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

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**Title and Subtitle**
The Reactive Bridge: A Novel Solid-State Low Energy Initiator

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**Distribution/Availability Statement**
Approved for public release, distribution unlimited

**Supplementary Notes**

**Abstract**

**Subject Terms**

**Report Classification**
Unclassified

**Classification of Abstract**
Unclassified

**Number of Pages**
27
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/cm²
  – Energy = 50keV
• Typical Drive-In
  – 1000°C, N₂
  – 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
- Lift-off
  - 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
- $15 \mu m^2 - 40 \mu m^2$, varying bridge size
- $100 \mu m^2$, 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
  - \( R = 2\Omega \) (bridge)
  - \( t = .1\)msec
Firing Results With
/Without Overcoat 2μF@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
• Random Vibration
  – 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

<table>
<thead>
<tr>
<th>Group</th>
<th>Bond</th>
<th>AF @ 1ms, 99.999% @ 95% Confidence -40C</th>
<th>AF @ 1ms, 99.999% @ 95% Confidence +21C</th>
<th>NF @ 10s, 99.999% @ 95% Confidence +90C</th>
<th>NF @ 10s, 99.999% @ 95% Confidence +21C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>Wirebond</td>
<td>1.037A</td>
<td>NA</td>
<td>.583A</td>
<td>NA</td>
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<tr>
<td>Post Serial Environ.</td>
<td>Wirebond</td>
<td>1.039A</td>
<td>NA</td>
<td>.617A</td>
<td>NA</td>
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<tr>
<td>Baseline</td>
<td>Conductive Epoxy</td>
<td>1.026A</td>
<td>NA</td>
<td>.613A</td>
<td>NA</td>
</tr>
<tr>
<td>Post Serial Environ.</td>
<td>Conductive Epoxy</td>
<td>1.040A</td>
<td>0.997A</td>
<td>.613A</td>
<td>.605A</td>
</tr>
</tbody>
</table>
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
- $2B + Ti \implies 1320\text{cal/gm}$
Laminated Reactive Bridge

Topview

Sideview
Sample Firing Of Laminated 110μm Bridge 35μF@30V
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 $5 \Omega$ ESR

A plot of firing voltage and energy for a 20 $\mu$m Laminated bridge
Firing Data for Laminated Bridge

Reactive SCB Mean Firing Voltage Vs Capacitance & Bridge Size

Mean Firing Voltage - volts

Firing Capacitor - microfarads

- 1.4 ohm 10x10u
- 1.2 ohm 30x30u
- 1 ohm 50x50u
- 0.89 ohm 70x70u
- 0.906 ohm 90x90u
- 0.753 ohm 110x110u
ESD Results for Laminated Bridge

ESD Threshold Voltage (500pf 5K ohm)

- ESD Threshold 5K ohm
- Reqmt

Bridge Size - Microns

ESD Threshold Voltage

0 50 100 150
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