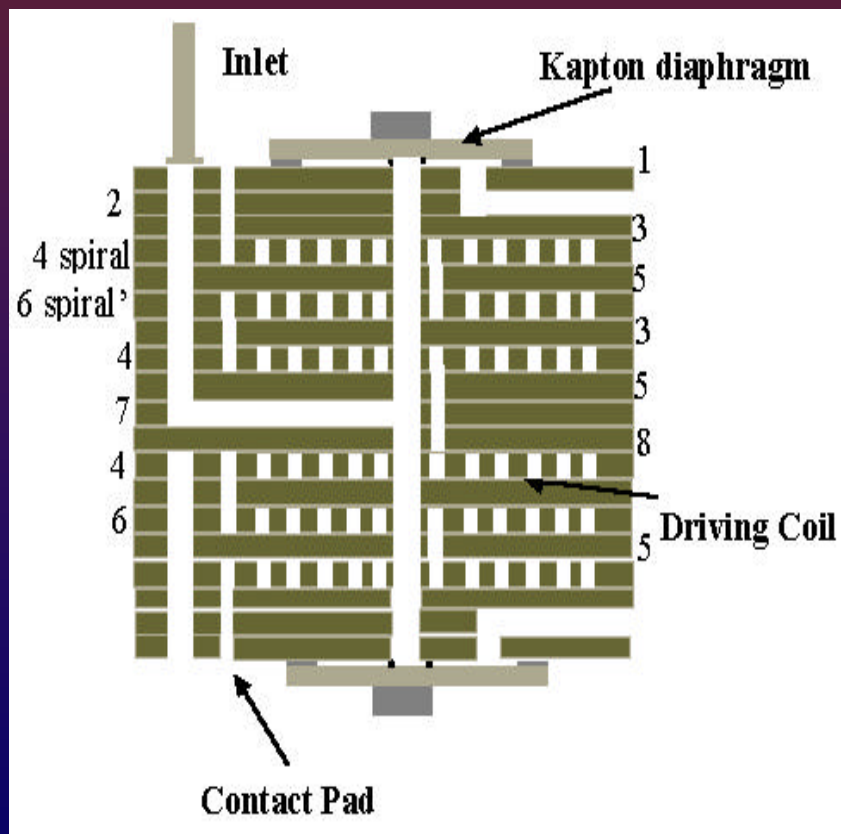


# Electromagnetically Actuated Gas Diverting Valve Using LTCC Tape



Jason Gillman

Sunfest `00

Advisors: Dr. Santiago

P. Espinoza



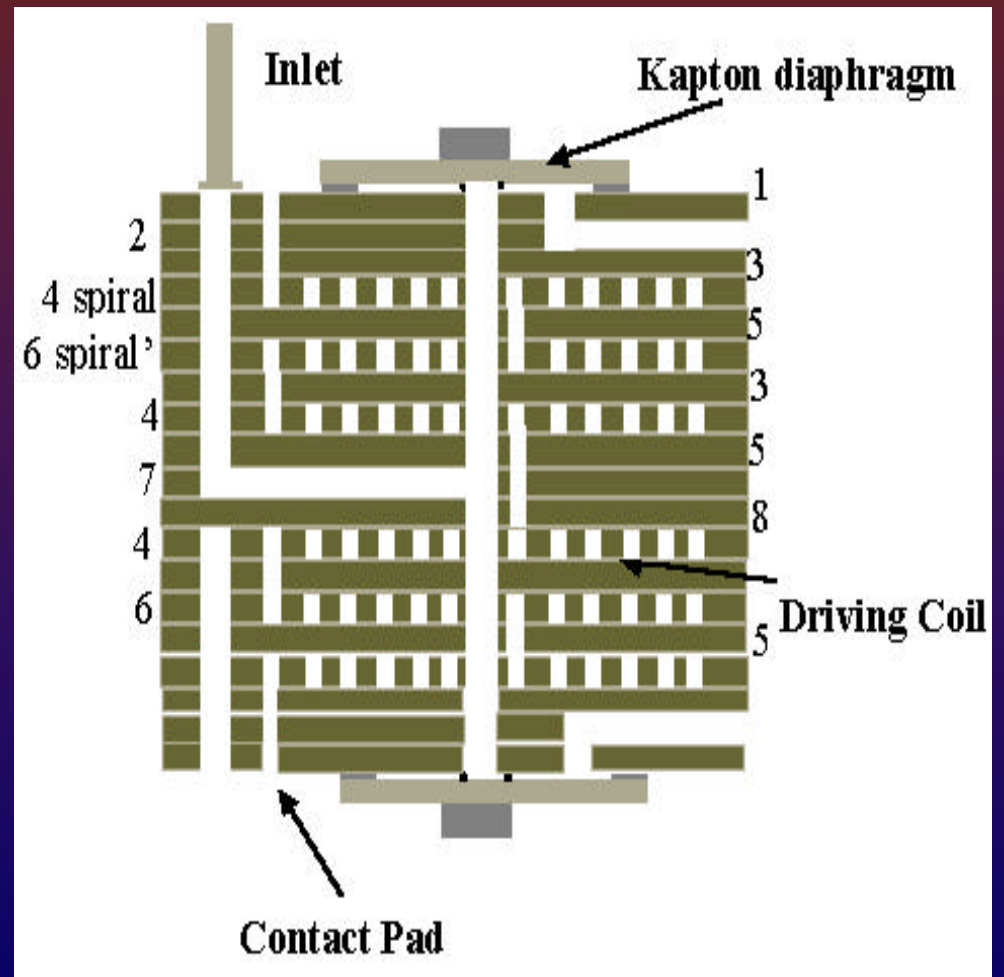
# Low Temperature Co-Fired Ceramics (LTCC)

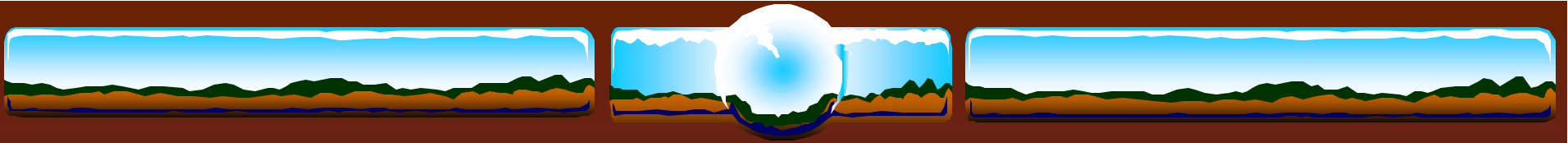
- ❖ What is it?
- ❖ Why LTCC?
  - ❖ 3-D Structures
  - ❖ Compatible w/Thick Film Technology
  - ❖ Temp Stability
  - ❖ Structurally Sound
  - ❖ Self-Packaged
  - ❖ Cheap (compared to Si)



# Gas Flow Diverter (Overview)

- ❖ What Does it Do?
- ❖ How Does it Work?
  - ❖ Push/Pull System
  - ❖ Electromagnetic Actuation
    - ❖ Permanent Magnets
    - ❖ Spiral Alternately N/S
    - ❖ Magnetic Force opens/closes pathways
  - ❖ 800 micron pathway





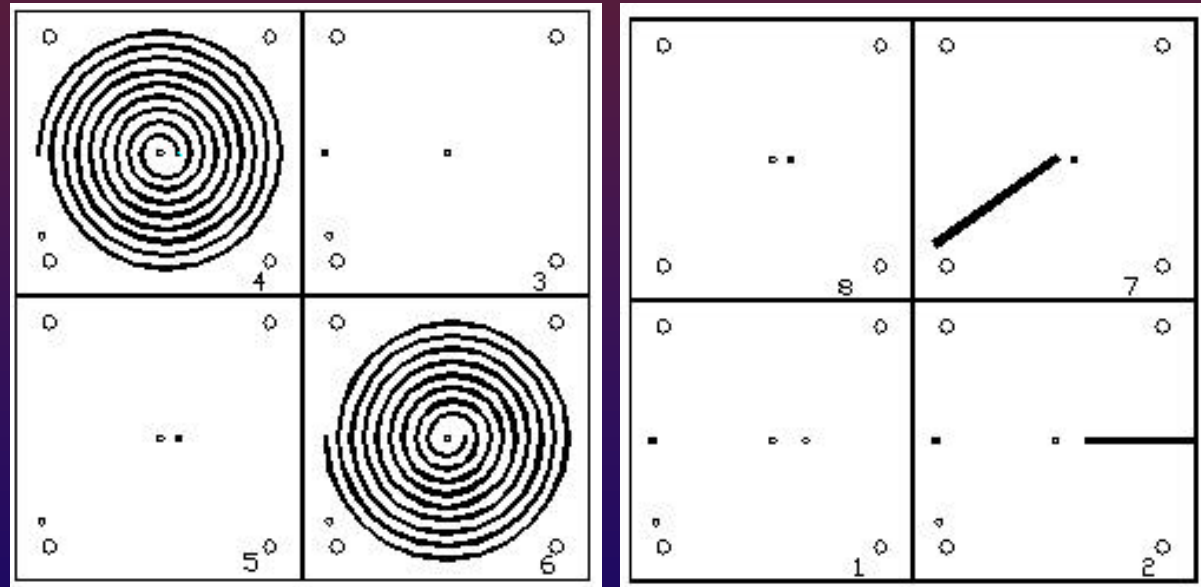
# Gas Flow Diverter (Methodology)

- ❖ Design
- ❖ Photolithography
  - ❖ DuPont Riston®
- ❖ Perm. Magnets
- ❖ Some Calcs:

Resistance:  $108.78\Omega$

For  $10\text{mA} \leq I \leq 30\text{mA}$

$1.09\text{ V} \leq V \leq 3.26\text{V}$



# DuPont Riston®

## ❖ Dry Photoresist

### ❖ Laminate onto Semi-Fired tape

- ❖ Facilitates Etching
- ❖ Mechanical Support

### ❖ Expose to UV light

### ❖ Develop

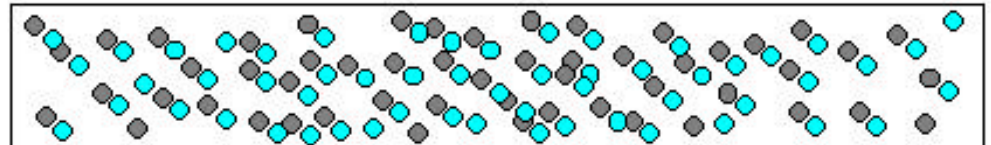
- ❖ Line size is half of desired

### ❖ Etch with BHF

### ❖ Strip (Acetone)

## ❖ Riston® 9015

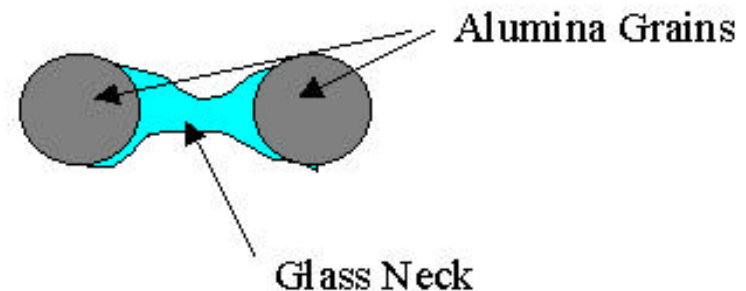
LTCC Tape:



● Alumina Grain

● Glass Grain

Above Glass Melting Temp:

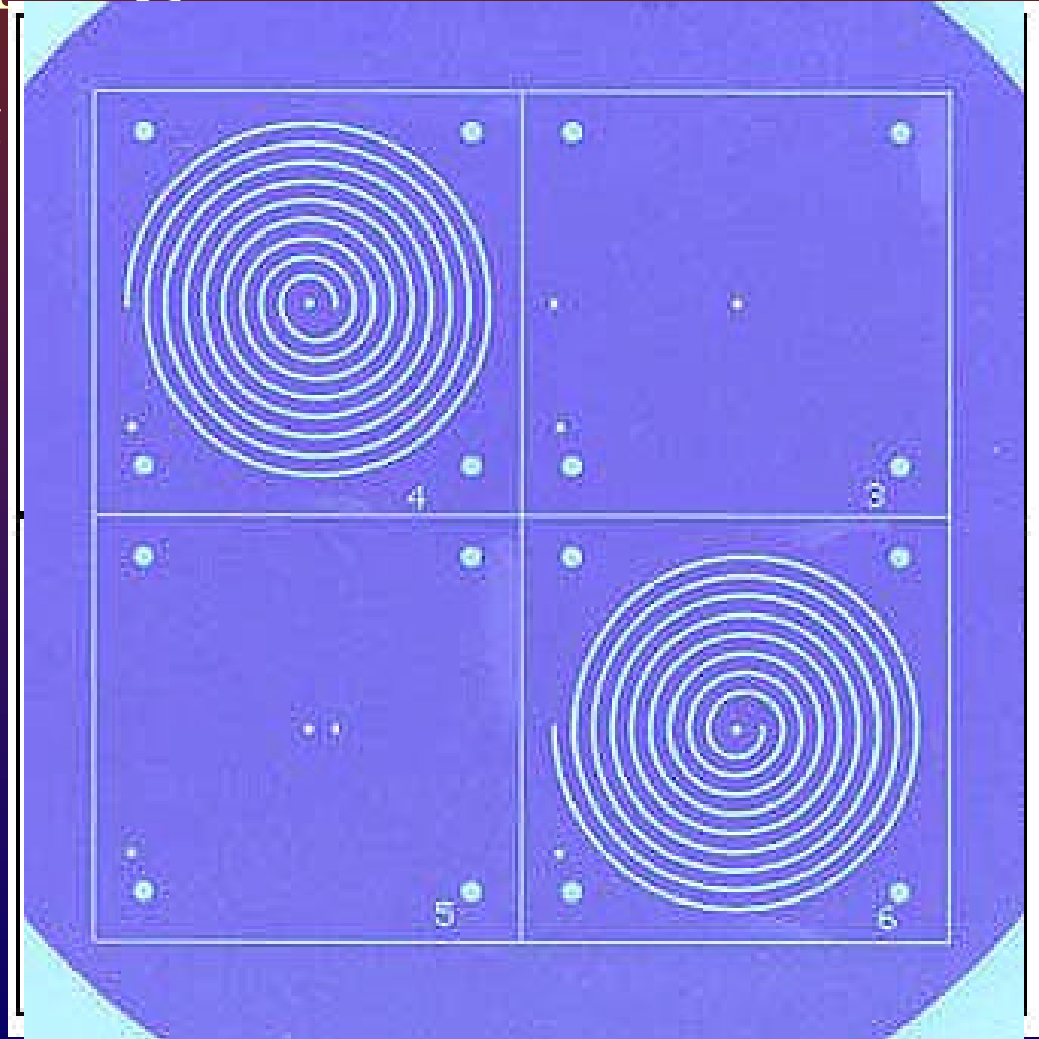


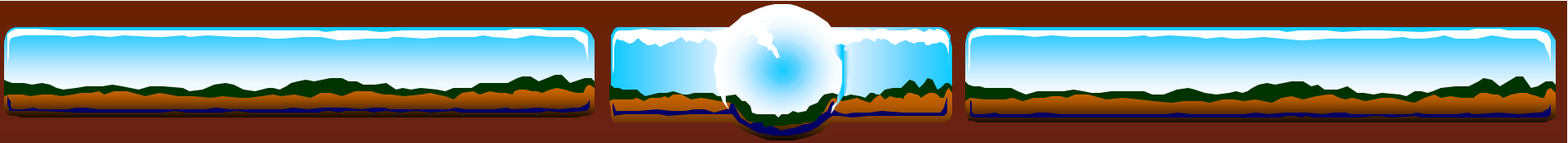
\* Schematics Courtesy of Patricio Espinoza



# Developing Results

- ❖ Perfect Develop for 9015
- ❖ Varied:
  - ❖ Exposure Energy
  - ❖ Hold Time
  - ❖ Spray Pressure
  - ❖ Type of Riston

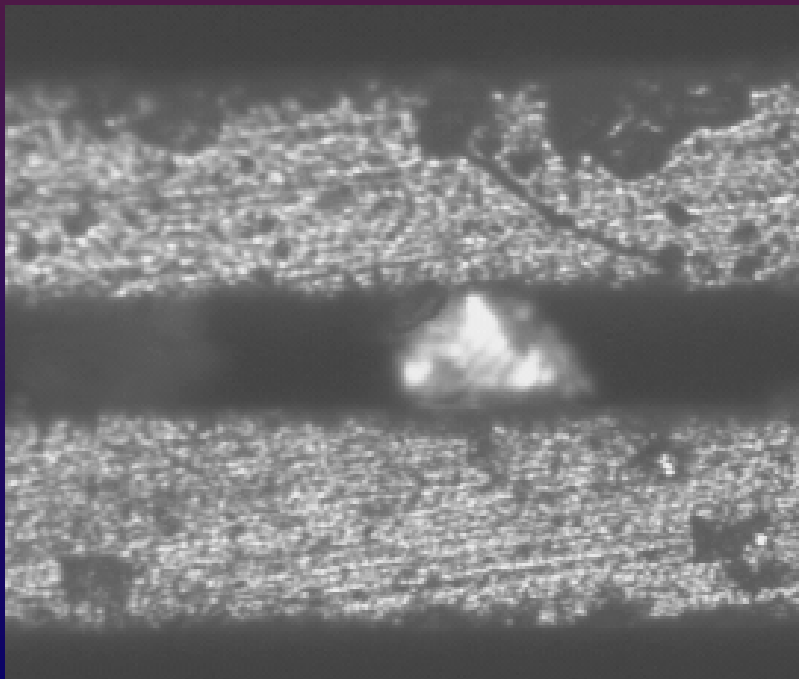




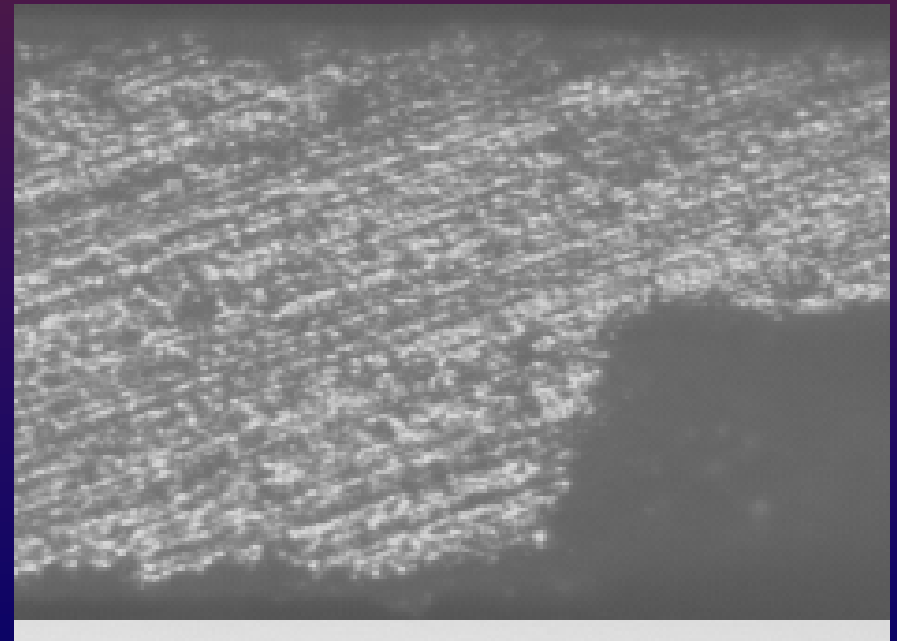
# Bonding Results

## ❖ Bonding Layers Together

Glass

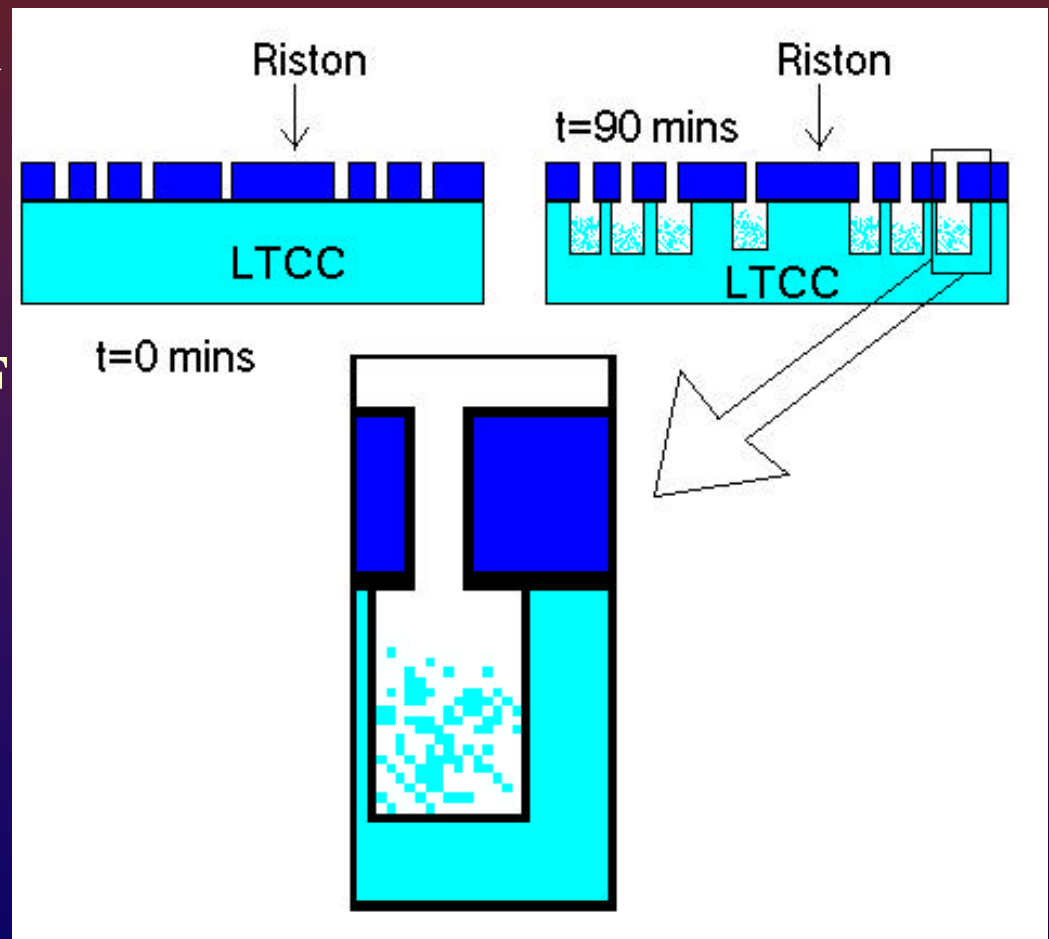


Nothing



# Etching Failure – Why?

- ❖ Not Etched Completely through 125 micron thick tape
- ❖ Material Blocking BHF Access to Bottom





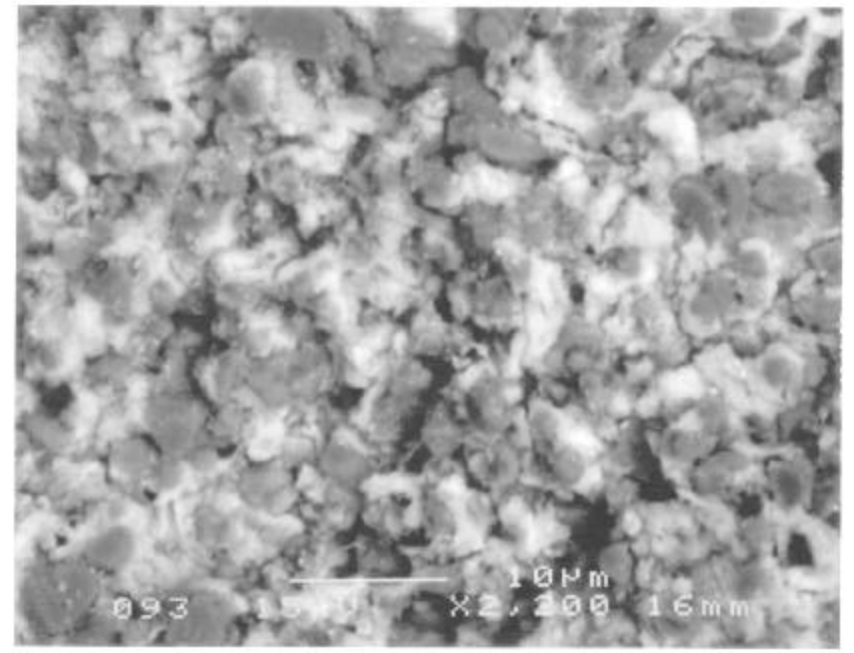
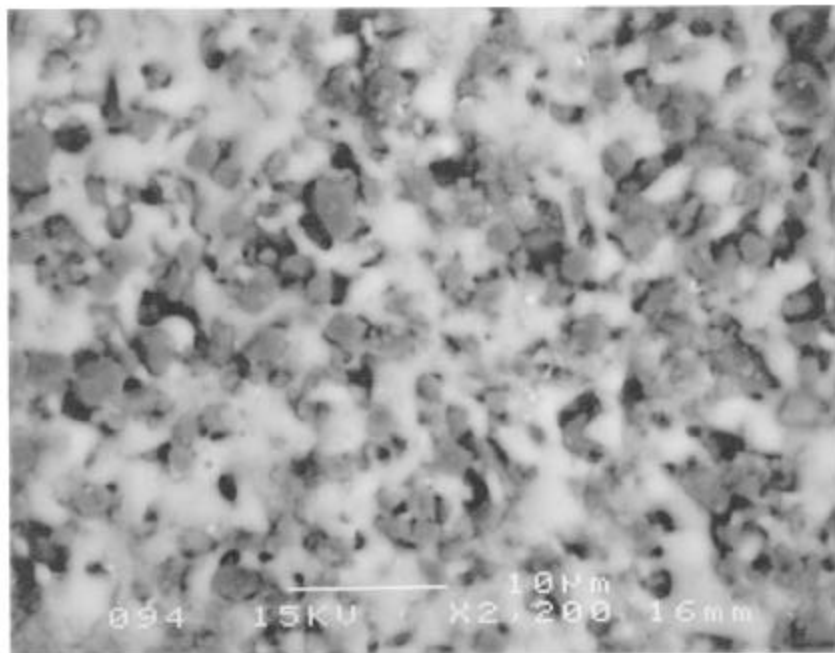


# SEM Pictures

- ❖ Backscattered Electron Imaging – Sensitive to Atomic # => White in Pictures is Glass. Also faces on dark portions => Crystalline Structure

Not Etched

Etched

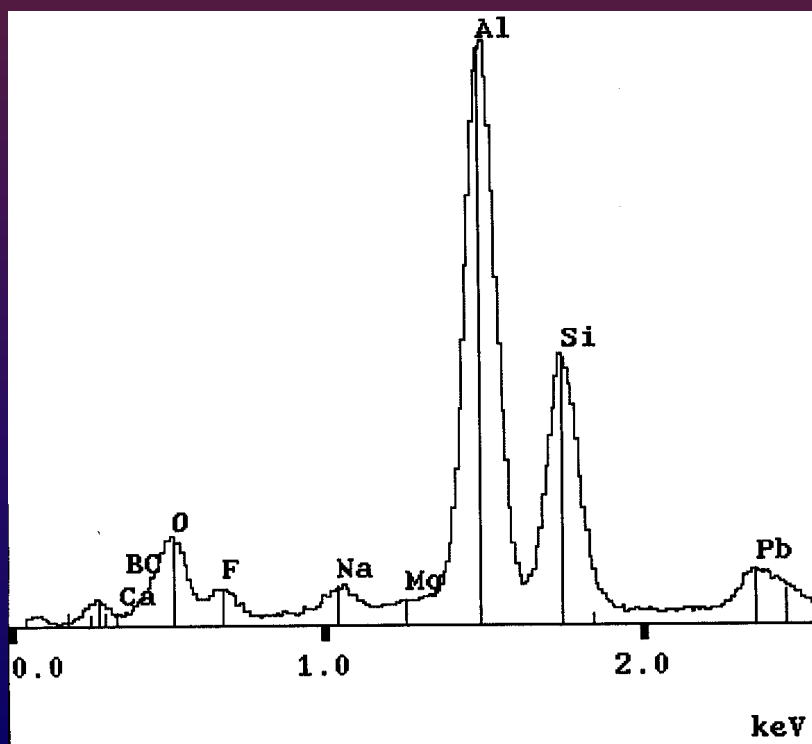




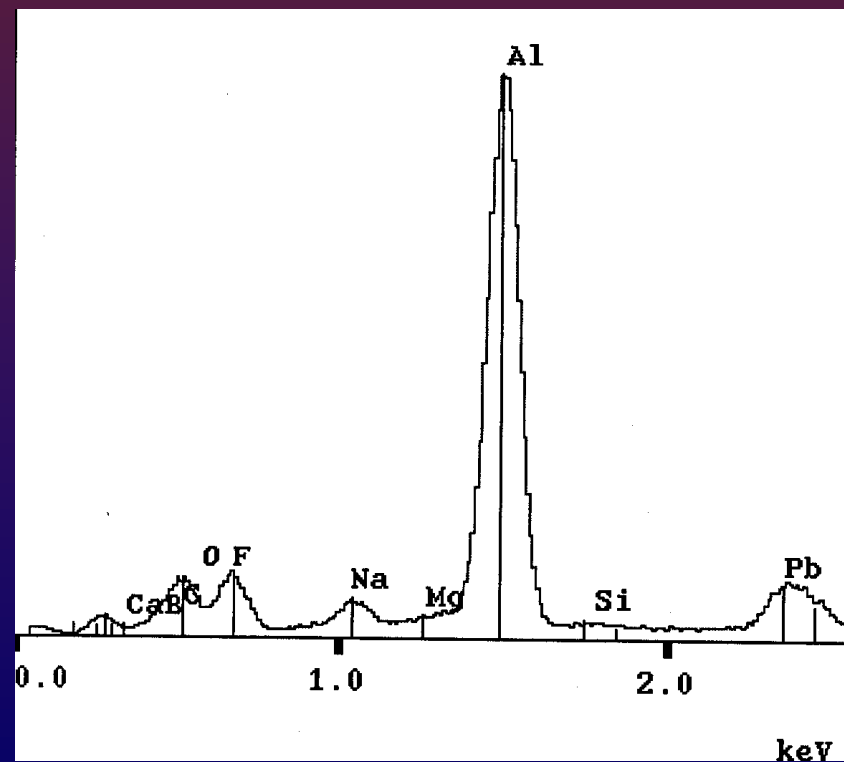
# Energy Dispersive X-ray Analysis (EDX)

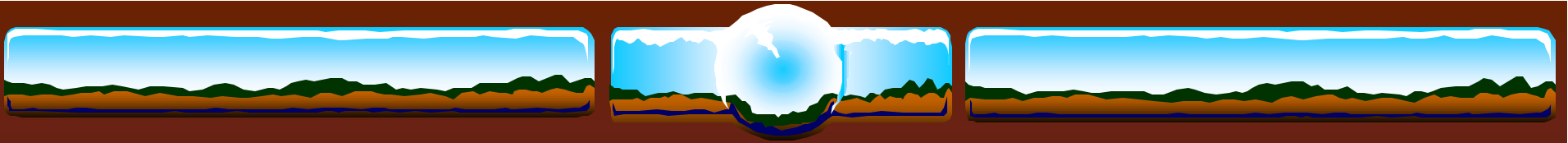
❖ Analyzes what elements are present

Not Etched



Etched





# SEM and EDX Analysis Results

- ❖ Glass still present after etching
- ❖ Si completely removed =>  $\text{SiO}_2$  completely etched by BHF
- ❖ Other glasses remain (i.e.  $\text{PbO}$ ,  $\text{Al}_2\text{O}_3$ )
- ❖ Need another etchant to remove these glasses
  - ❖ Phosphoric Acid ( $\text{H}_3\text{PO}_4$ )
- ❖ Result: Pure  $\text{H}_3\text{PO}_4$  cleaned extra material out, but Riston® did not hold



## What's Next?

- ❖ Combination BHF,  $H_3PO_4$ 
  - ❖ Etch and Clean at same time
- ❖ Different Etchant than  $H_3PO_4$ ? (HCl, Nitric)
- ❖ Higher Temp Etch. 90 degrees C?
- ❖ The Very Long Run
  - ❖ Manifold for Fluid Injection Analysis
  - ❖ Want to make Inexpensive and Portable Water Analysis Device