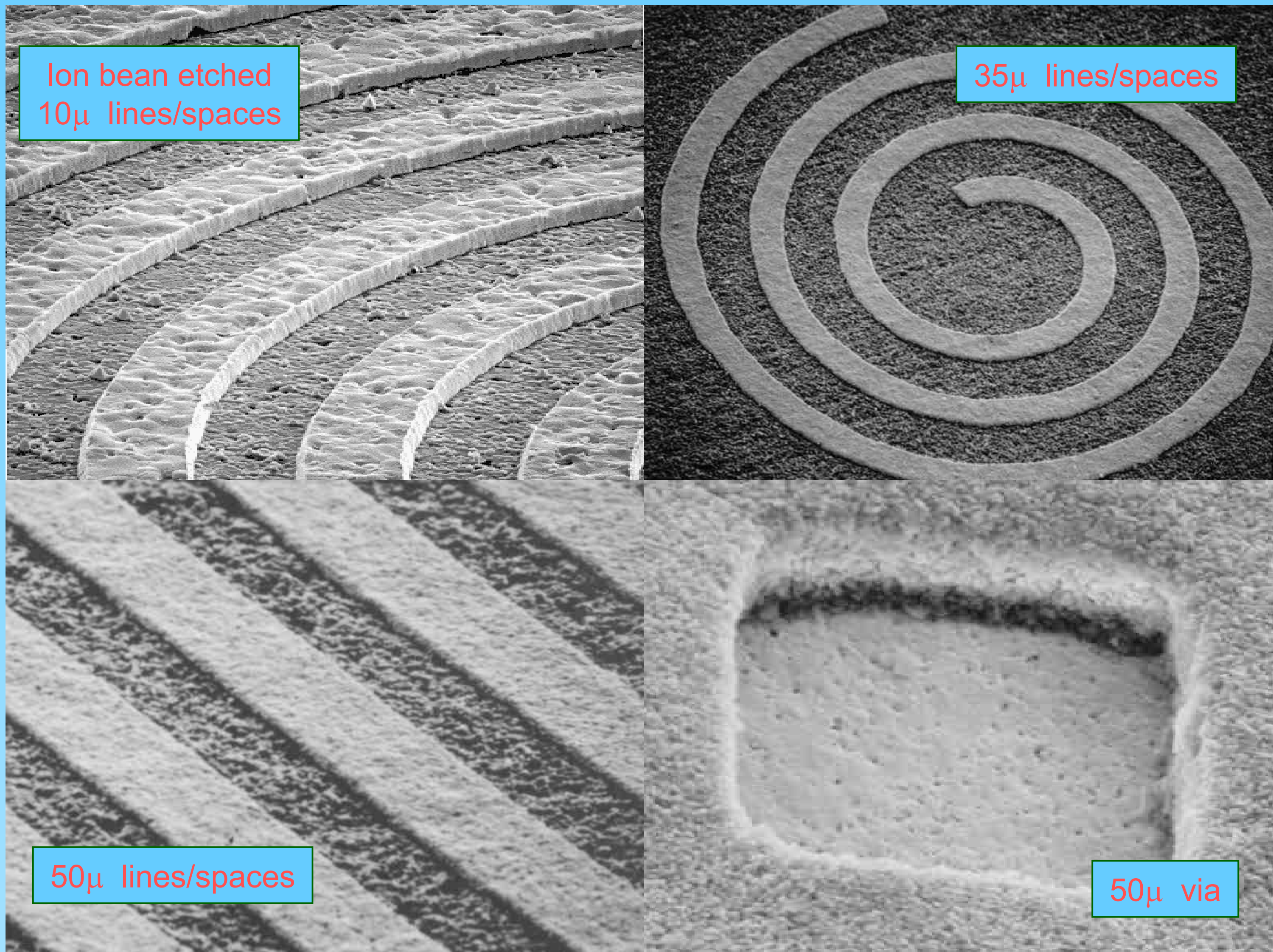


PHOTO SENSITIVE THICK FILM

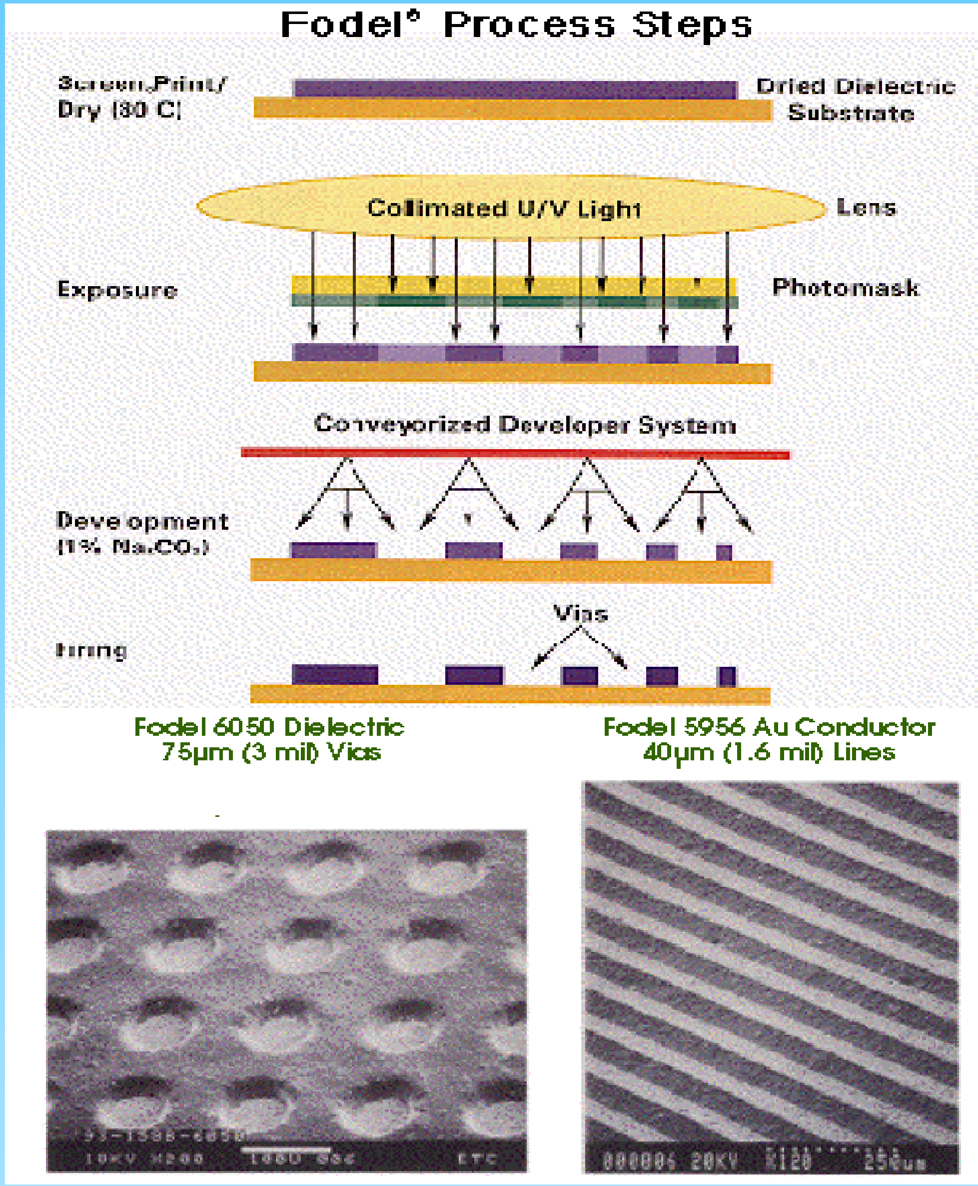
- Photosensitive Thick Film
  - Paste contains photosensitive material.
  - Patterned by exposing and washing before firing.

- Thick film on Ceramic, combined with photo-processing
  - Stability of thick film
  - Precision of thin film
  - Mass production capability of laminates and IC's

- High performance conductor & dielectric
  - Ideal for microwave

FODEL COMPOSITIONS

- Fodel® materials incorporate photosensitive polymers in the thick film.
- Circuit features are formed using UV light exposure through a photomask and development in an aqueous process.
- Fodel dielectrics can pattern 75 micron vias on a 150 micron pitch, Fodel conductors can pattern 50 micron lines on a 100 micron pitch.
- Fodel materials extend the density capability of the thick film process to allow densities typically achievable using more costly thin film processes.



4. NEW LTCC TAPE SYSTEMS

- **Zero Shrinkage LTCC Tapes**
- **LTCC on Metal (LTCC-M)**
- **Photo Imageable LTCC (PI-LTCC)**

ZERO SHRINKAGE LTCC TAPES

–Recent developments relating to the formulation, processing and manufacturing of ceramic and glass composites, which do not shrink upon co-firing to the degree of ordinary LTCC materials, a slight shrinkage (< 2%) can be controlled to a very tight tolerance of +/- 0.01%.

–Because ZR tapes exhibits a near zero shrinkage and zero shrinkage tolerance upon firing, precise feature locations are maintained in the X, Y, and Z axis's and yield improvements of over 30% can be realized when compared to conventional materials systems.

– Some properties include the embedding and co-firing of: discrete components such as ceramic chip capacitors for true passive integration, ceramic heatspreaders with integral heat pipes for thermal management (>2000 W/mK)

–The main difference between Zero Shrinkage tapes and all other LTCC tapes is its unique shrinkage properties during firing.

–Free sintered this tapes densifies by shrinking in the z-axis.

–Key Benefits are:

- Near zero (<0.2% ± 0.05%) x-y shrinkage with no added processing steps
- Compatible with co-fired solderable conductors
- Cavity structures cut into the green tape show no x-y shrinkage or distortion after firing
- Lead and cadmium free
- High Q

LTCC ON METAL (LTCC-M)

- LTCC-M Technology combines conventional LTCC technology with a metal base to provide constrained sintering. Constrained sintering leads to almost zero shrinkage in the x-y plane during the firing process step allowing the accurate placement of embedded components such as resistors, capacitors, transmission lines etc.
- The almost zero x-y shrinkage also leads to ruggedness, improved heat sinks and allows complex cavities with metal ground.

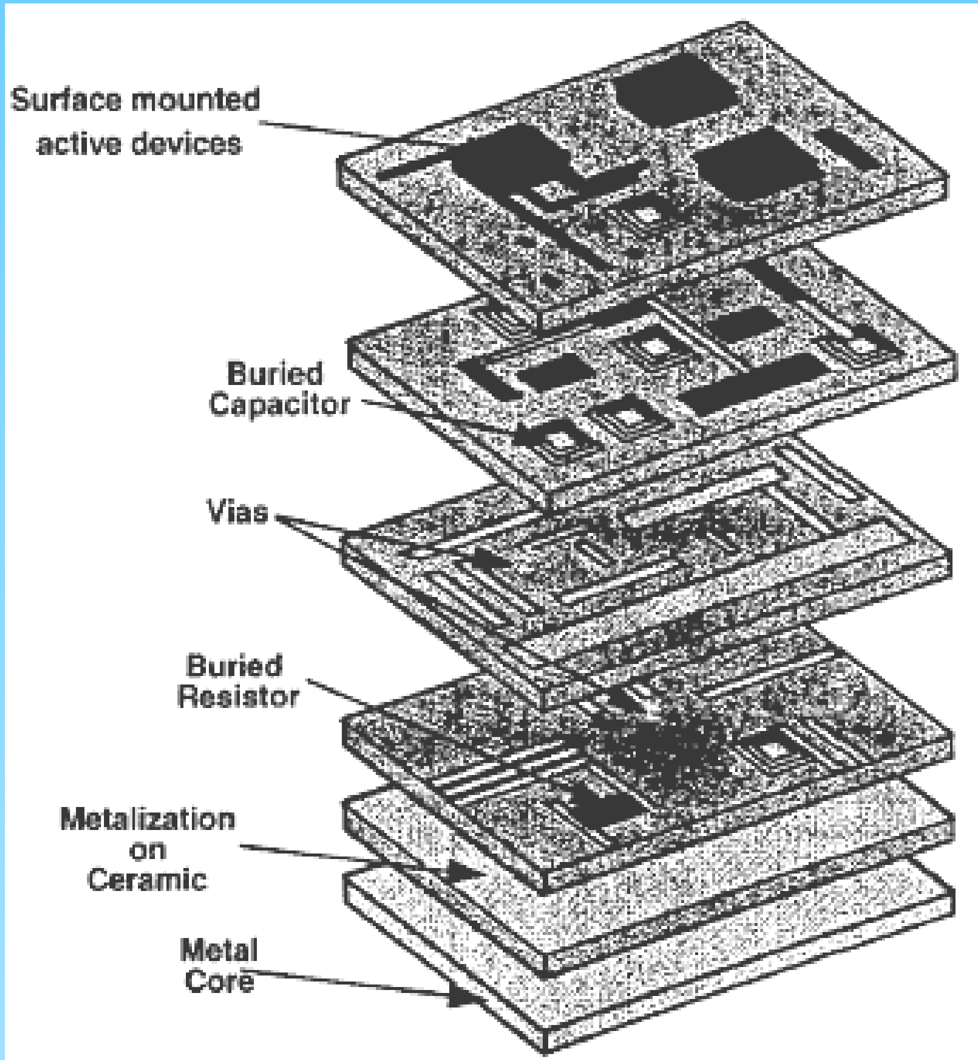
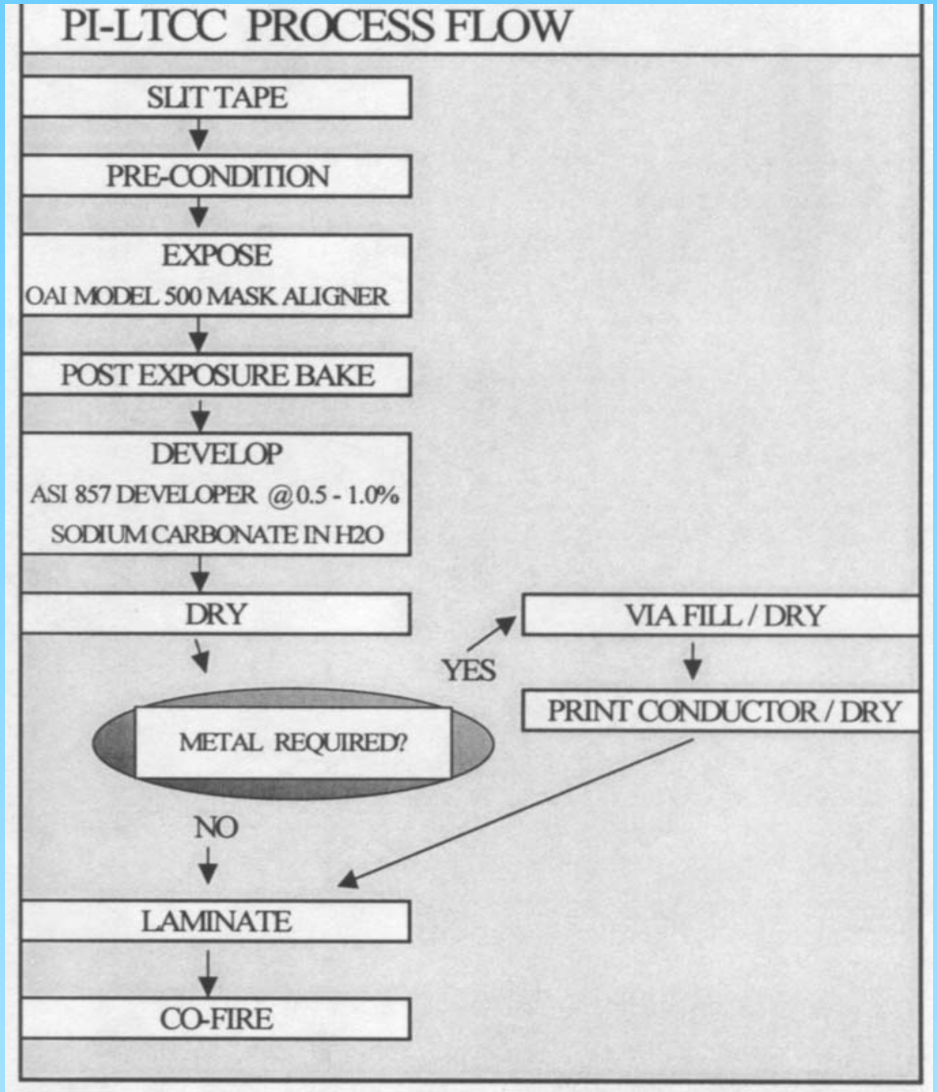


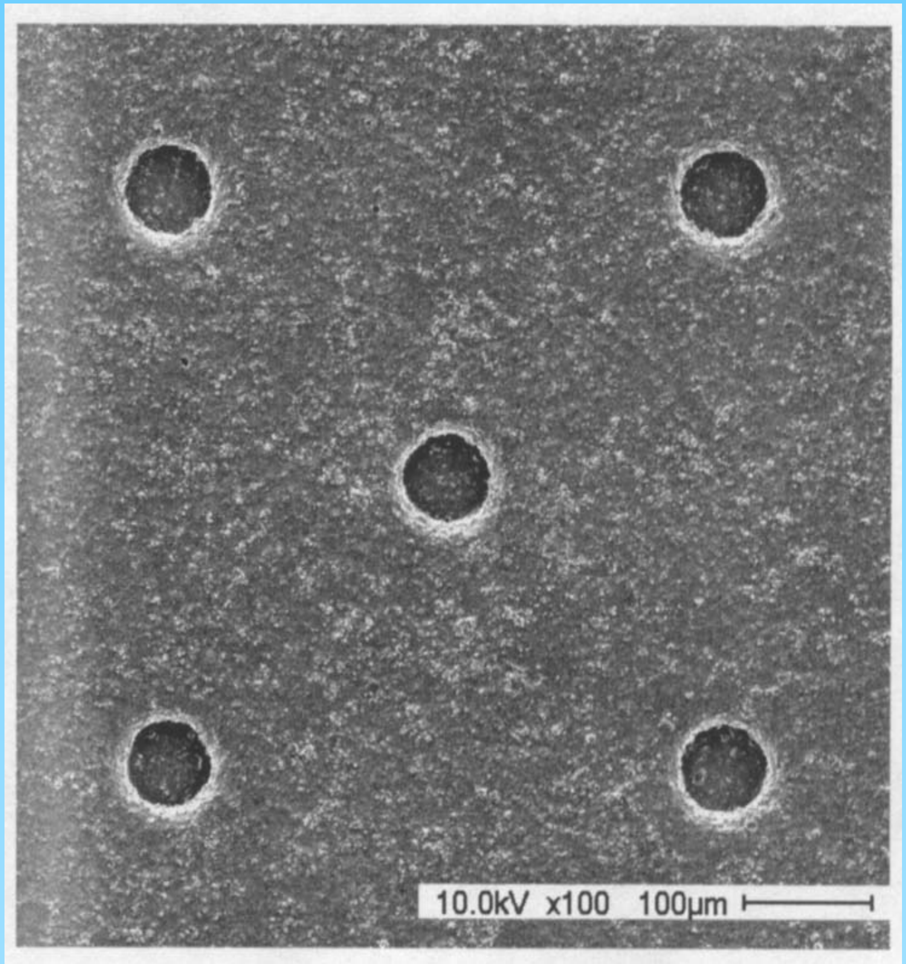
PHOTO IMAGEABLE LTCC (PI-LTCC)

- The PI-LTCC consists of a mixture of photo-polymer organics and ceramic / glass powders doctor bladed onto a 3 mils Mylar film.
- The Photo Imageable LTCC tape offers the advantage of economy by fast and efficient processing combined with the convenience of having an LTCC system very similar in properties to the conventional compositions.
- UV light (365 nm) passes through a photo mask to expose specific areas of the tape.
- The exposed areas will remain after processing and the unexposed area will be dissolved with a 1% aqueous sodium carbonate solution.
- The rest of the processing is similar to that of the conventional 951 series LTCC tape.



VIAS IN PI-LTCC

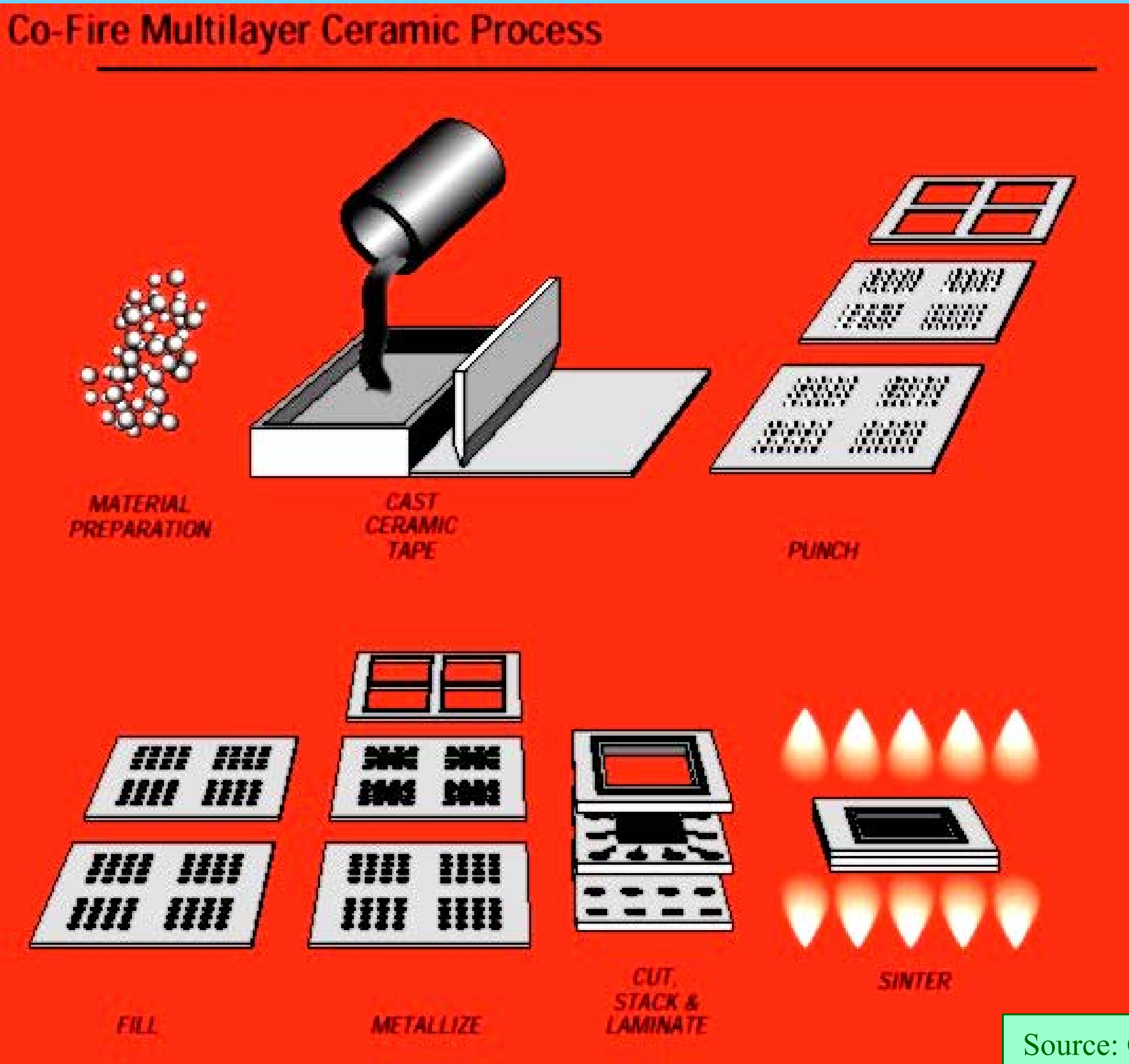
- A cluster of vias, 3 mils each with a pitch of 12 mils from a mask containing 18,000 vias (3”X 3” artwork).
- Note that the time required for such a task is dependent only on the tape resolution and the size capacity of the processing equipment.



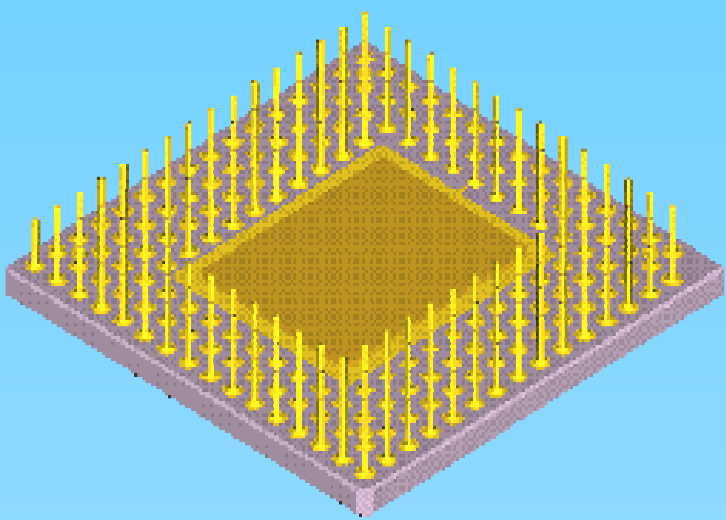
5. ADVANCED PACKAGING TECHNIQUES

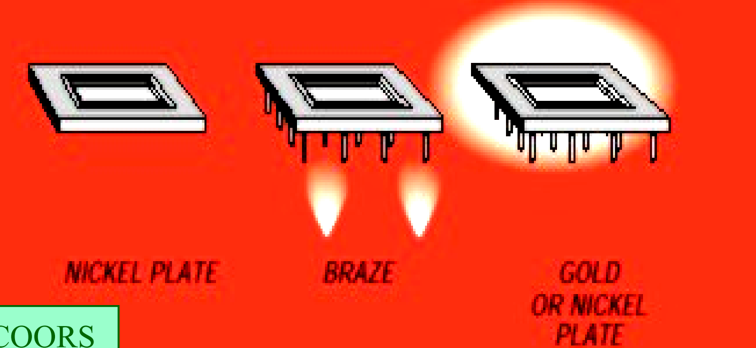
- 2D Packaging techniques
- Flip-chip & BGA packaging
- 3D Packaging Techniques
- Modular 3D Packaging

MULTILAYER LTCC (2D) CERAMIC PACKAGES



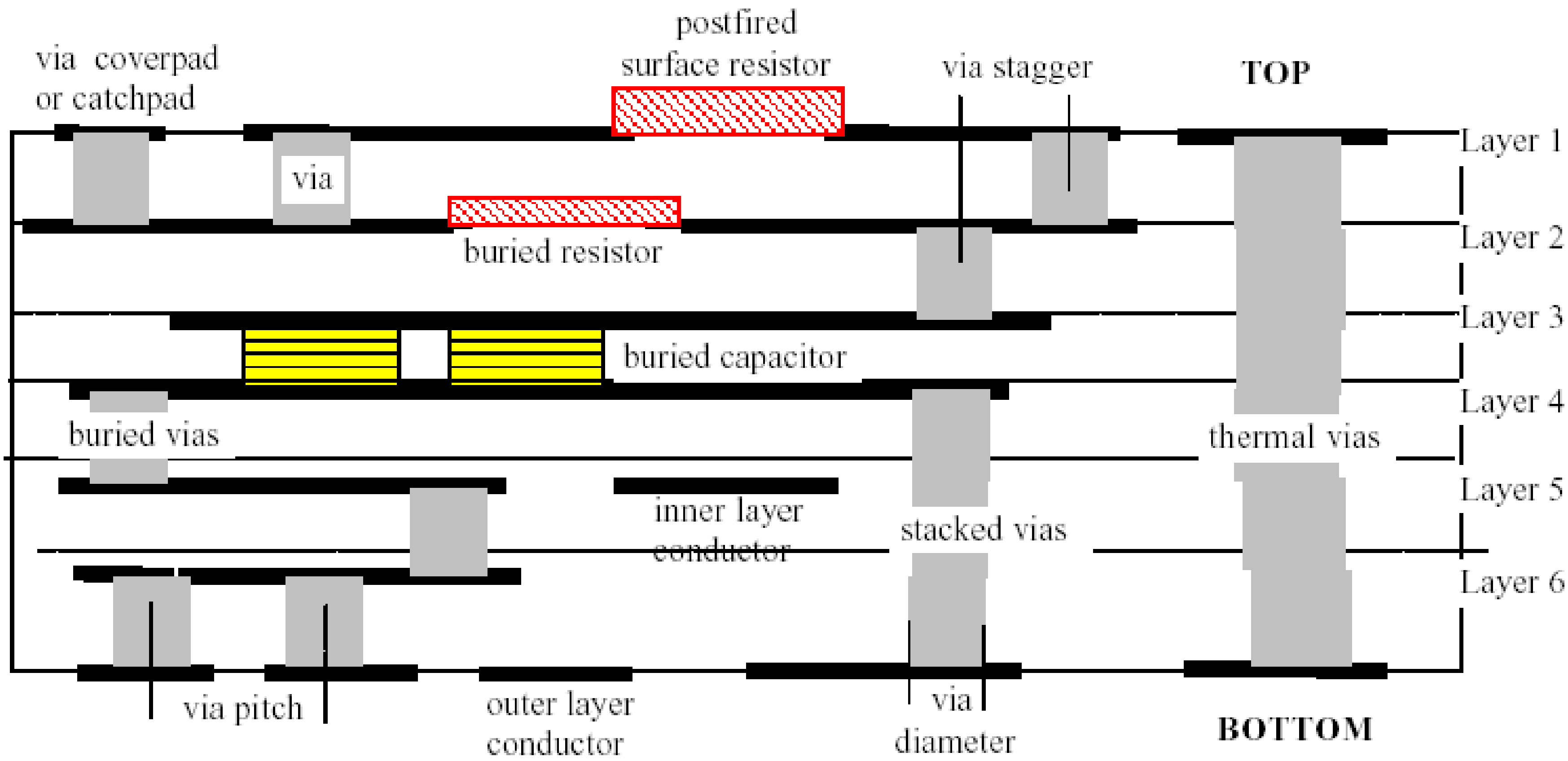
PIN GRID ARRAY





Source: COORS

FEATURE LTCC TERMINOLOGY (CROSS SECTION)

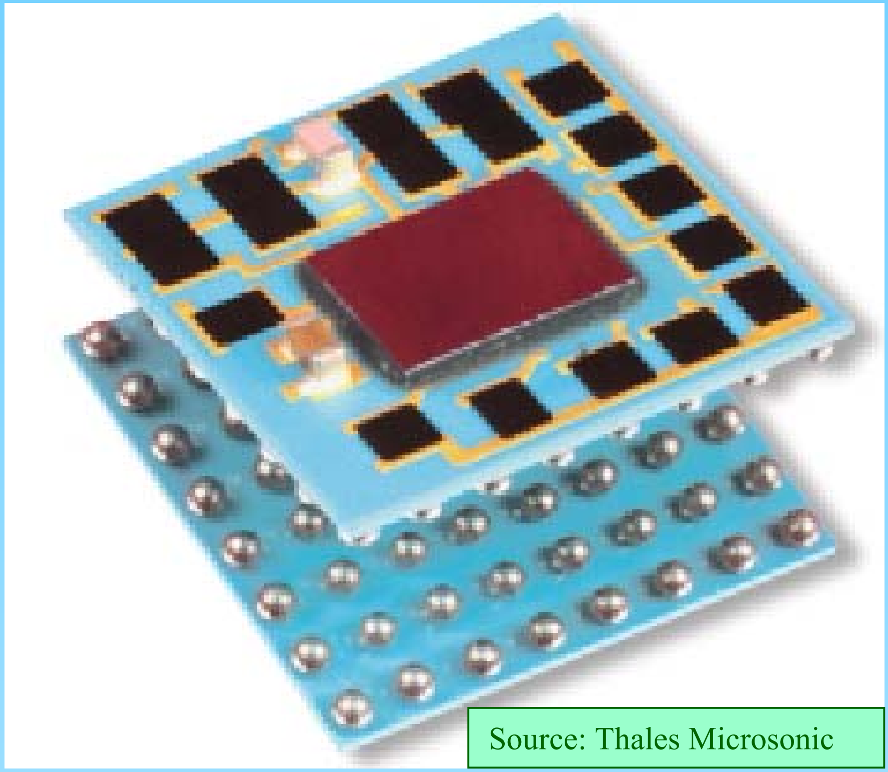


Source:Thales Microsonics

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 allows 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)
  - 3 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

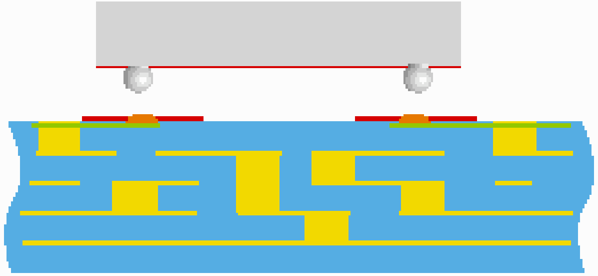
LTCC DESIGN RULES for FLIP-CHIP

FLIP CHIP ASSEMBLY

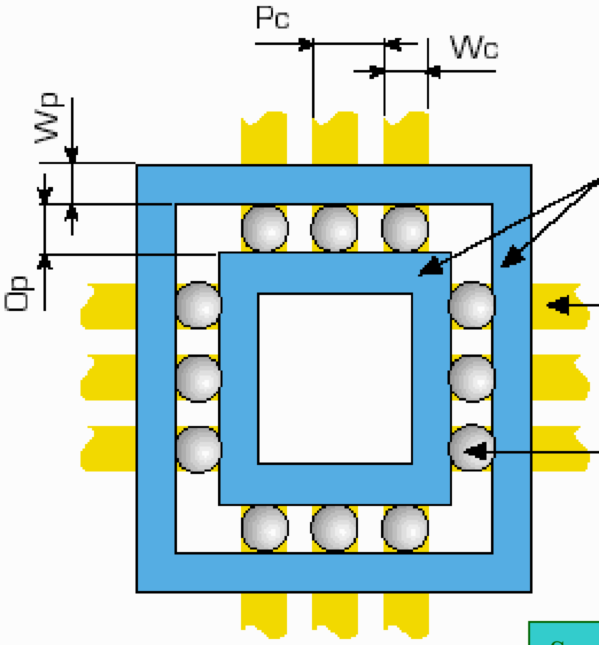
Flip Chip on co-fired AgPd conductor pads using solder reflow.

Parameter	Symbol	Value
AgPd pad width	Wc	150 µm min.
AgPd pad pitch	Pc	250 µm min.
Passivation opening	Op	150 µm min.
Passivation width	Wp	200 µm min.

Figure 1 : Flip chip assembly



Flip Chip Assembly on LTCC Structures for solder reflow techniques



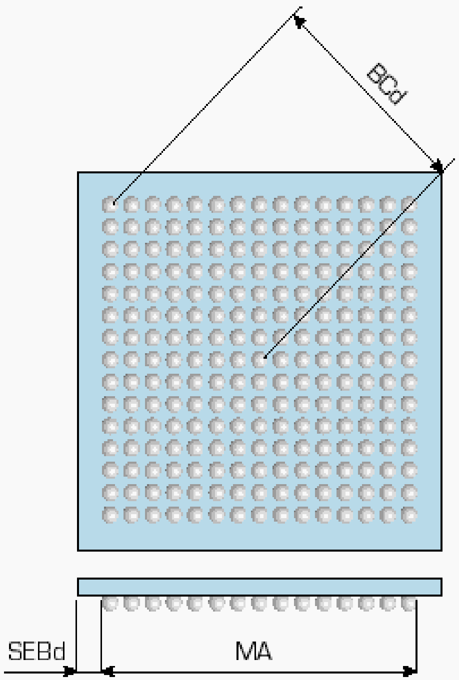
Source:Thales Microsonics

BALL GRID ARRAY WITH LTCC

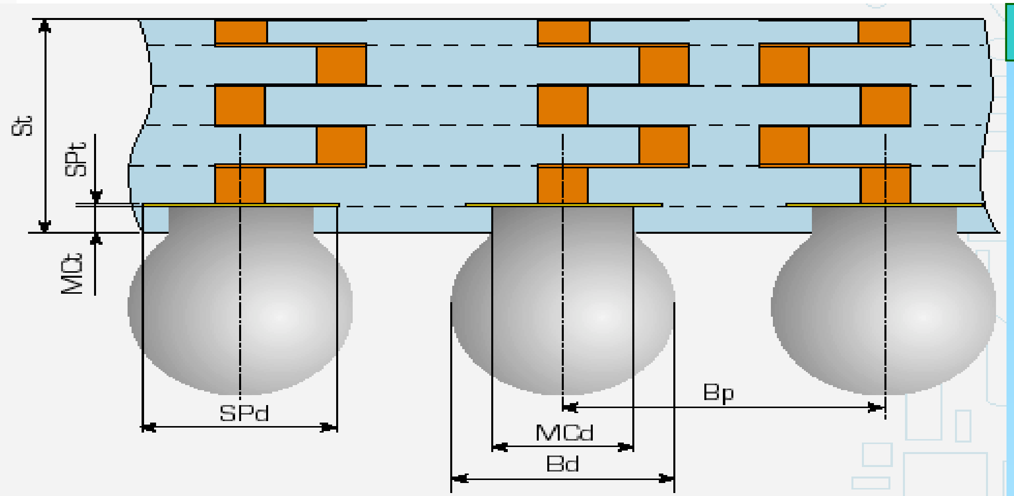
- Characteristics of BGA with LTCC
  - Ball pitch from 0.75 mm to 1.5 mm
  - Body size from 5 x 5 mm2 to 40 x 40 mm2
  - Number of I/Os up to 961
  - High temperature solder balls
  - Adapted to single and multi-chip module design
  - Large range of techniques for die protection
    - Glued metallic 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 DESIGN RULES for BGA



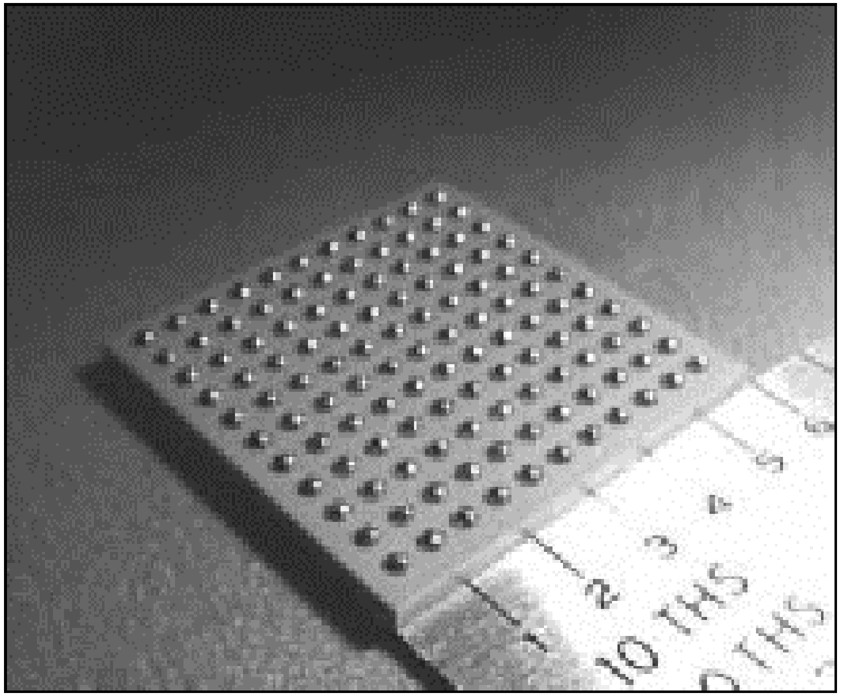
Parameter		Value	Remark
Ball pitch	Bp	1.27 mm	
Ball diameter	Bd	0.89 mm	
Micro-cavity diameter	MCd	0.57 mm	
Micro-cavity thickness	MCt	0.130 mm	
Solder pad diameter	SPd	0.770 mm	
Solder pad thickness	SPt	20 µm min.	
Solder pad material	PdAg		
Via material for layer 2	PdAg		
Conductor & via material for other inner layers	Ag		
Substrate thickness	St	0.9 mm min.	
Ball to package centre distance	BCd	20 mm max.	Depends on PCB material and temperature cycling requirements
Matrix area	MA	30 mm x 30 mm max.	For square distribution.
			Depends on PCB material and temperature cycling requirements
Substrate edge to ball distance	SEBd	0.5 mm min.	

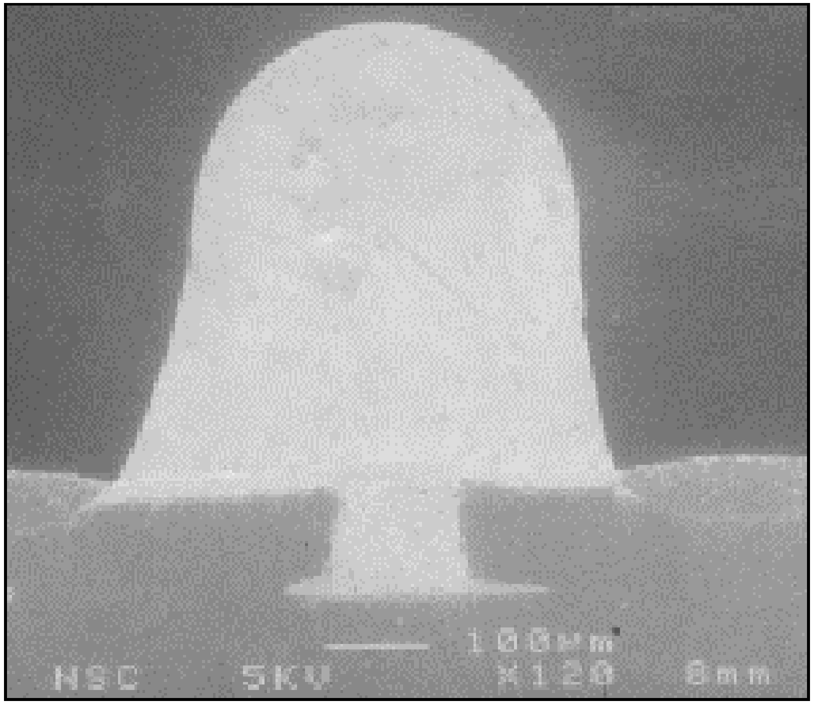


Source:Thales Microsonics

LTCC-BGA

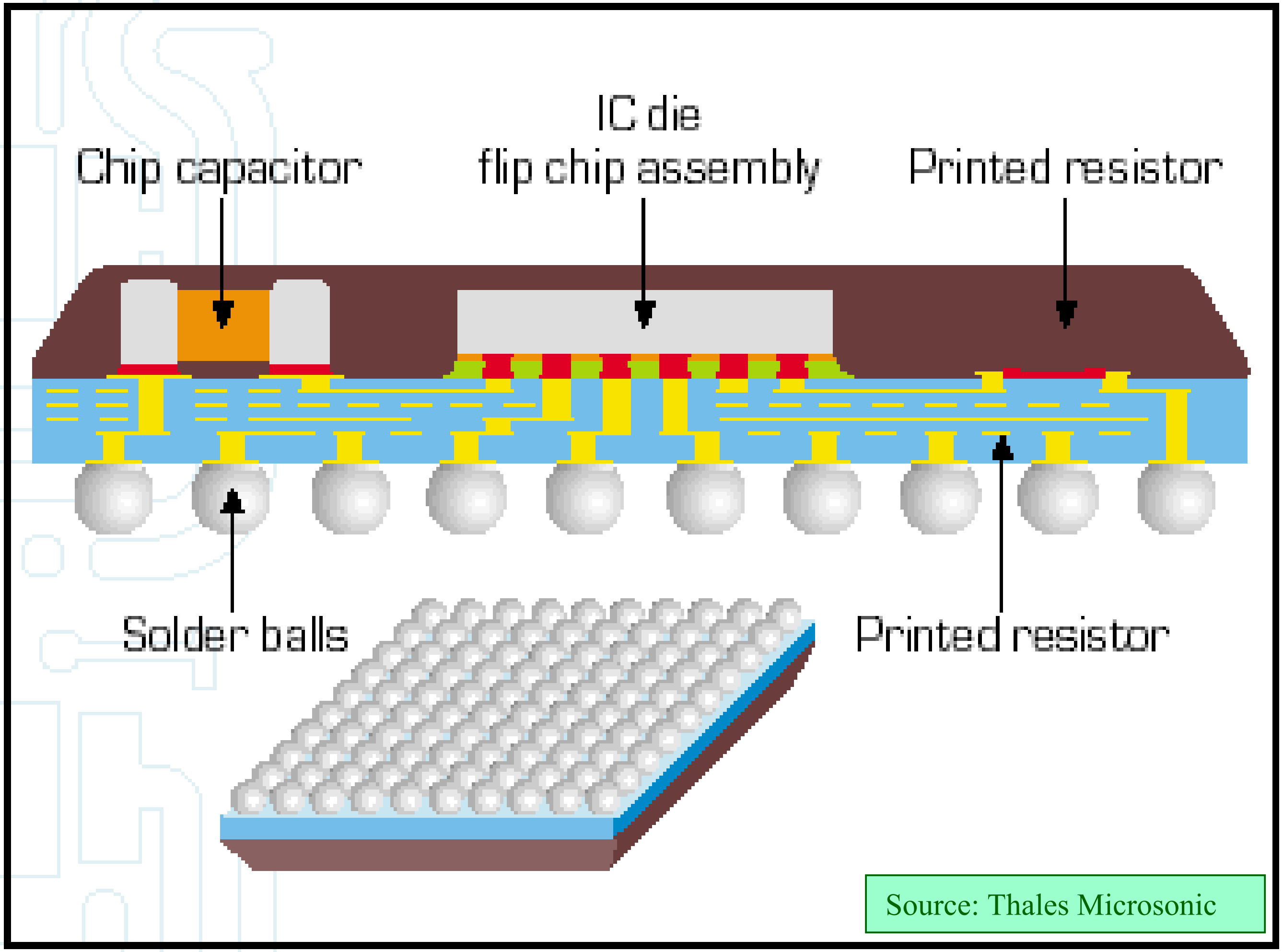
Part and Cross Section – 30 mil ball





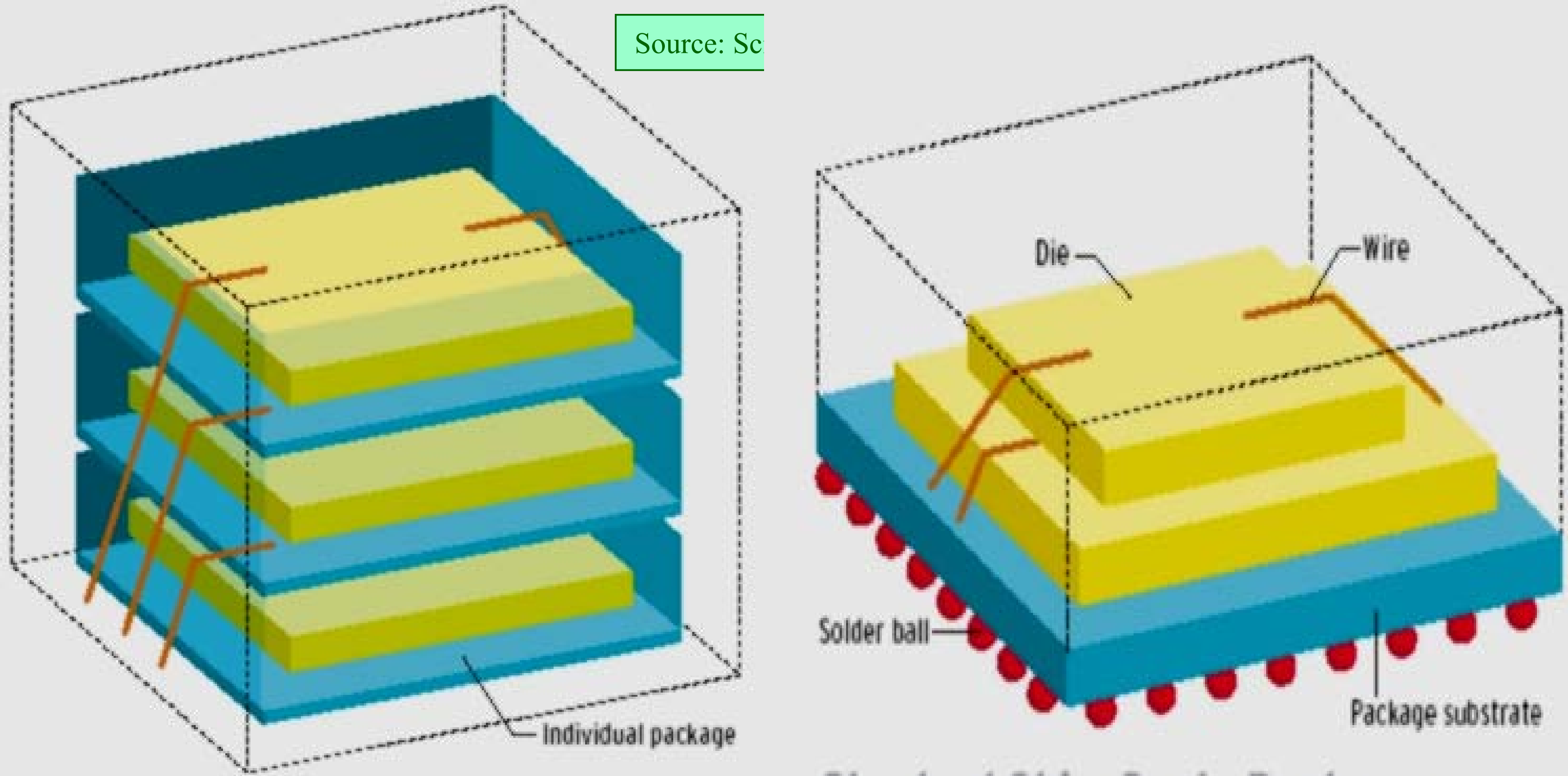
Source: National Semiconductors

COMBINATION OF BGA, FLIP CHIP AND LTCC TECHNOLOGIES



3D PACKAGING

Source: Sc



Stacked Packages

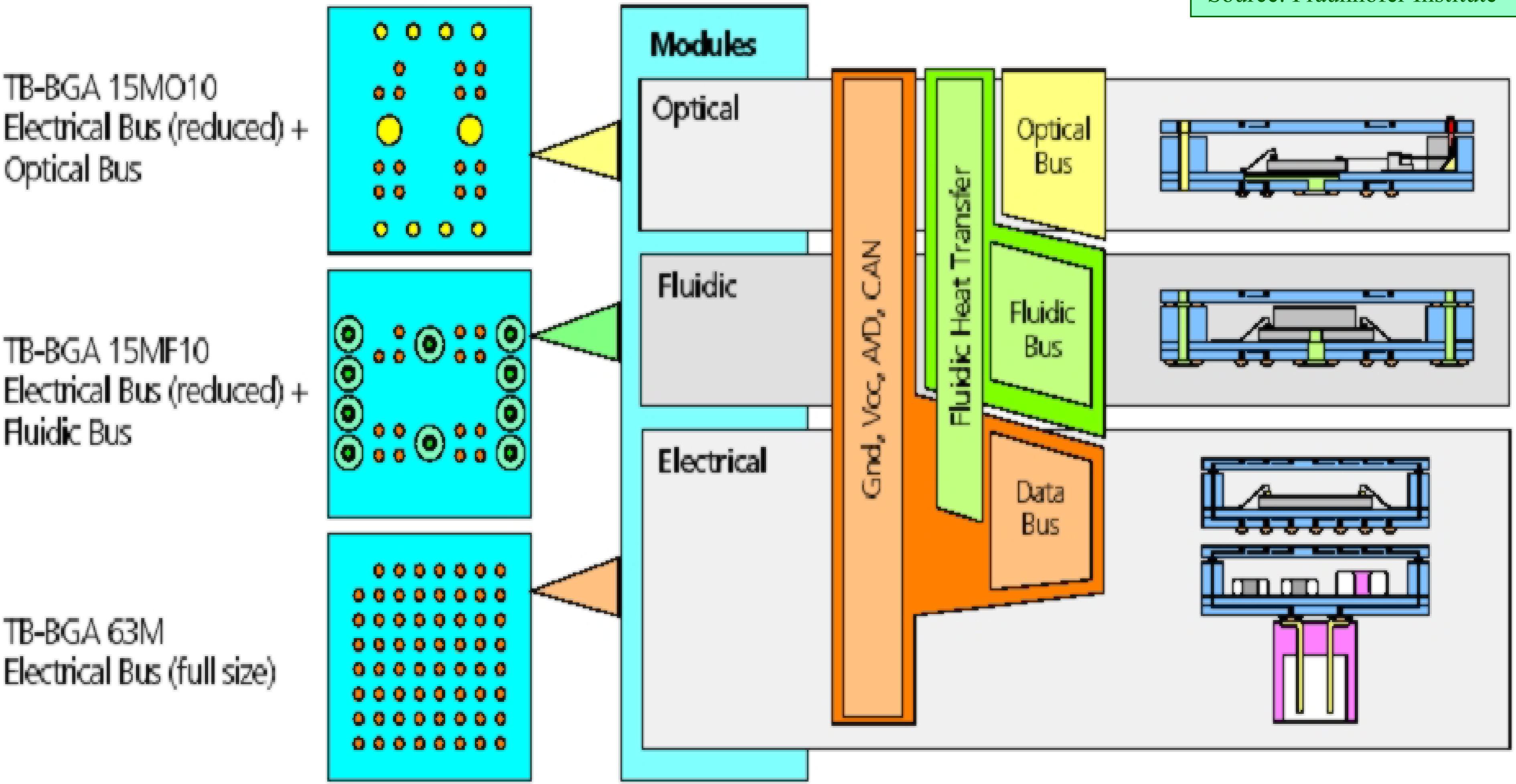
Packaged memory chips are commonly stacked on top of each other to supercharge memory in equipment ranging from cell phones up to high-end computers.

Stacked Chip-Scale Package

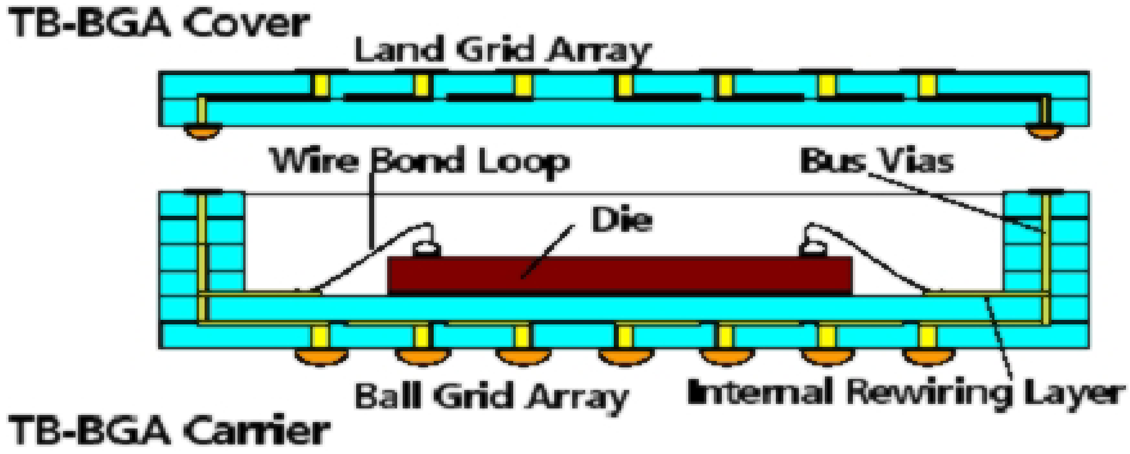
More compact are packages that stack bare die and wire-bond them to pads that connect to the solder balls leads on the substrate. The package is connected to a circuit board via the solder balls.

MODULAR SYSTEM INTERFACES

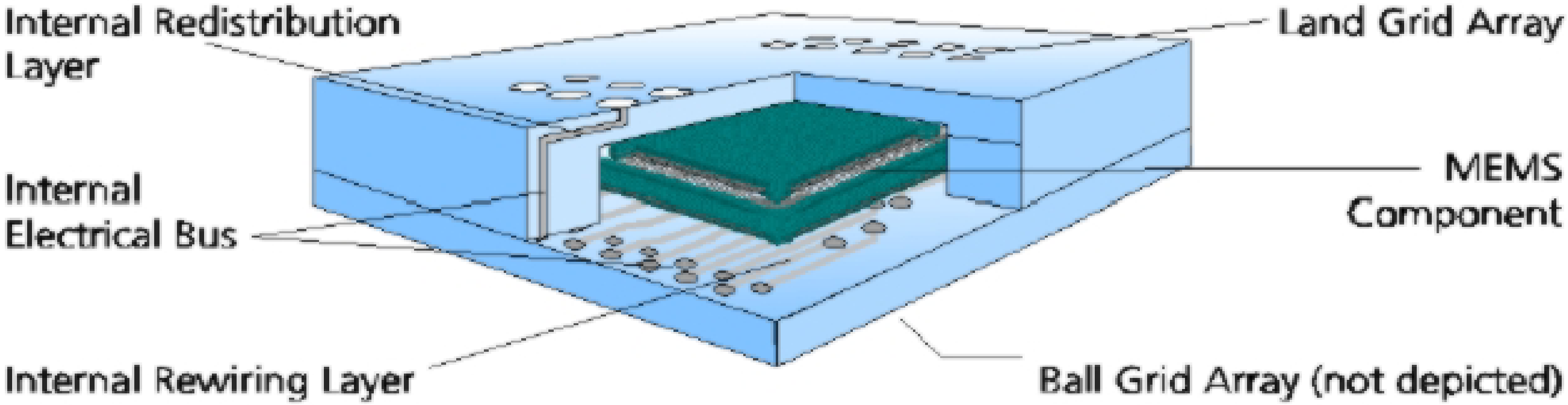
Source: Fraunhofer Institute



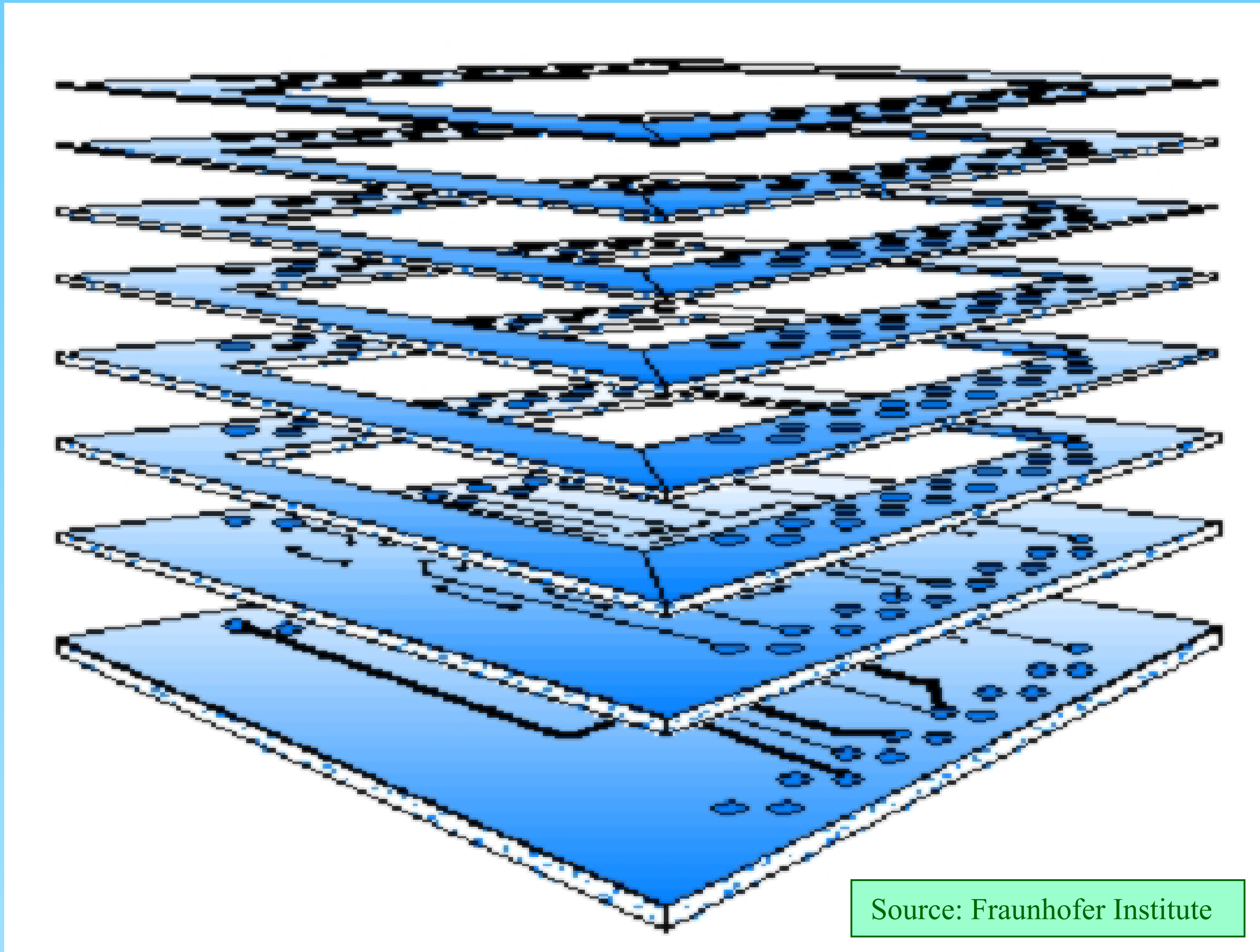
LTCC-TB-BGA (TOP-BOTTOM- BGA)



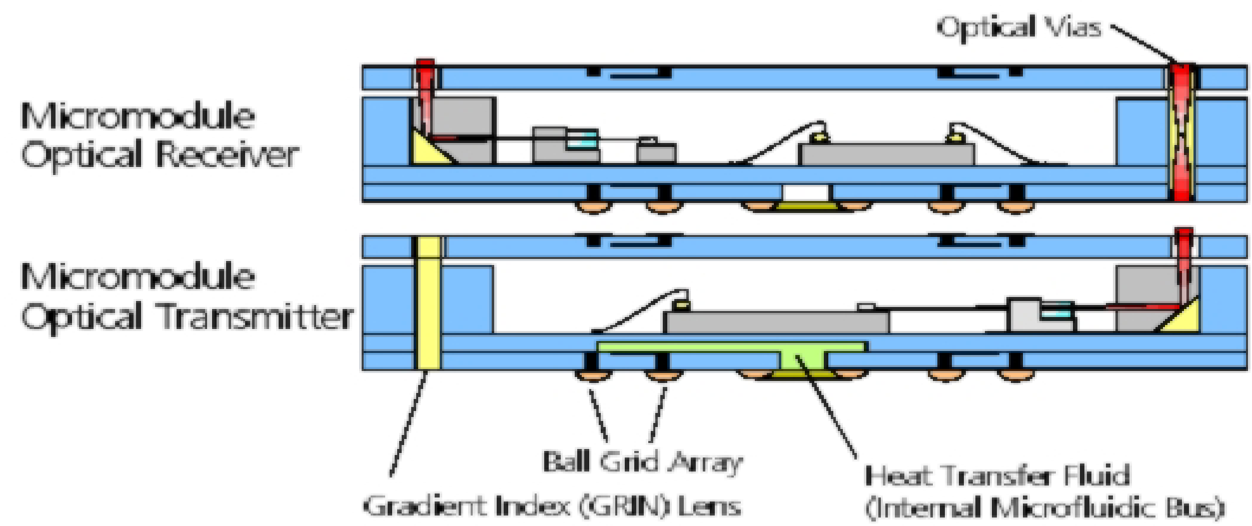
Source: Fraunhofer Institute



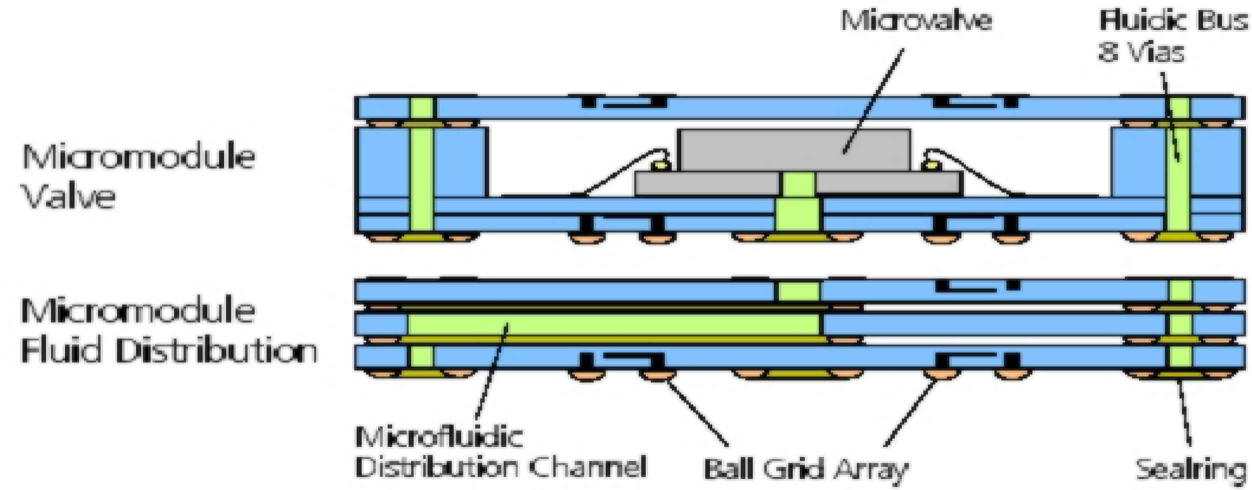
ASSEMBLY OF A LTCC CARRIER



OPTICAL & FLUIDIC INTERFACES

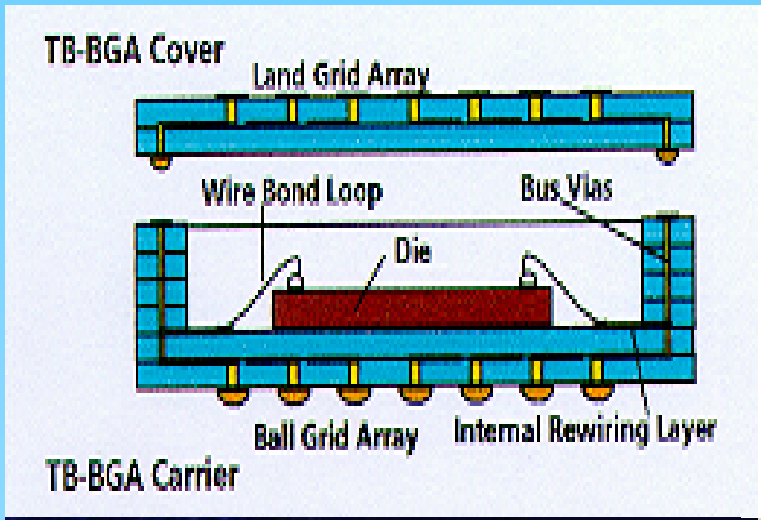


Source: Fraunhofer Institute



SOME 3D LTCC MODULES

- 16 Bits Microcontroller Flow Sensor



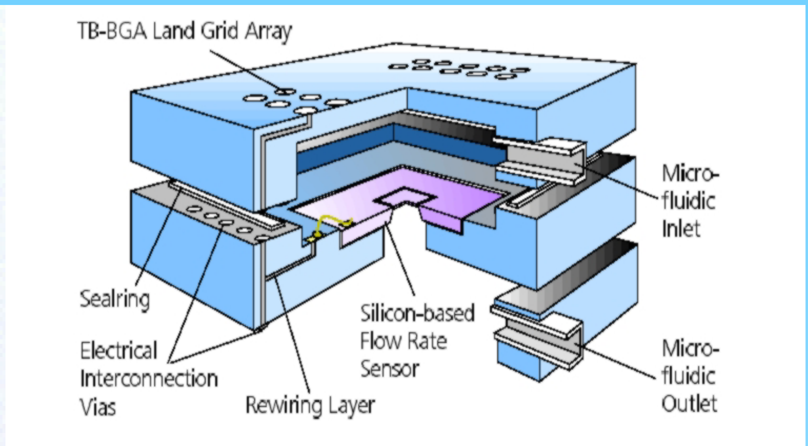
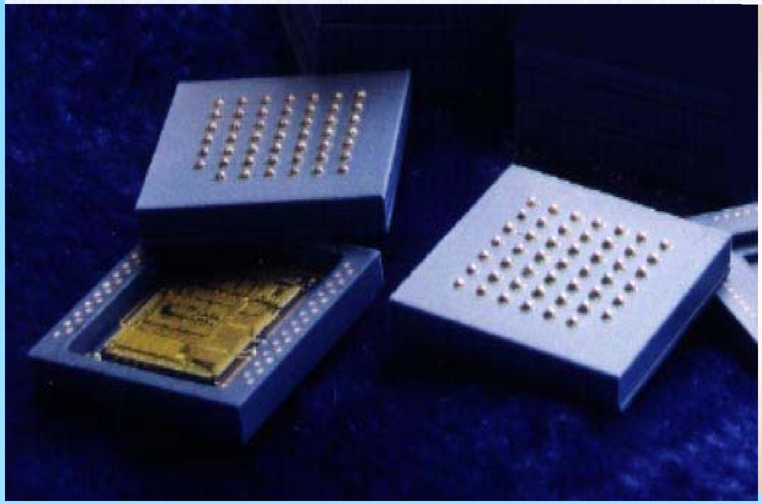


Figure 17: Design of a Flow Rate Sensor Module (LTCC)

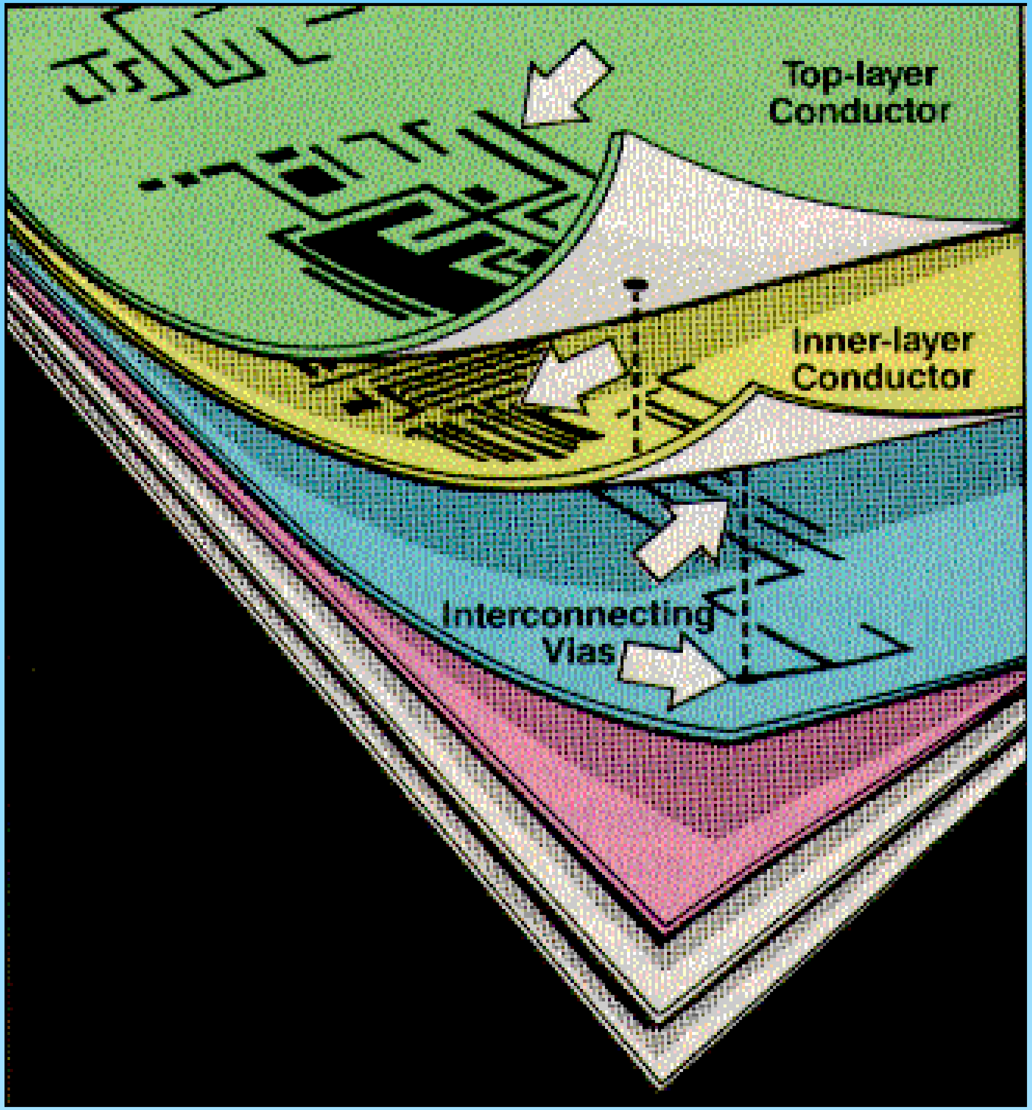


Source: Fraunhofer Institute

6. LTCC TECHNOLOGY FOR MICROELECTRONICS

- MCM devices
- Embedded Passives
- HF & Microwave Devices

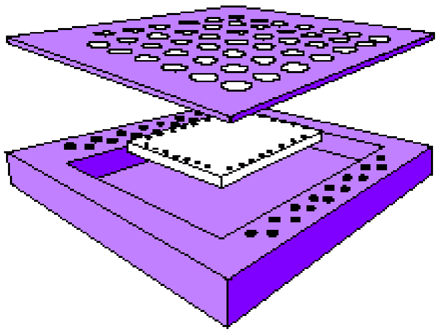
LTCC APPLICATIONS IN MCM

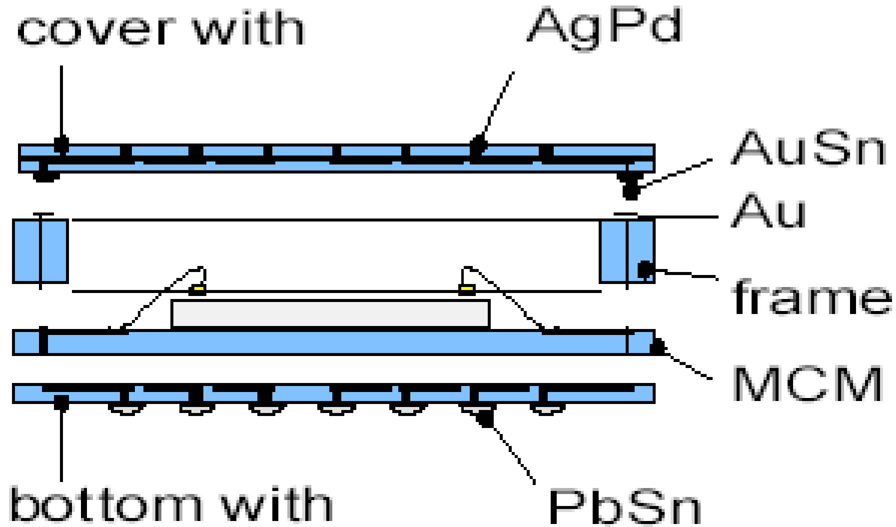


LTCC TB-BGA for MCM

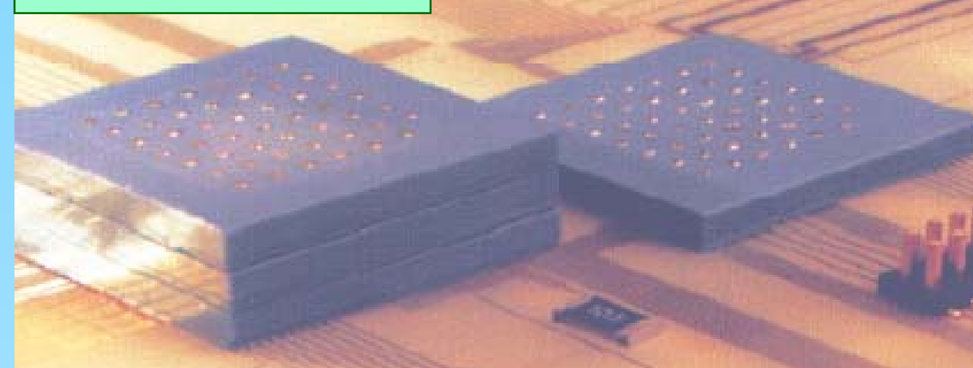
size	12,5 x 12,5
use	9,6 x 11,0
pin count	48
BGA pitch	1,27

units: mm





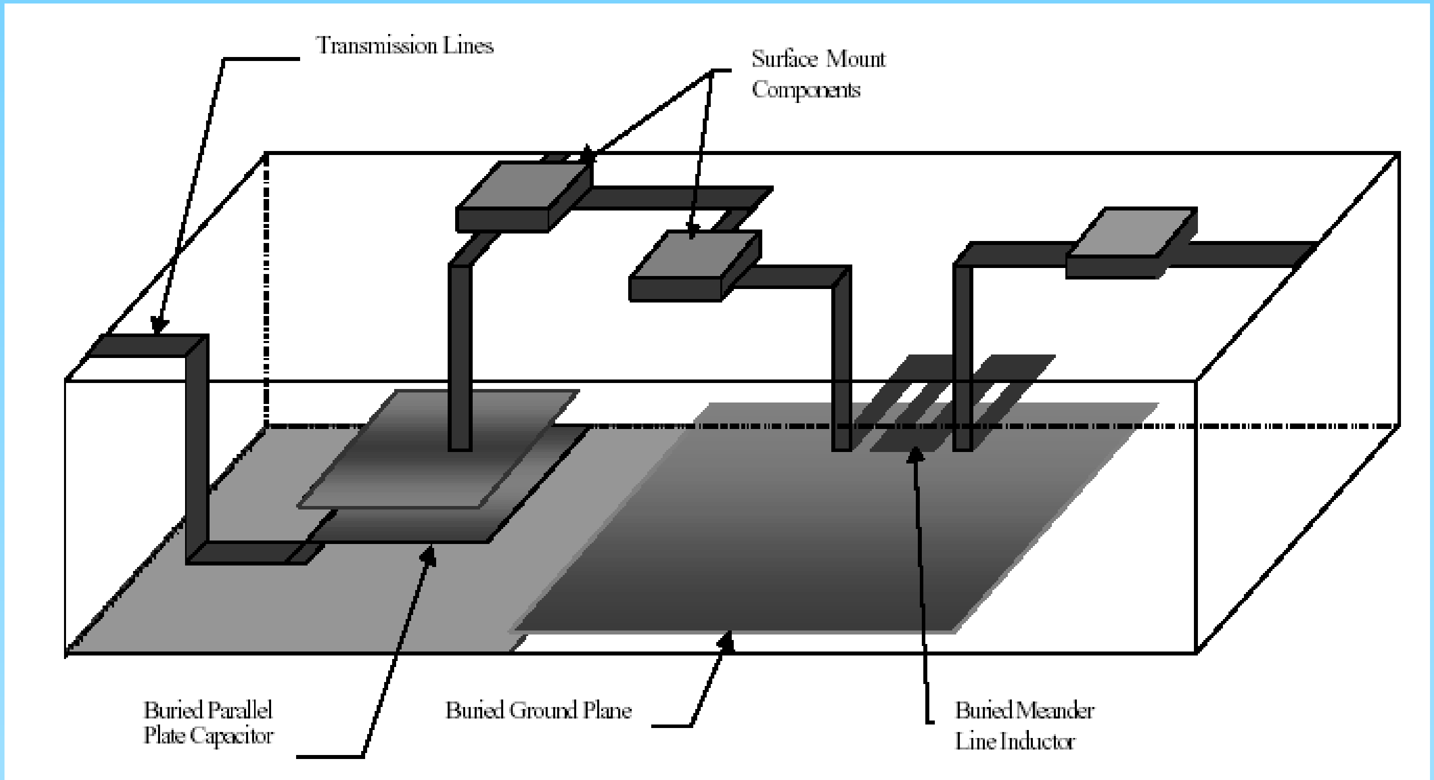
Source: Fraunhofer Institute



EMBEDDED PASSIVES

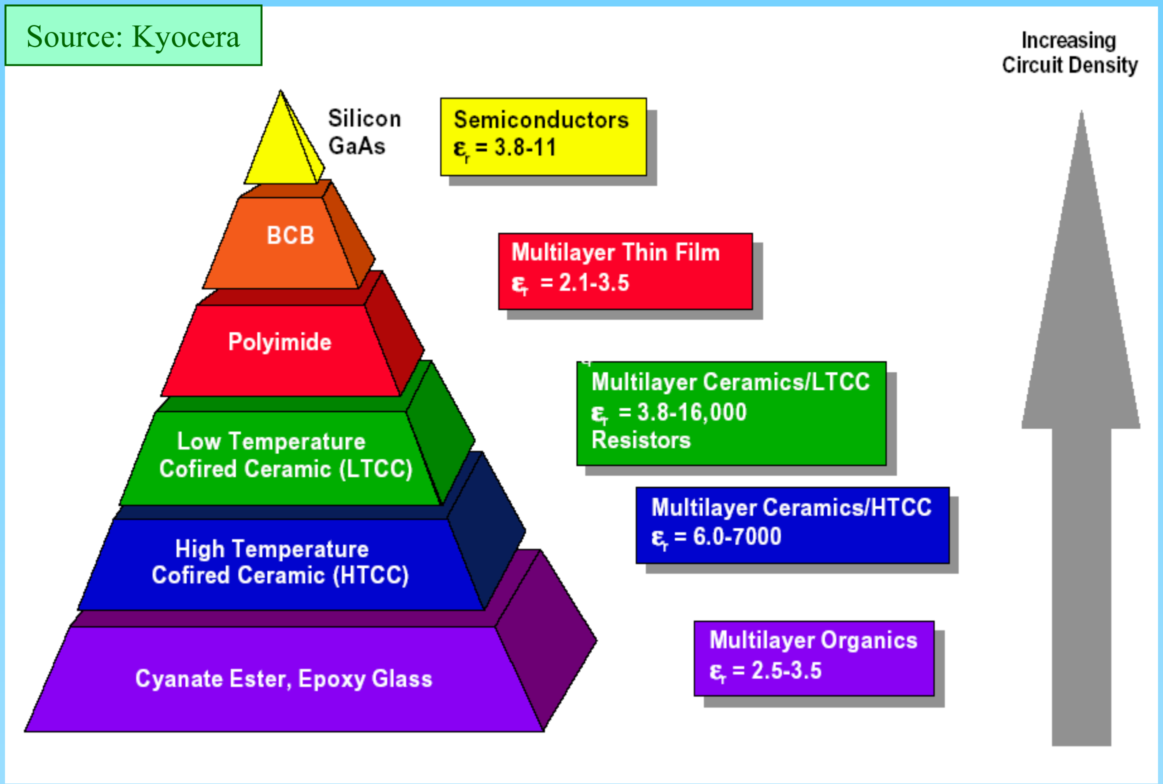
–Integrated Passive Components, IPC's, generally fall into three (3) categories:

- 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



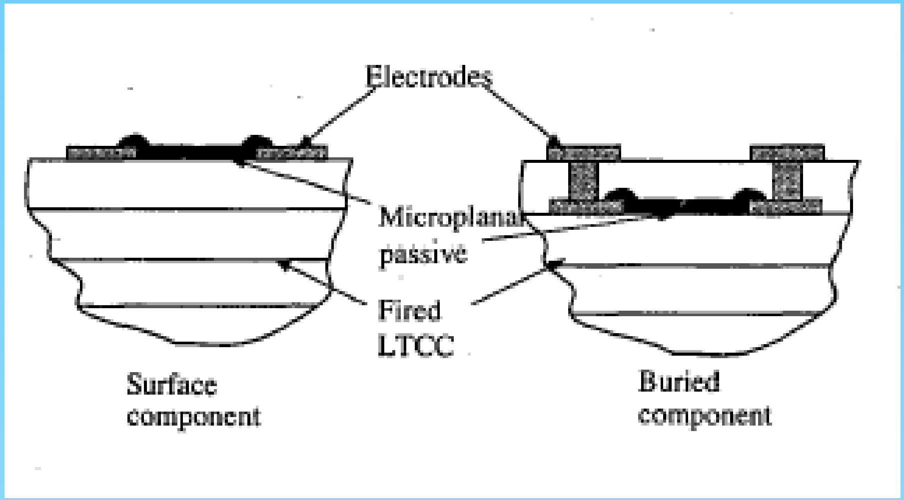
LTCC AND INTEGRATED PASSIVES TECHNIQUES

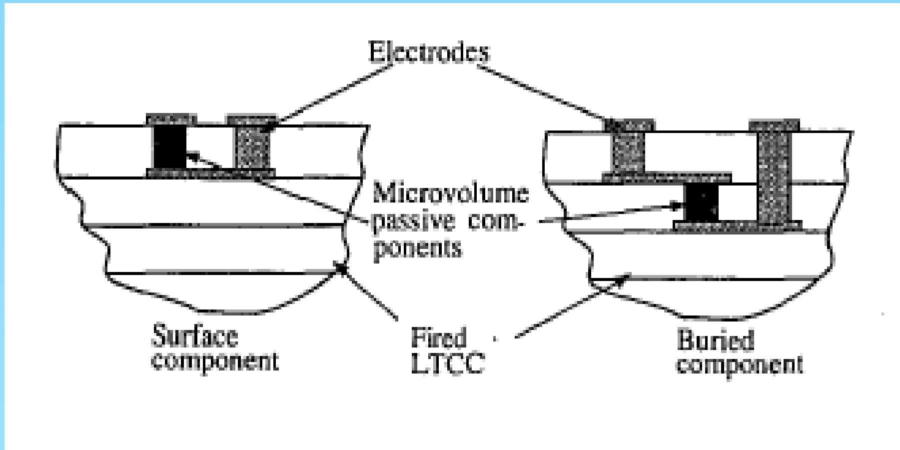
- LTCC displays the widest range of dielectric properties available for any packaging technology, enabling the incorporation of passive components.
- Furthermore, LTCC technology can incorporate resistive material thus enabling the integration of both resistors and capacitors within the substrate, as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



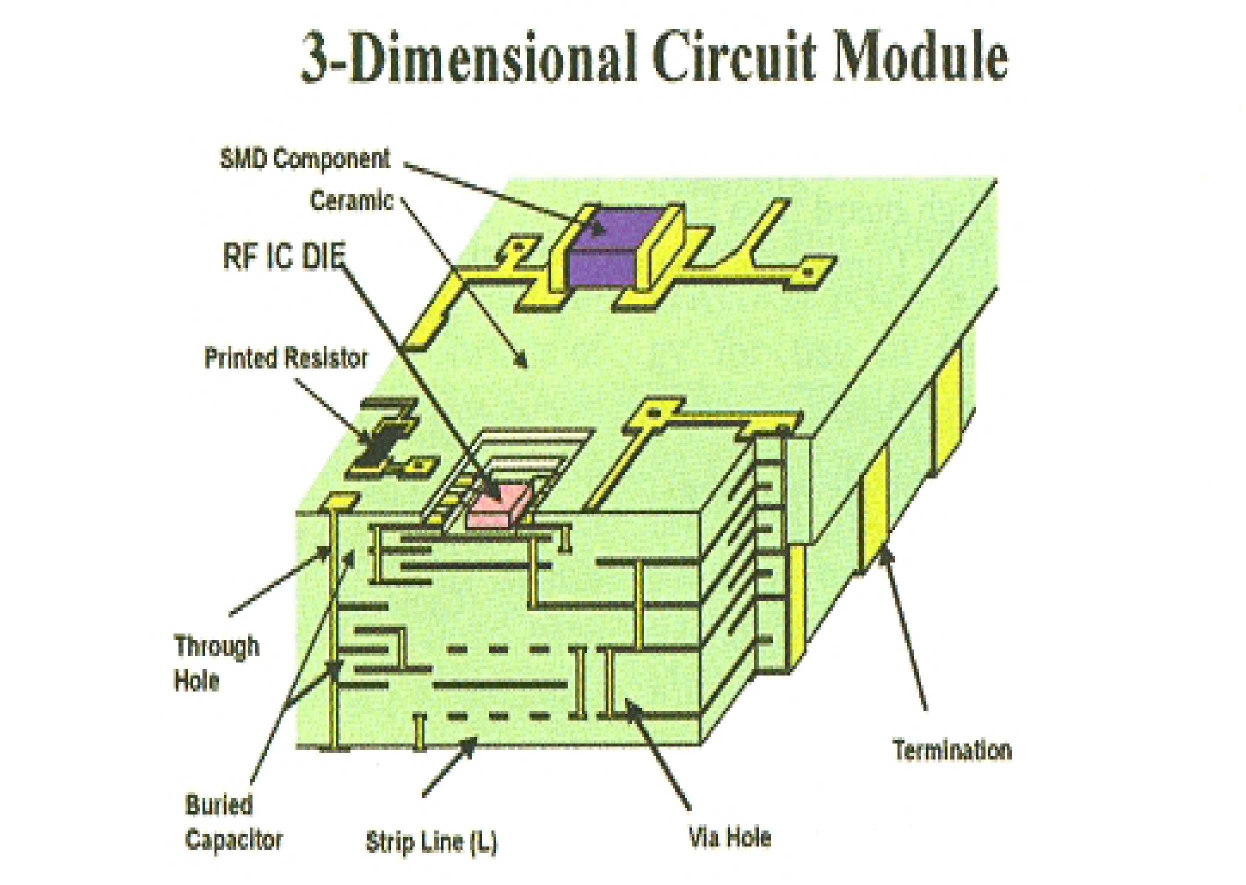
EMBEDDED RESISTORS

- 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





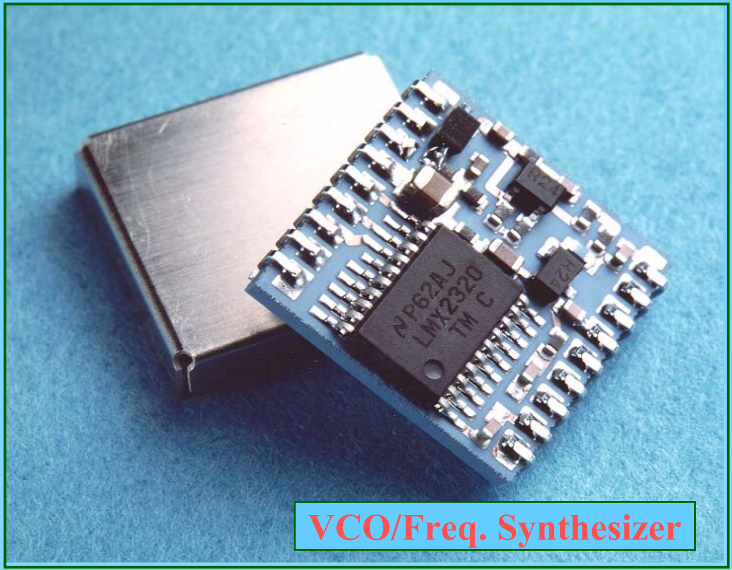
INTEGRATED RF/MW LTCC MODULES



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

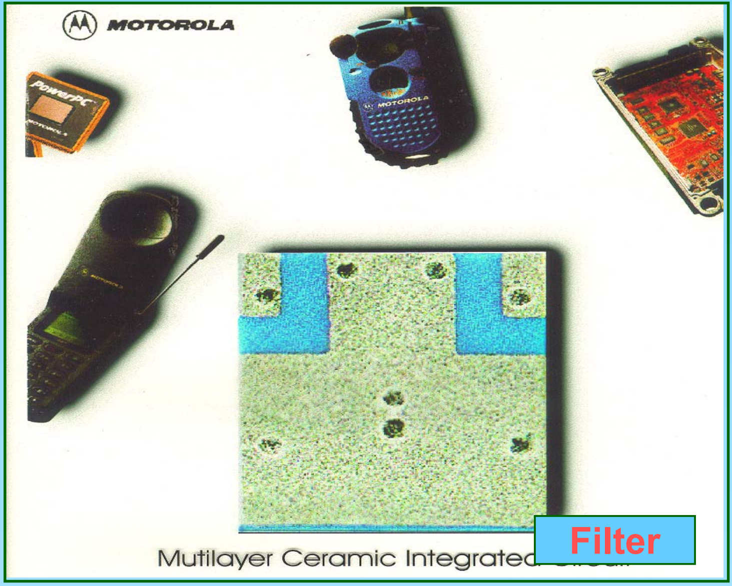
Source:Applied Microwave & RF July/Aug 1998 pg. 45 Murata Electronics

LTCC RF Applications

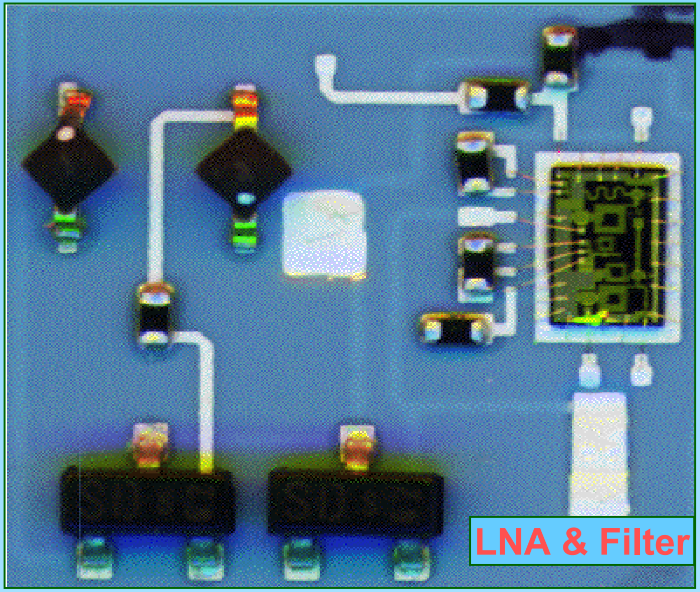


VCO/Freq. Synthesizer


Antenna

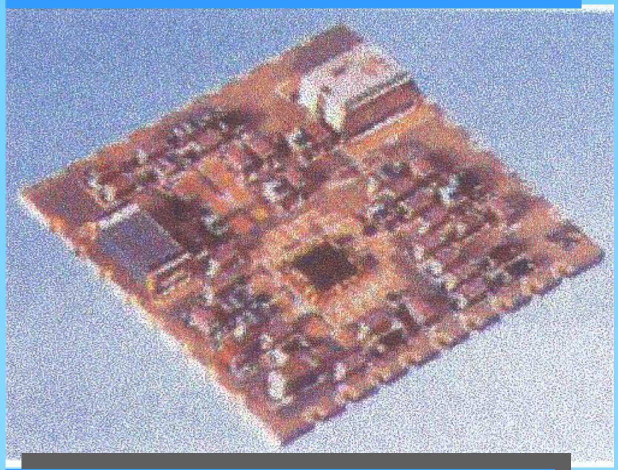


Filter

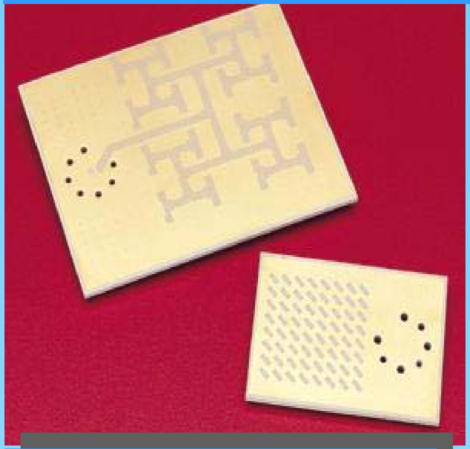

LNA & Filter

LTCC MW APPLICATIONS

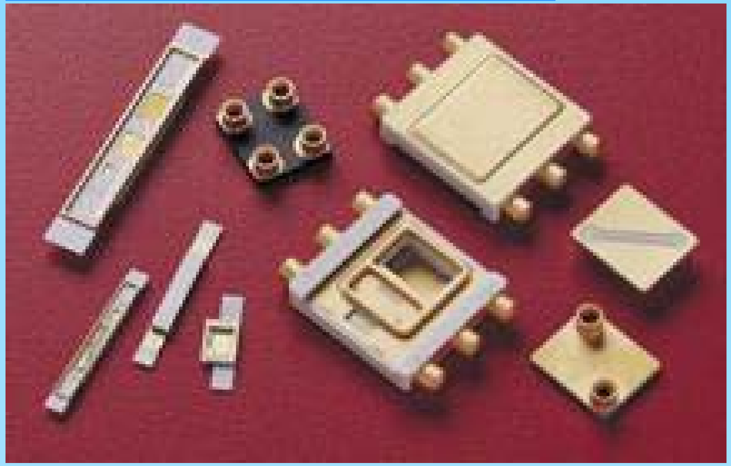
Bluetooth modules



77 GHz planar antenna substrates



Transceiver Modules

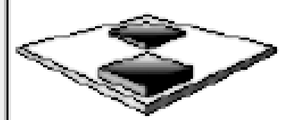
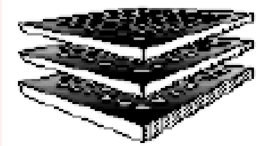
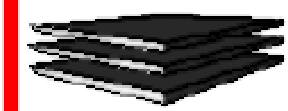


Spiral Antenna

7. LTCC FOR MEMS/MST

- MST Introduction
- LTCC for MST

MODULAR PACKAGING CONCEPTS COMPARISON

	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

MST APPLICATION FIELDS

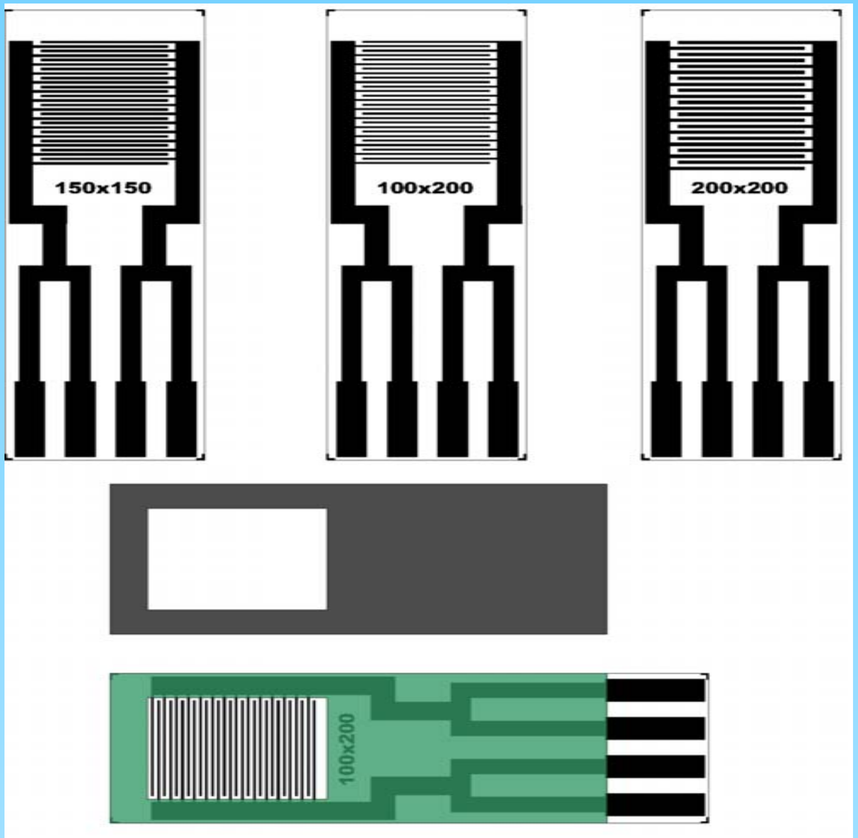
- Automotive /Transportation
- Information Technology, Peripherals
- Telecommunications
- Medical / Biomedical
- Environment / Industrial Processes
- Household Appliances/ Entertainment
- Other Applications (Defence, Aerospace)

SENSORS USING GREEN CERAMIC TAPES

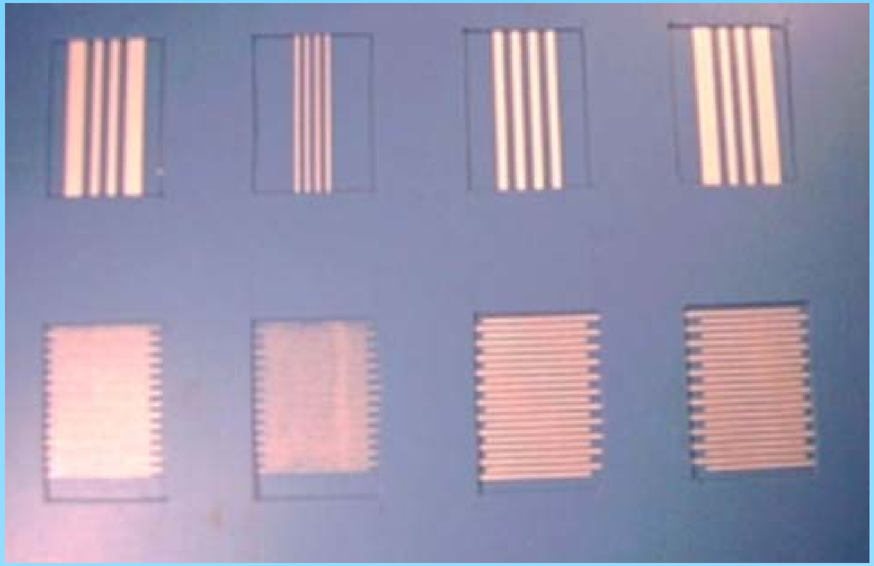
- **Displacement and attitude sensors**
  - LVDT type displacement sensor
  - Attitude sensor using ferrofluids
  - Eddy current proximity sensor
- **Pressure Sensors**
  - Load Cells
  - Differential pressure sensors
  - High temperature pressure
- **Basic Micro-Fluidic Devices**
  - Micro-channels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

CONDUCTIVITY SENSORS

INTERDIGITAL ELECTRODES



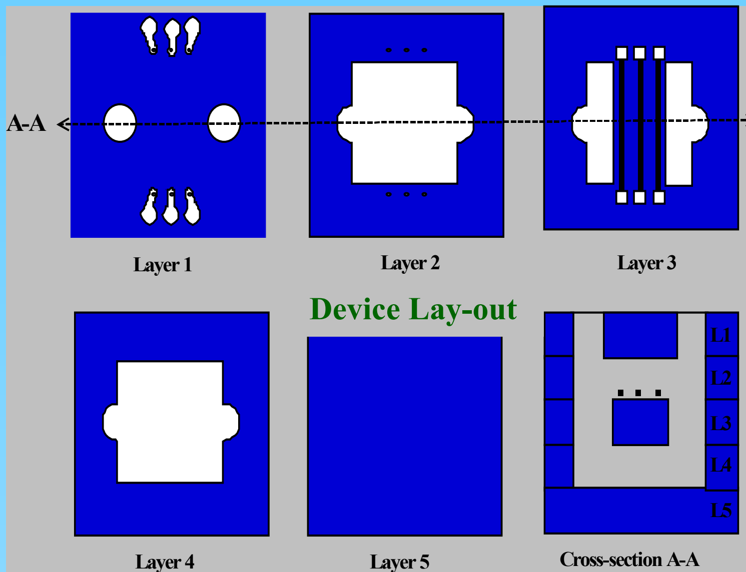
FABRICATED DEVICES

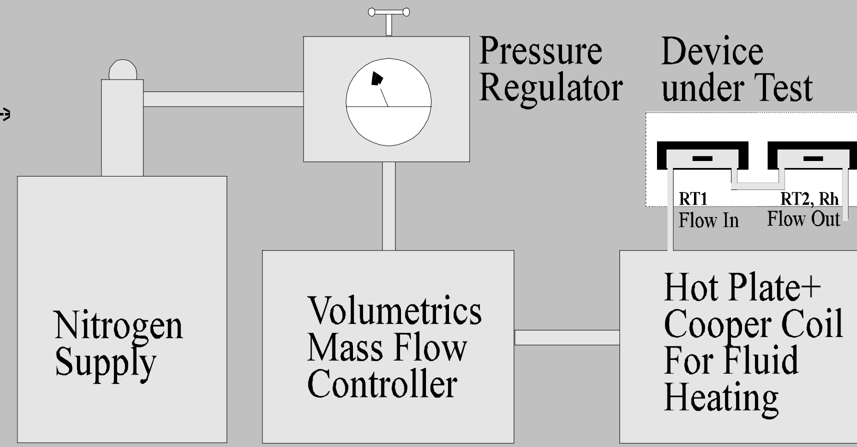


THERMAL FLOW SENSOR WITH GREEN CERAMIC TAPES

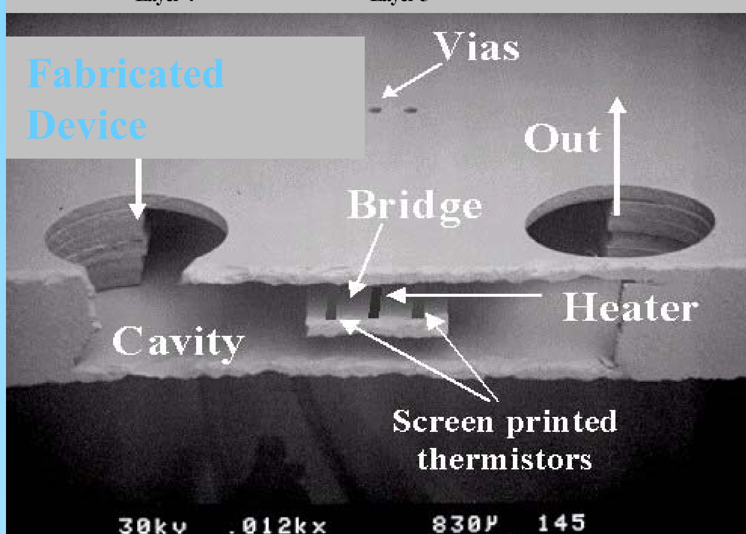
- Thermal methods display some advantages for implementing flow sensors as:
  - Thermal isolation between structure and support;
  - Low thermal capacity improving response times;
  - Small dimension devices;
  - Integration in a micro-system or MEMS scheme.

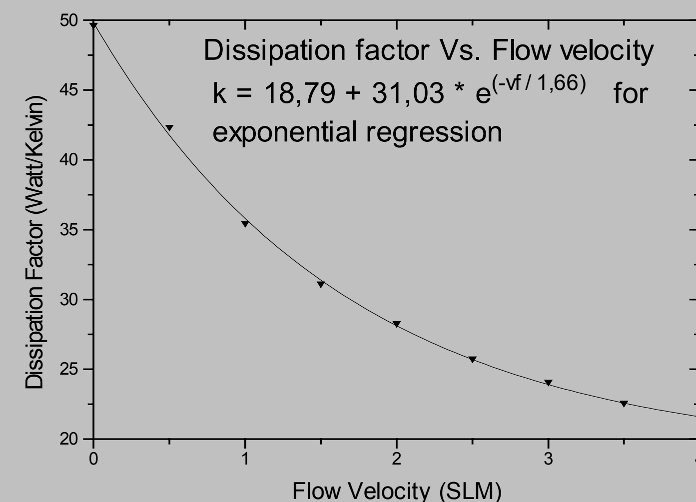
LTCC FLOW SENSORS





Experimental Set-Up



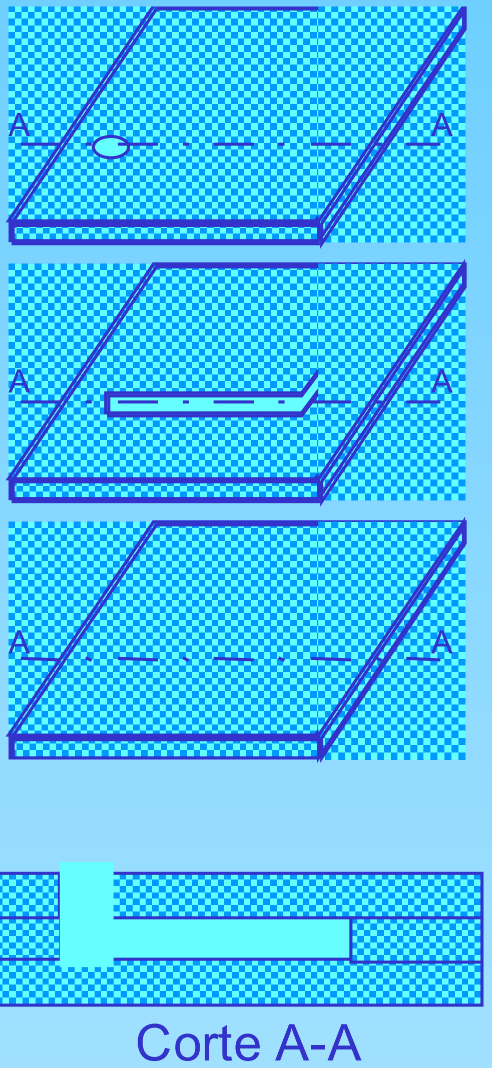


BASIC MICROFLUIDIC DEVICES

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

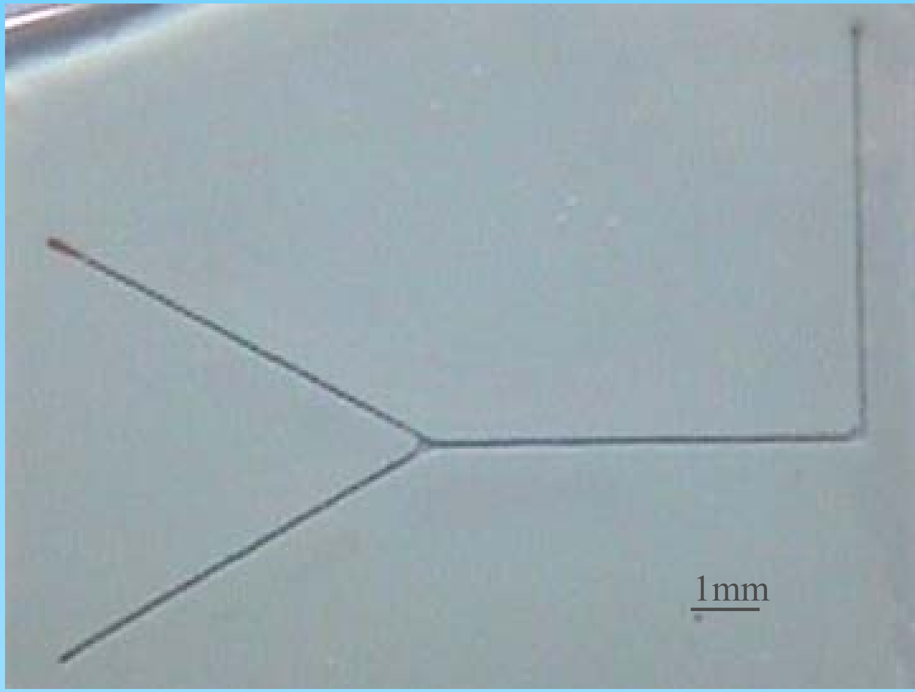
MICRO-CHANNELS

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



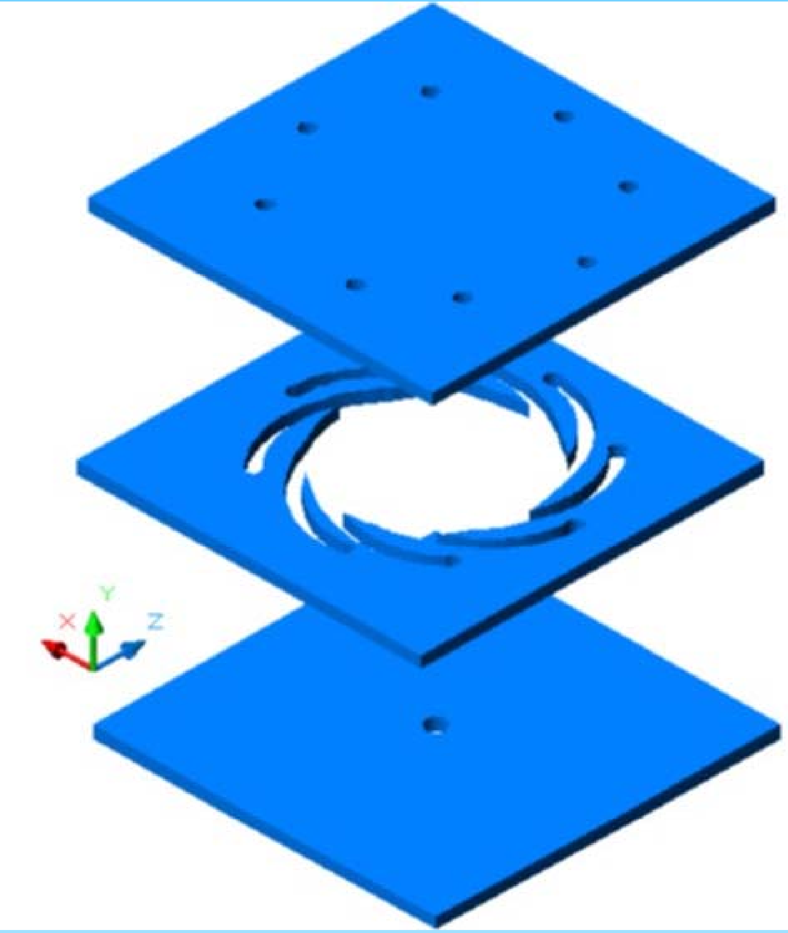
Y MICROCHANNEL FABRICATED USING GREEN TAPES AND GLASS.

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

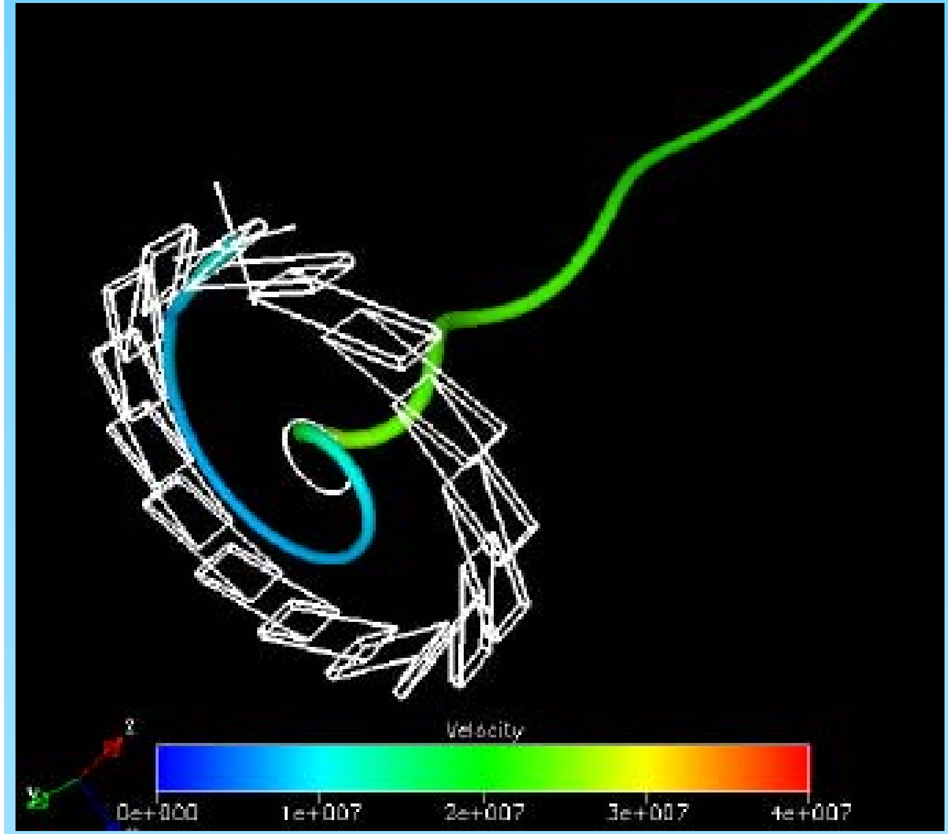


LTCC VORTEX MIXER

LTCC Layer

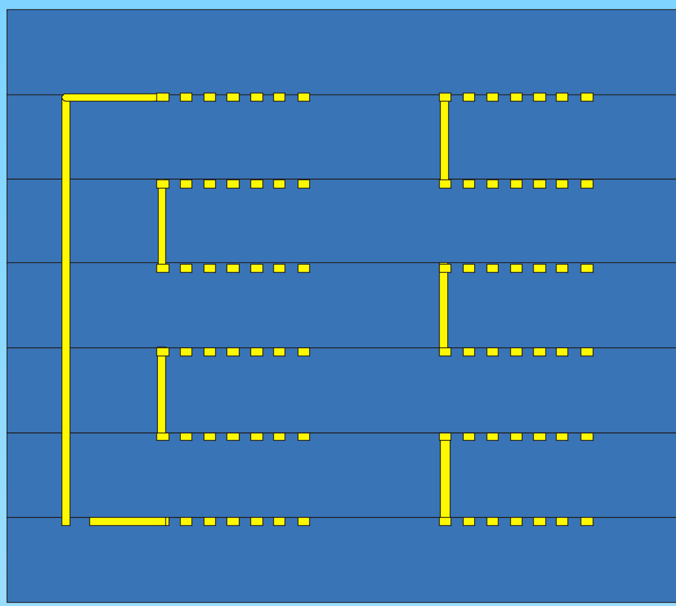


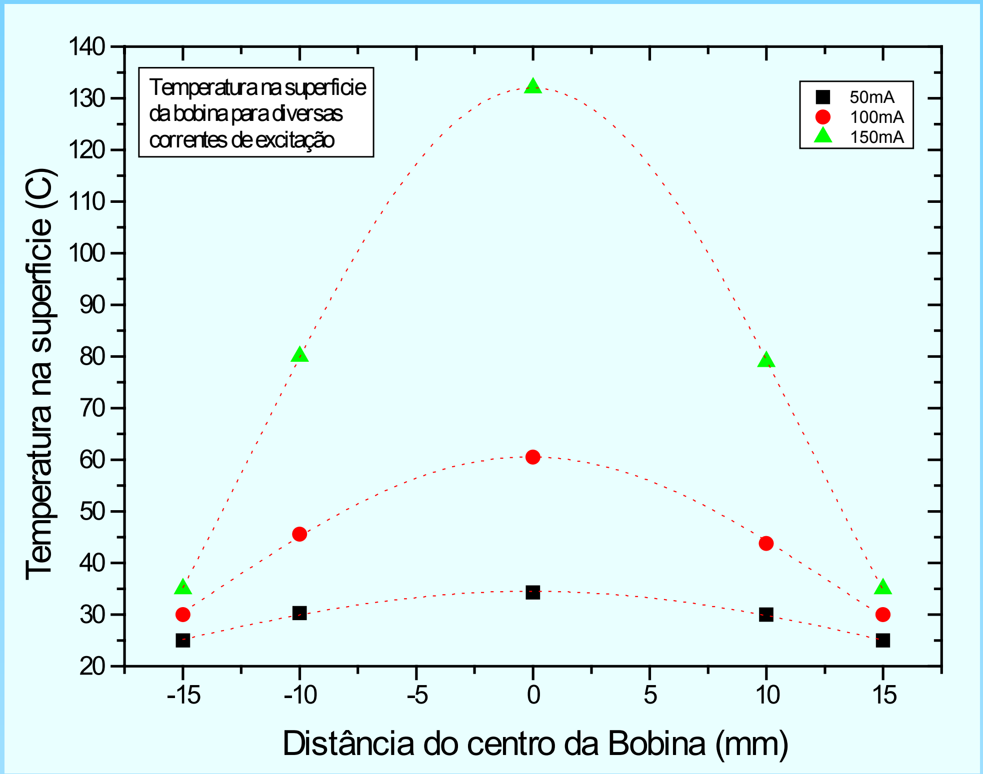
Streamline Simulation



HOT PLATES

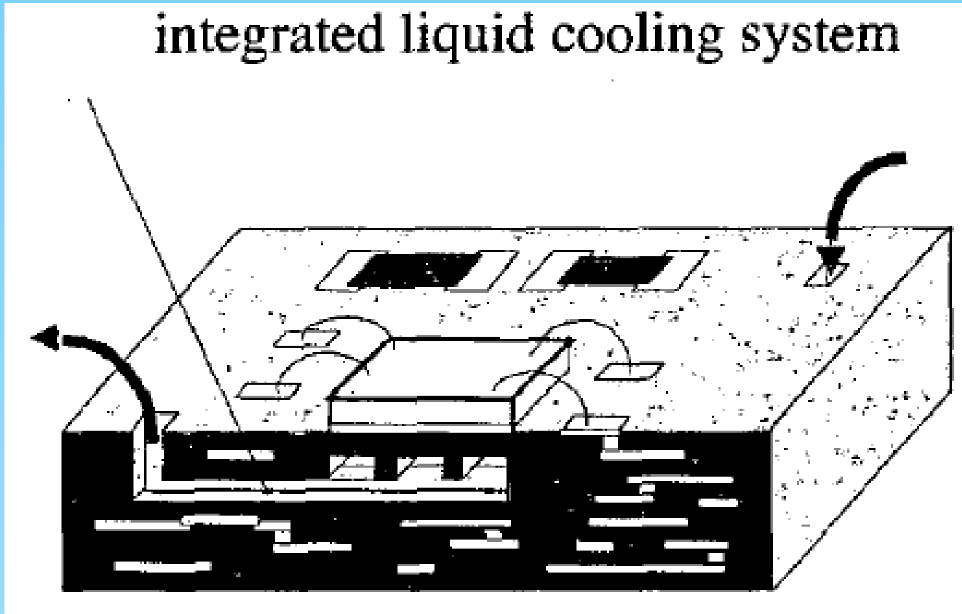
- With few layers it is possible to get a simple hot plate.
- Surface heating Vs. current in hot plate



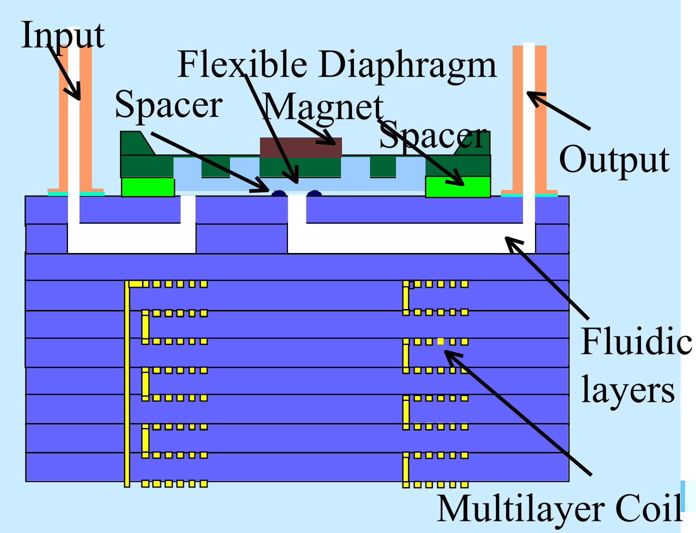


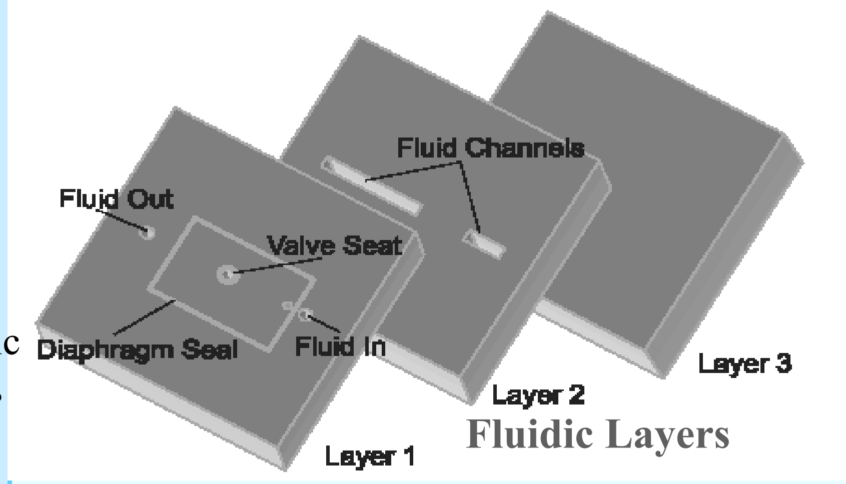
LIQUID COOLING SYSTEMS

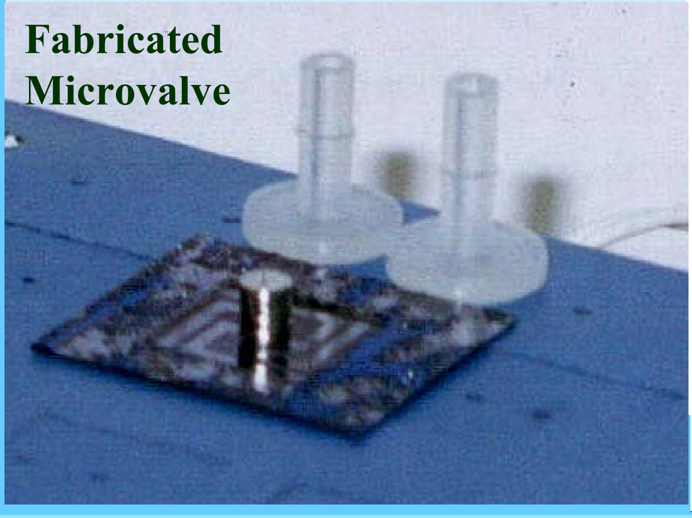
- Thermal management is an important problem in electronic packaging.
- LTCC thermal vias and microchannels can deliver liquid cooling systems with thermal dissipation of up to 50 W/cm^2

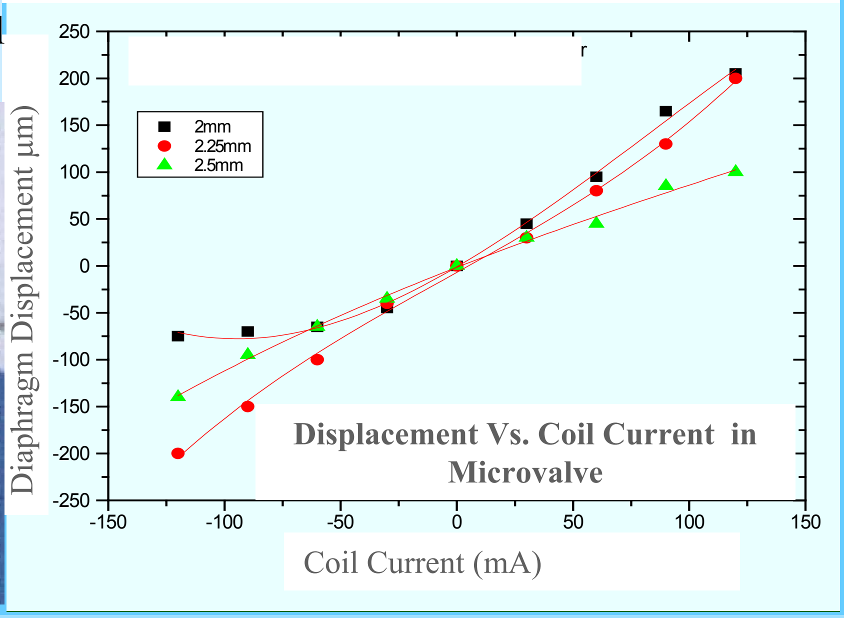


LTCC Hybrid Actuators (Microvalve)







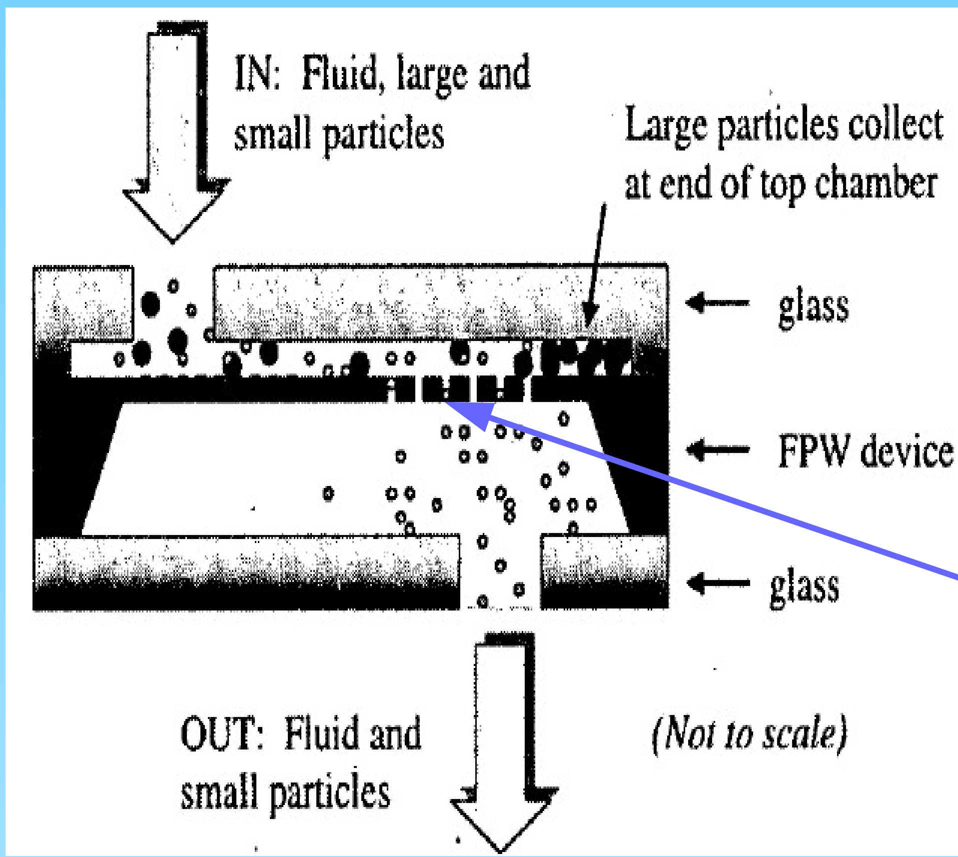


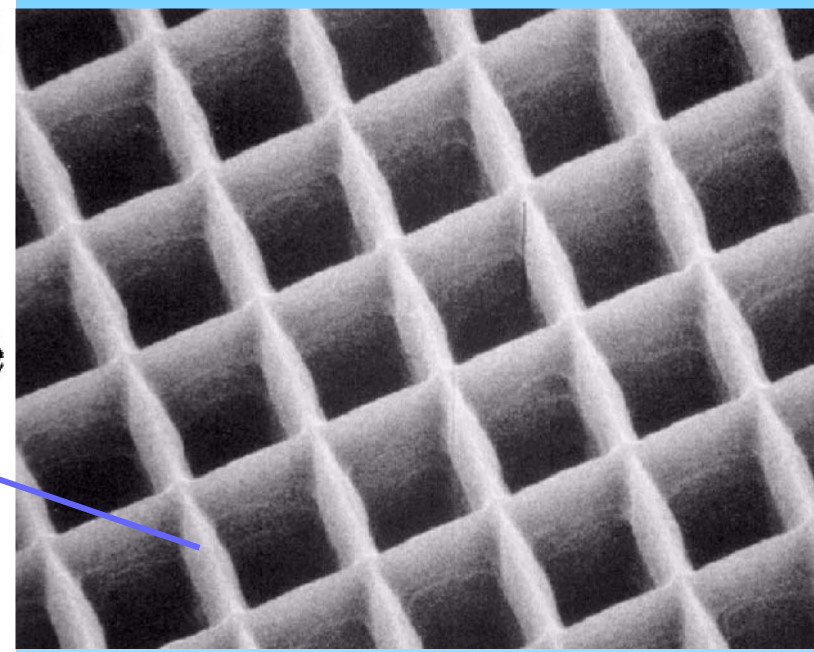
In: Gongora-Rubio M.R., Santiago-Aviles J.J. et al., SPIE (1.999), v.3877. p.230 - 239

8. MESO SYSTEMS, DEVICES AND APPLICATIONS

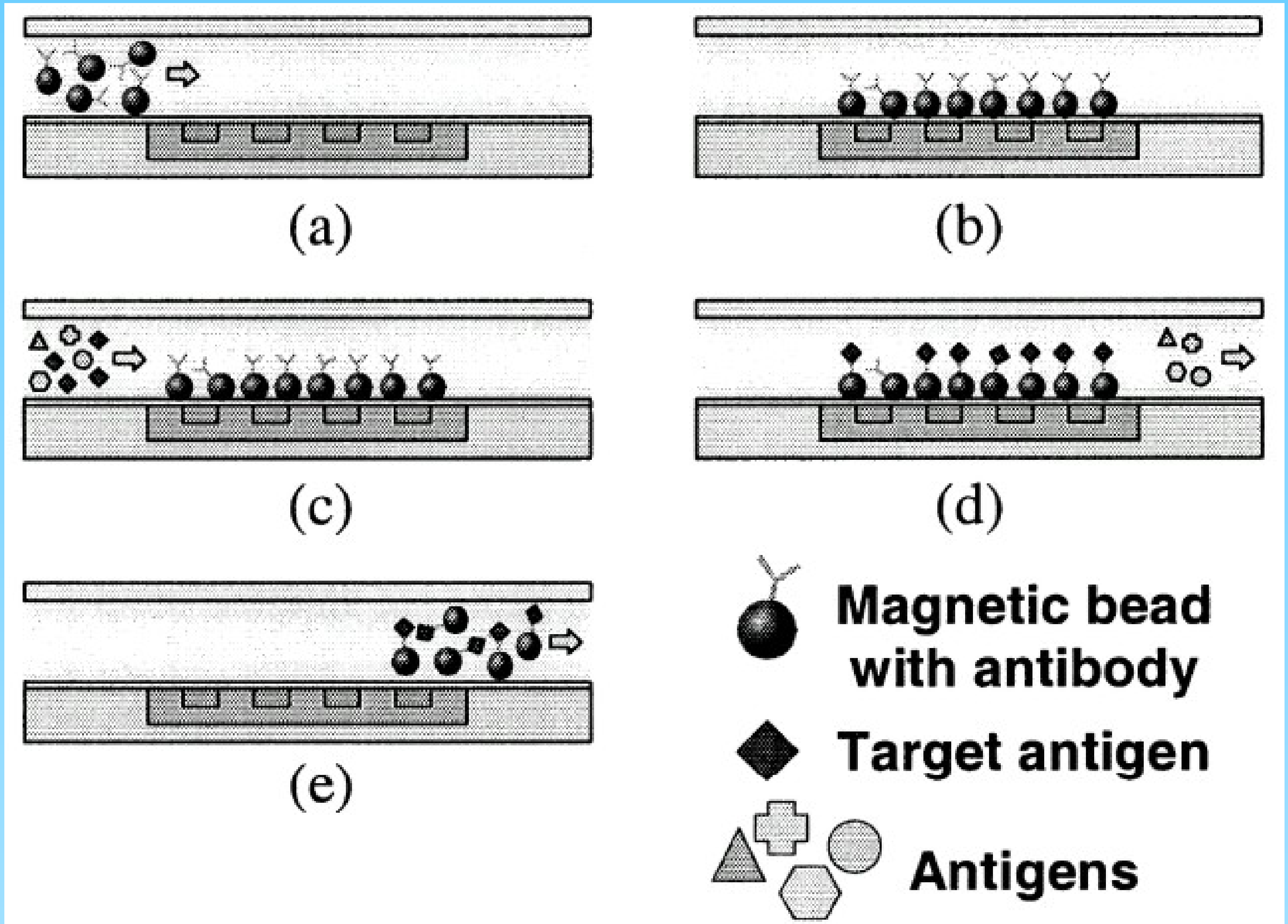
- Sensors
- Actuators
- Microfluidic devices
- Meso-Systems
- Micro-Combustor Systems
- Lab on a Credit Card

MST APPLICATIONS (MICROFILTERING)

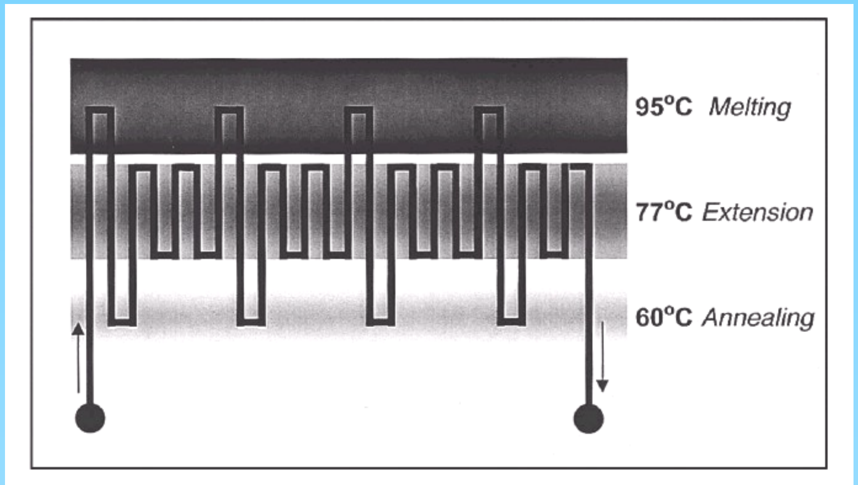


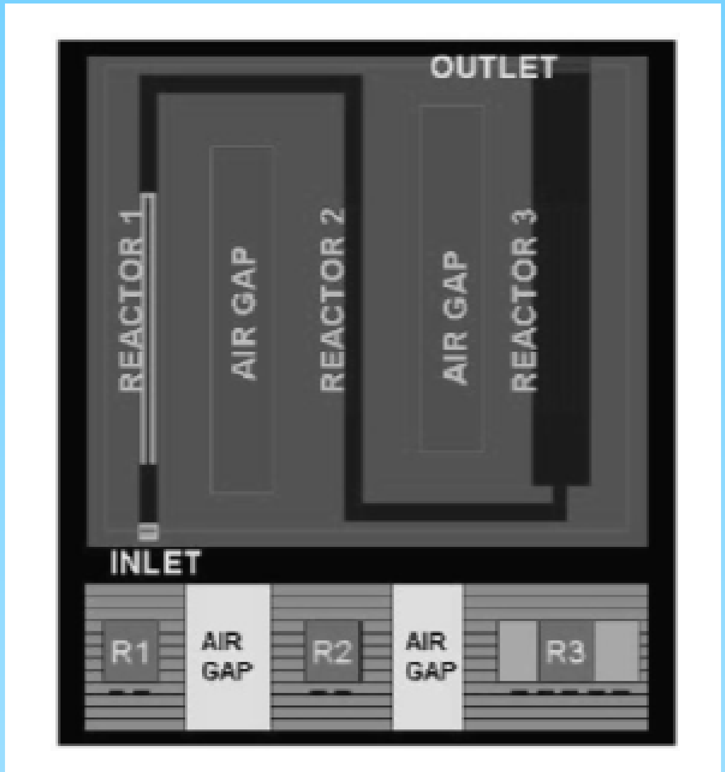


MST APPLICATIONS (BIO-SEPARATION)

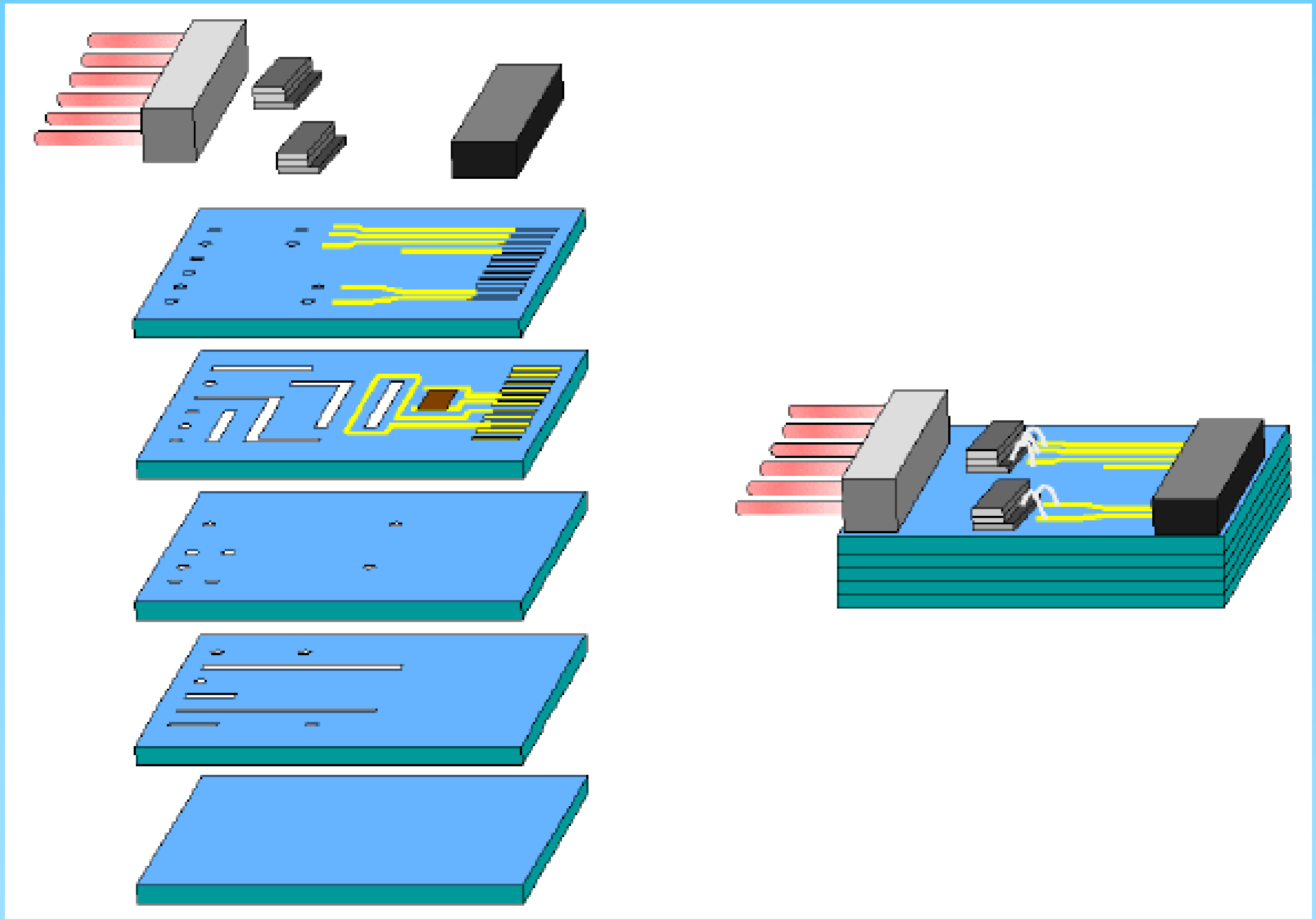


MST APPLICATIONS
(PCR IN CONTINUOUS FLOW)

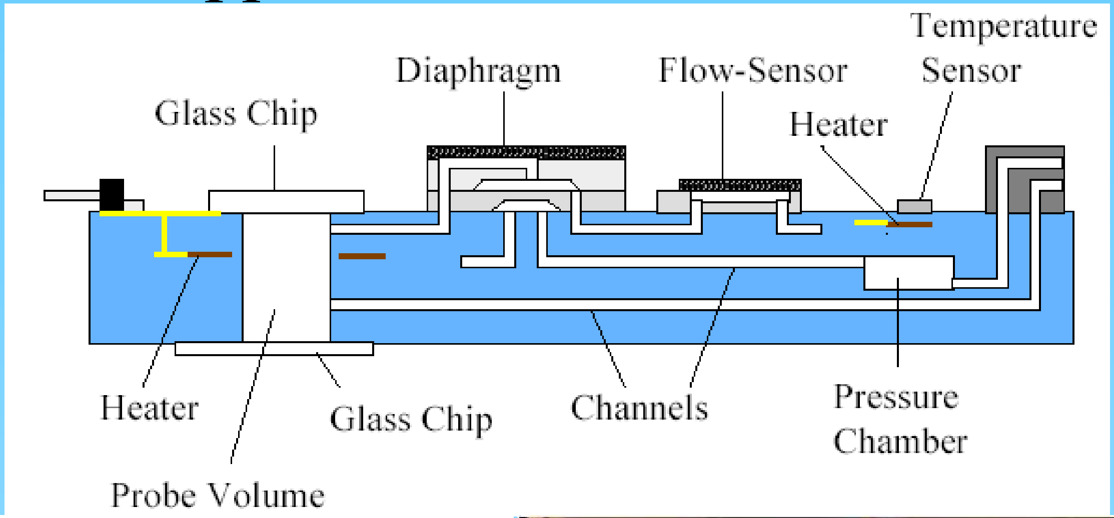


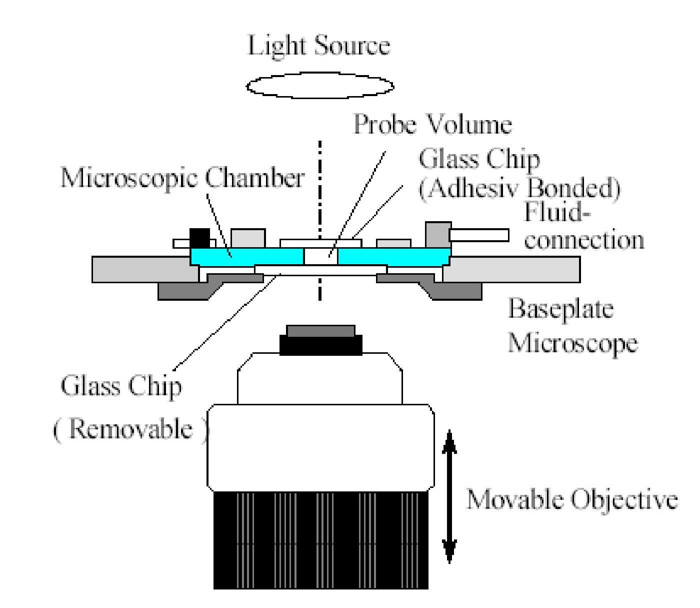


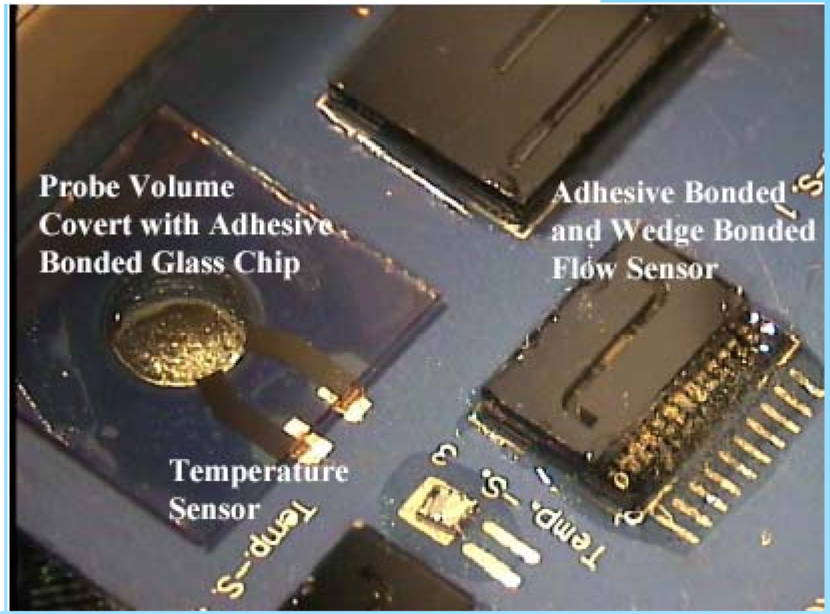
LTCC MANIFOLDS FOR MICROFLUIDICS



LTCC Applications on MICROFLUIDICS

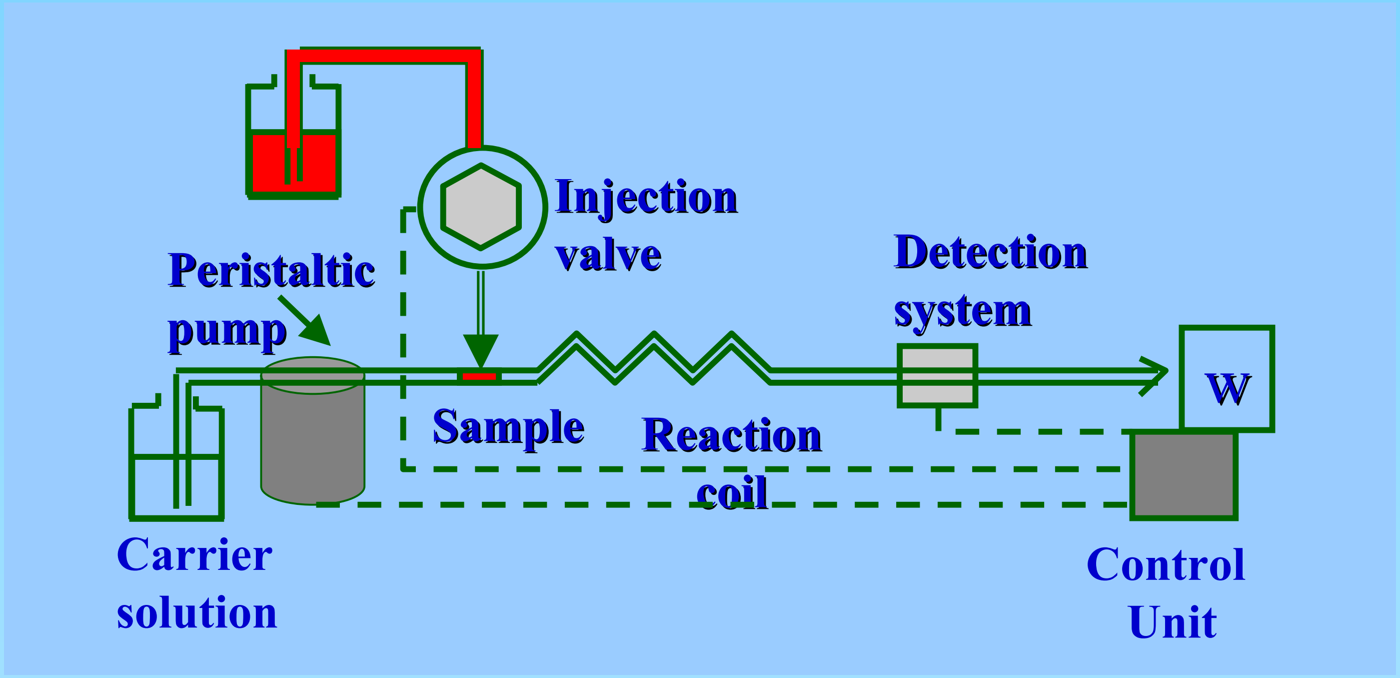




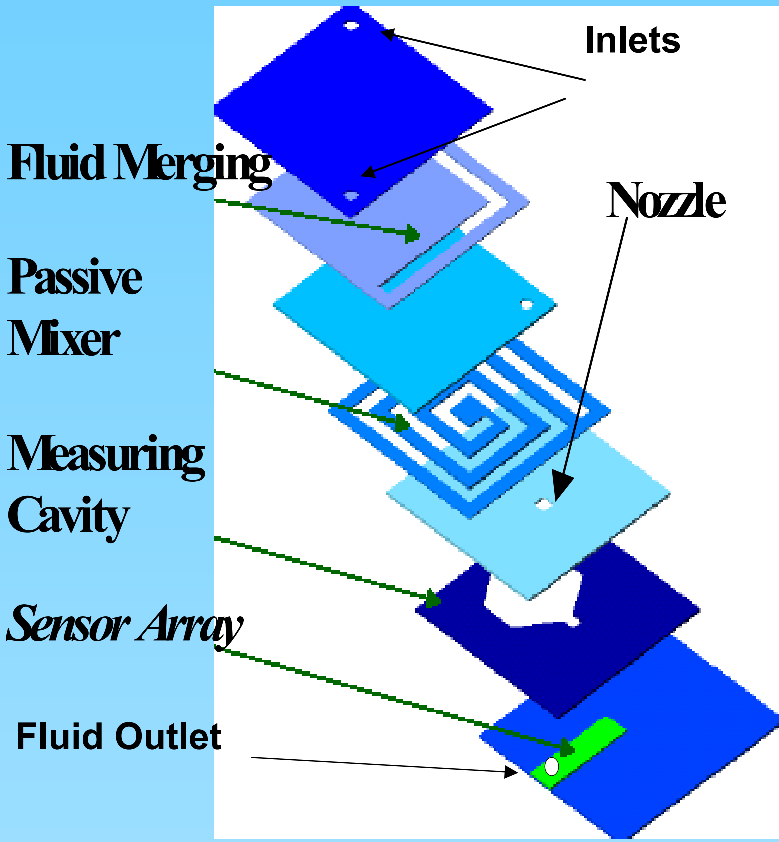


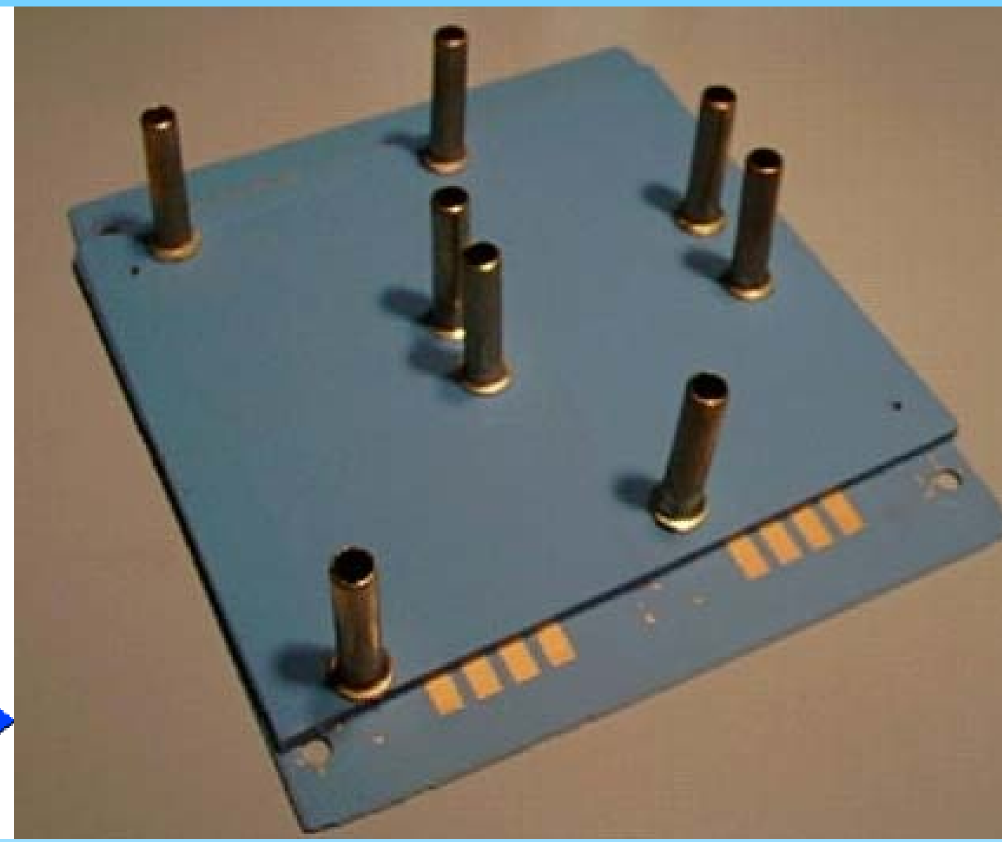
FLOW INJECTION ANALYSIS (FIA) FOR WATER STUDIES

- Sensitivity and selectivity of the sensor can be optimized
- Time for analysis is minimized
- Waste and sample size are minimized

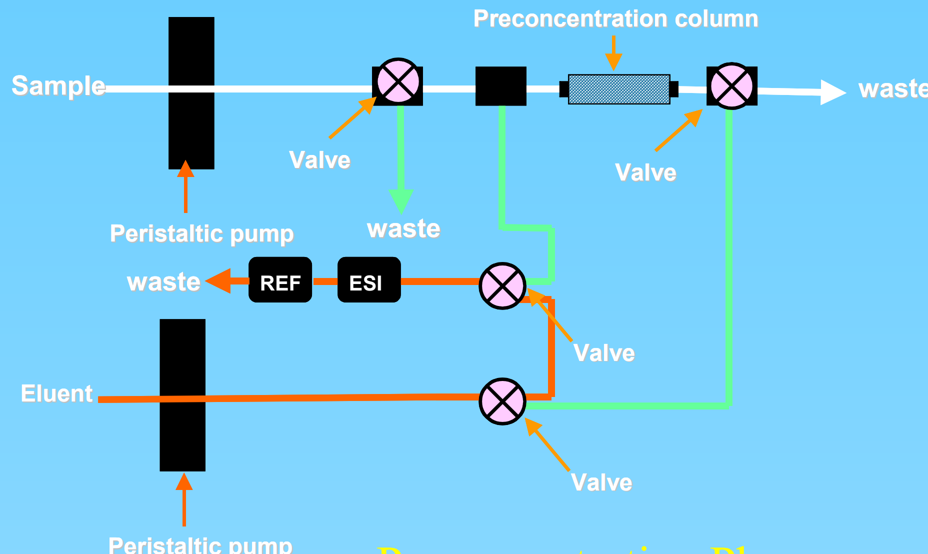


Fabricated FIA Manifold with sensor electrodes

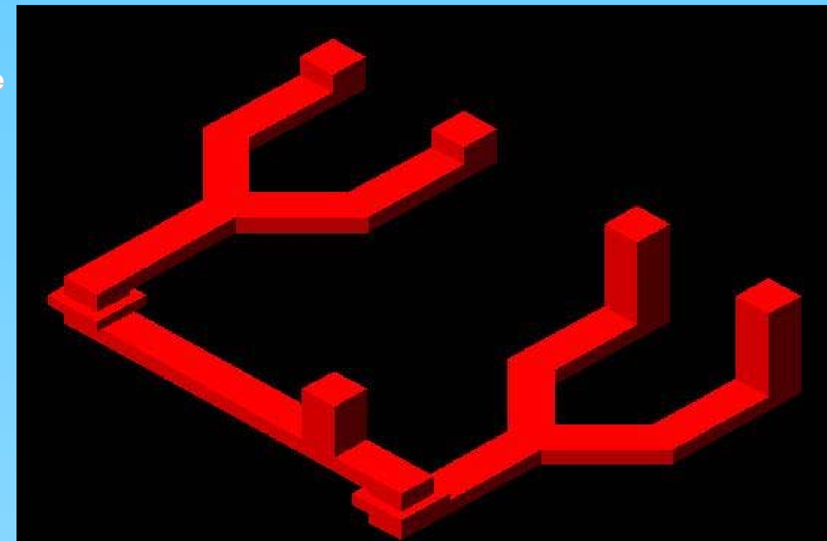


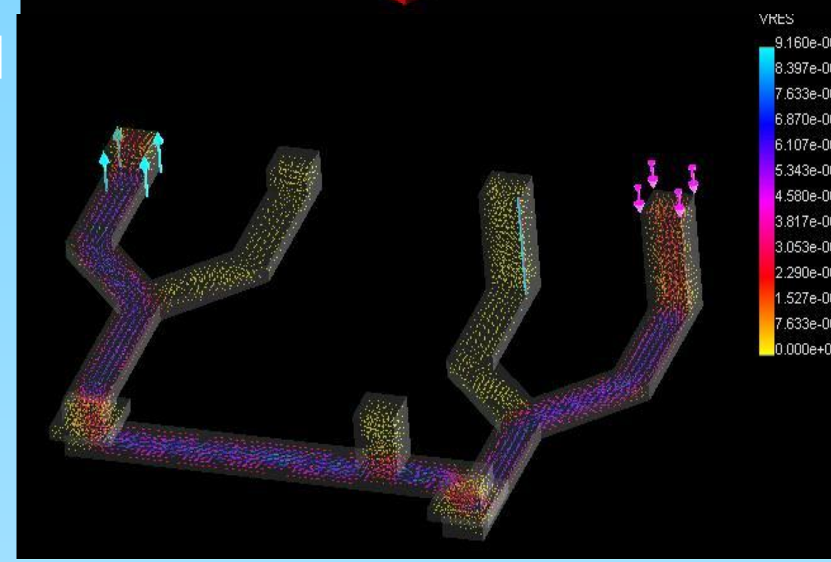


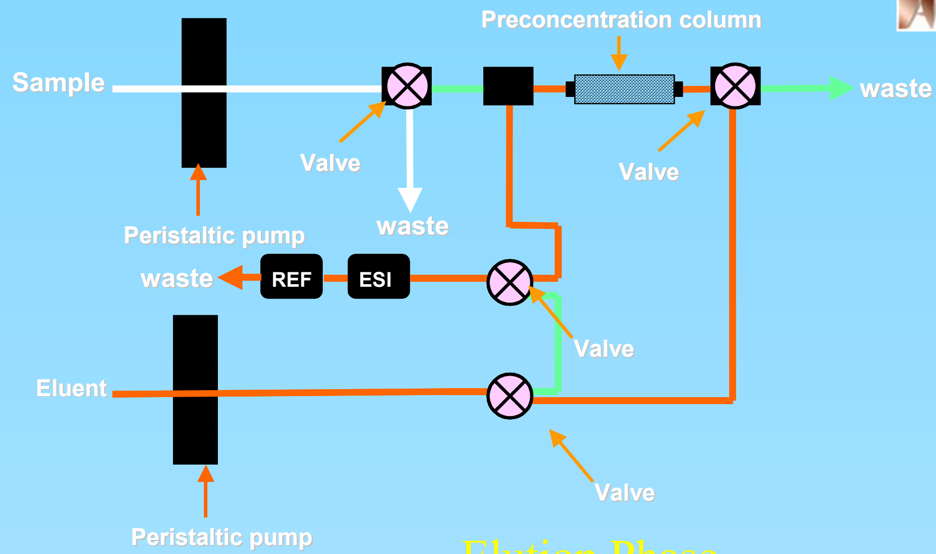
Lab on a Credit Card (AQUAFOS)



Preconcentration Phase







Elution Phase

9. 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