The Reactive Bridge: A Novel Solid-State Low Energy Initiator

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Abstract	
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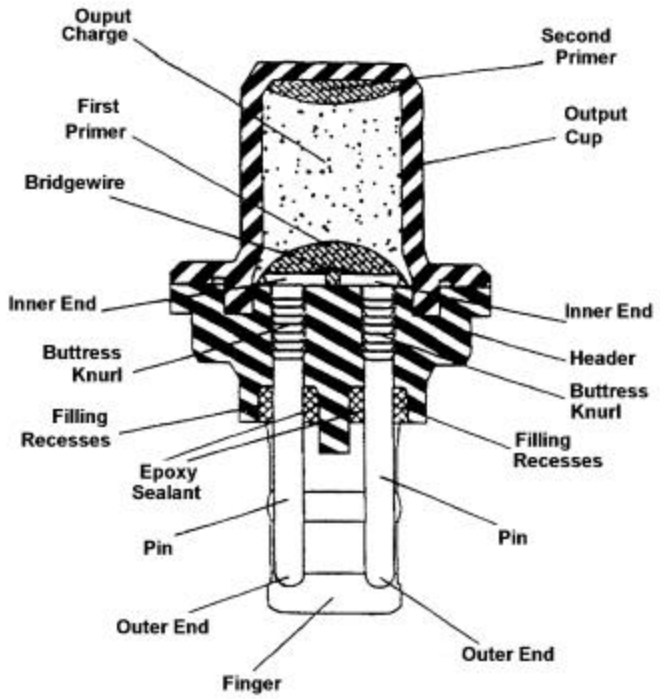
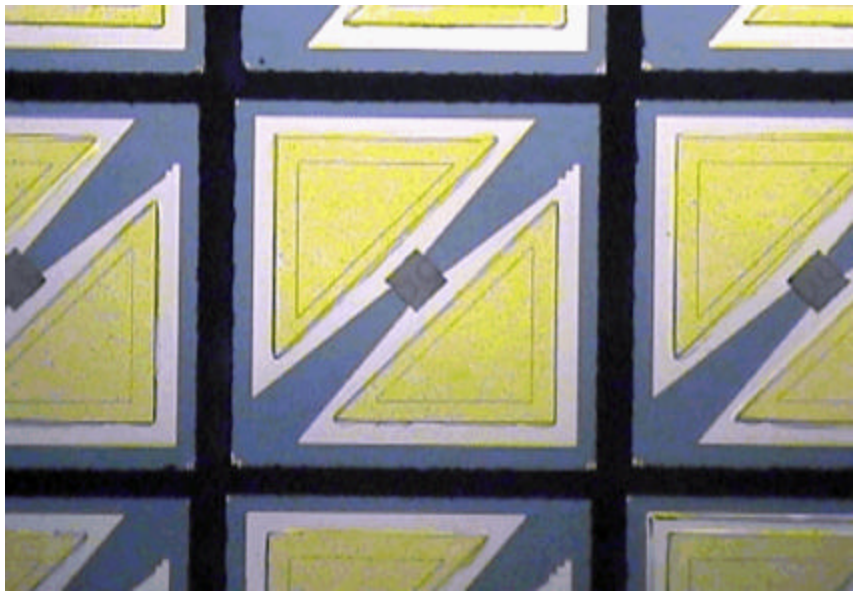
EED Structure

- Conductive Pins
- Header and Cup
- Bridgewire
- Primary Charge
- Output Charge



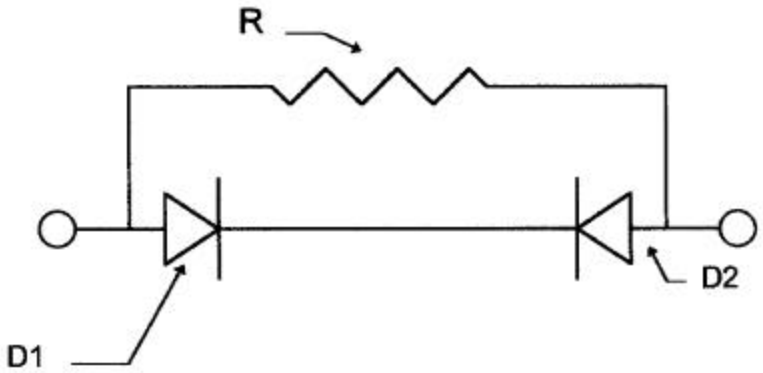
Reactive Bridge vrs. Bridgewire

- Faster Actuation (<5µsec)
- Lower Firing Energy (<30µJ)
- Smaller Dimensions (Feature size <20µms)
- Reliable Ignition Across Airgap
- Insensitive to ESD
- Fabricated with Conventional Microelectronic Processes



Design Model

- Resistive Heating Element (1Ω -10Ω)
- Two PN Junction Diodes in Parallel for ESD Protection (Breakdown Voltage ~4V ⇔20V)

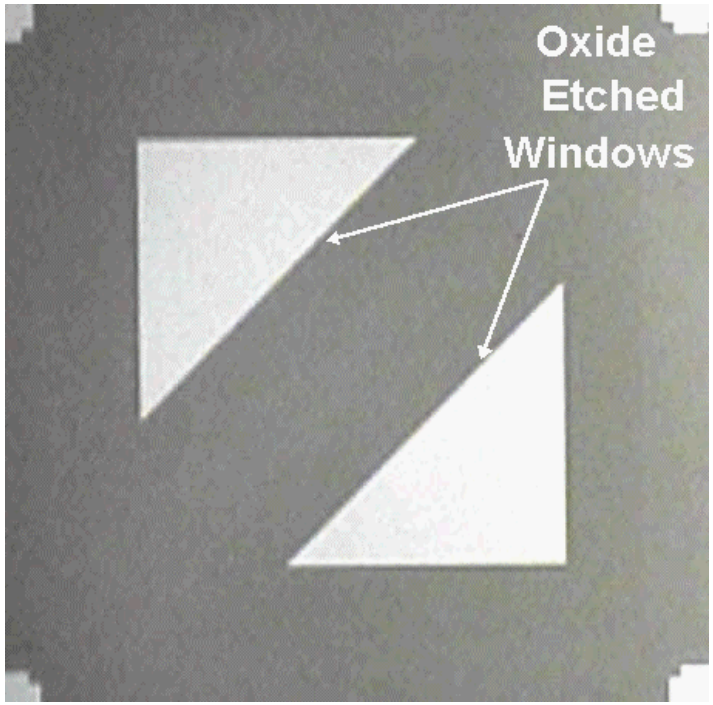


Composite Reactive Bridge Fabrication

- Utilizes Basic Fabrication Techniques
- Photolithography
- Wet Chemical Etching
- Sputtering and E-beam Metal Deposition
- Liftoff Process

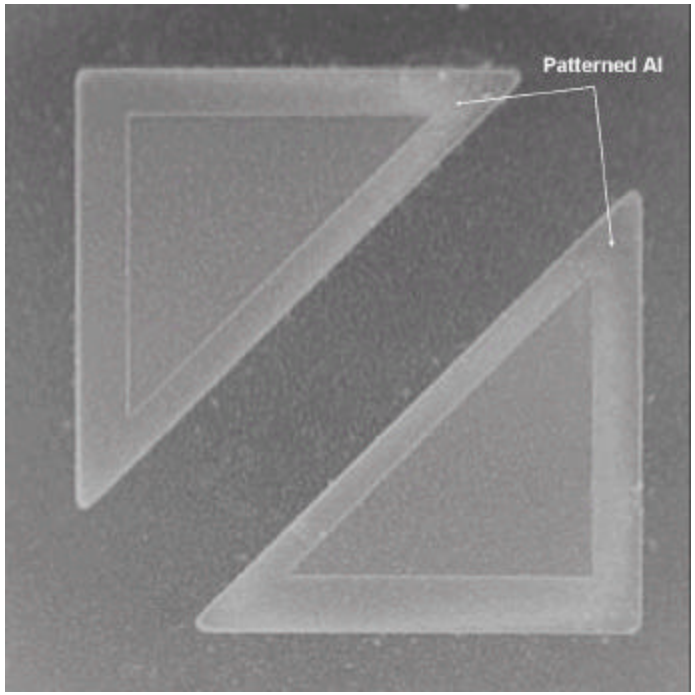
Implant and Diffusion

- Etch Oxide Window using BOE
- Typical Ion Implant
  - B
  - Q = 5E15/cm^2
  - Energy = 50keV
- Typical Drive-In
  - 1000°C, N_2
  - 15 minutes



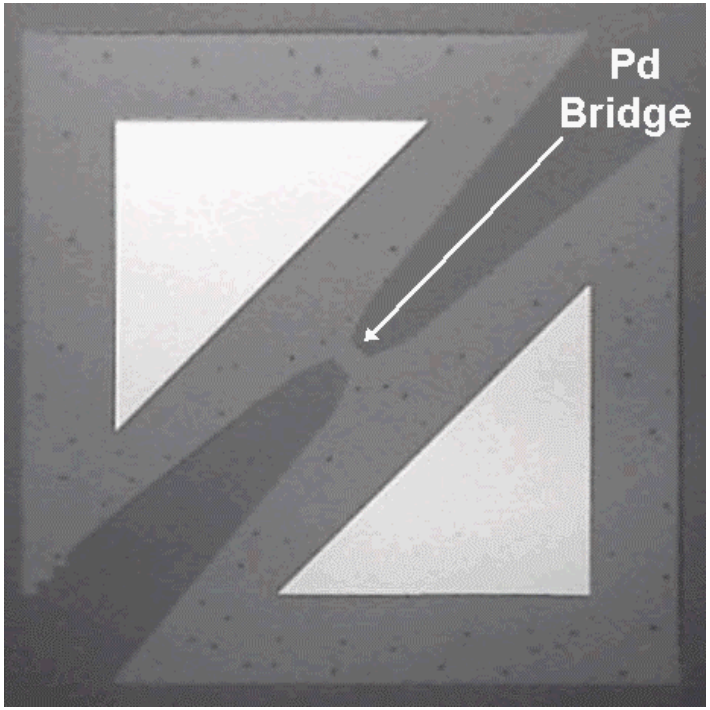
Aluminum Deposition

- Sputter ~12,000Å of Si/Al
- Mask off Window
- Etch Al with PAE
- Etch Residual Si
- Alloy Al at 450°C for 30 minutes



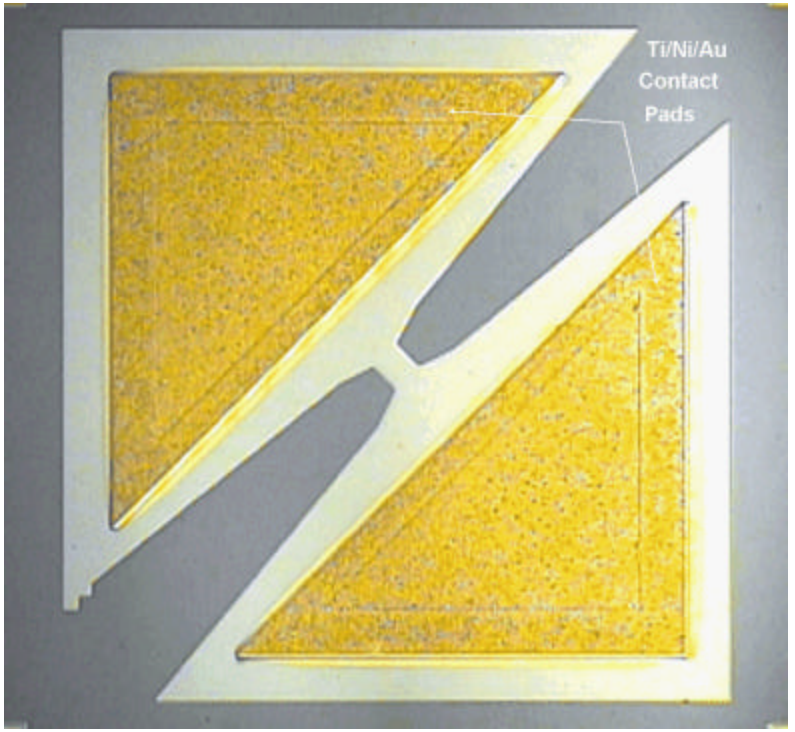
Palladium Deposition

- Mask and Develop
- Deposit
  - 500Å of Ti
  - 2000Å of Pd
- Liftoff
  - Ultrasonic and Acetone



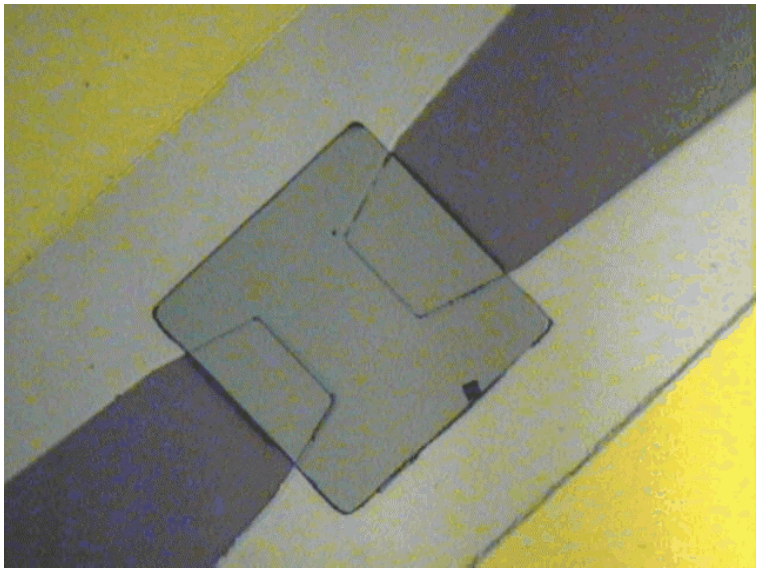
Gold Deposition

- Mask and Develop
- Deposit
  - 500Å of Ti
  - 1000Å of Ni
  - 2000Å of Au
- Liftoff
  - Ultrasonic and Acetone



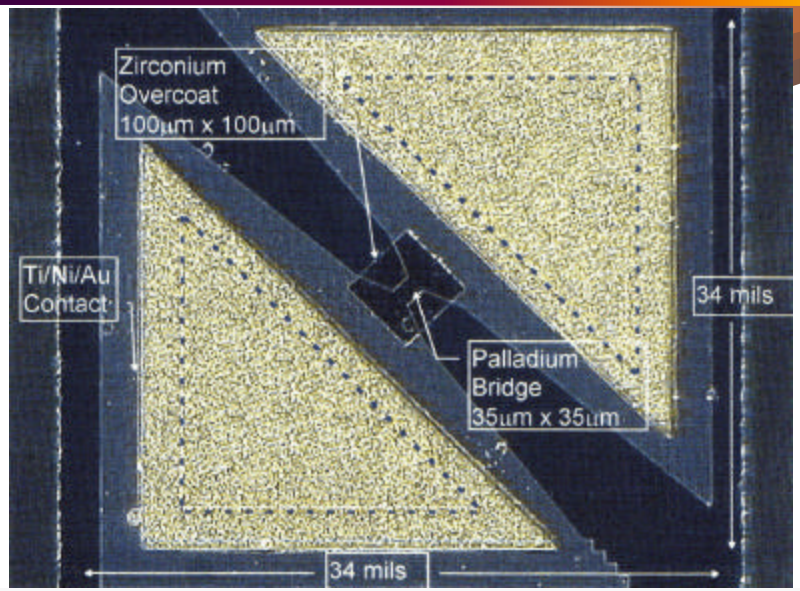
Zirconium Deposition/Reactive Overcoat

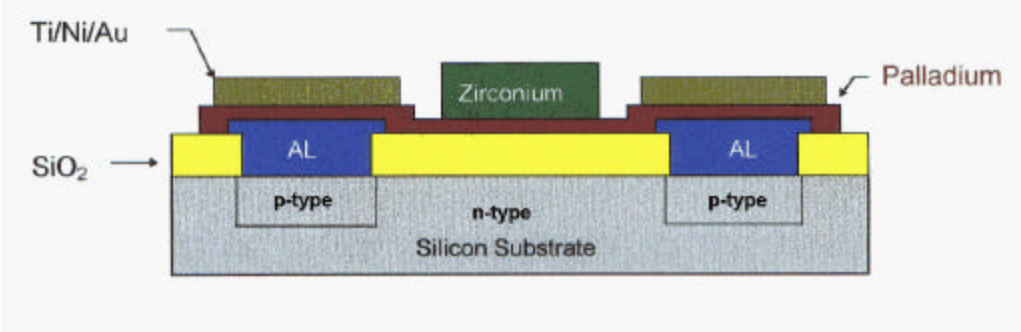
- Mask and Develop
- Deposit
  - 500Å of Ti
  - 10,000Å of Zr
- Additional Mass for Plasma Formation
- Chemically Reactive
- Liftoff
  - Ultrasonic and Acetone



Typical Dimensions

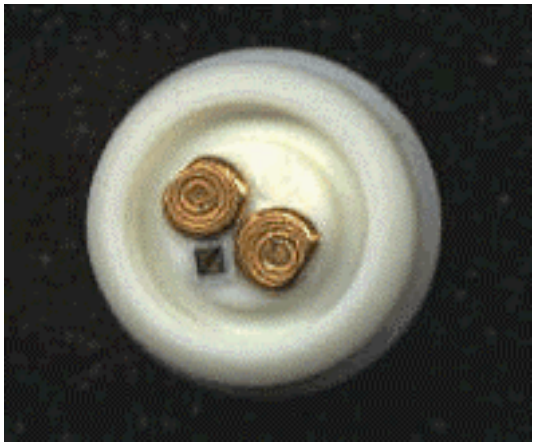
- ~1mm x 1mm, overall size
- 15µm^2 - 40 µm^2 , varying bridge size
- 100µm^2, overcoat size





Packaging

- ValoxDR48 Plastic Header
- Conducting Pins
- Output Cup

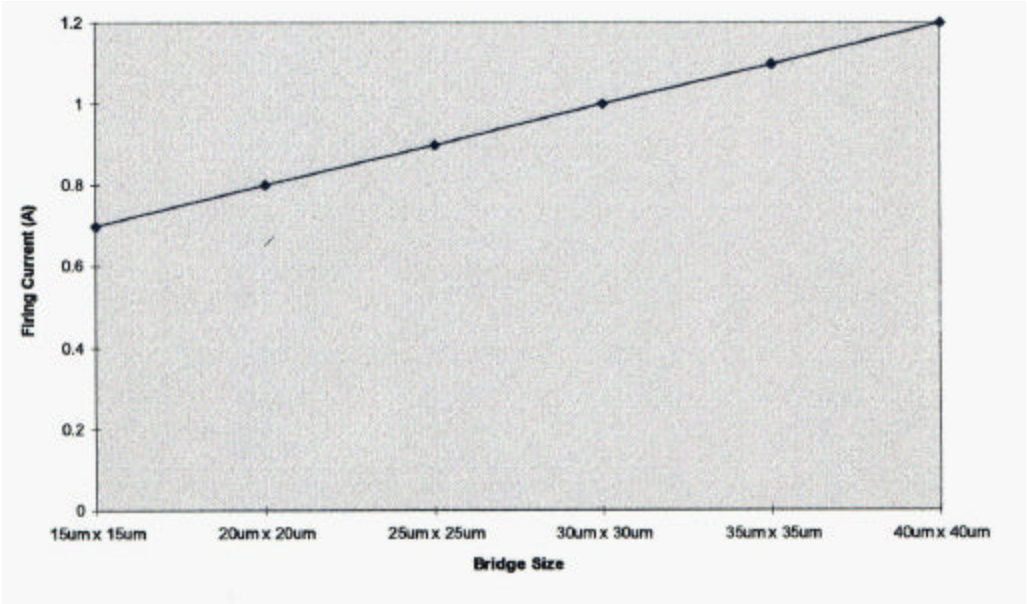


Design Validation Testing

- Firing Current Proportional to Bridge Size
- Firing Energy,

$$Q = \int_0^t (I^2 R)\,dt$$

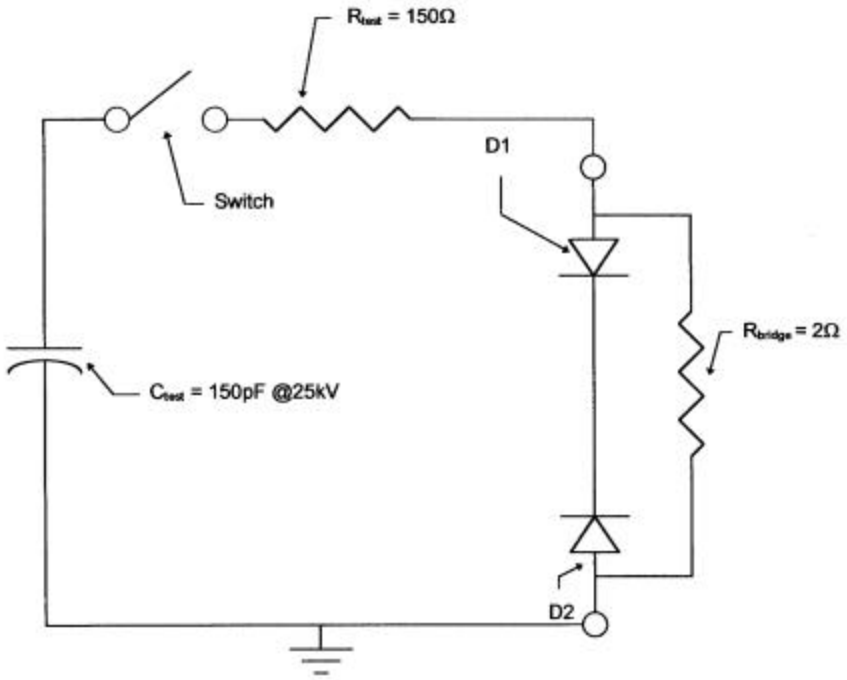
  - I = Firing Current
  - R = 2Ω (bridge)
  - t = .1msec



Firing Results With /Without Overcoat 2mF@30V

ESD Test Setup

- 150pF Capacitor Charged to 25kV
- Series Resistor of 150Ω
- Close Switch
- Repeat 5 times



Environmental Test Setup

- 320 Parts
- High Temp, 144 hrs @ 107°C
- Thermal Shock and Humidity
  - 6 cycles(-40°C and 107°C) for 12 hrs
- RandomVibration
  - Method S14:4 category I
  - 3 perpendicular axis, -40°C, 21°C, and 90°C

All Fire/No Fire Data

All Fire / No Fire Summary

Group	Bond	AF @ 1ms, 99.999% @ 95% Confidence -40C	AF @ 1ms, 99.999% @ 95% Confidence +21C	NF @ 10s, 99.999% @ 95% Confidence +90C	NF @ 10s, 99.999% @ 95% Confidence +21C
Baseline	Wirebond	1.037A	NA	.583A	NA
Post Serial Environ.	Wirebond	1.039A	NA	.617A	NA
Baseline	Conductive Epoxy	1.026A	NA	.613A	NA
Post Serial Environ.	Conductive Epoxy	1.040A	0.997A	.613A	.605A

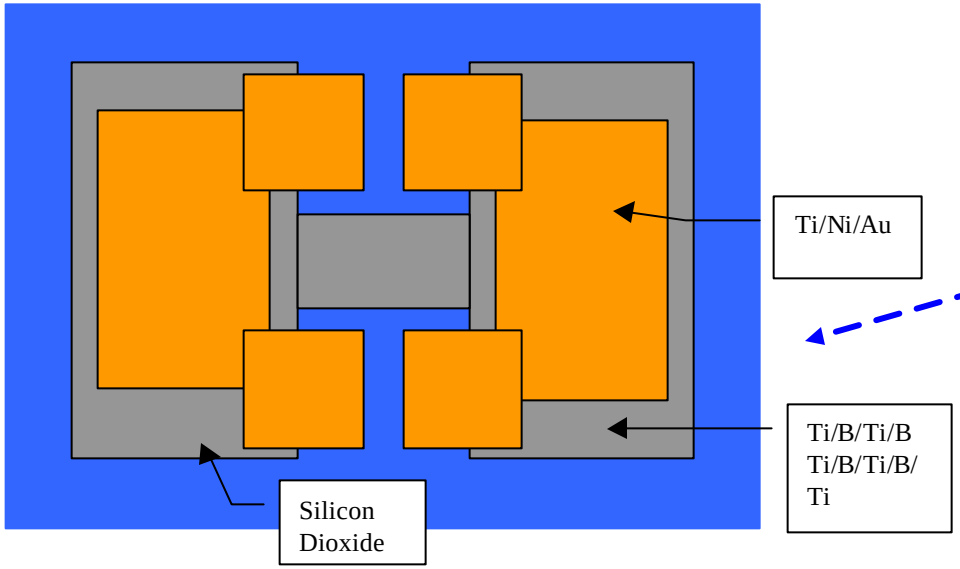
Validation Testing Results

- Results Extremely Positive
- 1.2A, 1msec all-fire
- 0.5A, 10s no-fire
- 99.999% reliability, 95% confidence
- Time to Peak Pressure, < 1ms

The Laminated Reactive Bridge

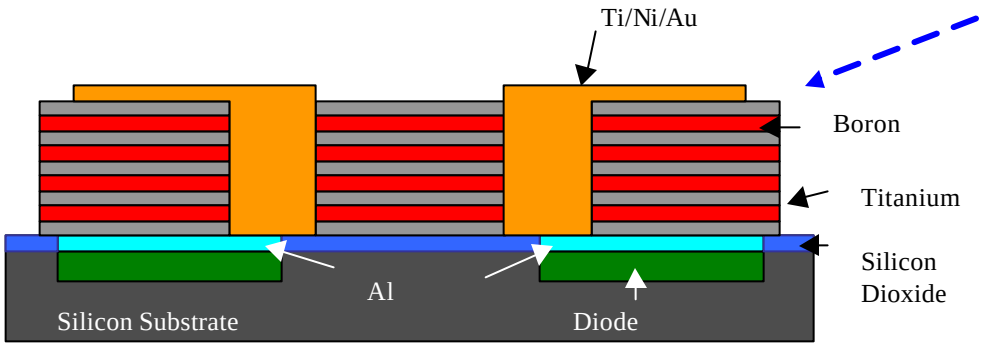
- Structure employs laminations of B/Ti
- Exothermic inter-metallic alloy
- No oxidizer required
- $2B + Ti \Rightarrow 1320 cal/gm$

Laminated Reactive Bridge

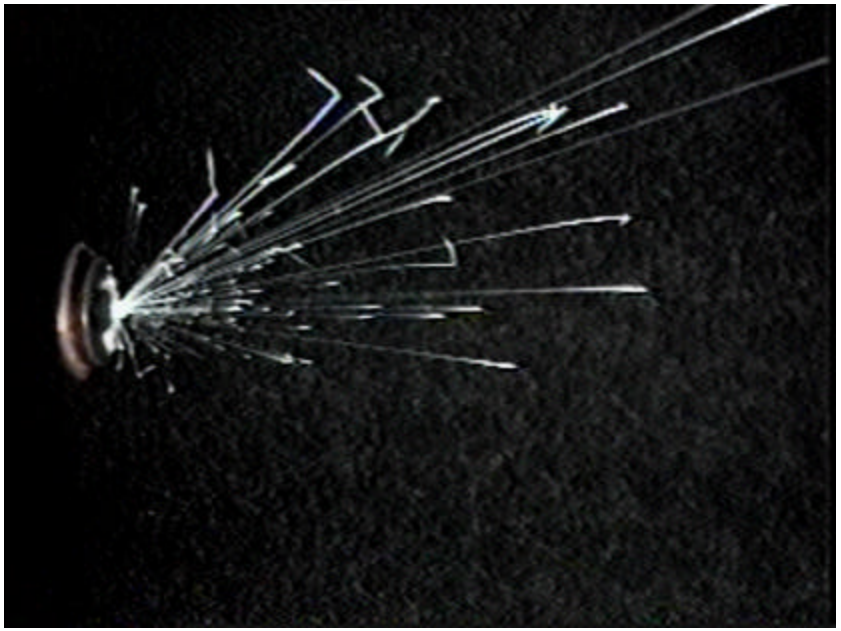


Topview

Sideview



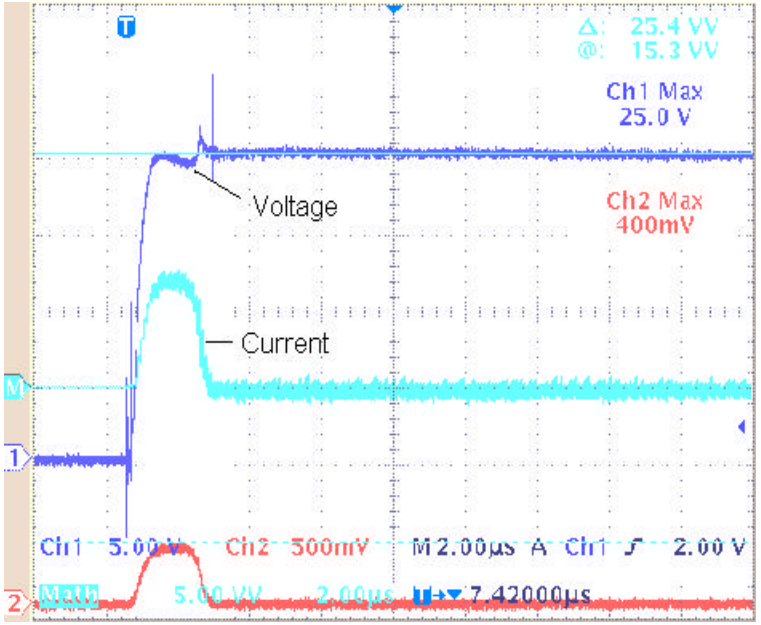
Sample Firing Of Laminated 110mm Bridge 35mF@30V



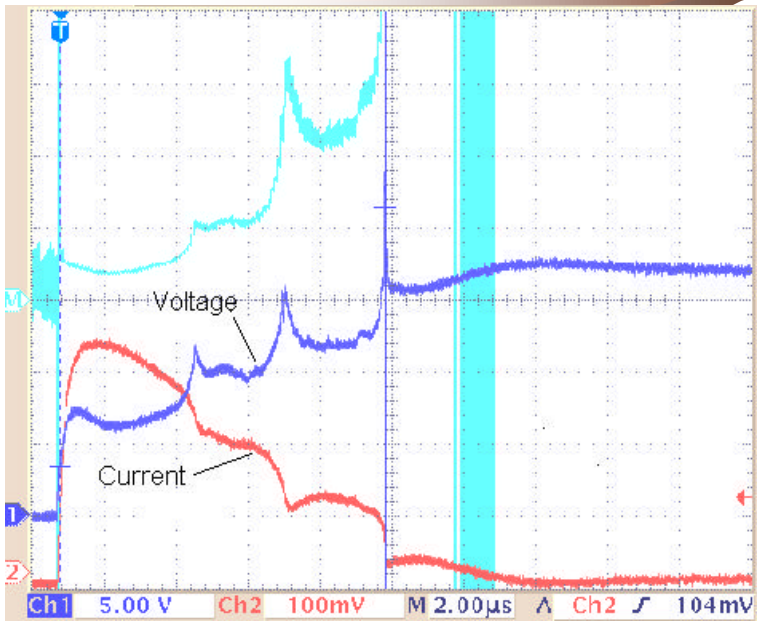
4cm

4cm

Firing Current Waveforms

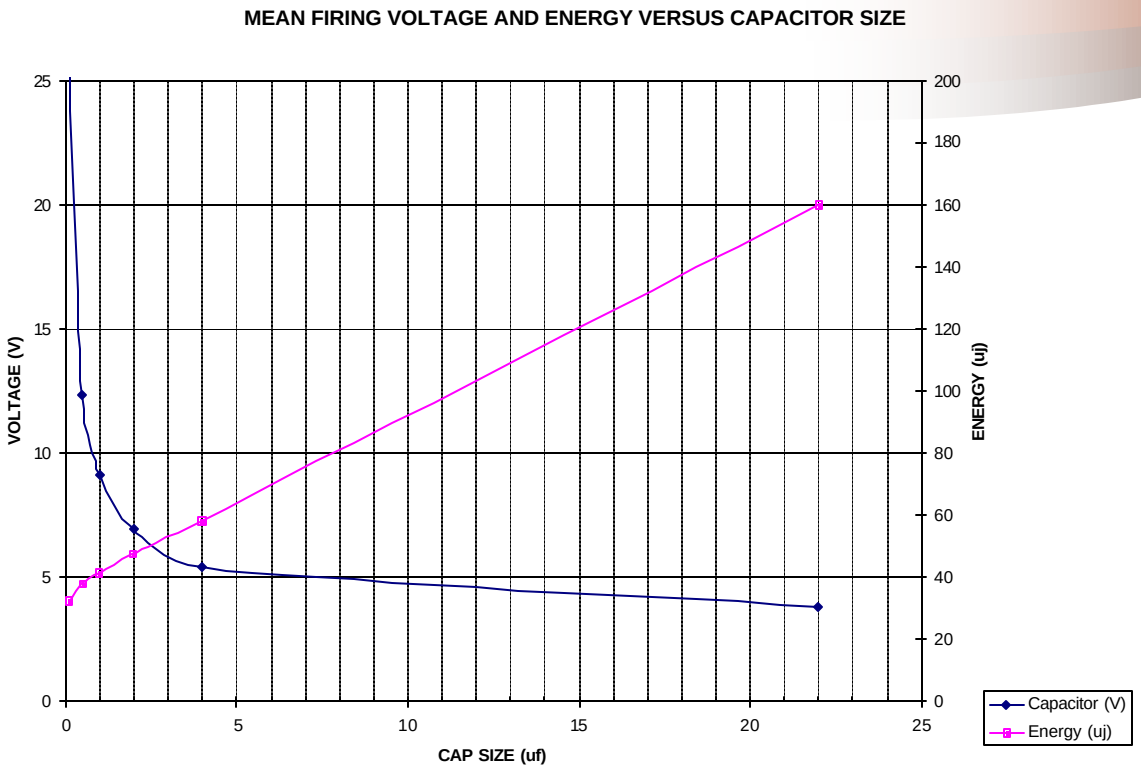


Typical Firing Trace of a Composite Bridge
(30µm bridge)



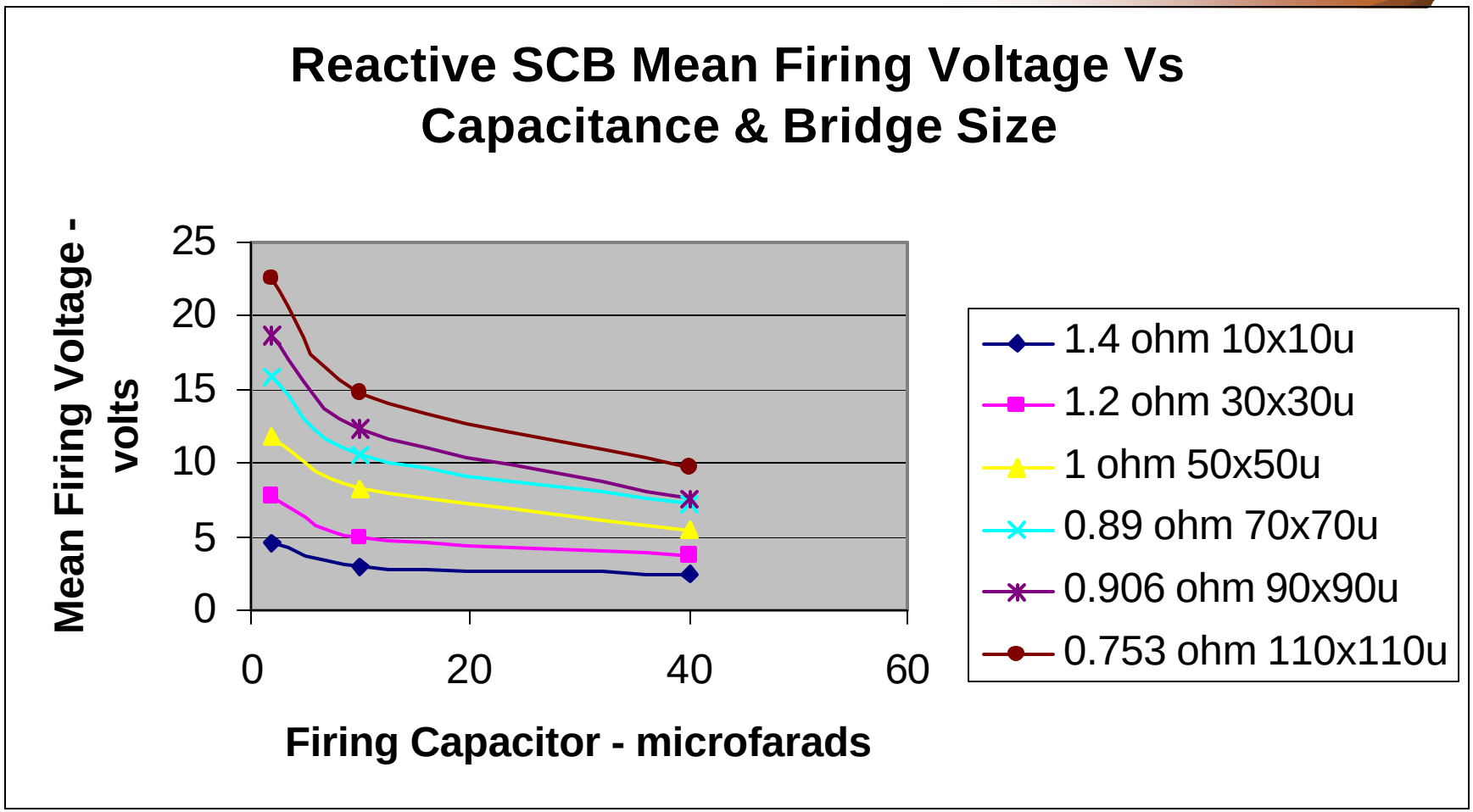
Typical Firing Trace of a Laminate Bridge
(30µm bridge)

Firing Characteristics of Laminated Bridge with 5W ESR

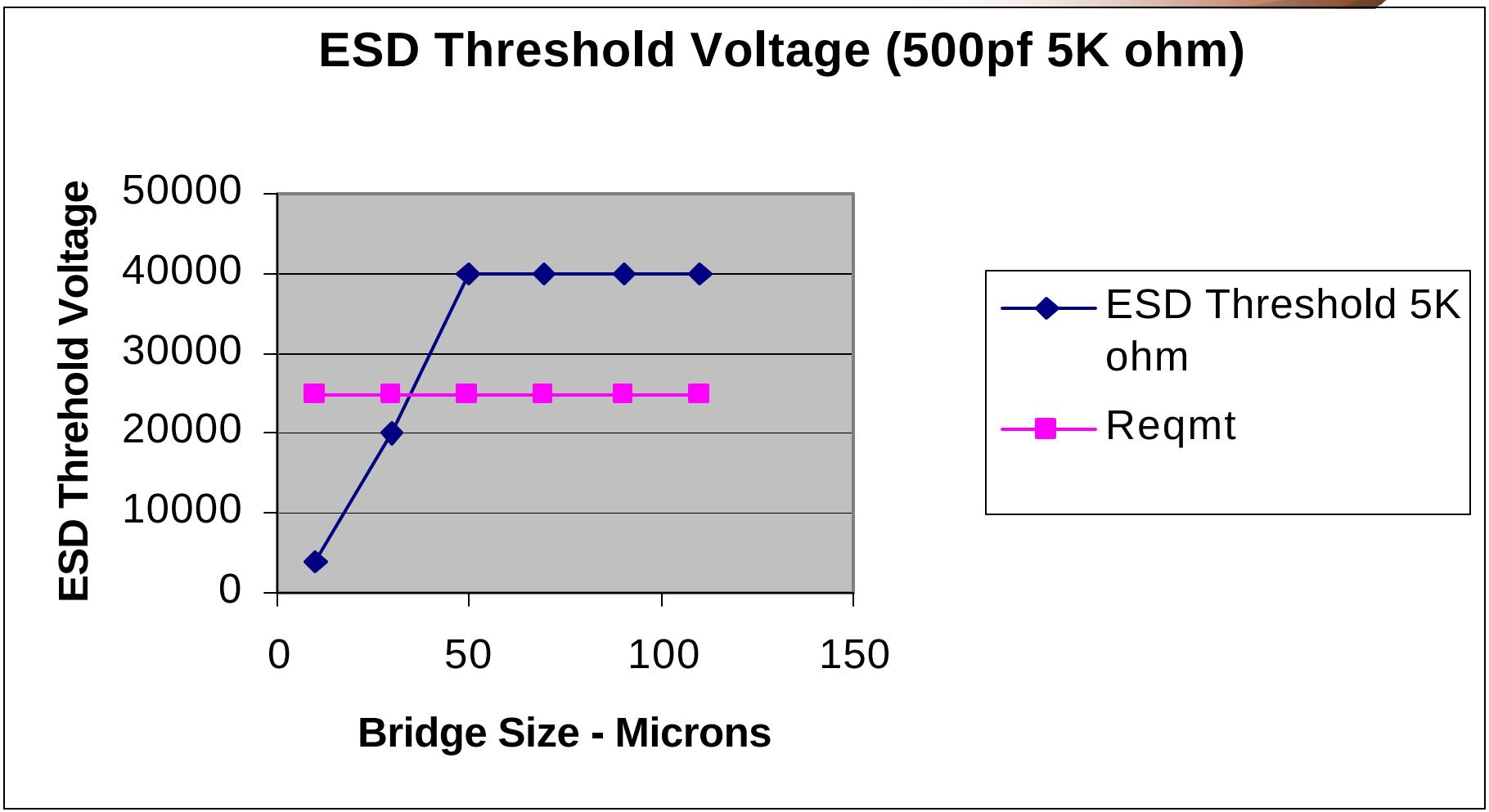


A plot of firing voltage and energy for a 20 μm Laminated bridge

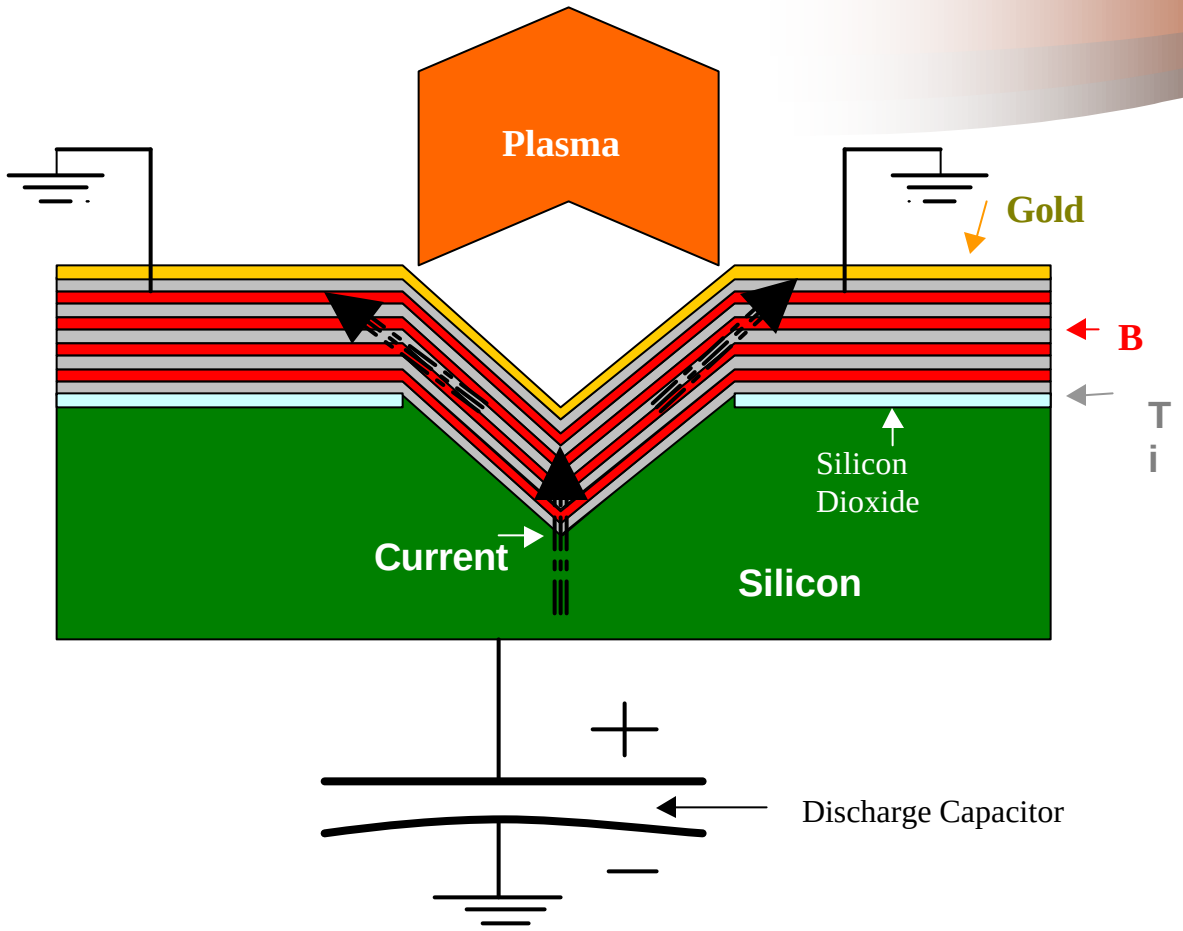
Firing Data for Laminated Bridge



ESD Results for Laminated Bridge



Integrated Shaped-Charge



Conclusion

- Devices Fabricated Using Conventional Techniques
- Demonstrates Lower Firing Energy
- Diodes Protect Against ESD Events
- Reliably Fires in Less Than 1μsec
- Plasma Output Capable of Jumping a Gap
- Very Economical for Large Volumes