Electrical characterization of a SemiConducting Bridge initiator with and without pyrotechnic mixture

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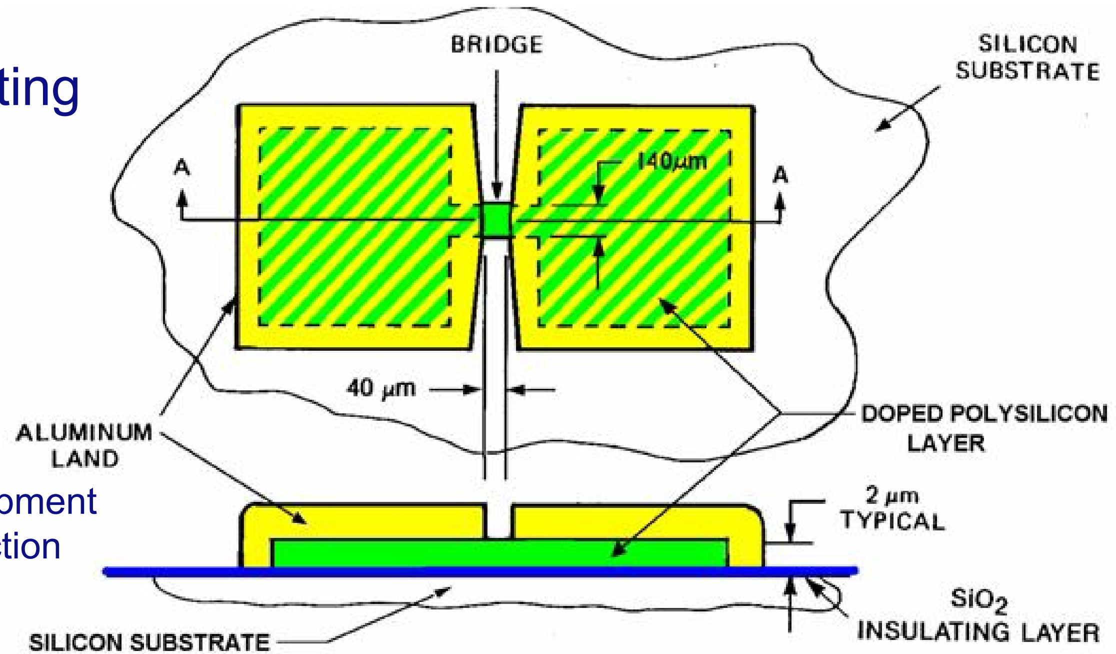
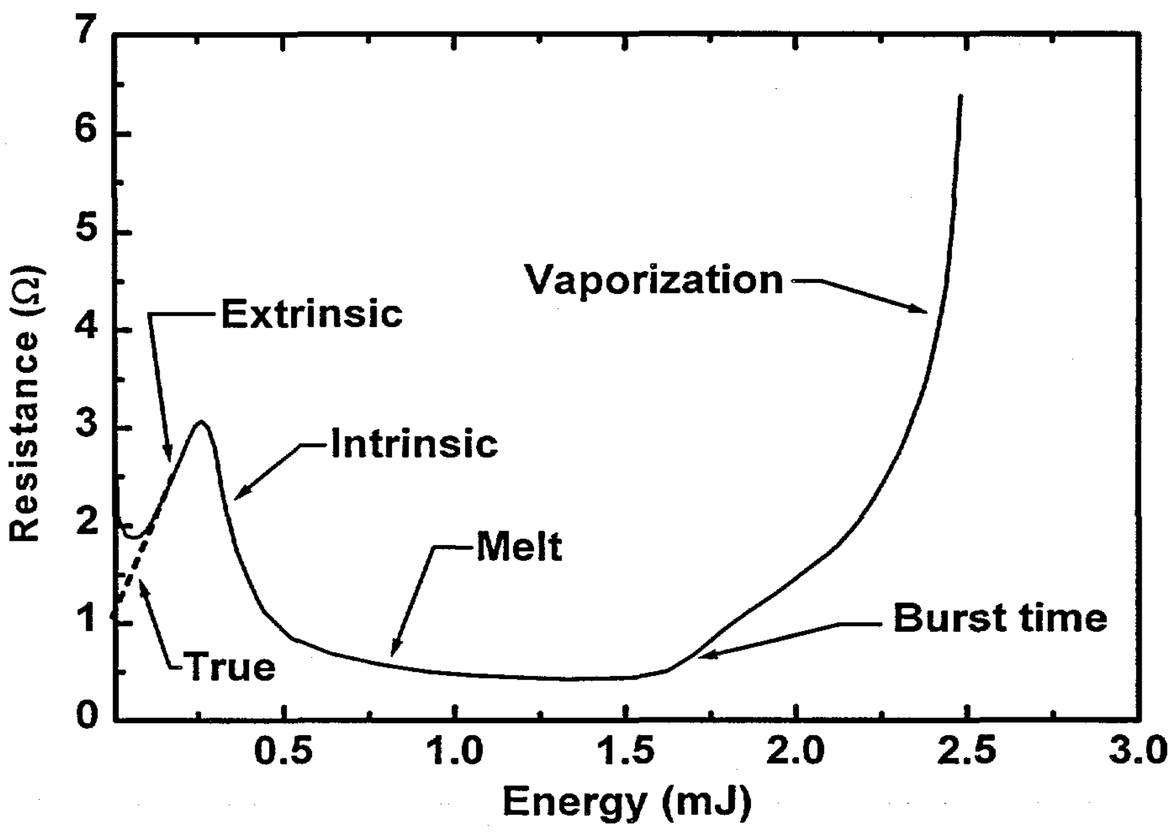
Introduction

- 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 and loaded SCBs
- Non-destructive testing
- PESD assessment



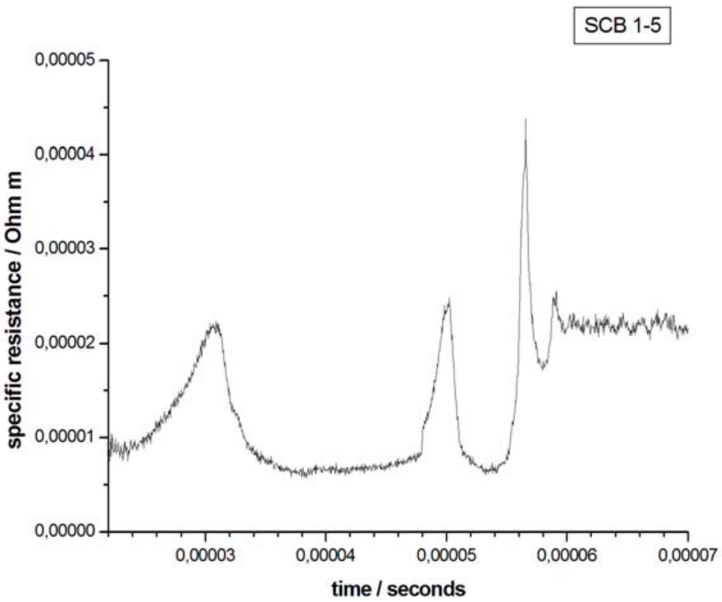
SCB detonator development for the Navy multi-function fuze, A. Wyman

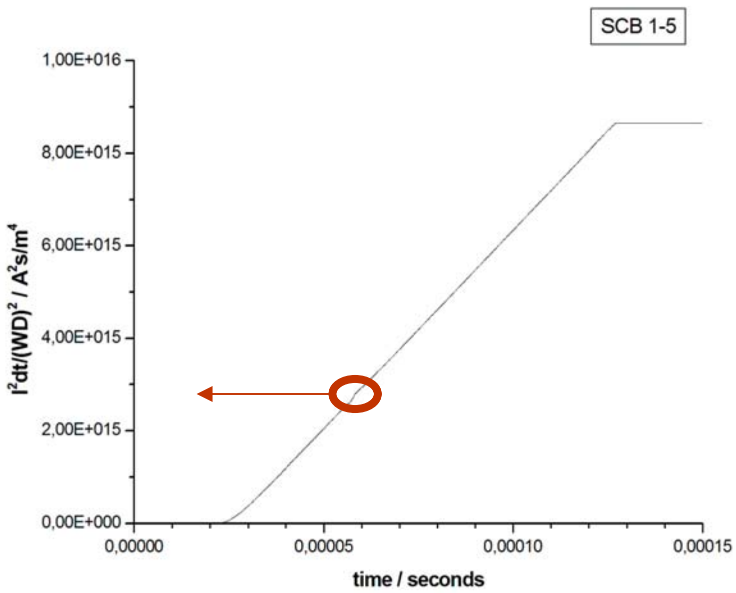
Generic behaviour of SCB
Resistance vs deposited electric energy



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

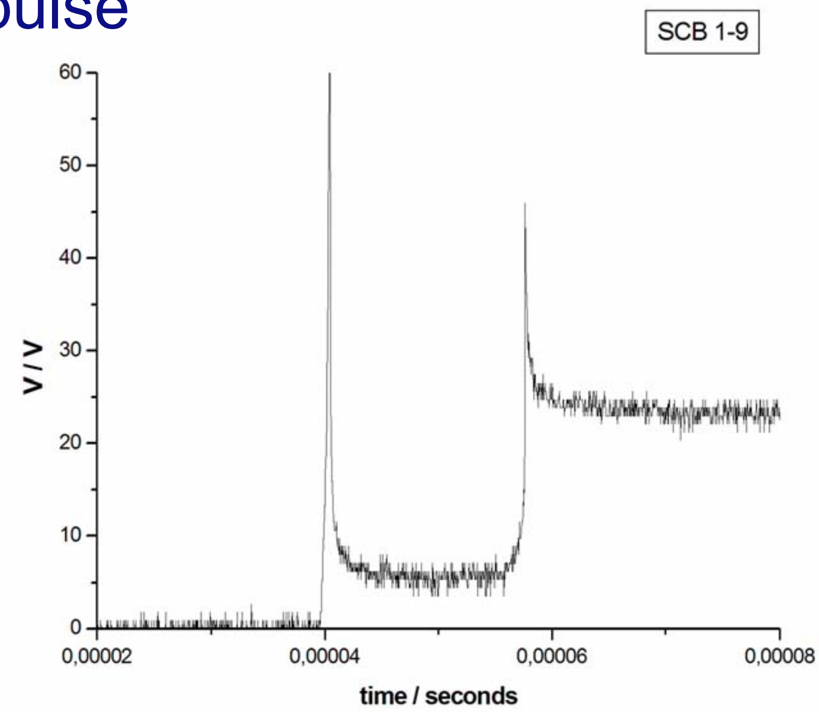
Firing of bare SCB at 7.0 A - 100 µs pulse
Specific resistance and action integral

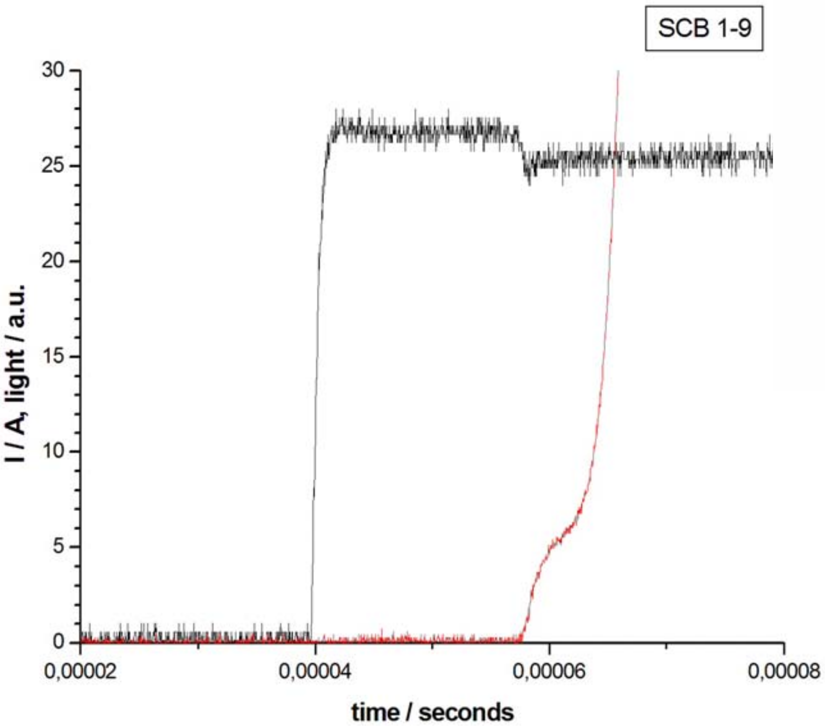




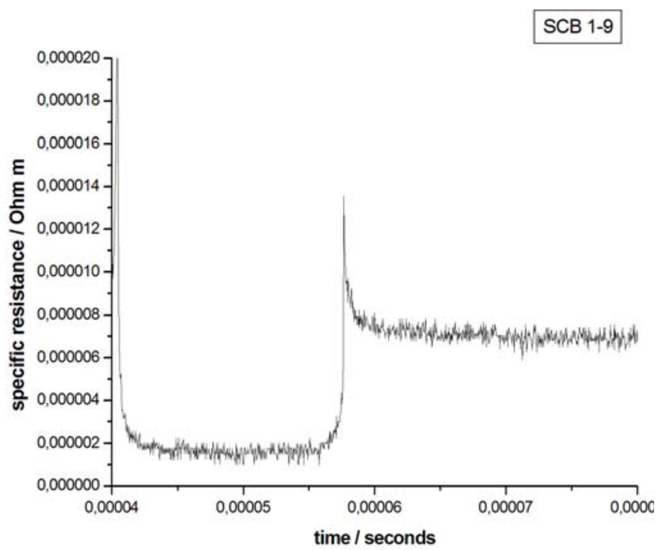
- Specific resistance evaluated directly from voltage, current and bridge dimensions
- $\int I^2dt / (W \cdot D)^2$ at moment of bridge explosion is a complex function of temperature dependent density, specific heat and specific resistance, and enthalpies associated with phase changes

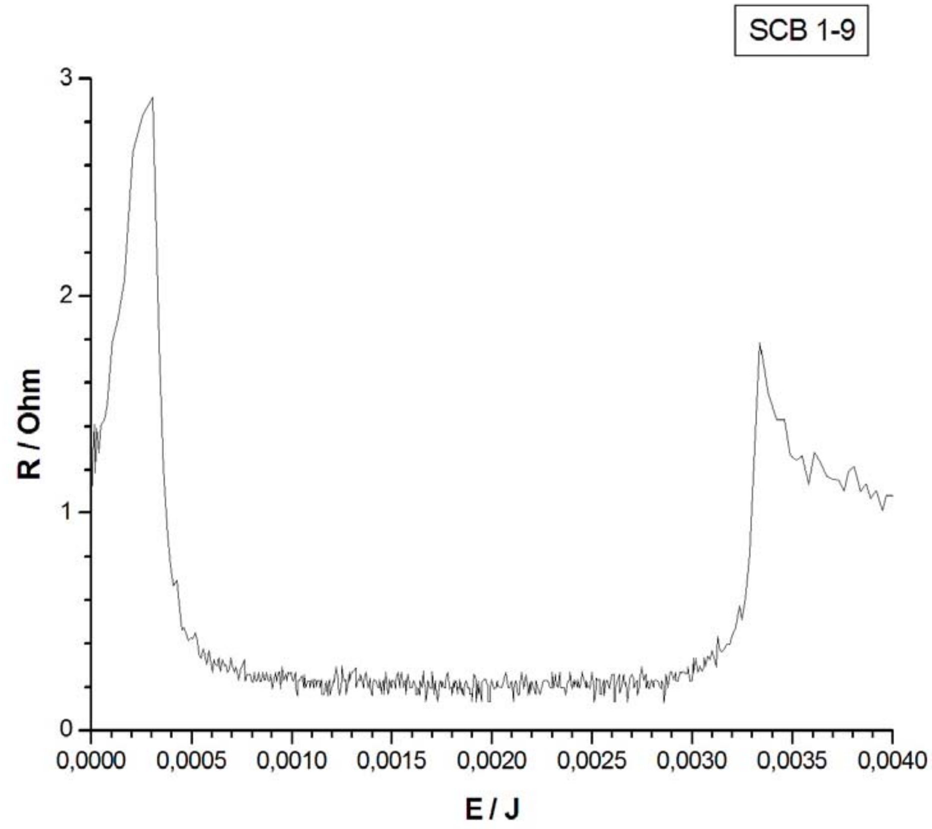
SCB firing at 25 A - 100 µs pulse
Voltage and current profile





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



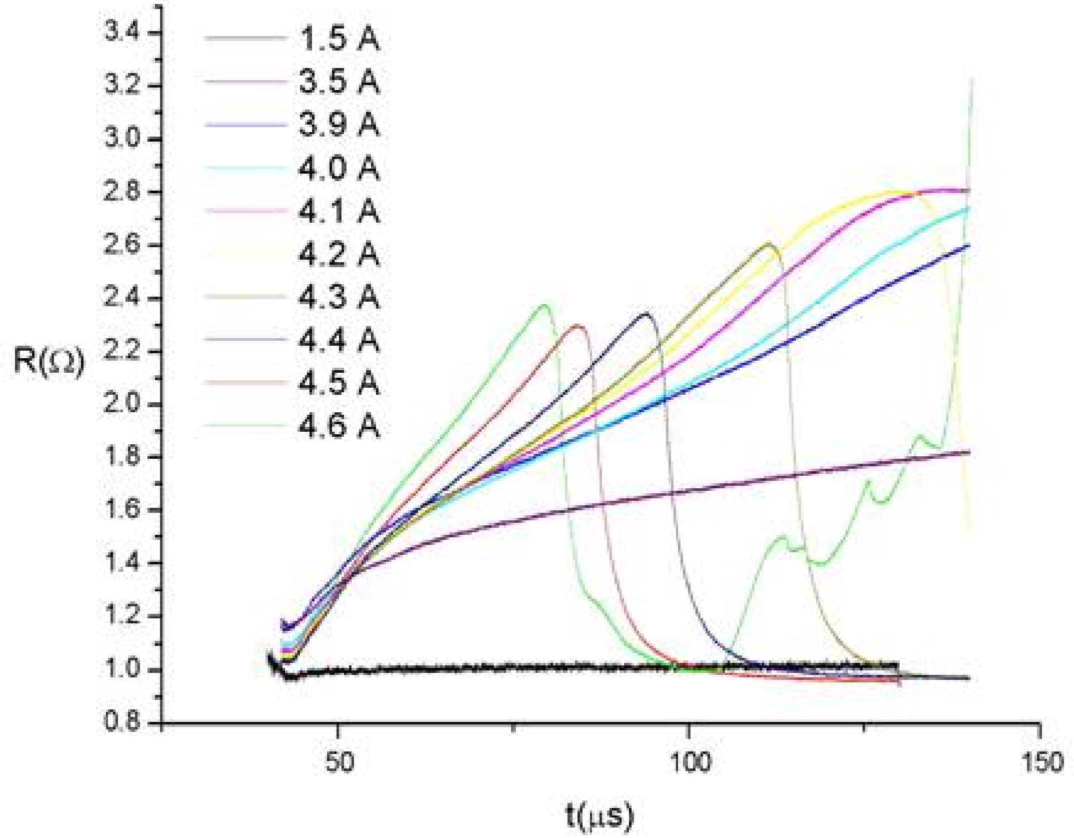


Summary of destructive tests, bare SCB

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

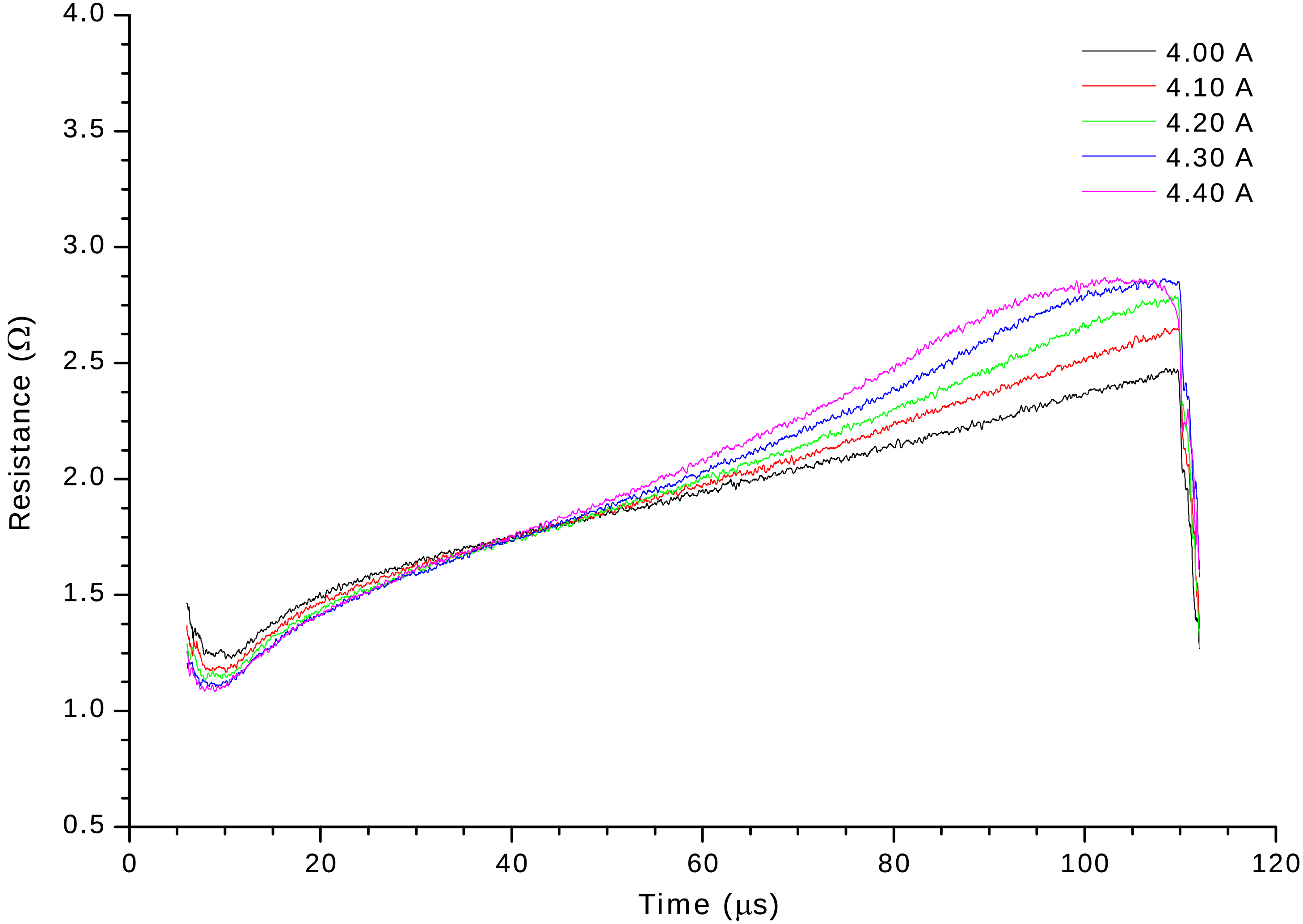
* Specific resistance level after first maximum, melt region

Non-destructive testing of bare SCB with 100 μs pulse

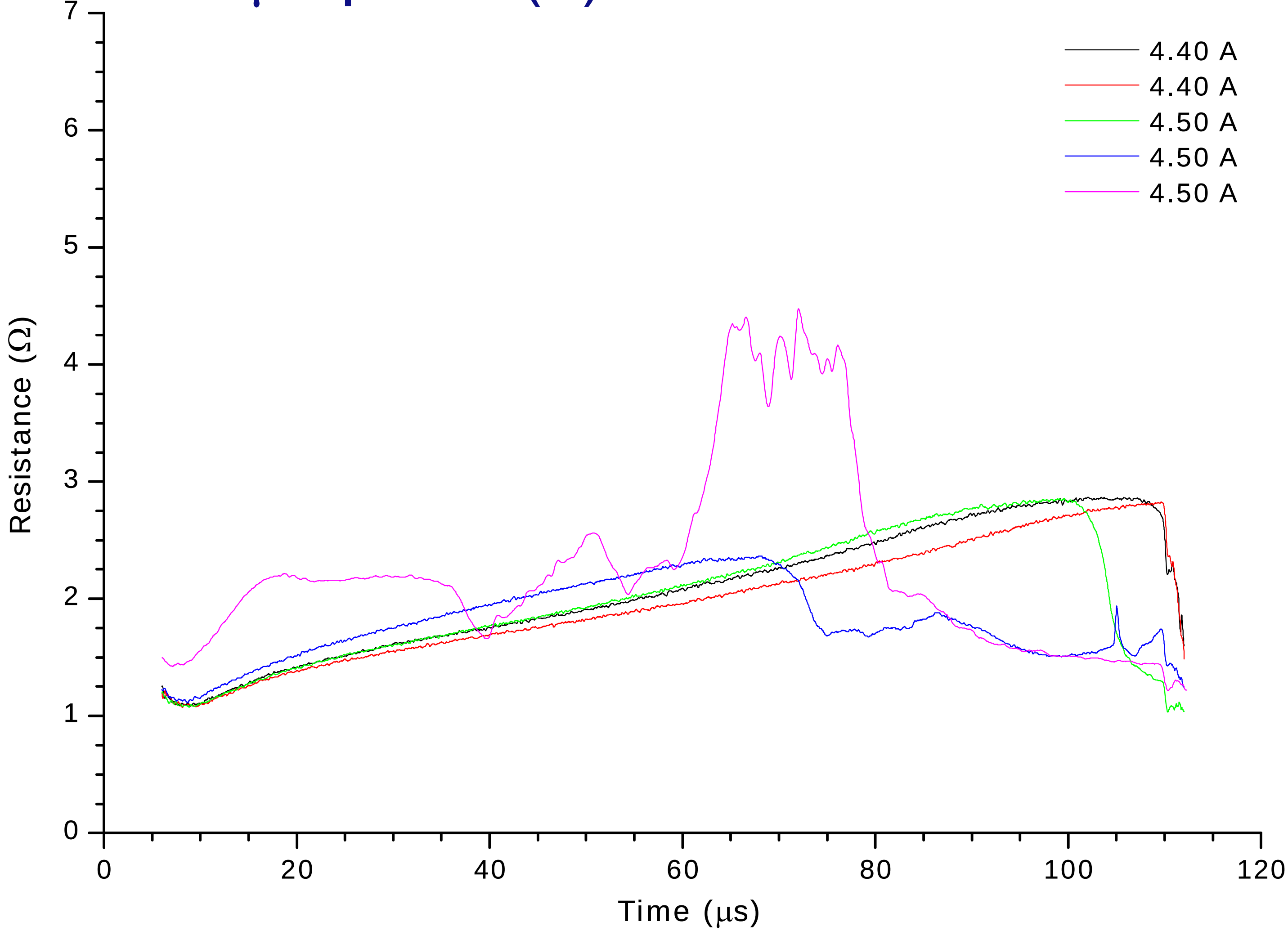


- Short duration pulse of increasing strength applied to a single SCB, indicates reversible behaviour up to the moment of bridge fusion
- NB: the No-Fire current has not been determined here, even though 1.5 A – 100 μs pulse hardly shows a resistance increase

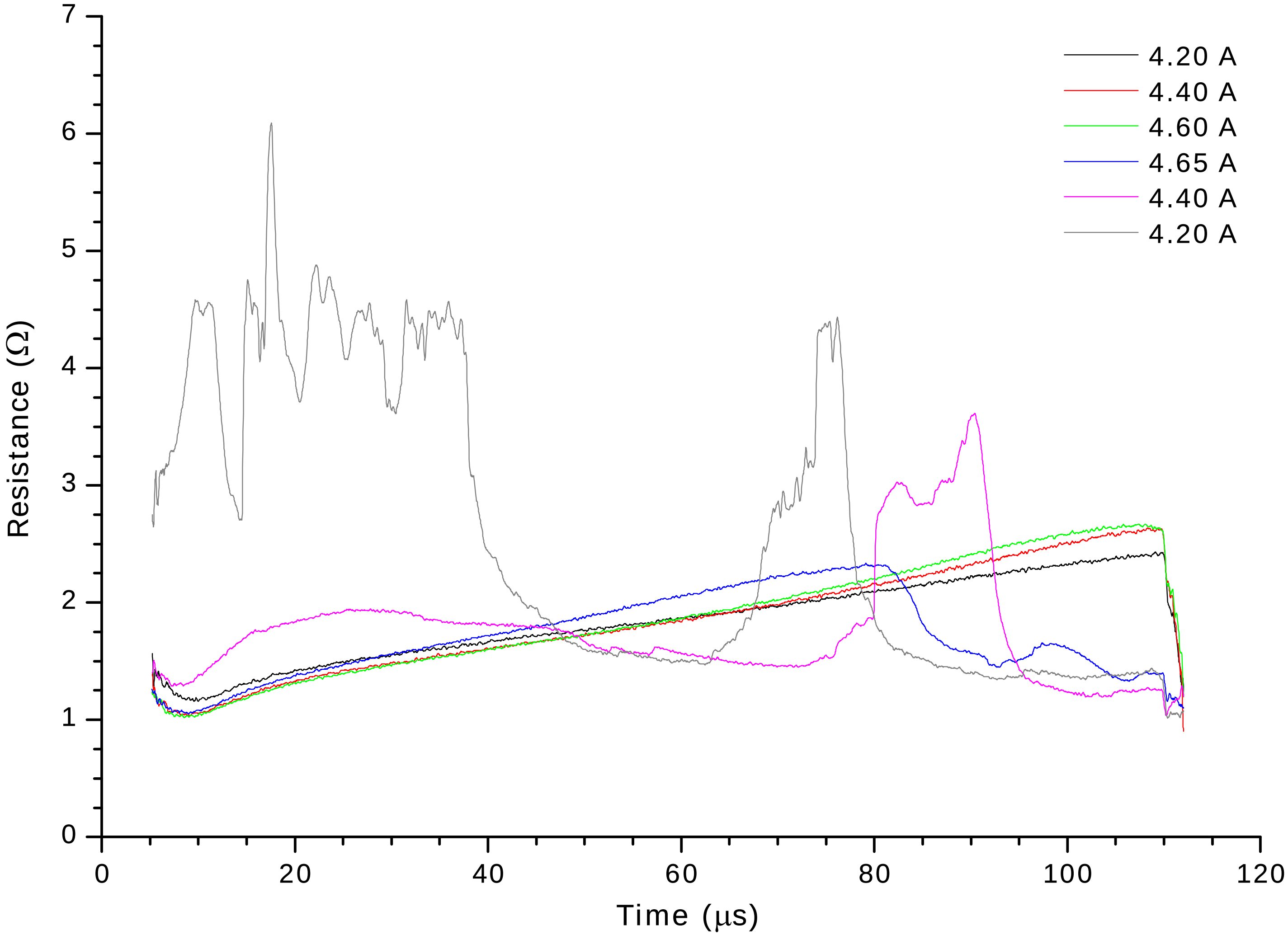
Non-destructive testing of SCB with B/Bi_2O_3, and 100 μs pulse (I)



Non-destructive testing of SCB with B/Bi_2O_3, and 100 μs pulse (II)



Non-destructive testing of another SCB with B/Bi_2O_3, and 100 μs pulse: effect of current aging



Summary of destructive tests, SCB with B/Bi_2O_3

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
103	6.0	100	44	2.3	3.0	11
104	8.0	100	28	2.5	2.3	6.7
105	10.0	100	21	2.7	2.1	6.1
107	15	Discharge	15	5.9	2.3	3.3
108	25	Discharge	10	9.8	3.3	2.3
109	50	Discharge	3.4	13.6	3.9	1.9
106	100	Discharge	1.1	15.9	4.5	1.8

* Specific resistance level after first maximum, melt region

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

PESD experimental

- 25 kV, 500 Ω in series with B/Bi_2O_3 loaded SCB, duplo experiment
  - 1st experiment, 1.5 Ω before and 4.9 Ω after PESD
  - 2nd experiment, 1.1 Ω before and 2.4 Ω after PESD

Discussion and conclusions

- SCBs (bare and loaded with B/Bi_2O_3 pyrotechnic mixture) have been characterized electrically
- In destructive testing the electrical characteristics (ignition time, firing energy, specific resistance) are the same for bare and loaded SCBs, when comparing similar current pulses
- The presence of the pyrotechnic mixture on the SemiConducting Bridge is noticed in non-destructive testing
- One can thermally age a loaded SCB by application of a non-destructive current pulse, and eventually lower the initiation threshold
- The SCB is assessed to pass the PESD test. This is verified in a duplo test, but resistance of SCB has increased after PESD pulse

Acknowledgement

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