Constant current testing of a SemiConducting Bridge initiator

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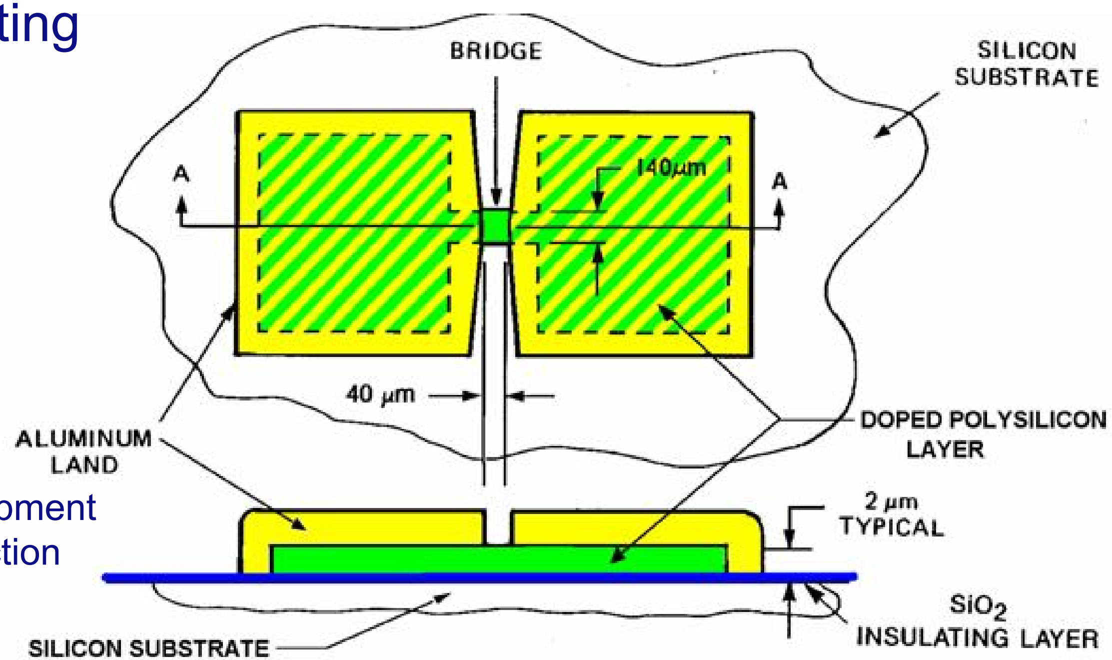
Introduction

- 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

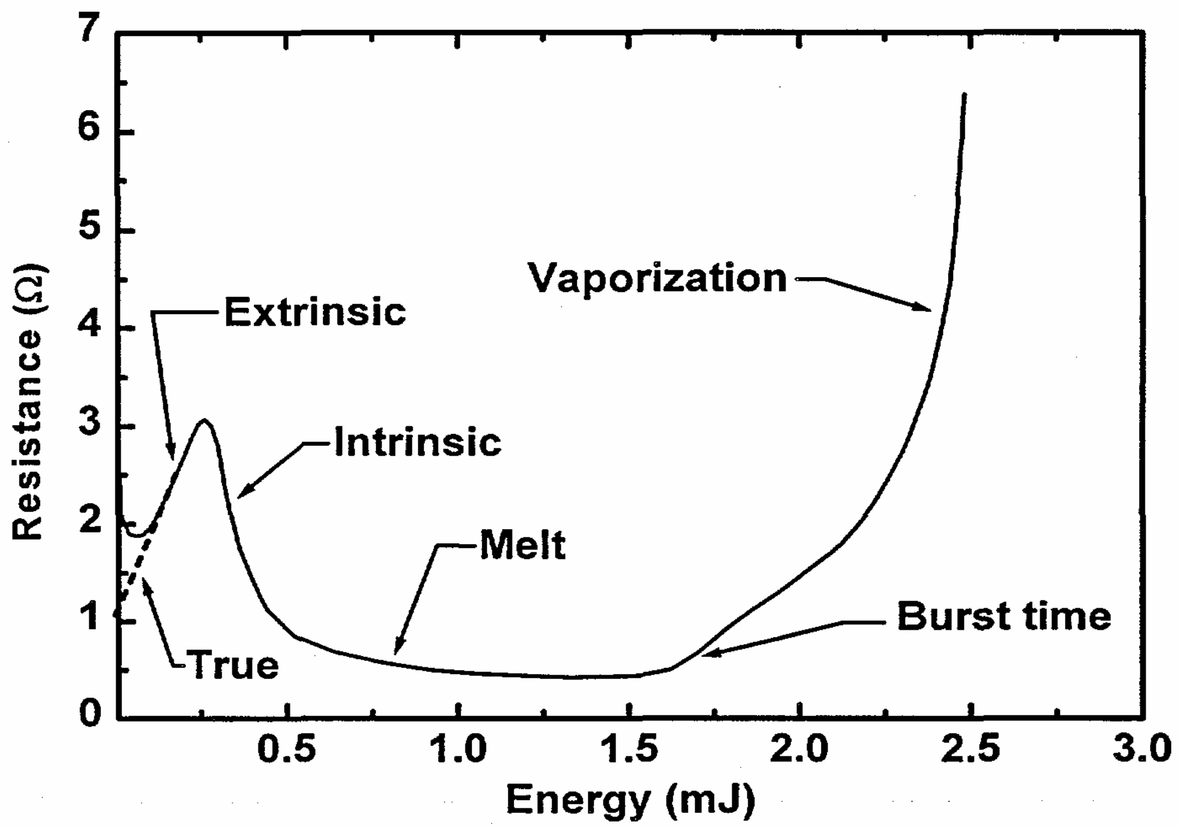


SCB detonator development for the Navy multi-function fuze, A. Wyman

Destructive and constant current characterisation

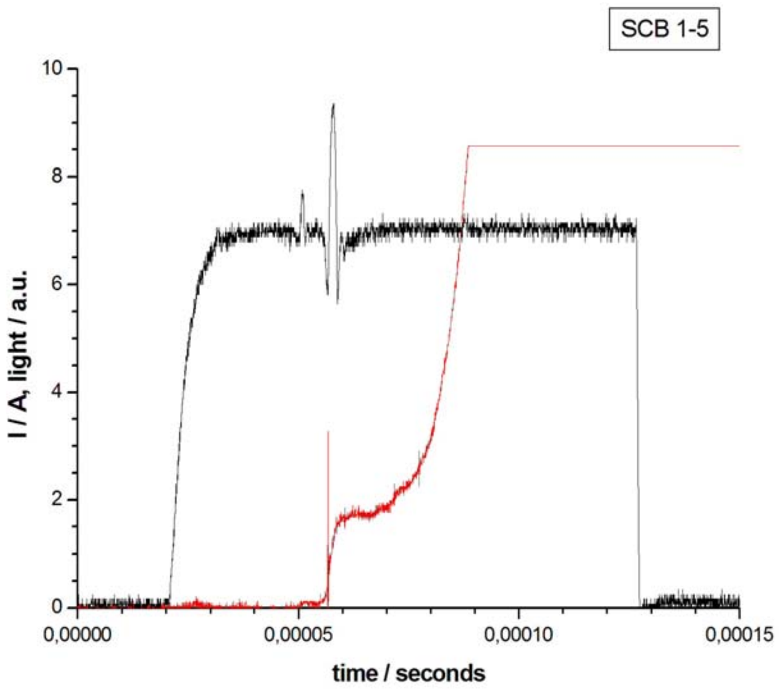
- Three different set-ups used to impose a constant current
  - BNC 555 pulser, 1.5-10 A, 0.10 ms pulse
  - Dynasen piezo-resistive pulse power supply, 24.0-25.0 A, 0.10 ms pulse
  - Capacitor discharge, 1 μF, SCB in series with large Ω, 8.5 -100 A
- Detection of functioning with photodiode
- Evaluation 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

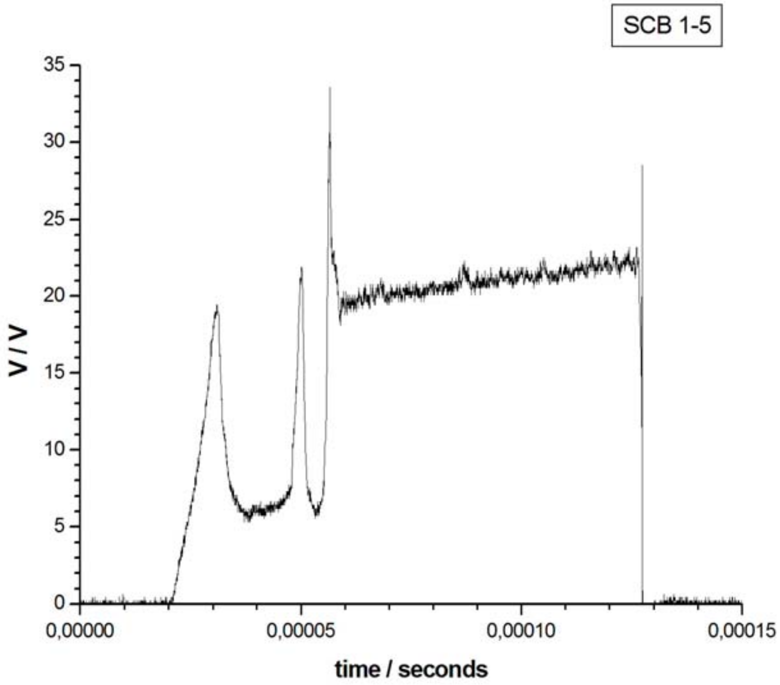
Generic behaviour of SCB
Resistance vs deposited electric energy



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

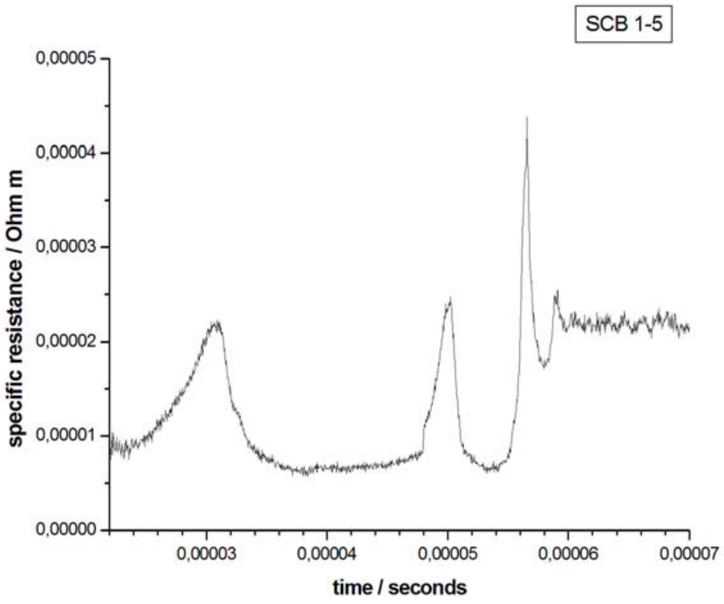
SCB firing at 7.0 A - 100 µs pulse
Voltage and current profile

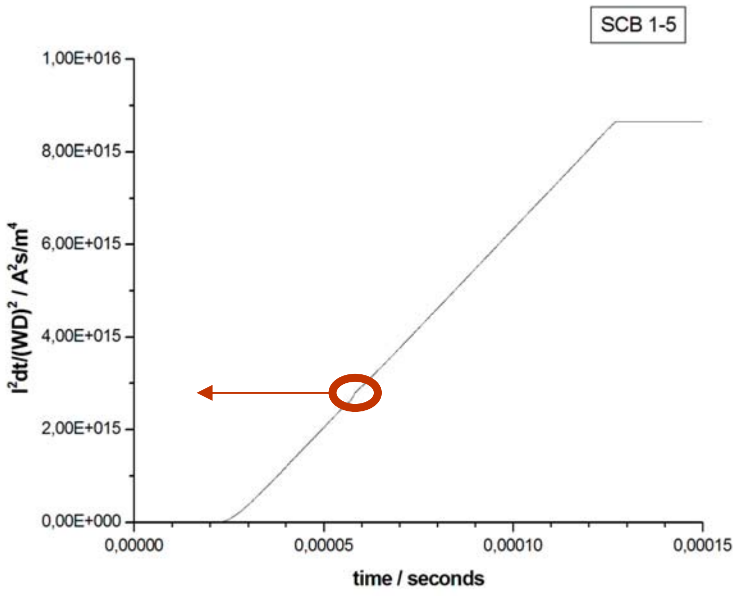




- Registration of light is necessary to detect bridge explosion
- Two maxima in resistance before explosion (one maximum expected)

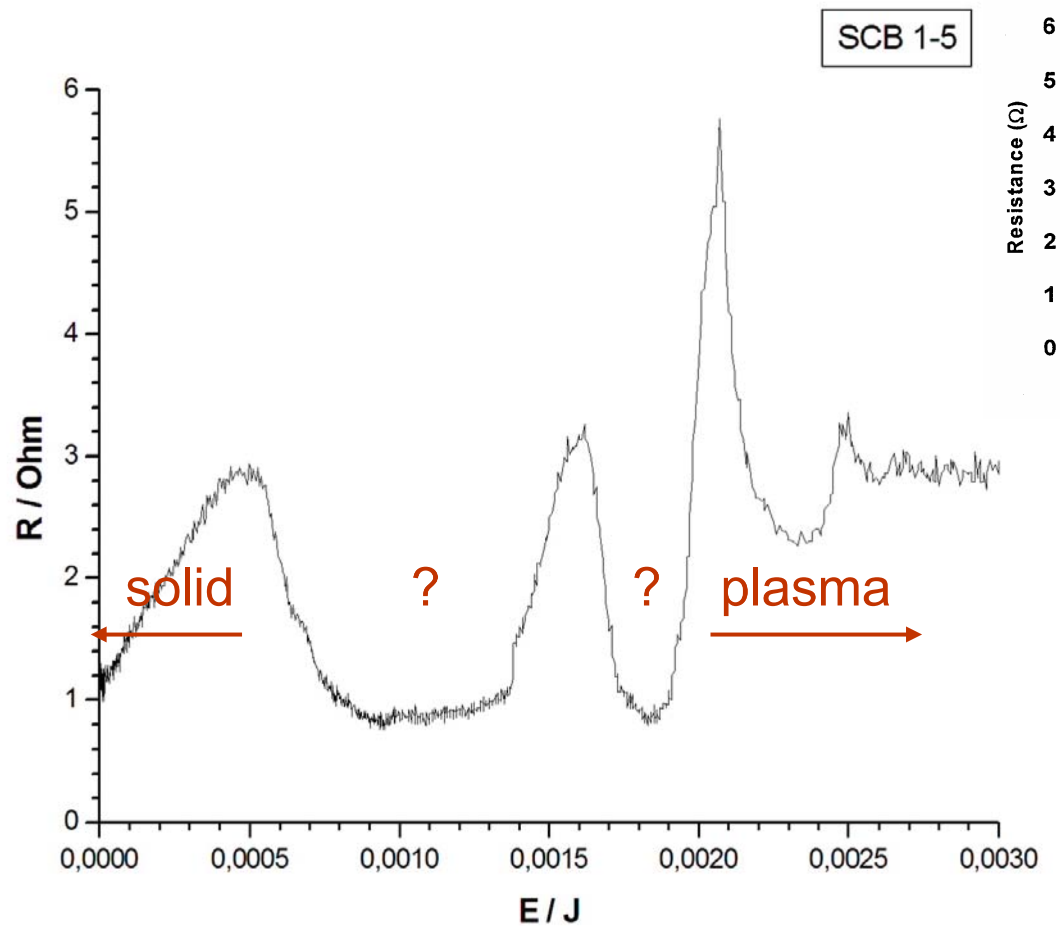
SCB firing at 7.0 A - 100 µs pulse
Specific resistance and action integral

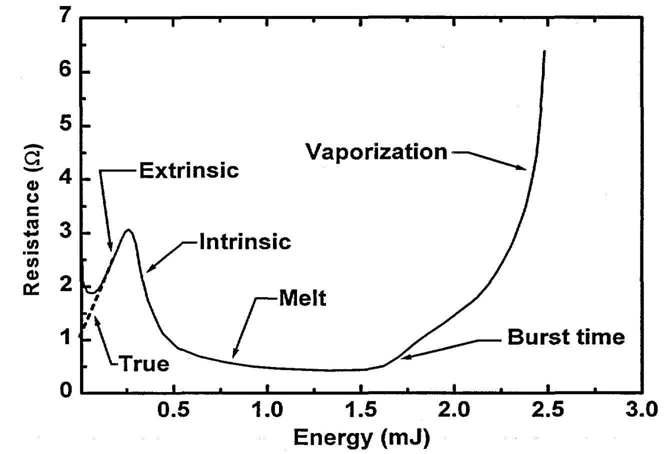




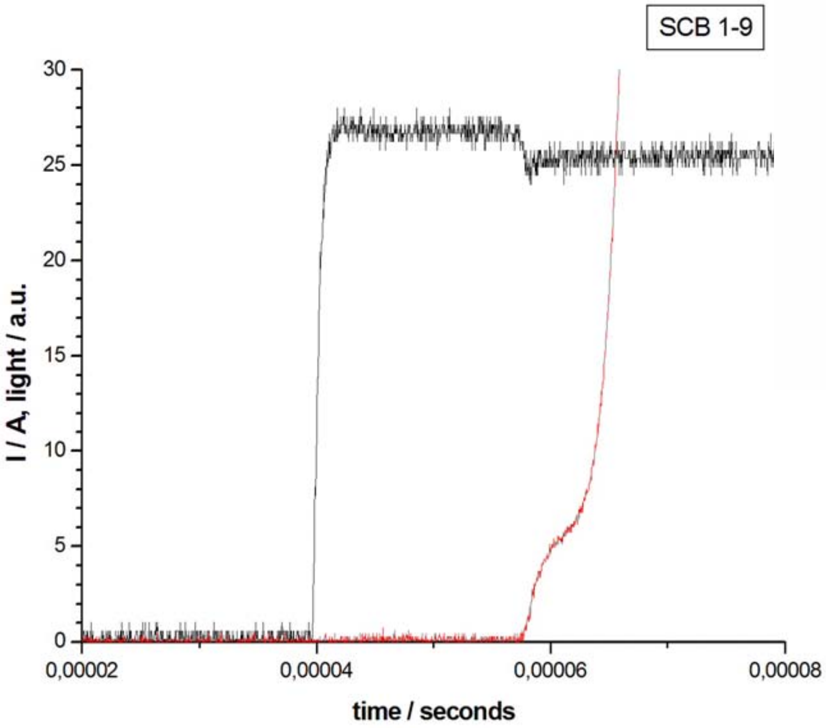
- Specific resistance evaluated directly from voltage, current and bridge dimensions
- $\int I^2 dt / (W \cdot D)^2$ at moment of bridge explosion is a complex function of temperature dependent density, specific heat and specific resistance, and enthalpies associated with phase changes

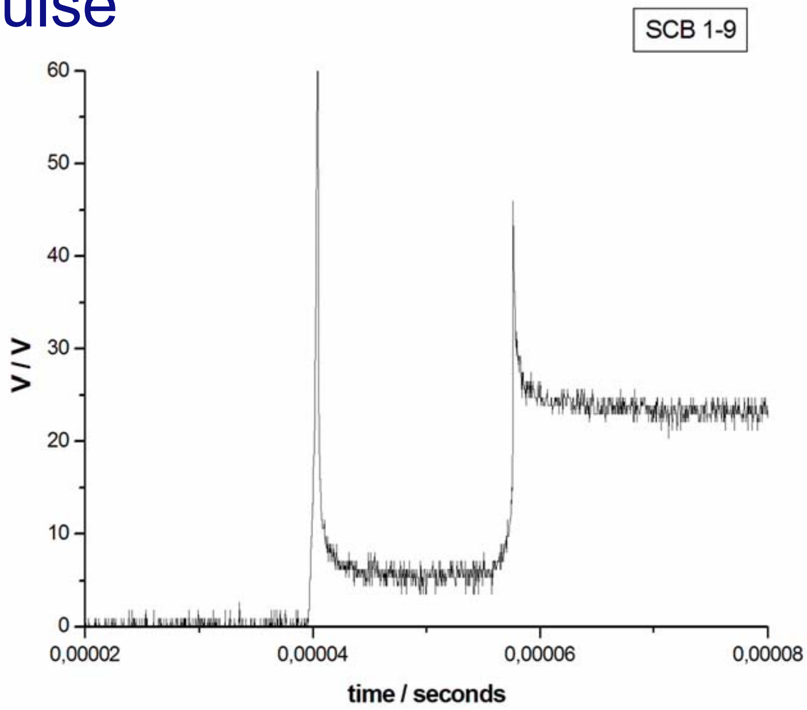
SCB firing at 7.0 A - 100 μs pulse
Resistance versus deposited electric energy



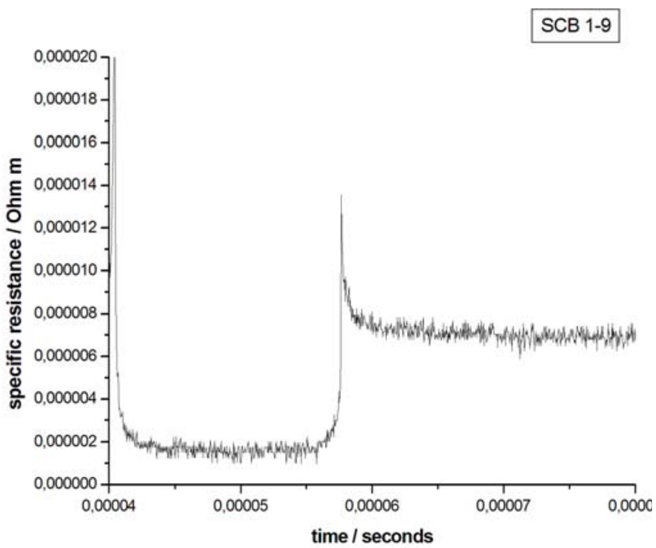


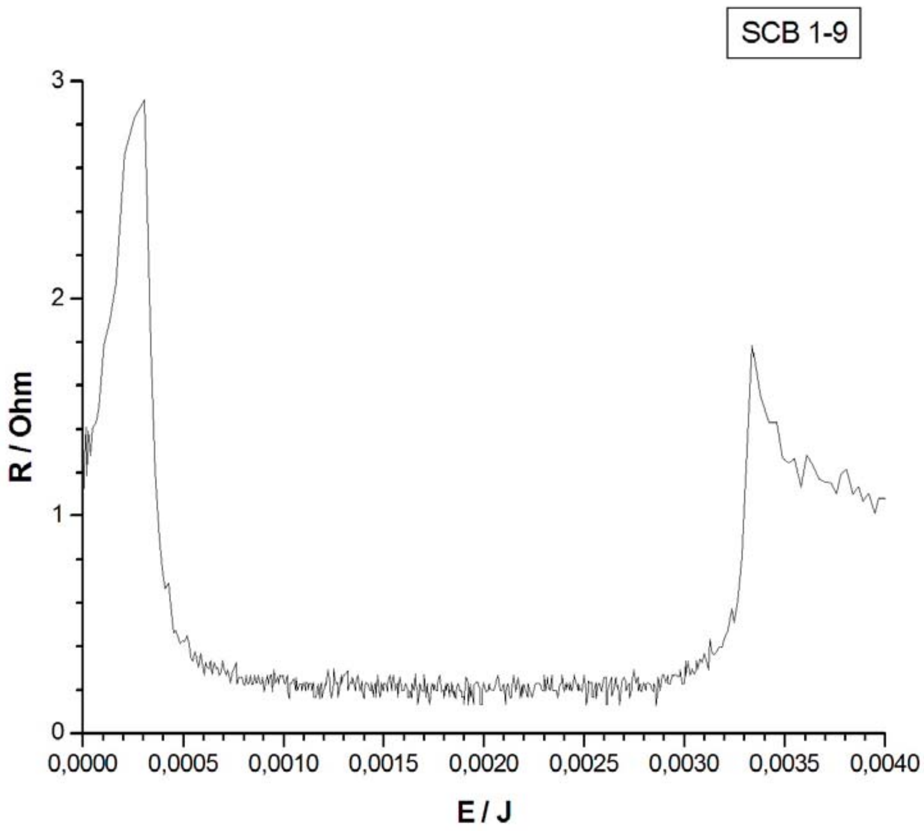
SCB firing at 25 A - 100 µs pulse
Voltage and current profile



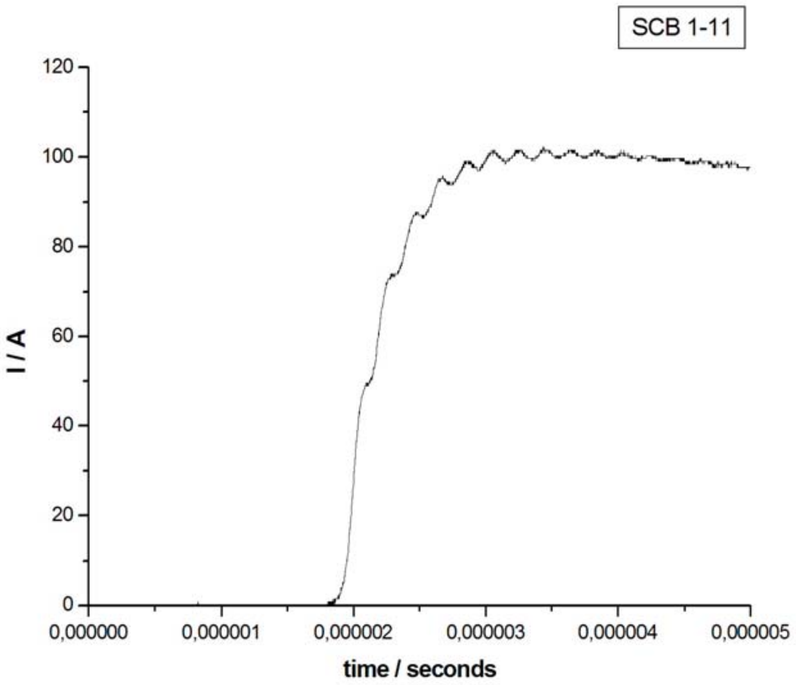


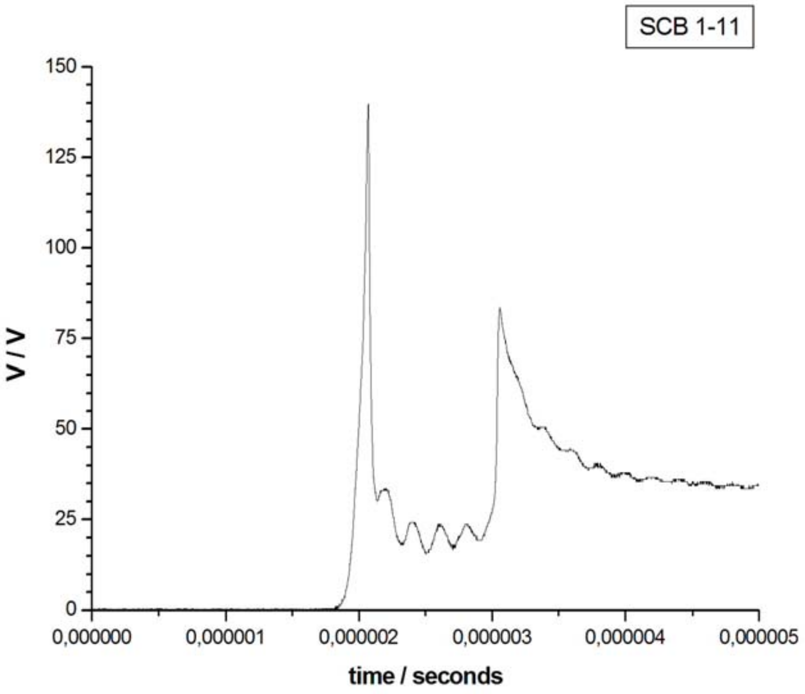
SCB firing at 25 A - 100 µs pulse
(Specific) resistance





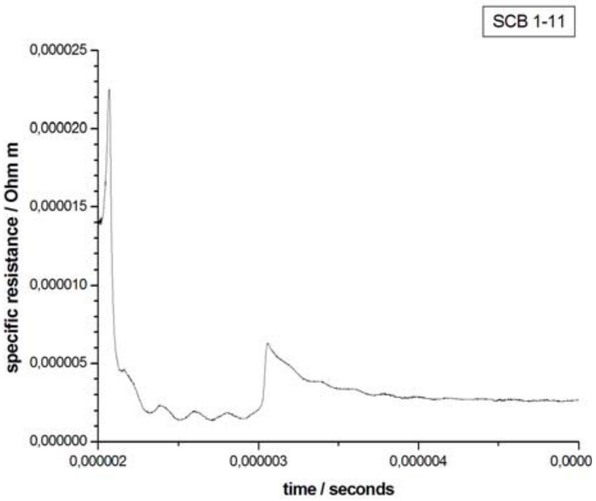
SCB firing at 100 A – capacitor discharge
Voltage and current profile

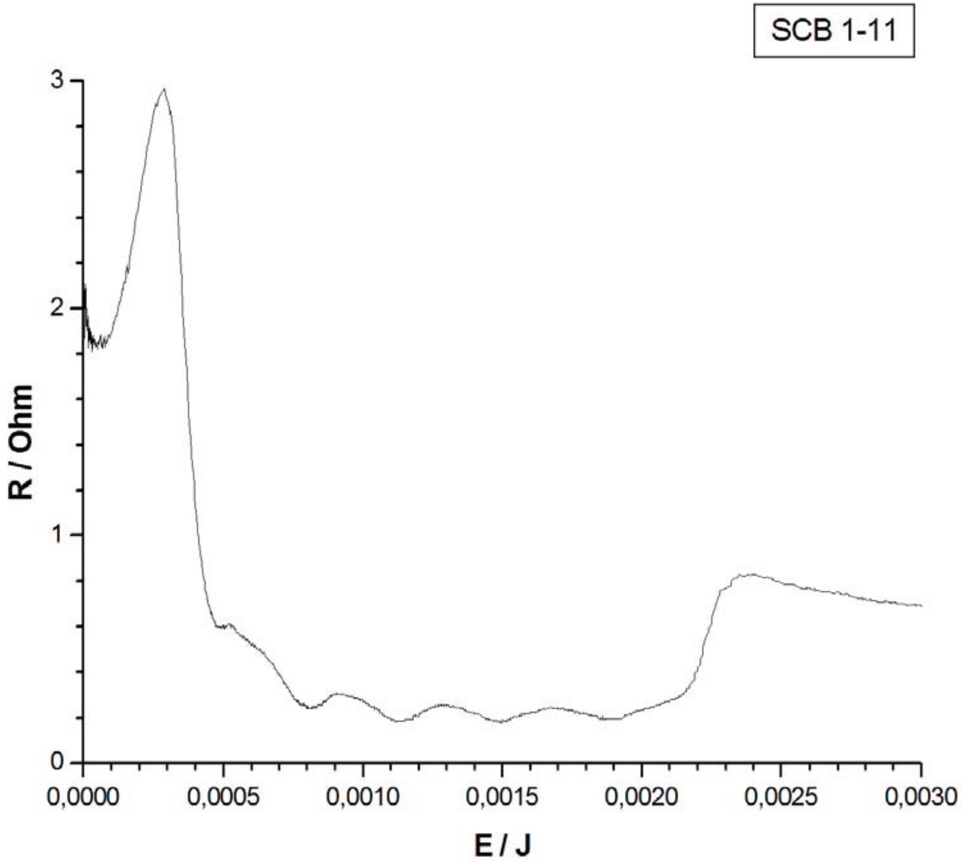




- Oscillations/ringing on current and voltage signal
- Functioning after 1.0 μs

SCB firing at 100 A – capacitor discharge
(Specific) resistance



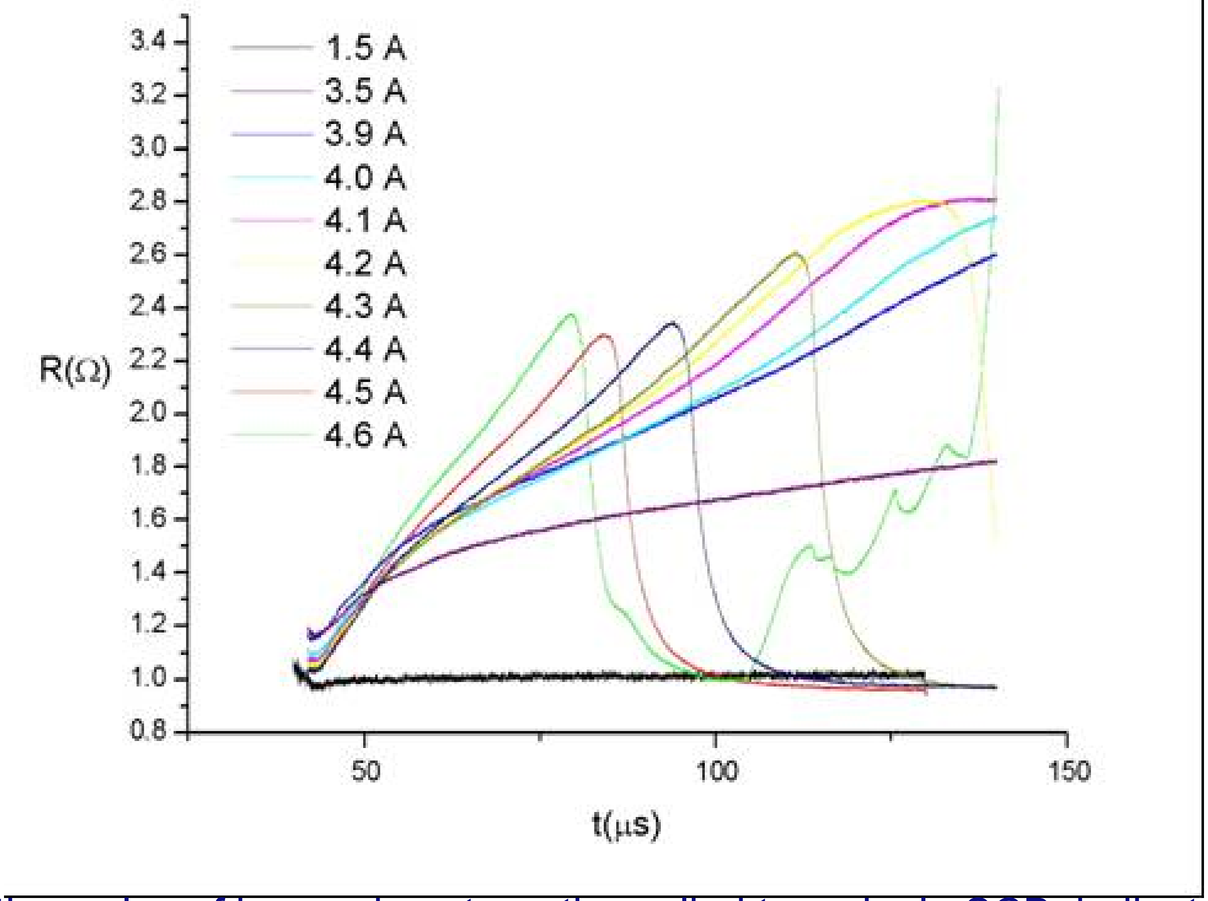


Summary of destructive tests

SCB	I A	Pulse μs	Firing μs	$\int I^2 dt/(WD)^2$ 10^{15} A^2s/m^4	E 10^{-3} J	σ* 10^{-6} Ωm
1-4	4.6	100	100	3.5	3.2	11
1-2	5.5	100	100	5.0	3.2	5.5
1-5	7.0	100	35	2.6	2.0	5.5
1-12	8.5	Discharge	32	3.4	2.2	5.0
1-13	8.5	Discharge	49	5.5	2.8	5.0
1-6	10.0	100	35	5.3	2.5	4.0
1-14	15	Discharge	15	5.9	2.2	3.0
1-8	24	100	16	17.7	3.0	2.0
1-9	25	100	17	20.7	3.1	1.2
1-10	52	Discharge	3.7	15.9	2.6	2.0
1-11	100	Discharge	1.0	13.0	2.5	1.5

* 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

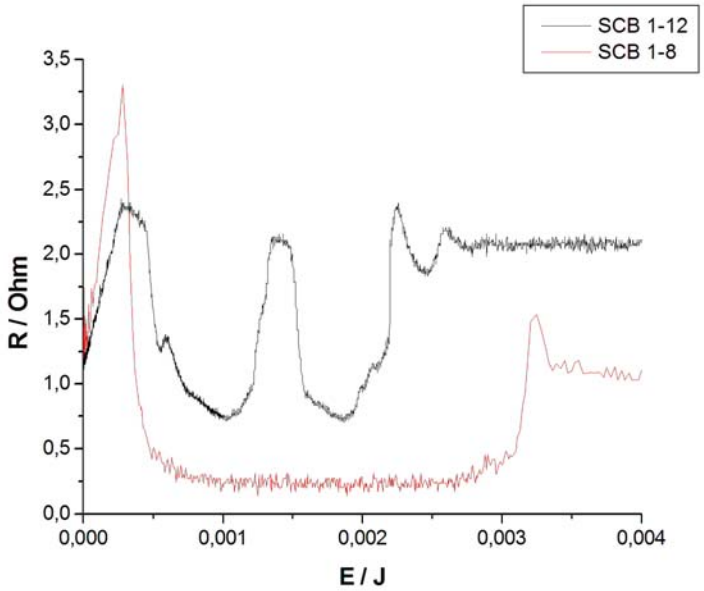
- Personnel ElectroStatic Discharge threat (STANAG 4239)
  - ±25 kV, ±20 kV, ±15 kV, ±10 kV, ±5 kV discharge from 500 pF capacitor
  - 500, 5000 Ω resistance in series with munition
- Available energy 156 mJ, RC-time 0.25, 2.5 μs

- 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

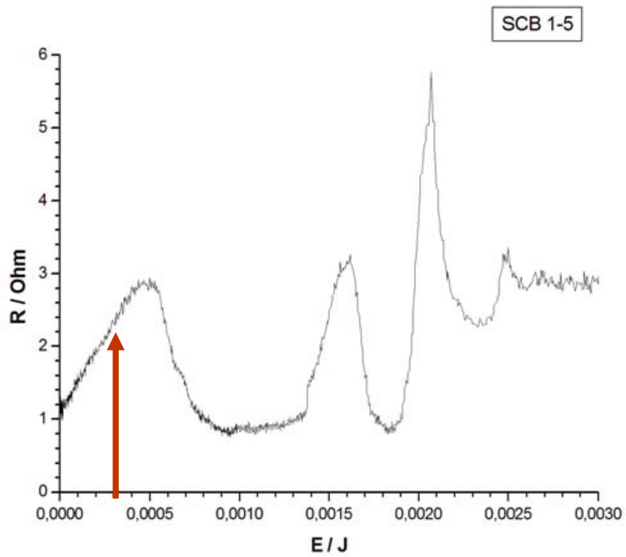
Discussion and conclusions

- 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 A typically 2, I < 15 A, typically 3 maxima
  - Commonly described behaviour: solid➔liquid➔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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