Constant current testing of a SemiConducting Bridge initiator

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Introduction

- SemiConducting Bridge initiator
  - A promising new type of initiator
  - Relatively insensitive to Personnel Electrostatic Discharge and Electromagnetic Interference
  - Fast acting device
  - Mass production feasible
- Destructive and constant current characterisation of bare SCBs
- Non-destructive testing
- PESD assessment
Destructive and constant current characterisation

- Three different set-ups used to impose a constant current
  - BNC 555 pulser, 1.5-10 A, 0.10 ms pulse
  - Dynasen piezo-resistive pulse power supply, 24.0-25.0 A, 0.10 ms pulse
  - Capacitor discharge, 1 µF, SCB in series with large Ω, 8.5 -100 A
- Detection of functioning with photodiode
- Evaluation of firing bare SCB using
  - Voltage V
  - Current I
  - Resistance R, specific resistivity σ
  - Energy $E = \int V \cdot I \, dt$
  - Material constant $\int I^2 dt / (W \cdot D)^2$, characteristic for Ohmic heating until explosion
    - With W width and D thickness of SCB bridge
Generic behaviour of SCB
Resistance vs deposited electric energy

- Characterization and Electrical Modeling of Semiconductor Bridges, K.D. Marx et al., Sandia report

4 Constant current testing of an SCB initiator
SCB firing at 7.0 A - 100 μs pulse
Voltage and current profile

- Registration of light is necessary to detect bridge explosion
- Two maxima in resistance before explosion (one maximum expected)
SCB firing at 7.0 A - 100 µs pulse
Specific resistance and action integral

- Specific resistance evaluated directly from voltage, current and bridge dimensions
- $\int I^2 dt / (W\cdot D)^2$ at moment of bridge explosion is a complex function of temperature dependent density, specific heat and specific resistance, and enthalpies associated with phase changes
SCB firing at 7.0 A - 100 μs pulse
Resistance versus deposited electric energy
SCB firing at 25 A - 100 µs pulse
Voltage and current profile
SCB firing at 25 A - 100 µs pulse (Specific) resistance
SCB firing at 100 A – capacitor discharge
Voltage and current profile

- Oscillations/ringing on current and voltage signal
- Functioning after 1.0 µs
SCB firing at 100 A – capacitor discharge
(Specific) resistance
### Summary of destructive tests

<table>
<thead>
<tr>
<th>SCB</th>
<th>I A</th>
<th>Pulse µs</th>
<th>Firing µs</th>
<th>$\int I^2 dt/(WD)^2 \times 10^{15}$ A²s/m⁴</th>
<th>E $10^{-3}$ J</th>
<th>$\sigma^*$ $10^{-6}$ Ωm</th>
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<tbody>
<tr>
<td>1-4</td>
<td>4.6</td>
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<td>3.4</td>
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<td>15.9</td>
<td>2.6</td>
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<tr>
<td>1-11</td>
<td>100</td>
<td>Discharge</td>
<td>1.0</td>
<td>13.0</td>
<td>2.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

* Specific resistance level after first maximum, melt region
Short pulse, non-destructive testing

- Short duration pulse of increasing strength applied to a single SCB, indicates reversible behaviour up to the moment of bridge fusion
- NB: the No-Fire current has not been determined here, even though 1.5 A – 100 µs pulse hardly shows a resistance increase
PESD assessment

- Personnel ElectroStatic Discharge threat (STANAG 4239)
  - ±25 kV, ±20 kV, ±15 kV, ±10 kV, ±5 kV discharge from 500 pF capacitor
  - 500, 5000 Ω resistance in series with munition
- Available energy 156 mJ, RC-time 0.25, 2.5 μs
  - Resistance SCB is not constant, R ≤ 1 Ω with peaks up to ≈ 3 Ω
  - The maximum electrostatic discharge threat of personnel, simulated by a 500 pF capacitor at 25 kV and discharged through 500 Ω in series with a “1 Ω” SCB, will deposit 0.3 mJ
  - Deposited energy 0.3 mJ < 2.2-3.2 mJ measured firing energy
  - SCB passing PESD seems promising, only needs experimental verification
Discussion and conclusions

- SemiConducting Bridge initiators are a promising new type of initiator; their electric behaviour however is complex.
- Depending on current level a number of maxima in resistance are observed:
  - $I > 10\,\text{A}$ typically 2, $I < 15\,\text{A}$, typically 3 maxima
  - Commonly described behaviour: solid $\rightarrow$ liquid $\rightarrow$ plasma
  - Transition of liquid to vapour? Reaction of air with Si? ..
- Action integral seems to increase and specific resistance of melt to decrease with increasing power of electric pulse. This is still unexplained.
Discussion and conclusions

- Energy to bridge fusion no function of pulse shape (2.2-3.2 mJ)
- Experimental results are promising regarding No-Fire current and robustness against PESD threat, experimental verification needed
  - Estimated PESD 0.3 mJ energy even before phase transition

- Experimental work with loaded SCBs is under way
Acknowledgement

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