SAND2009-5794C

Applications and Processing: Full-Tape-Thickness Features in LTCC

Ken Peterson[1], Rick Knudson[1], Frank Smith[2], Charlie Sandoval[1], Chris Rodenbeck[1], Gregg Barner

***peterska@sandia.gov**

[1] Sandia National Laboratories
P.O. Box 5800, MS0959, Albuquerque, NM 87185-0959 USA

[2] Honeywell, FM&T, Kansas City, MO USA

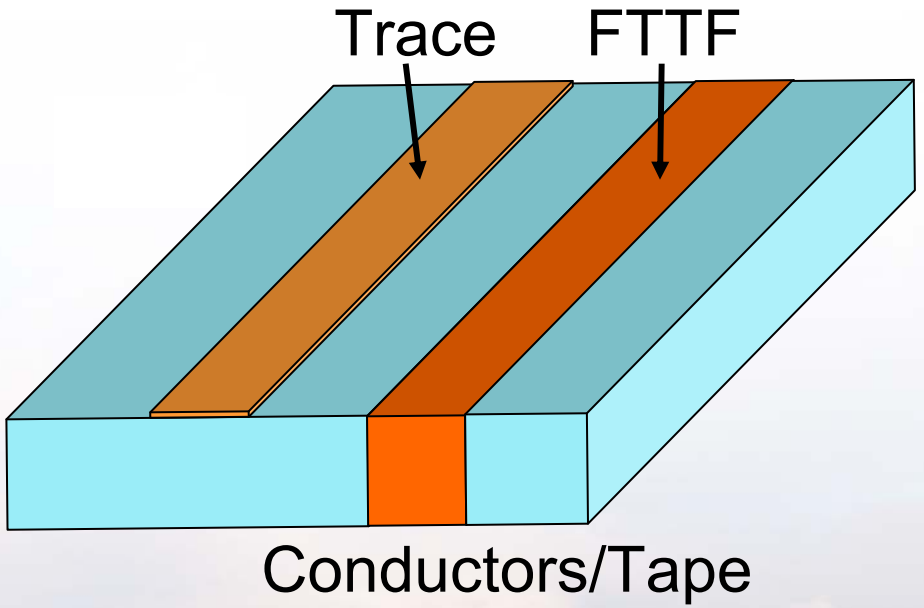
2nd MacroNano-Colloquium on Ceramic Microsystems
Ilmenau University of Technology, Ilmenau, Germany
September 9-10, 2009

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.

Sandia National Laboratories

Outline

- Sandia Overview (3 slides)
- Technical Introduction
  - Processing for low temperature cofired ceramic (LTCC)
  - Motivation
  - Review of FTTF
- Feature Construction
  - Staggered FTTF
  - Solid FTTF
  - Sidewall Metallization
- Summary



Sandia's Sites

Albuquerque,
New Mexico

Livermore,
California

Kauai,
Hawaii

Yucca Mountain,
Nevada

WIPP,
New Mexico

Pantex, Texas

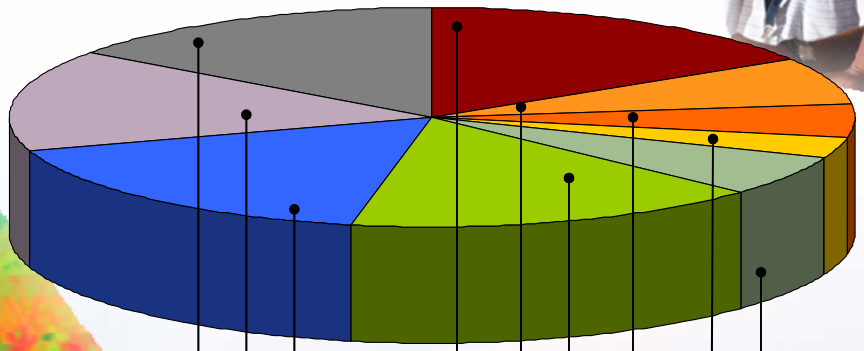
Tonopah, Nevada

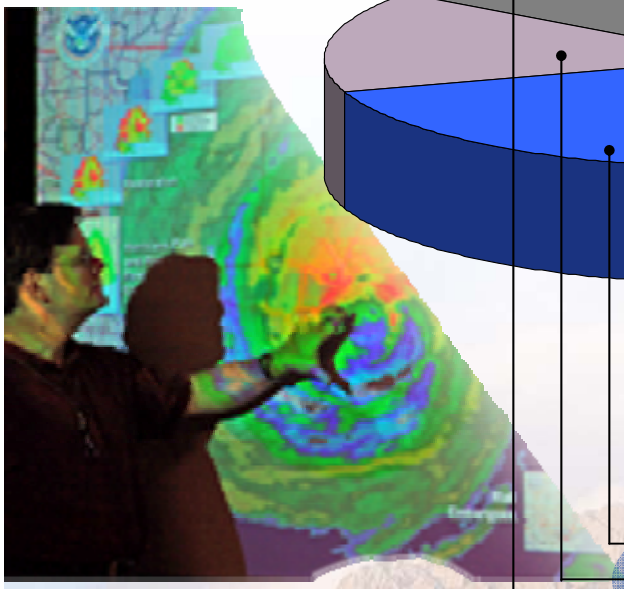
Sandia National Laboratories

Sandia's People

- On-site workforce: 11,200
- FY08 permanent workforce: 8,400
- FY08 gross payroll: $886.1M
- FY08 budget: $2.3B

Technical Staff (3,844) by Degree
(End of FY08)





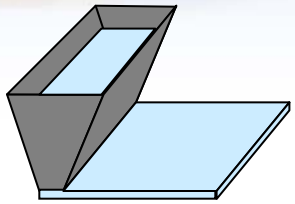
Sandia National Laboratories

Technologies for National Security

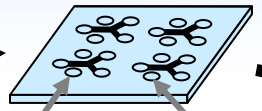
- We develop technologies to:
  - Sustain, modernize and protect our nuclear arsenal
  - Prevent the spread of weapons of mass destruction
  - Provide new capabilities to our armed forces
  - Protect our national infrastructures
  - Ensure the stability of our nation's energy and water supplies.
  - Defend our nation against terrorist threats

Sandia National Laboratories

LTCC Processing



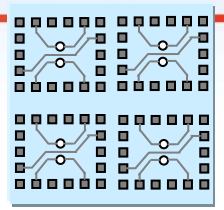
Tape casting



Structure formation

Electrical interconnect (Z)
or microfluidic channels (X,Y,Z)

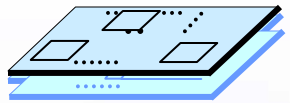
Via filling, screen printing, direct-write



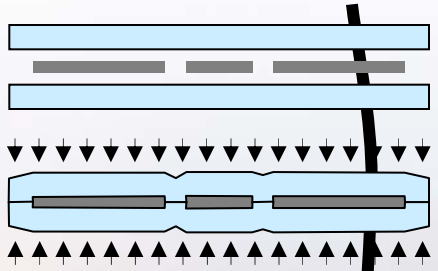
Interconnect formation

Electrical interconnect
n layers (< 80 layers)

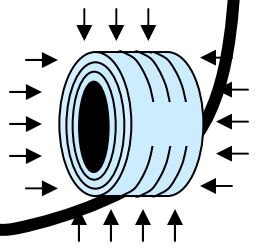
Inspection

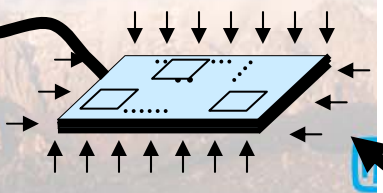


Collation, stacking

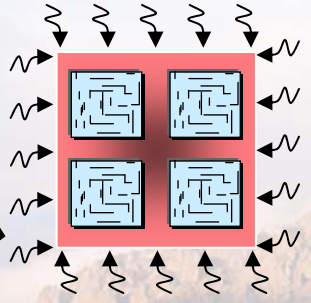


Lamination





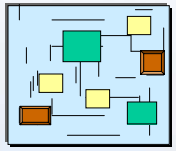
Singulation



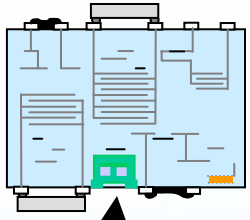
Sintering 850 ~ 900°C

Unconventional forming,
physical structure insertion

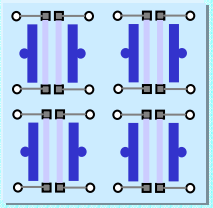
Shapes, SVMs



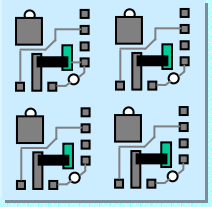
Attach devices



Integrated active component (e.g. sensor)



Integrated passive components

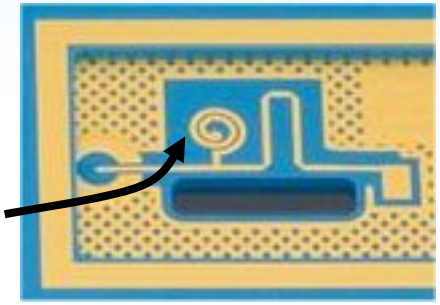


L,C,R

Integration

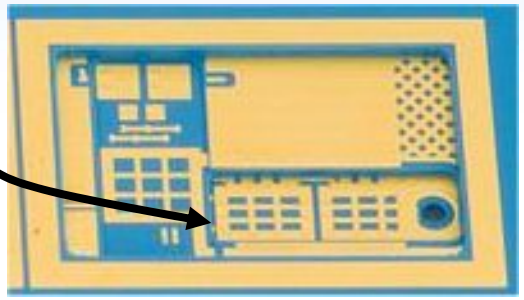
Courtesy: Pin Yang, D/2454, Sandia, pyang@sandia.gov

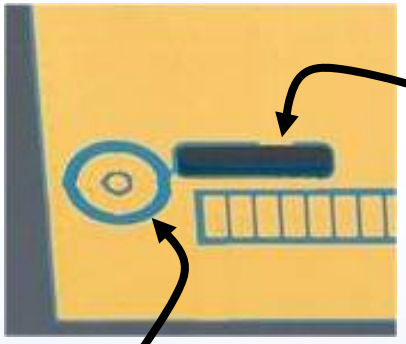
Planar MCM Features



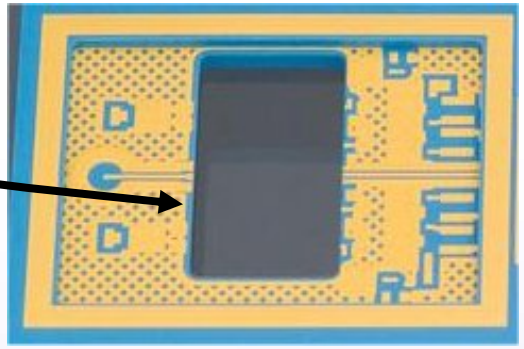
Integral limiter

Multiple cavity levels



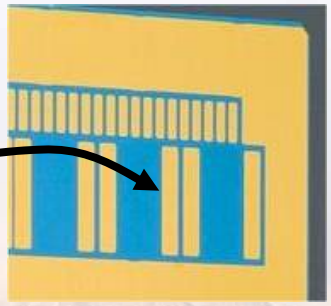


Cutouts for high-power devices



Connectors

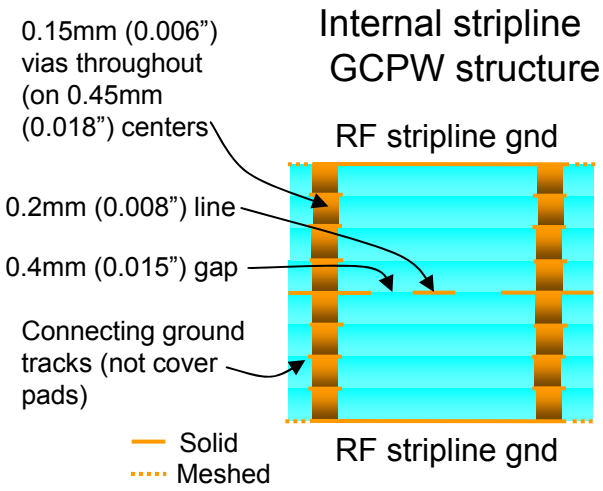
Discrete component pads

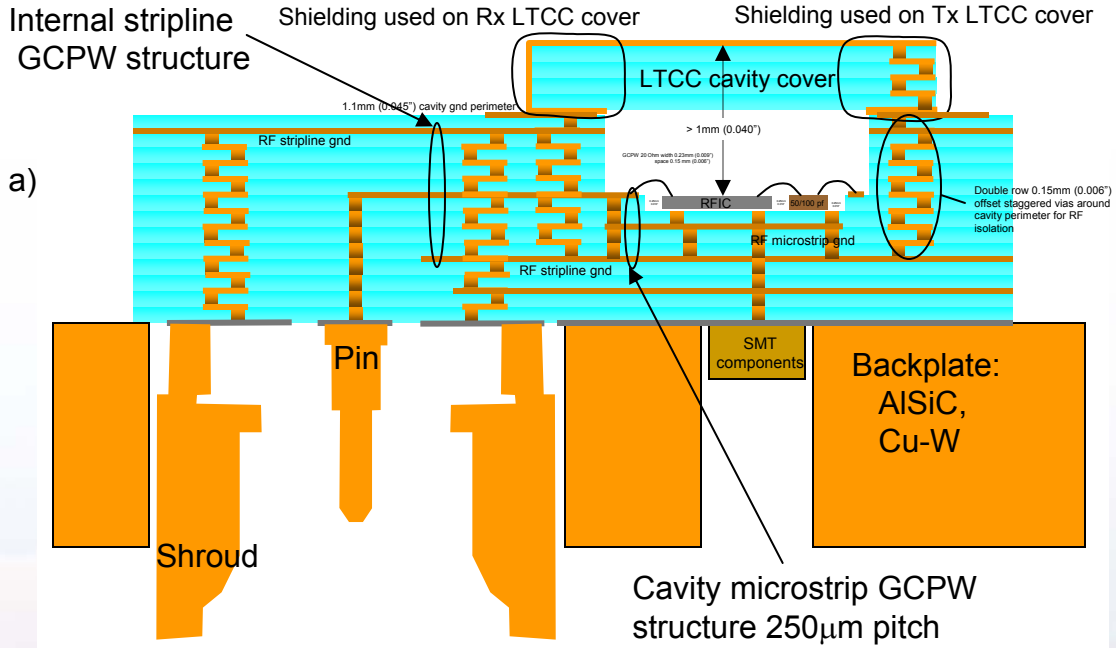


1 cm

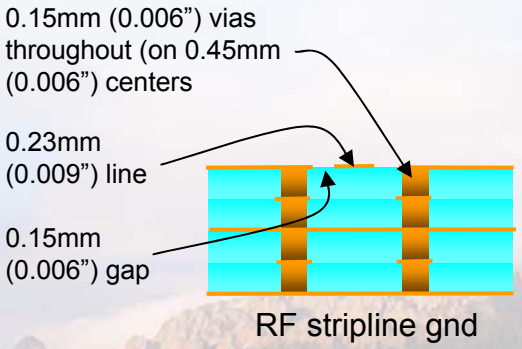
Sandia National Laboratories

MCM: Sectional View





Cavity microstrip GCPW structure 250μm pitch



Well-suited to RF features; stripline, microstrip.

Sandia National Laboratories

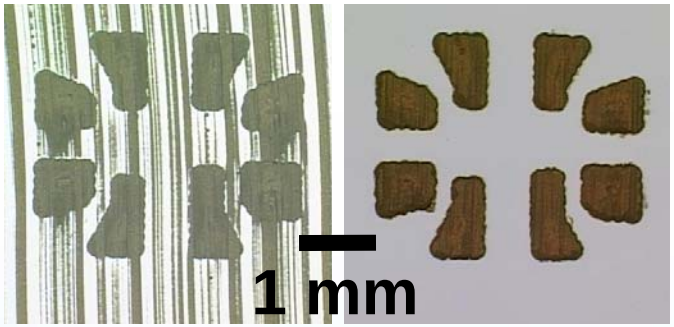
FTTF Background

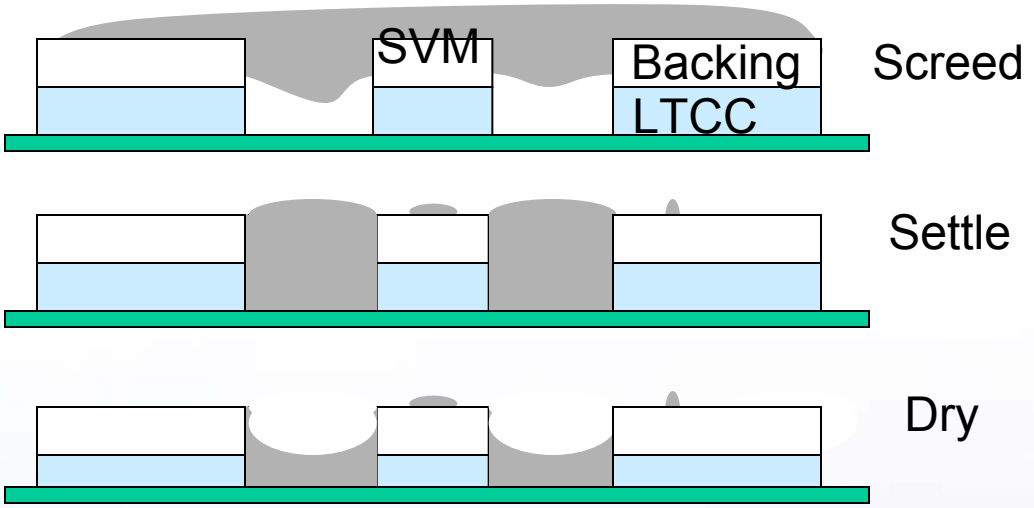
- Via-fill technology
- Commercial materials
  - LTCC tapes (DuPont 951)
  - Thick film pastes (DuPont 5738, 6141)
- Many standard practices
  - Tape punching
  - Screen printing
  - Stencil via-fill
  - Lamination (20.7 MPa (3000 psi), 70°C)
  - Cofiring cycle (450°C dwell, 850°C peak)

Standard processes are still the backbone.

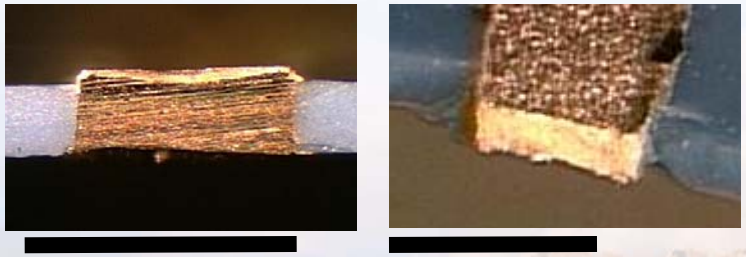
Paste Screeding

Backing in-place **Backing removed**





Screeded conductors



Screeding without artwork or stencils saves time, $.

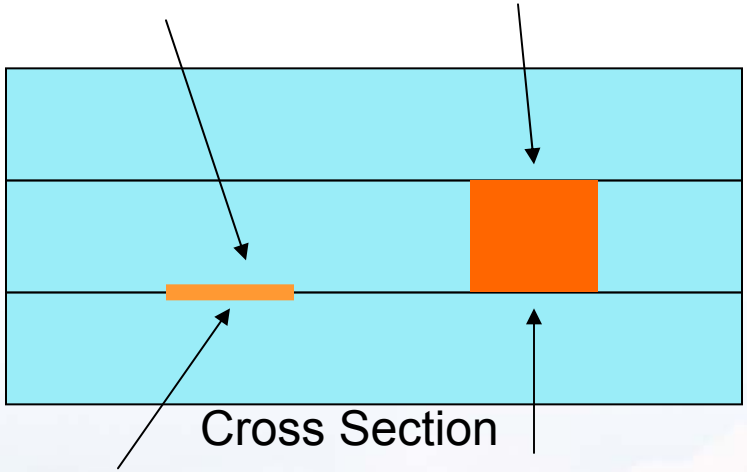
Sandia National Laboratories

FTTF Reduces Resistance

Trace material vs. via fill material

5 mΩ /sq. at
9 µm thickness

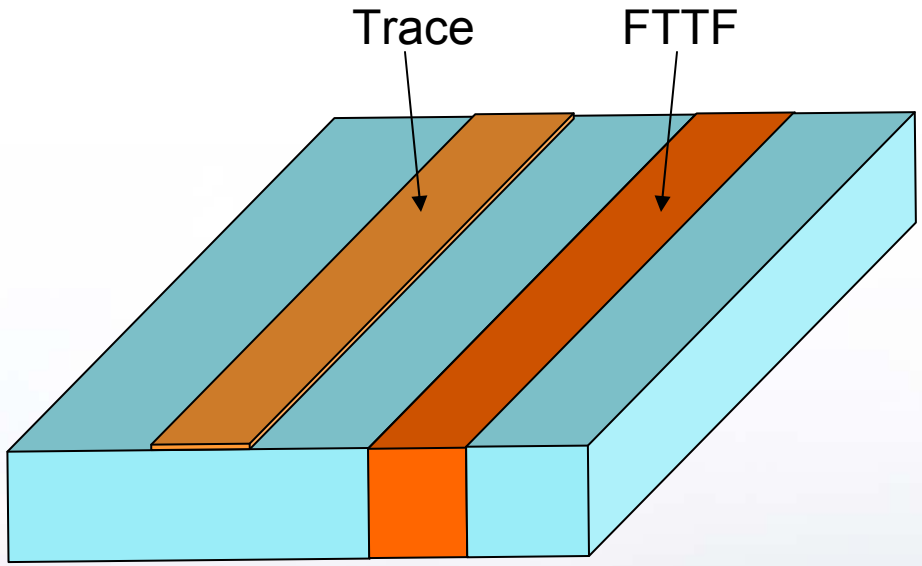
5 mΩ /sq. at
25 µm thickness



Cross Section

5 mΩ /sq. for
thick film line at
9 µm thickness

0.6 mΩ /sq. for
FTTF at 216 µm
thickness

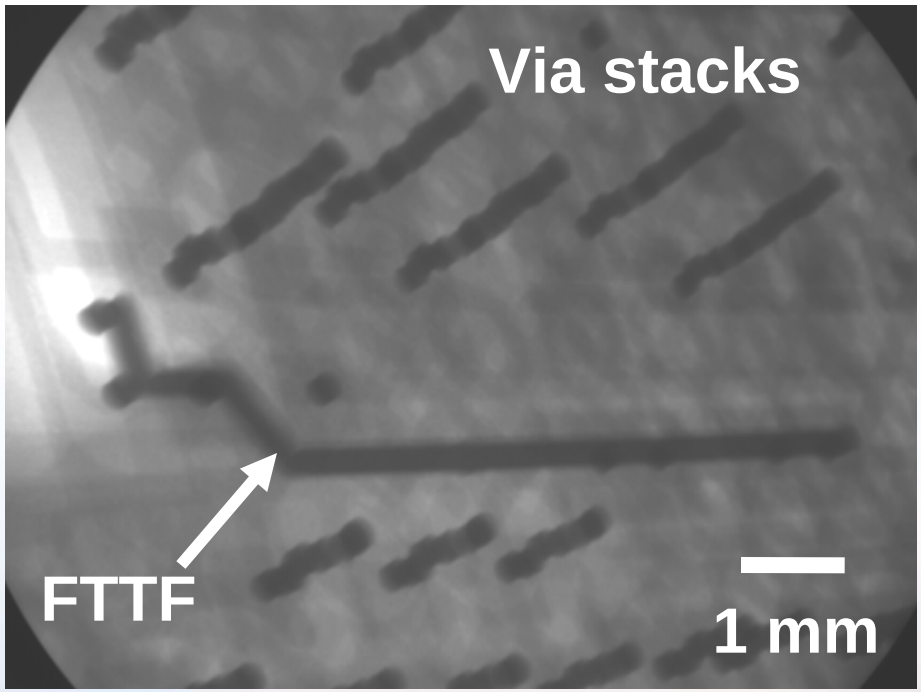


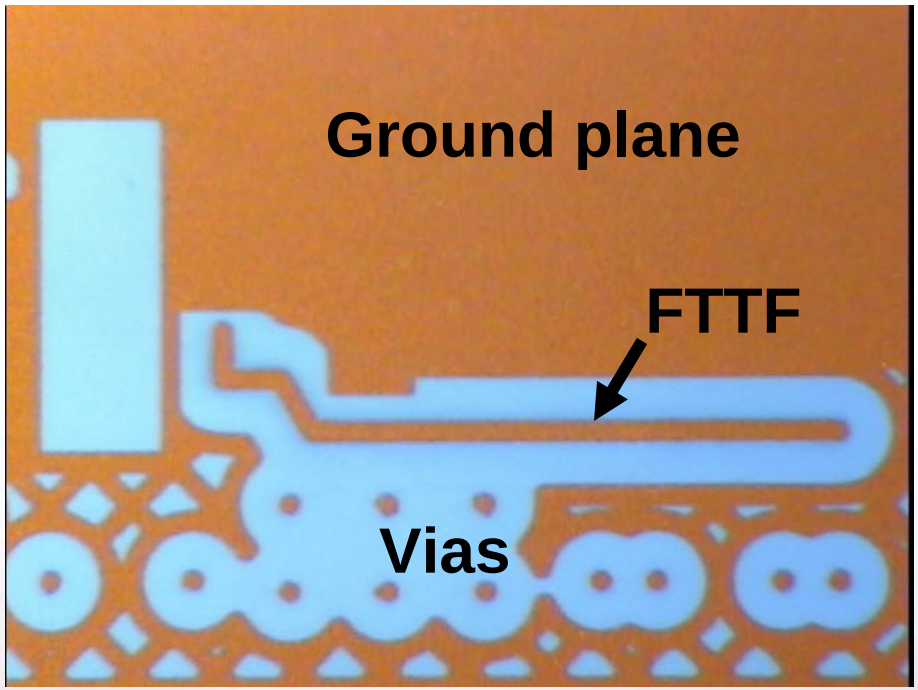
Total sheet resistance

A ‘via’ shaped like a slot.

Sandia National Laboratories

FTTF Conductor Trace





X-ray: fired board

Optical Image: Unfired layer

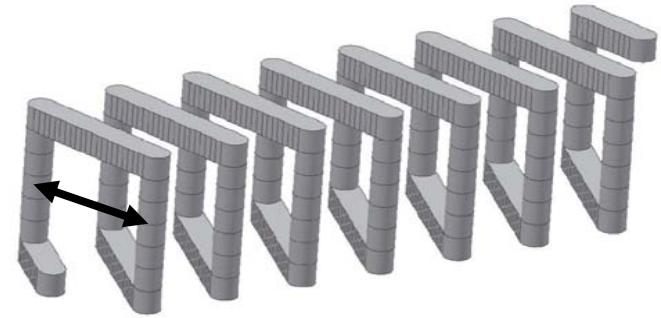
Feeds DC bias to 4W high efficiency PA
Maximize drain voltage to FET

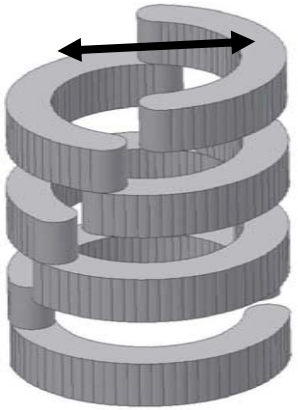
Sandia National Laboratories

Full Tape Thickness Features (FTTF)

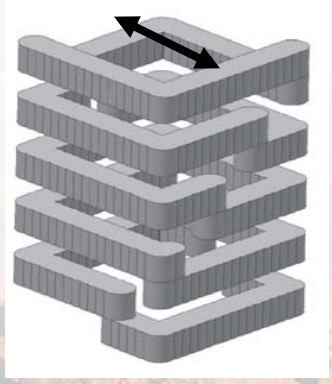
$$Q = \frac{\omega L}{R}$$

Q Quality factor
ω Frequency
L Inductance
R Resistance





Diameters: 1mm and 2mm

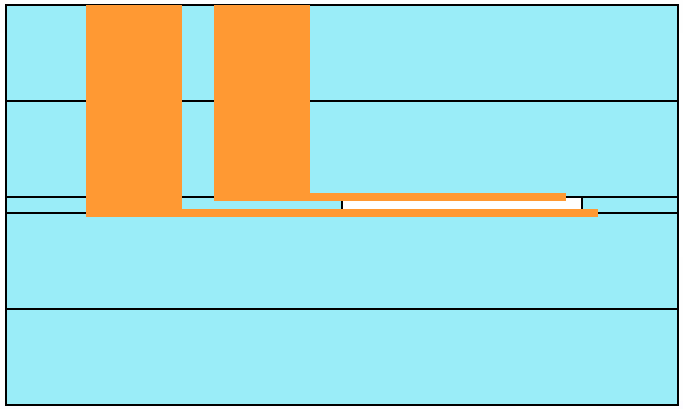


10 Layers

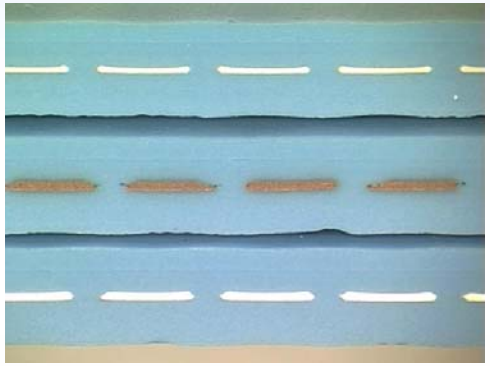
Sandia National Laboratories

High-Q inductors result from lower resistance.

FTTF Capacitors



5 layers



Cross section

500 μm

Replace 2-3 dielectric prints
Eliminate pinholes
Laminate, then screed technique
Electrodes on facing layers

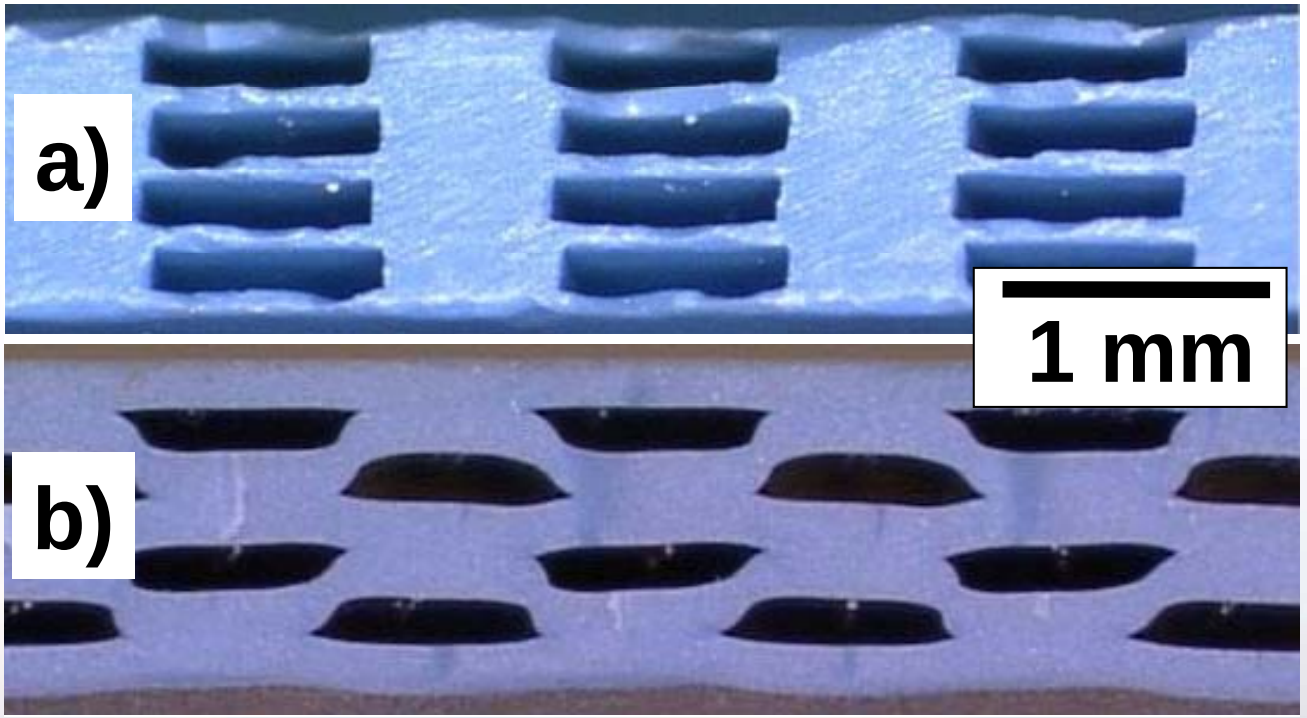
Functional capacitors result.

Sandia National Laboratories

FTTF Channels

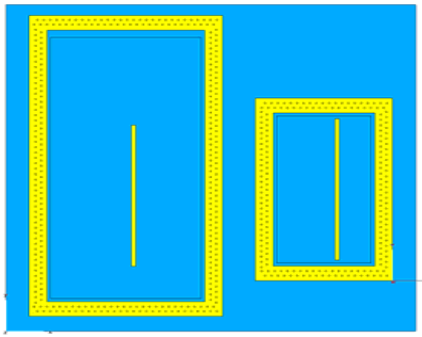
Walls predefined

Walls defined upon lamination

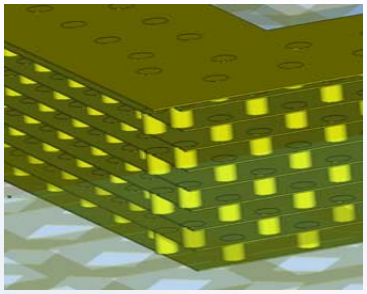


Complex channels are compatible with LTCC.

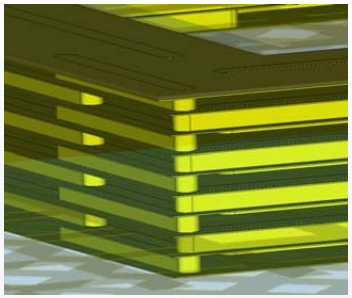
Dense E-M Shields with FTTF



3D-EM simulator antenna radiator & receiver

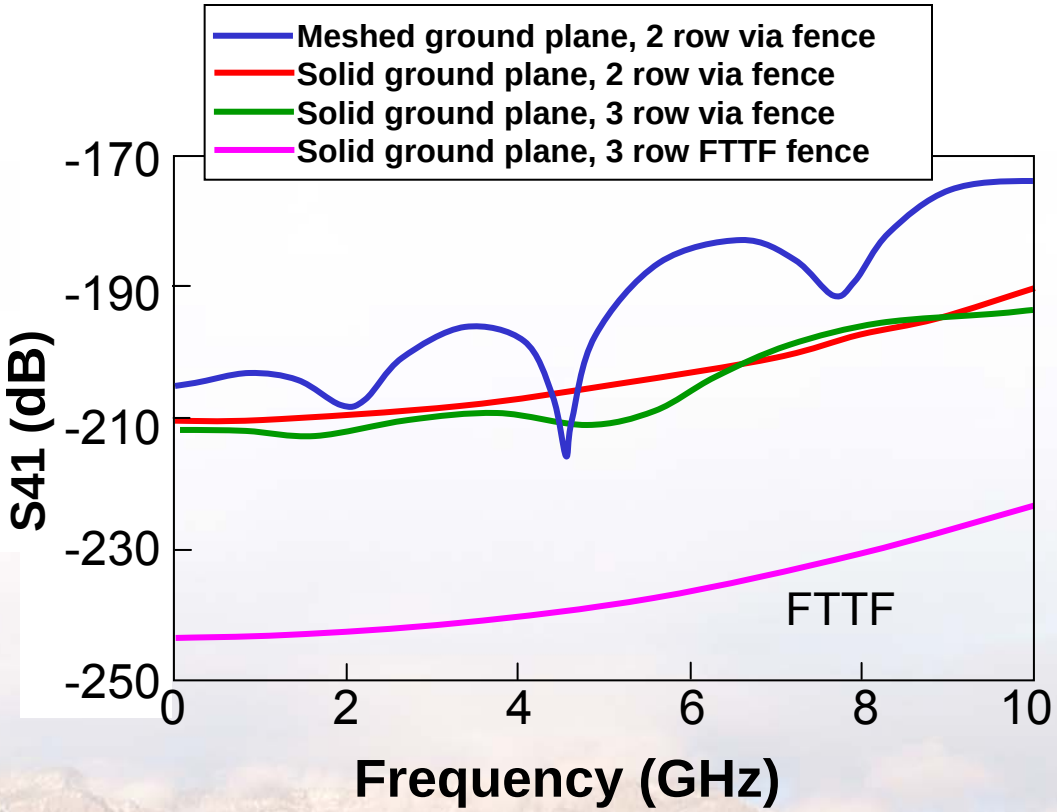


Conventional 2X staggered via fence



New 2 row FTTF segment fence isolation

Comparison of cavity isolation (model)

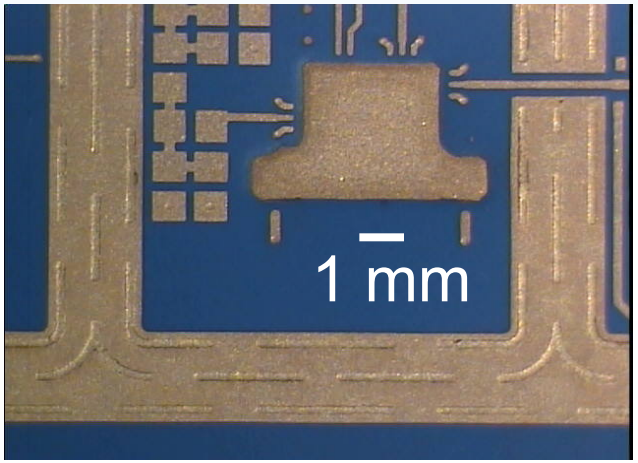


Superior isolation for the FTTF segment fence.

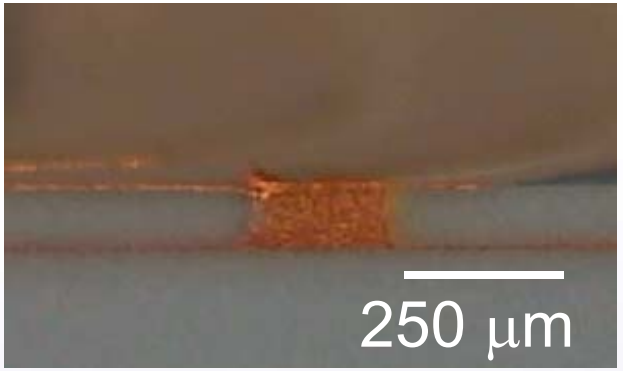
Sandia National Laboratories

Acknowledgement: Brian Duverneay, D/5353, Sandia, bbduver@sandia.gov

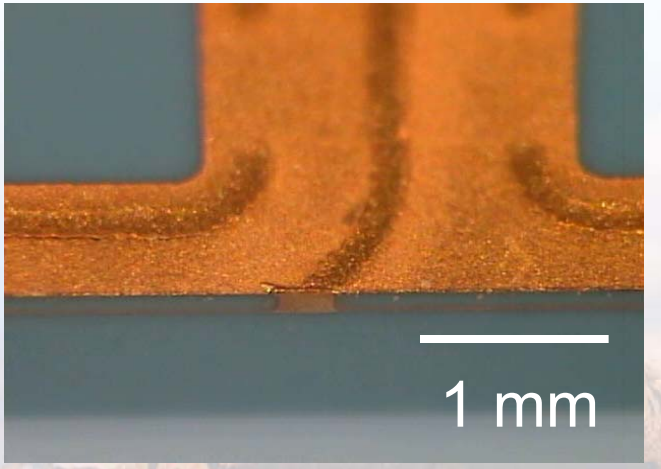
FTTF Segment Fence Isolation Structures



Structures beneath Seal Ring—3 Rows

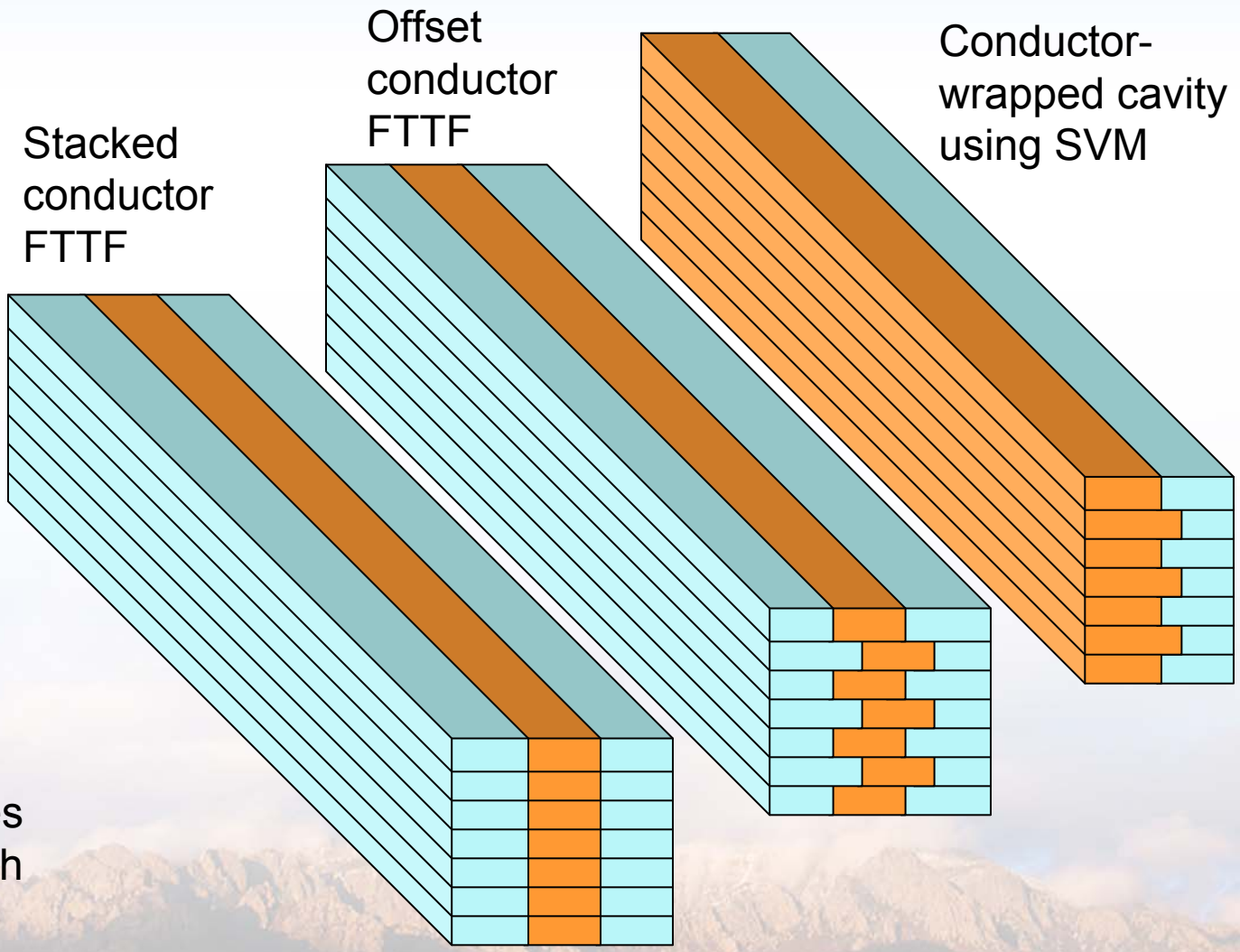


Magnified Cross Section



Cross Section

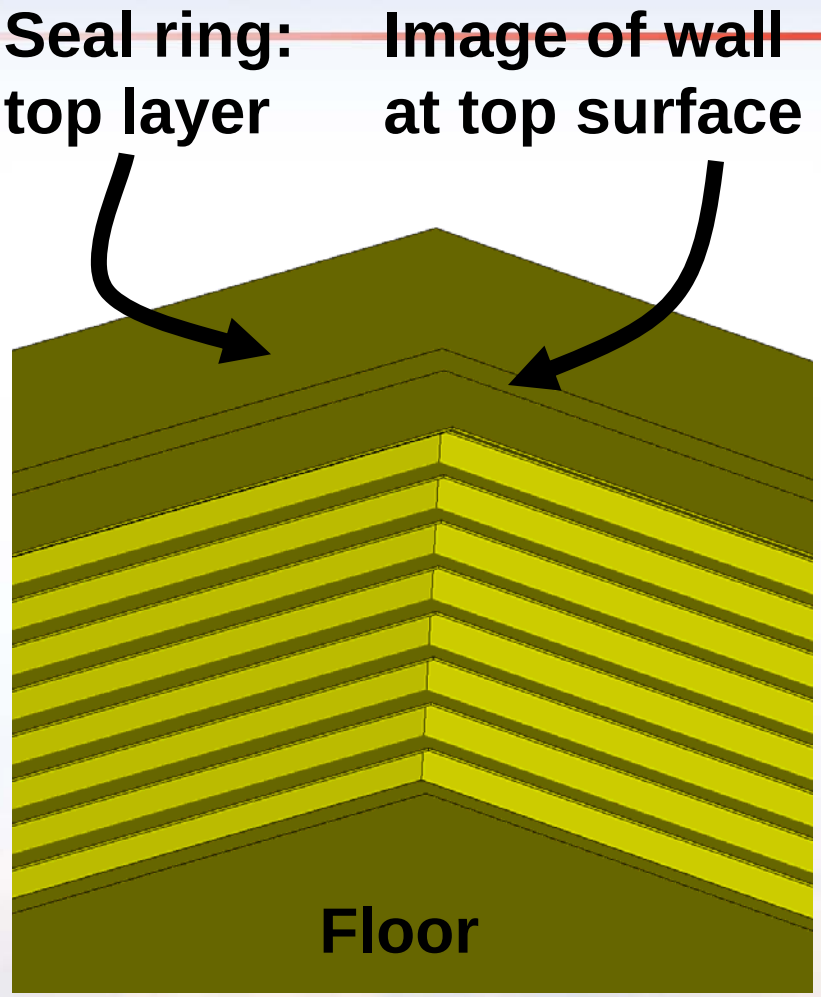
Solid Conductor Wall E-M Shield



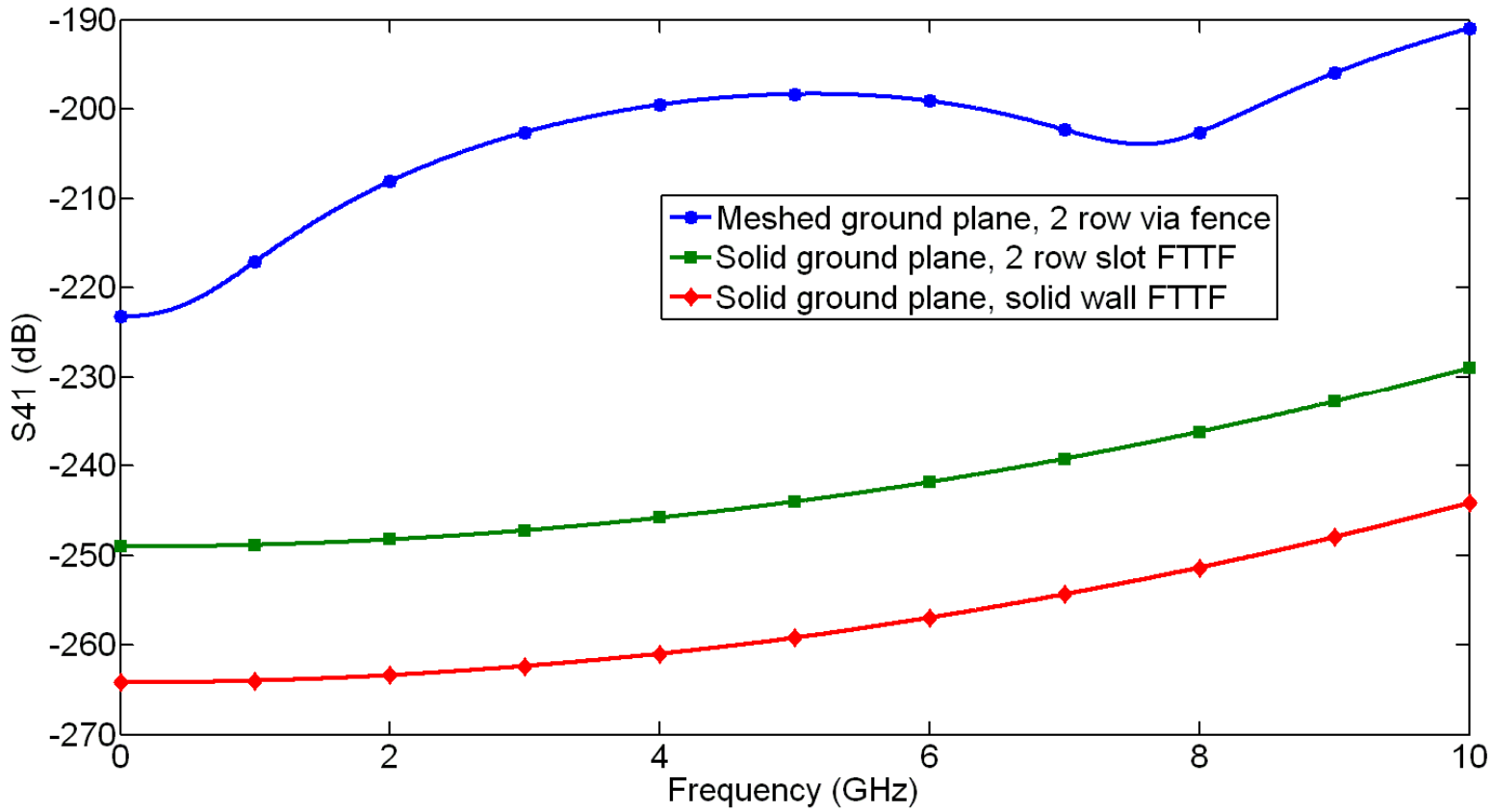
- Provides complete shielding.
- Uses less material than slots.
- More compact than staggered vias or slots.
- Overlapping features for additional strength in handling.

Solid wall E-M shield shows feasibility.

Sandia National Laboratories

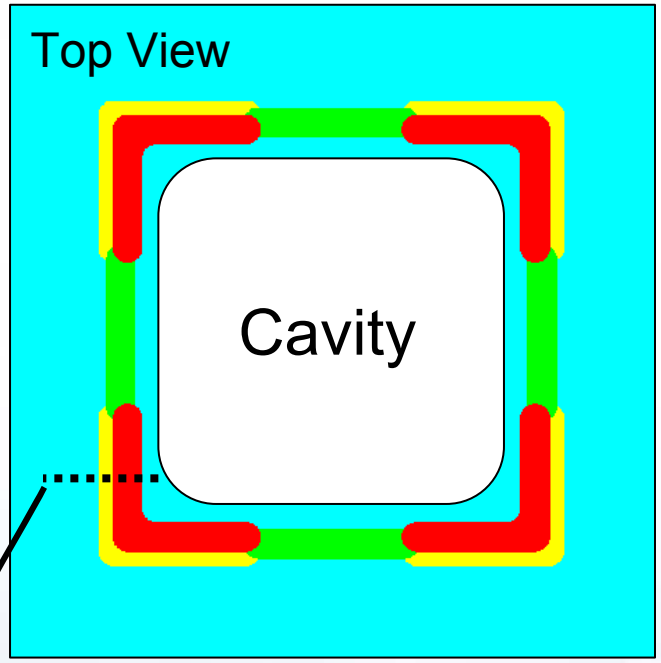

Seal ring:
top layer
Image of wall
at top surface
Floor

Simulation of Solid Wall Performance

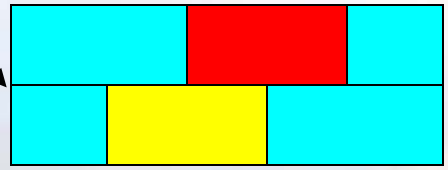


Sandia National Laboratories

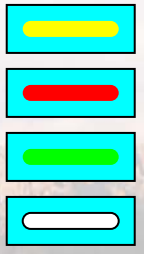
Process Sequence

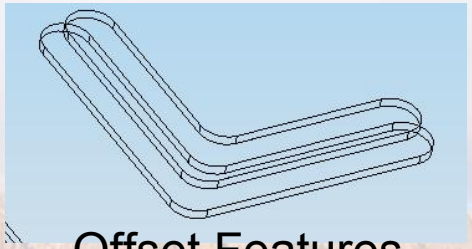


1) Punch and fill layer 1 (yellow)
2) Punch and fill layer 2 (red)
3) Laminate 1 to 2 (lamination and offset are optional)
4) Punch and fill layers 1+2 (green)
5) Note: inner track of tape completely supported by dried thick film.
6) Repeat for other layers
7) Collate and laminate all layers



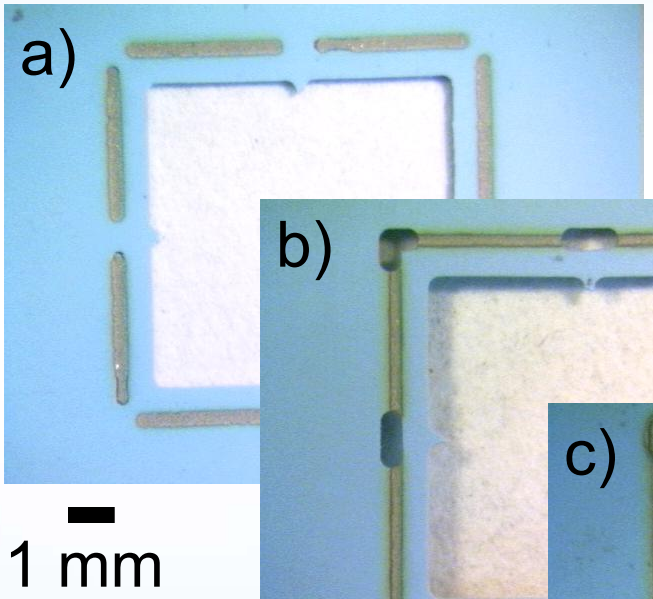
Sectional View



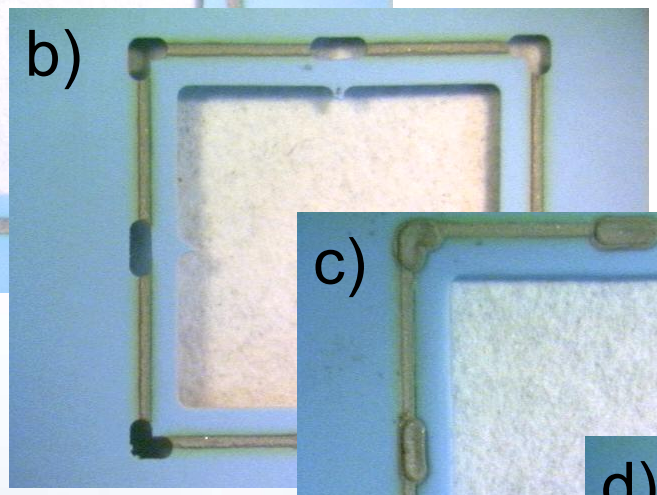


Offset Features

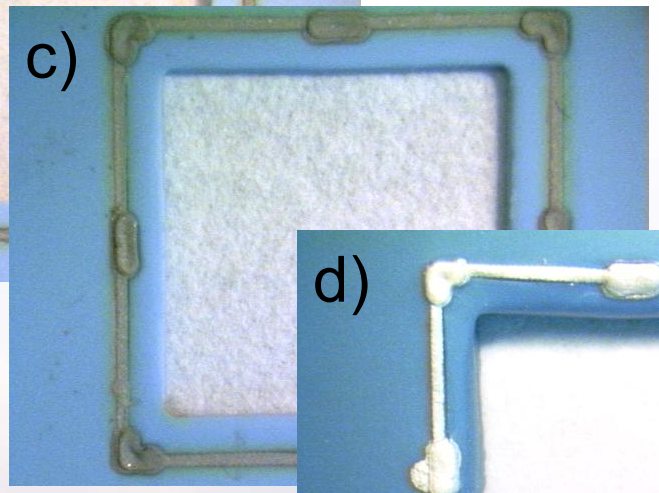
Cavity Isolation Construction Sequence



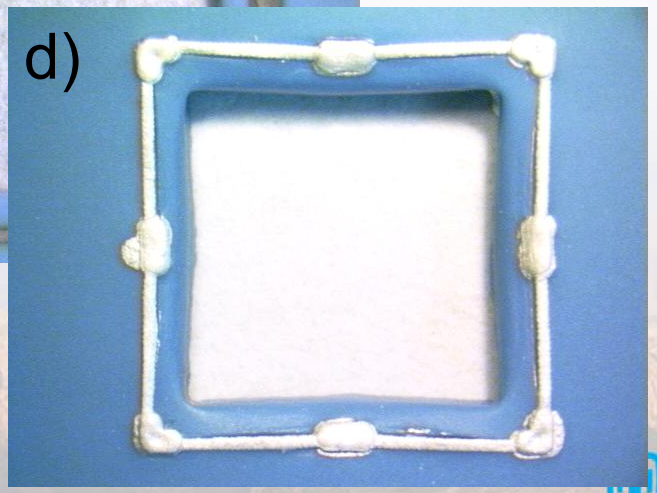
a) 254 μm (0.010”) track punched and screeded in 254 μm (0.010”) tape



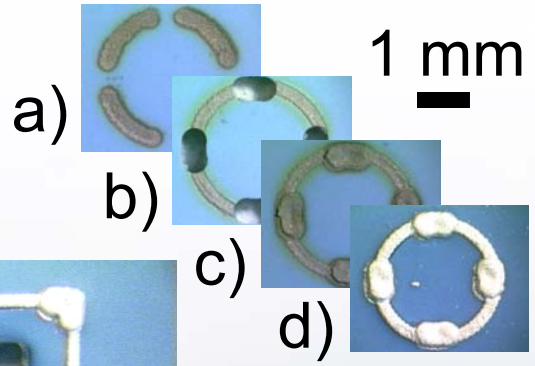
b) 2 ea laminated, 508 μm (0.020”) dia. tethers punched



c) Tether region screeded and dried

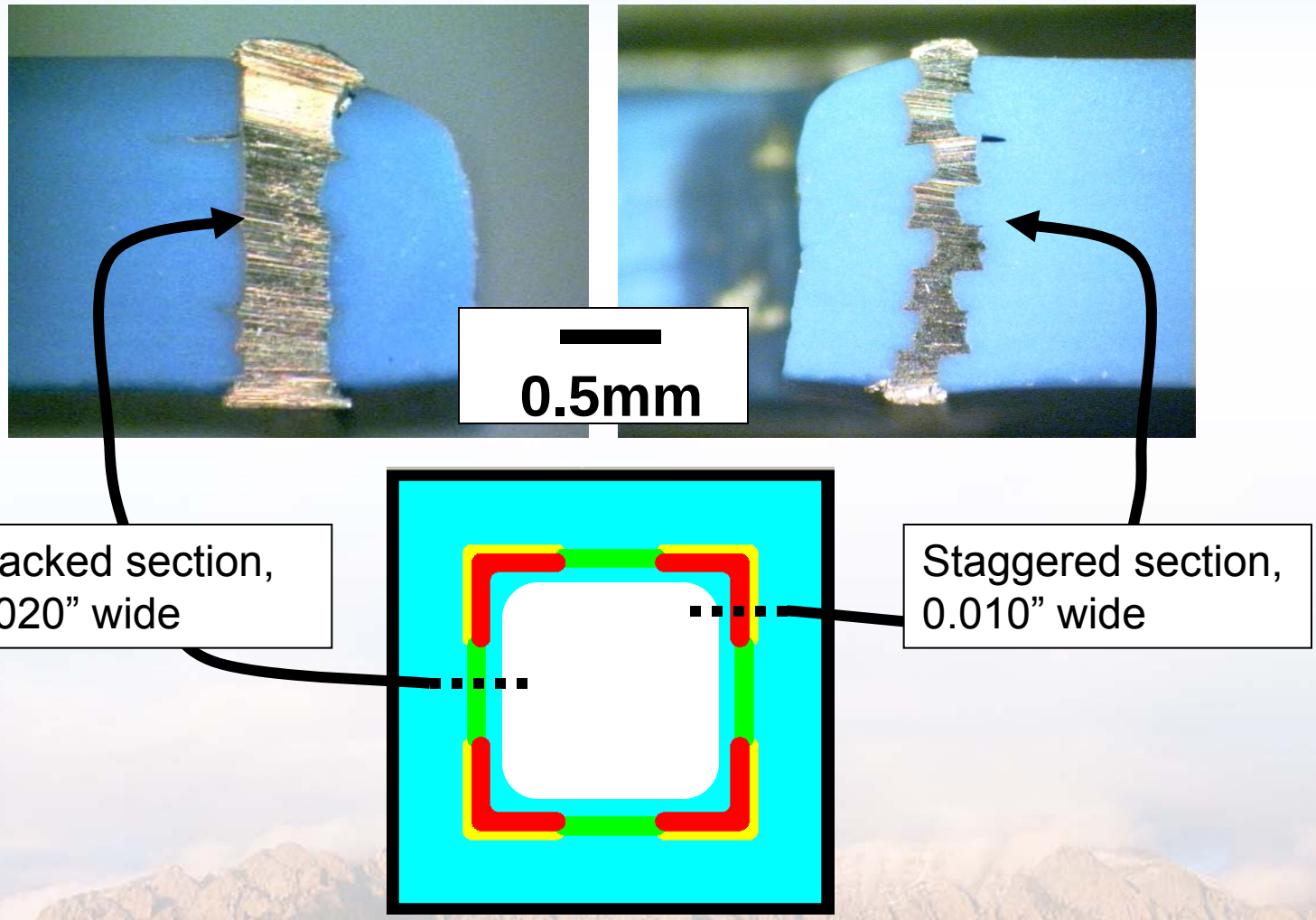


d) 8 layer tall solid wall surrounding cavity as-fired



Connector

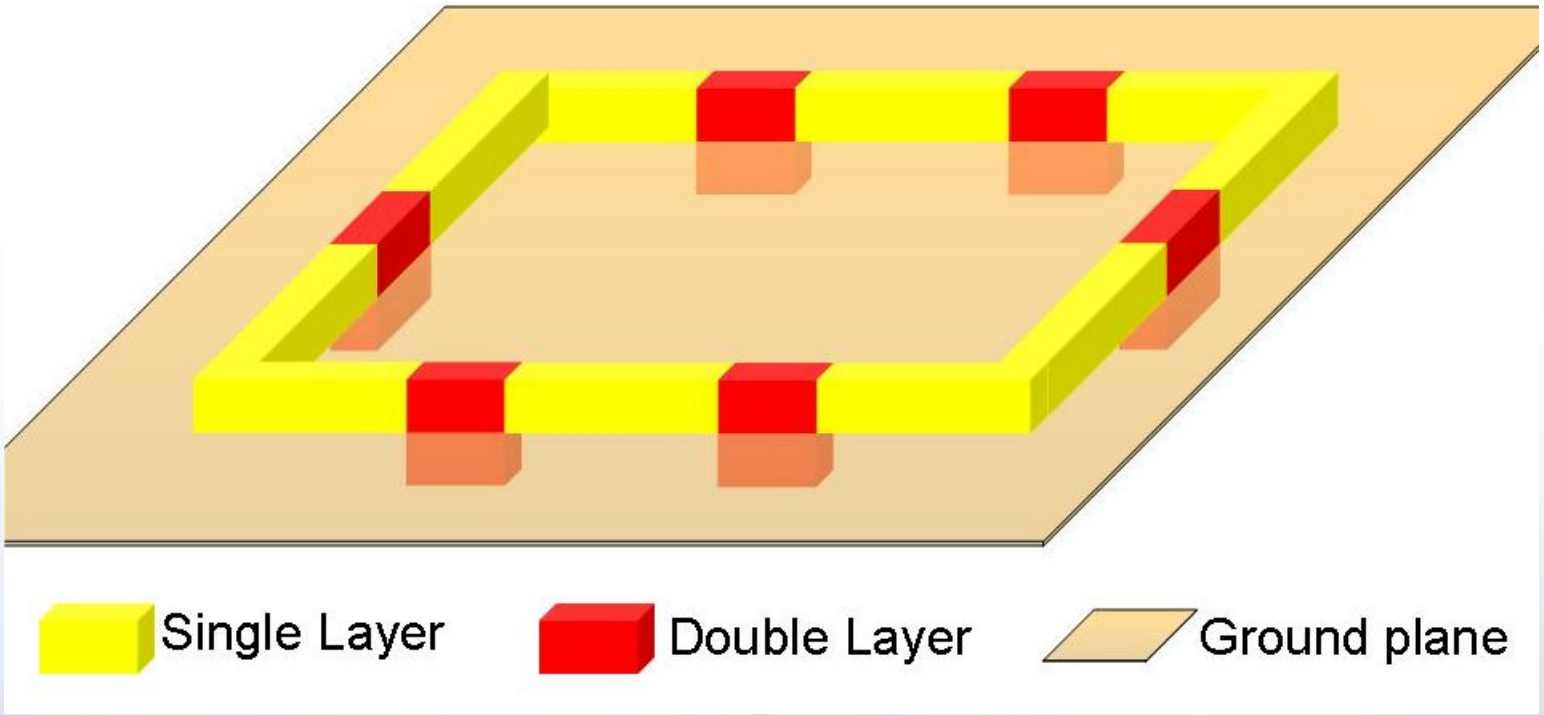
Fired Cross Section (Sawed)



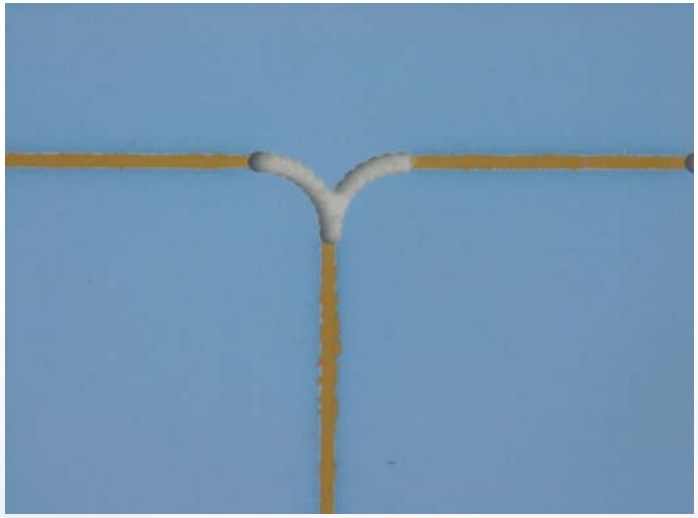
Solid wall E-M shield shows feasibility.

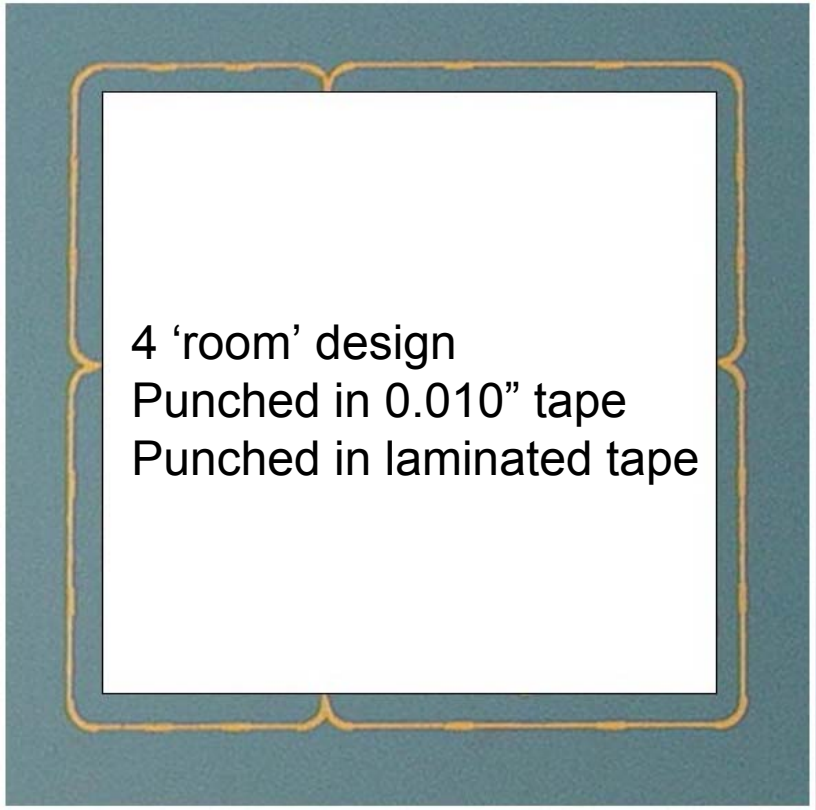
Sandia National Laboratories

Solid Wall Sequence



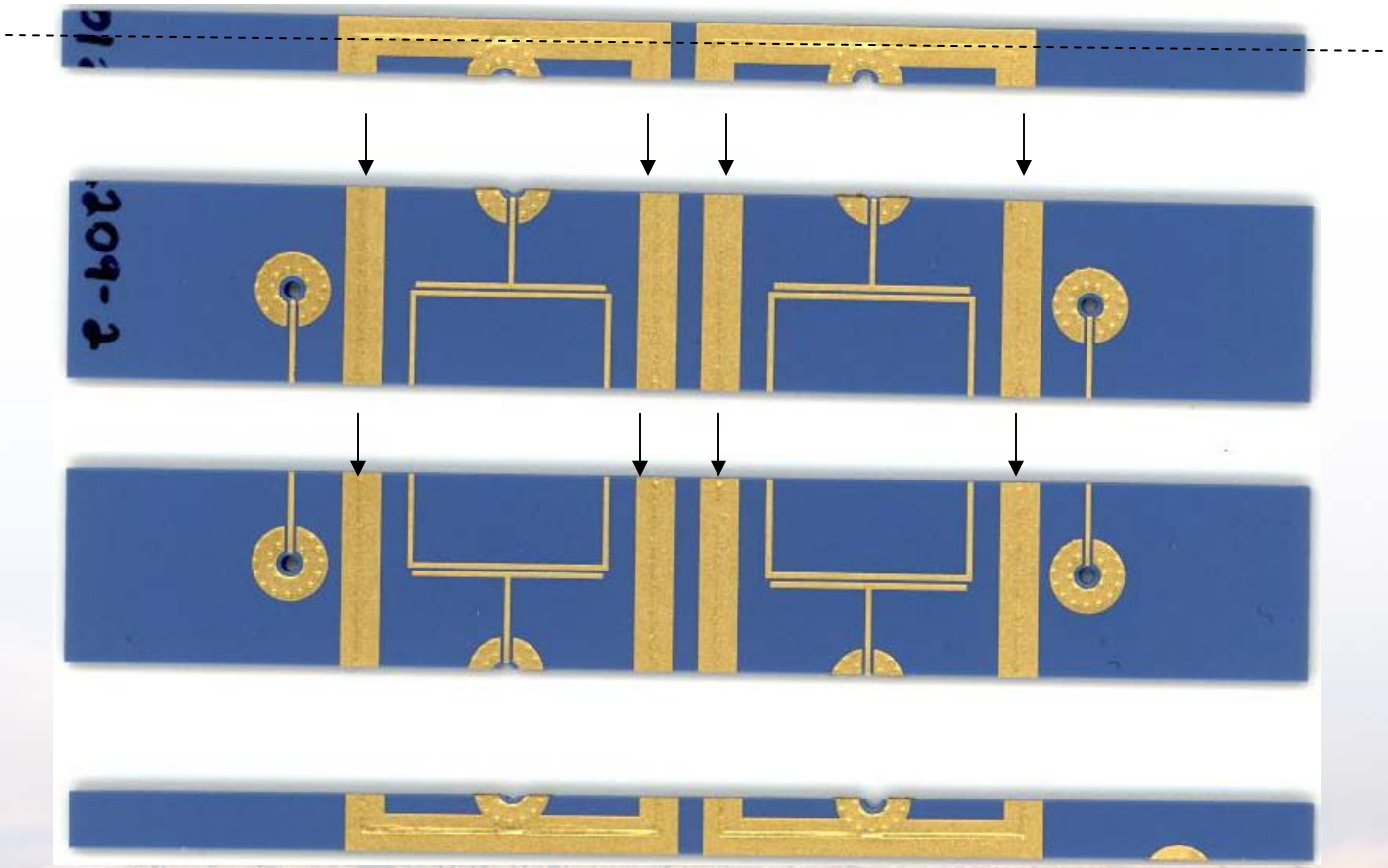
Single Layer Solid Wall Isolation



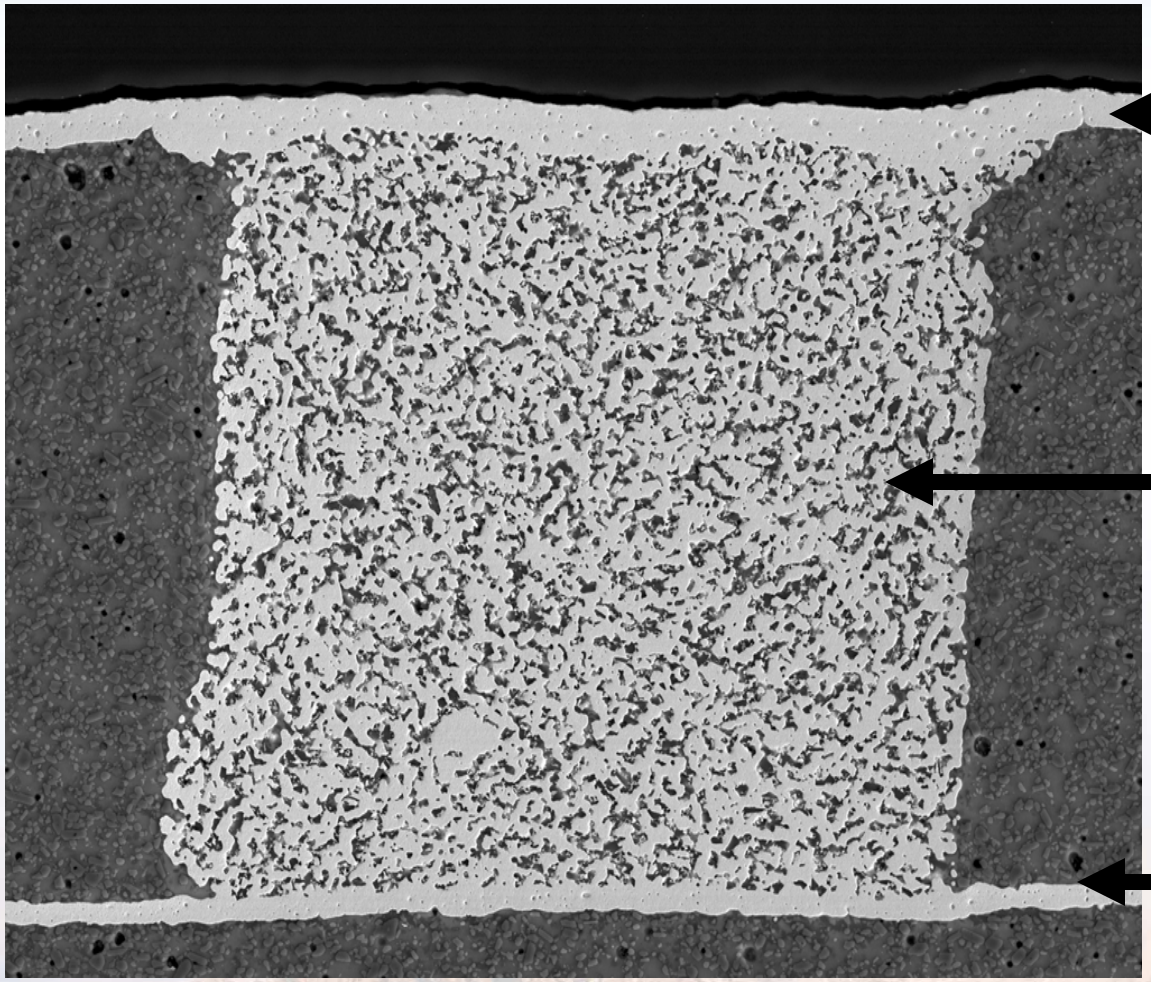


Sandia National Laboratories

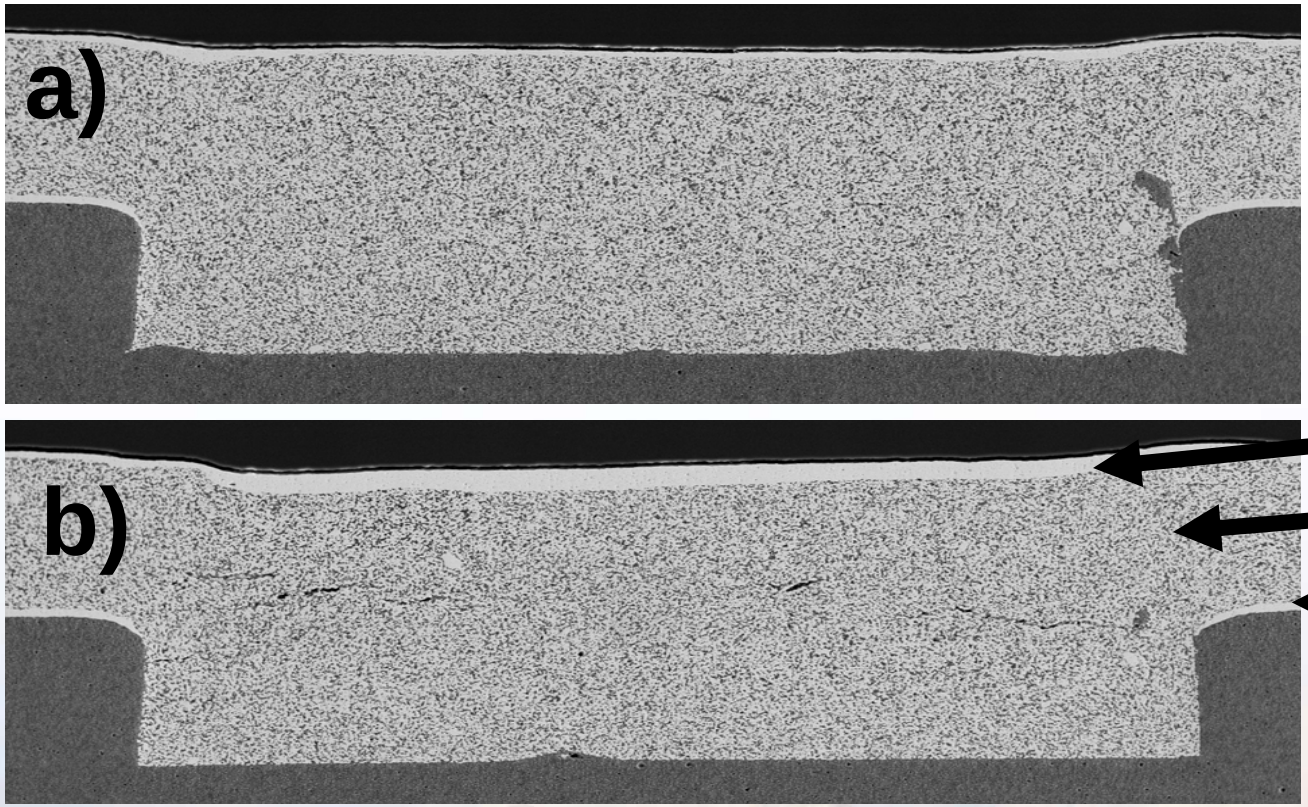
Single Layer Solid Wall Isolation



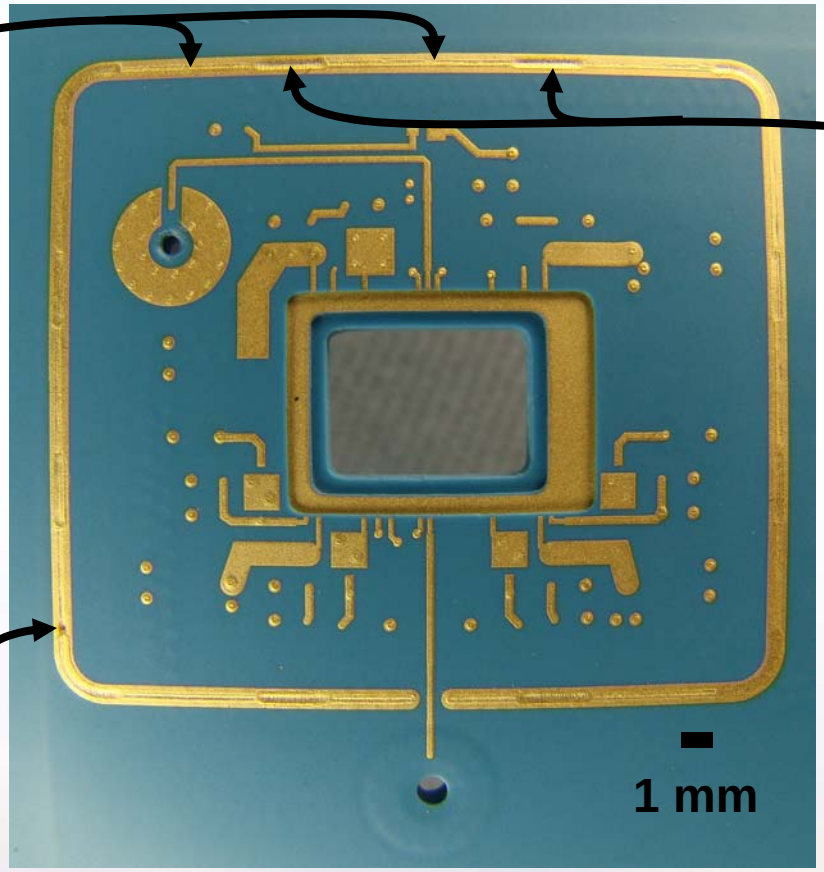
Single Layer FTTF Cross-Section



Cross-Section Along Length



Fired Solid Wall
(eight layer test fixture)



Primary punching of top layer

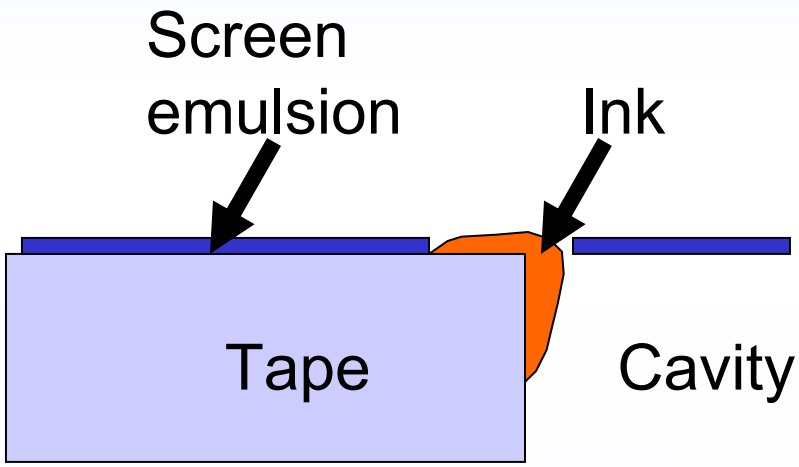
Secondary punching of top two layers

Defect: missing via-fill material

Solid wall covered by cofired barrier layer; No cracks.

Aside: Sidewall Metallization

a)



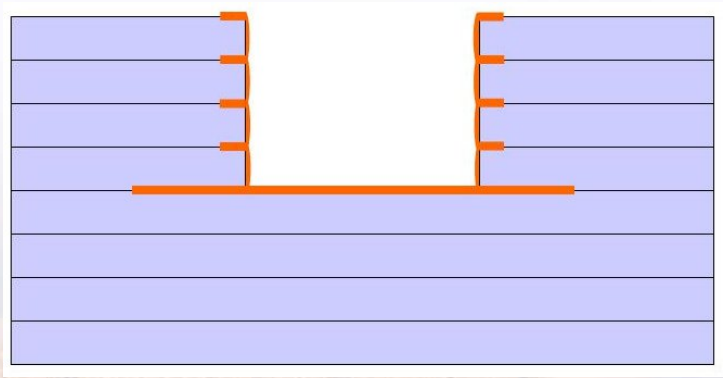
Single screen print

b)

c)

Invert and print second side

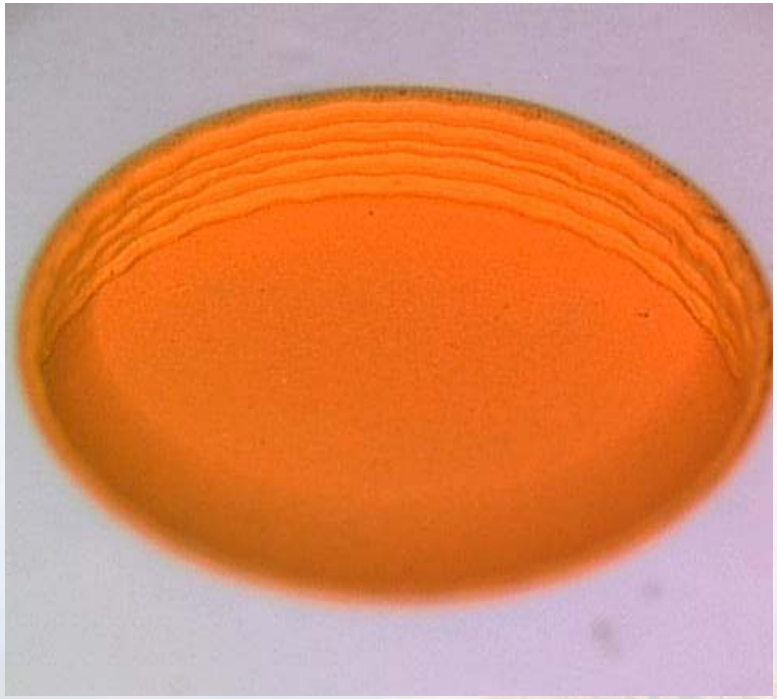
d) Stacked, laminated



Sandia National Laboratories

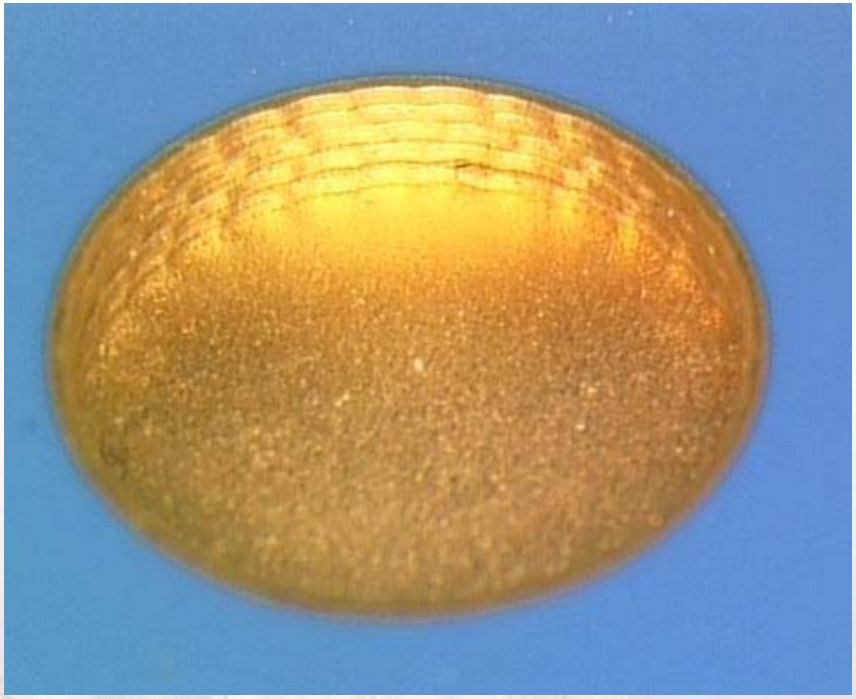
Metallized Cavity Sidewall

Unfired



1 mm

Cofired



1 mm

Sandia National Laboratories

FTTF Summary

- Useful features
  - Critical lines
  - High Q inductors
  - Thermal spreaders
  - Capacitors
  - Channels
  - Interleaved E-M shielding—Superior to via fences
  - Solid E-M shielding—Superior to interleaved FTTF
- Future work
  - RF performance
  - Material compatibility

Sandia National Laboratories

Acknowledgements

- Marcelino Armendariz, Damien Brandenburg, Kirk Buckholz, Adrian Casias, Rajen Chanchani, Dennis De Smet, Jeff Dimsdle, Brian Duverneay, John Dokos, Mike Girardi, Steve Goldammer, Randy Hamm, Brooke Hillis, Matt Johnson, Jesse Lai, Cristie Lopez, Ken Reaves, David Saiz, Tom Swiler, Tim Turner, Paul Vianco, Ambrose Wolf, Roger Woodrum, Pin Yang, and Gary Zender for technical contributions that made this work possible.

- DuPont Microcircuit & Component Materials

- Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

- The Kansas City Plant is operated and managed by Honeywell Federal Manufacturing and Technologies for the United States Department of Energy under contract No. DE-AC04-01AL66850.

Sandia National Laboratories