SWTW

IEEE SW Test Workshop

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Small contacts, high currents, short pulses

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Problem

- **Device pad sizes and pitch decrease**
- **Device voltages decrease**
- **Device power decreases**
- **But ……**
  - *p=v*i*, so if *v* decreases and *p* were to remain constant, *i* must increase
  - Under the assumption that contact cross section decreases roughly quadratically with pitch dimensions it follows that current handling will also decrease similarly
  - Device current decrease does not generally follow this trend

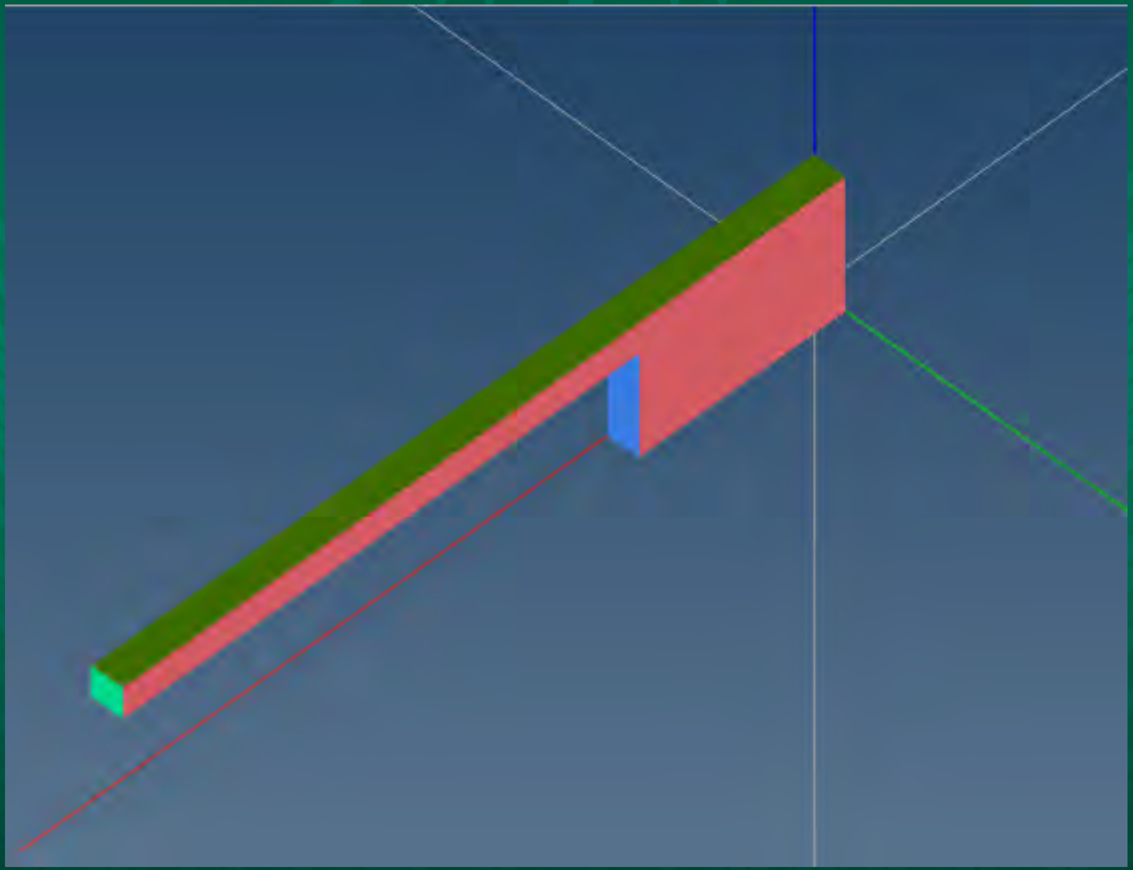
Objective

- **Provide insight into contact behavior**
    - At DC
    - Under short pulse loading (single pulse)
- **Point out potential design improvements**
- **Explore impact of power delivery network**

Approach

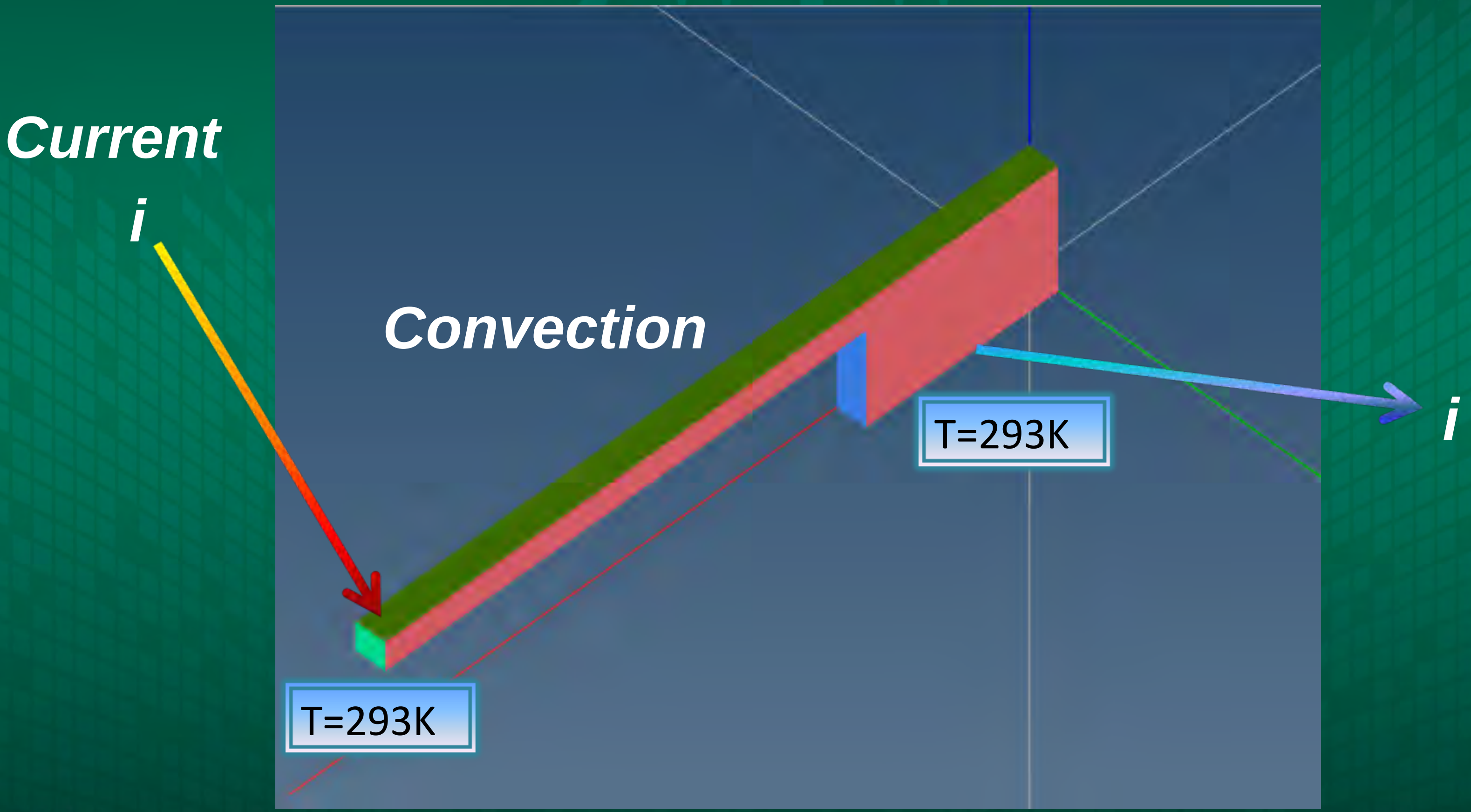
- Examine contact thermal response via coupled electrical-thermal simulation
- Select a specific short pulse condition (electrical pulse length = 10% of thermal time constant) since longer pulses approach DC behavior

Geometry



Generic probe

Boundary conditions



Temperature dependence

$$R=Ro*(1+alpha*(T-To))$$

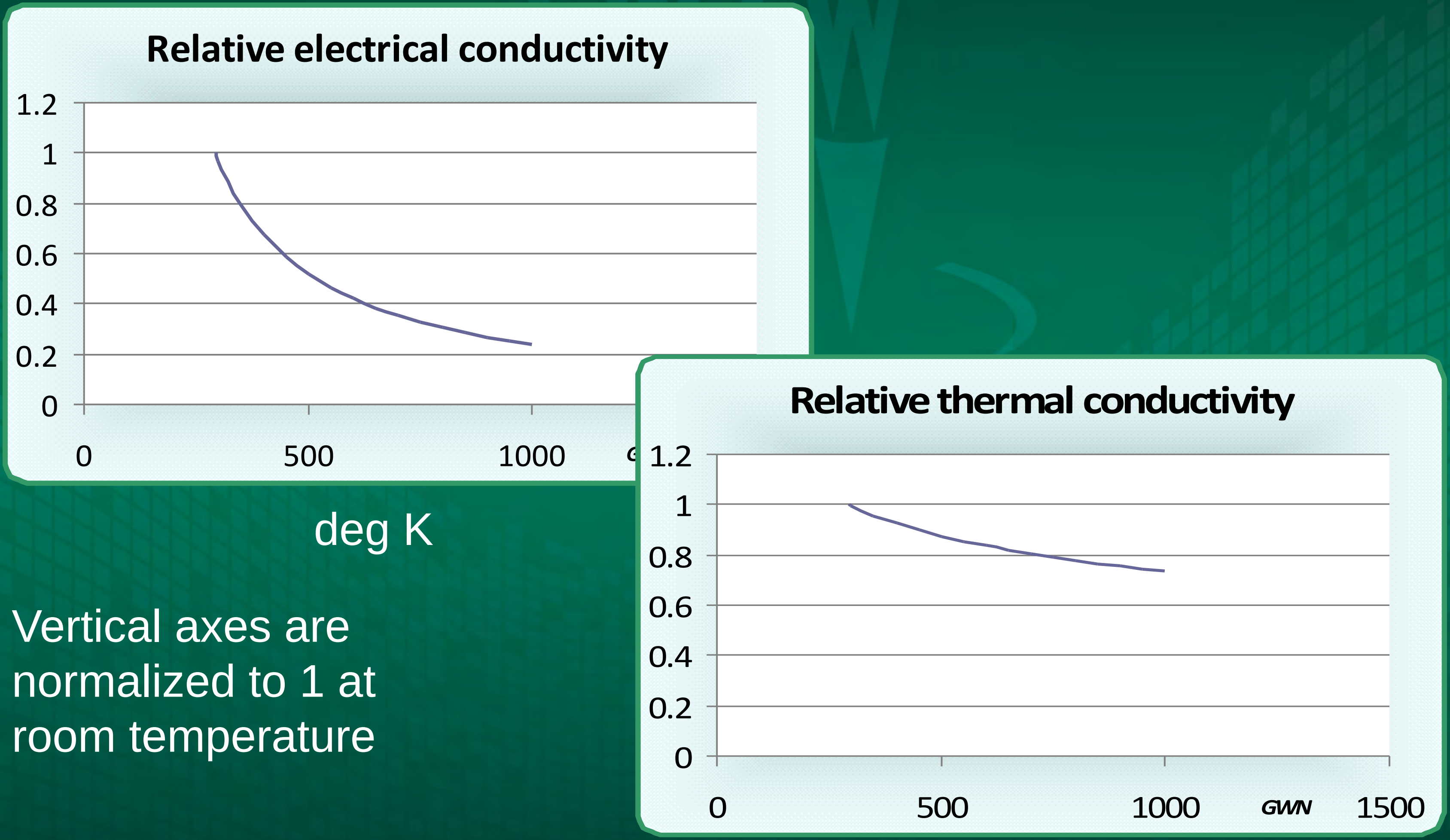
$$kI=k_{300}*(TI/300)^{\wedge}alpha*T$$

Source: Wikipedia

There are many different ways to describe temperature dependence of thermal and electrical resistance.

In general, resistance increases with increasing temperature.

Temperature dependence

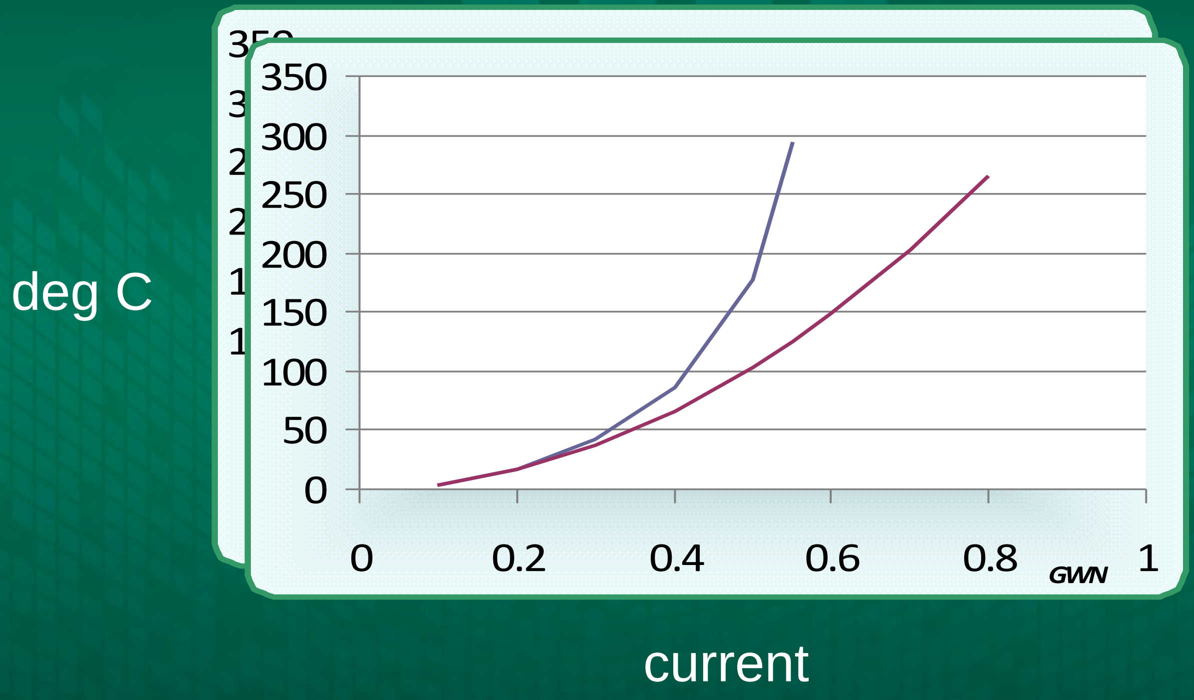


deg K

deg K

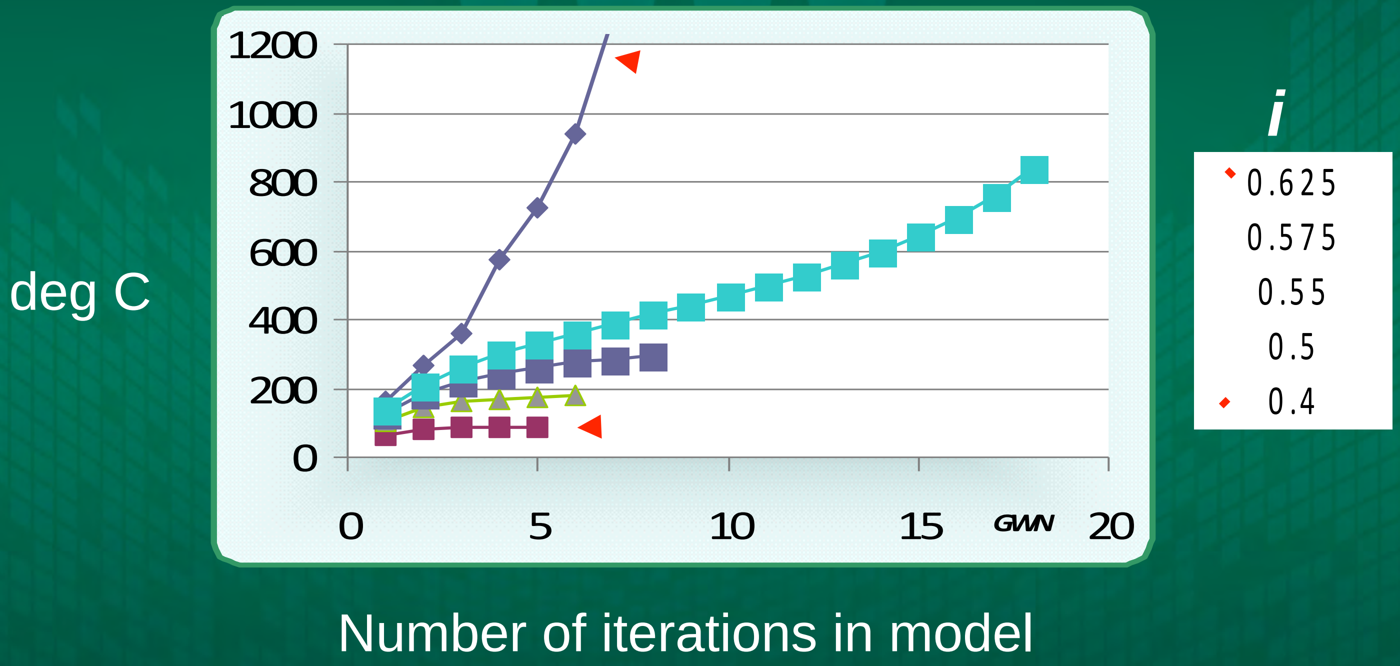
Vertical axes are normalized to 1 at room temperature

Constant vs. T-dependent properties



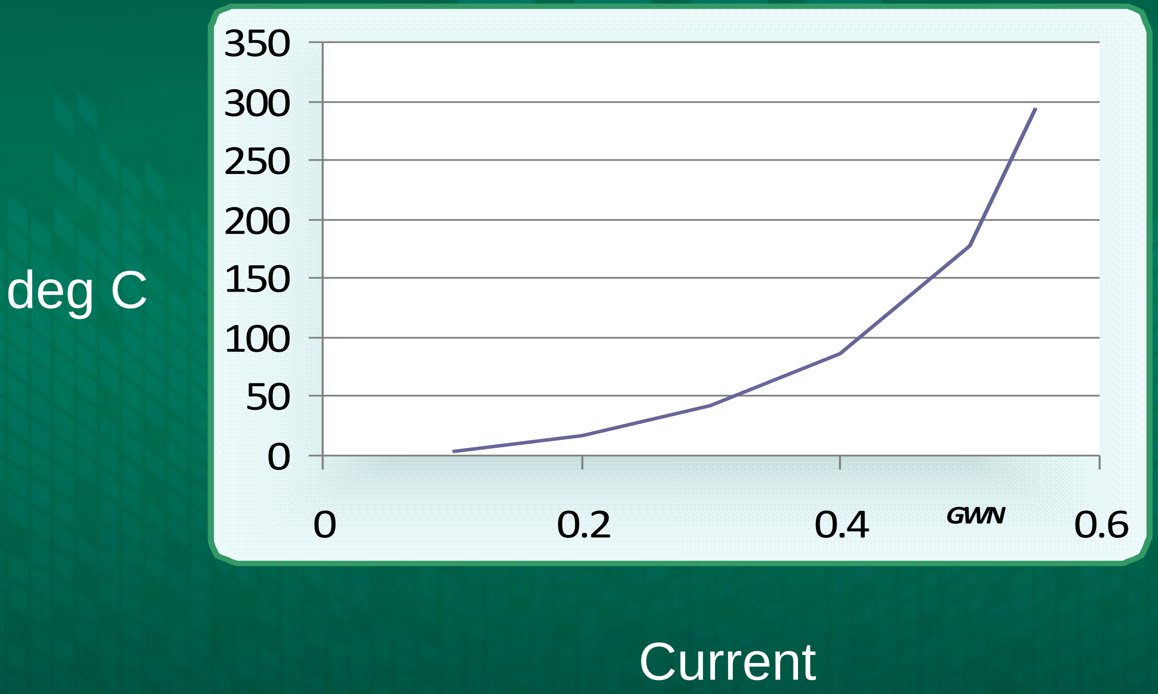
Temperature dependent materials properties must be included in model

Temperature rise, DC



Temperature dependent materials properties necessitate a sufficient number of iterations in the model

Temperature rise Tr, DC

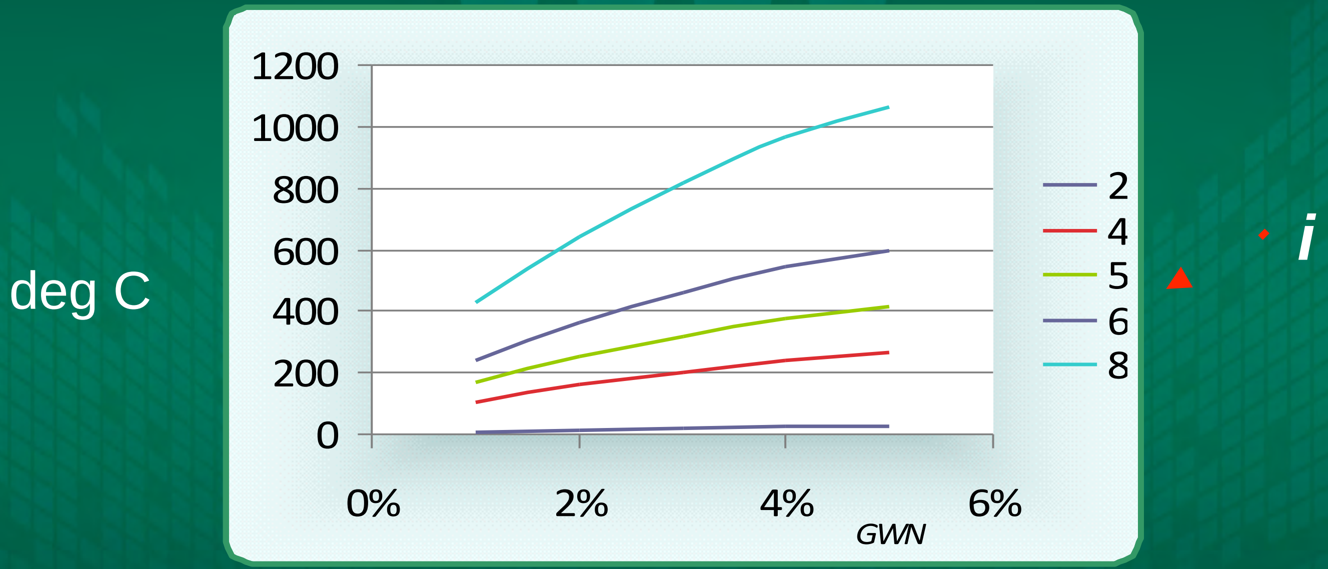


Pulse current parameters

- **Pulse length vs. Time constant**
- **Duty cycle**
  - In a linear system with constant conductivities the energy delivered to a contact increases linearly with duty cycle as well as with pulse length
  - This does not hold true for temperature dependent parameters

Pulse length, Tr=f(%)

Single pulse



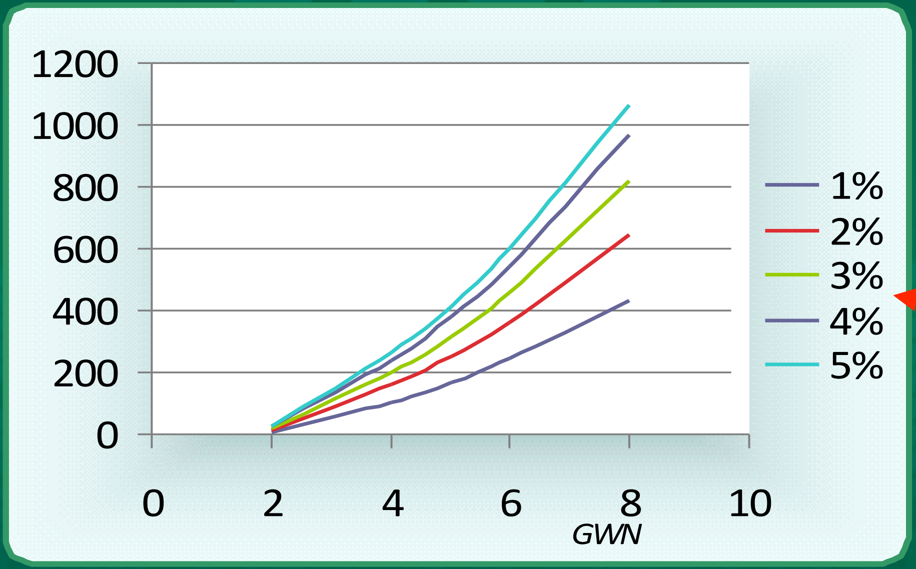
Pulse length [% of thermal time constant]

Temperature rise does not increase linearly with pulse length as current levels increase

Pulse length, Tr=f(i)

Single pulse

deg C



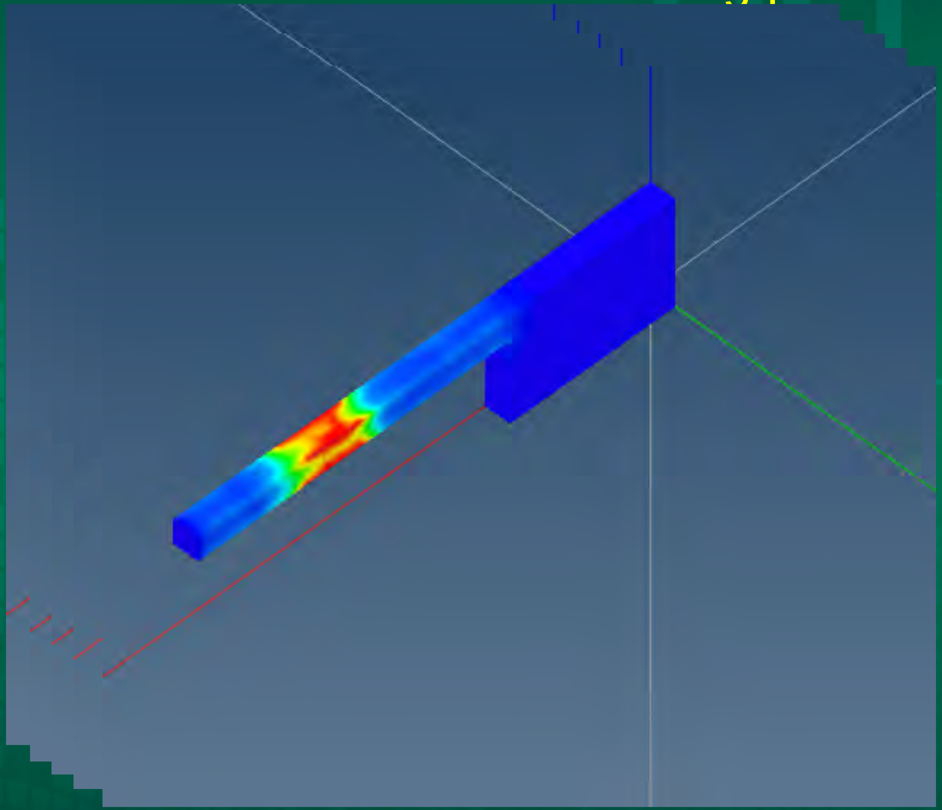
Pulse length in % of thermal time constant

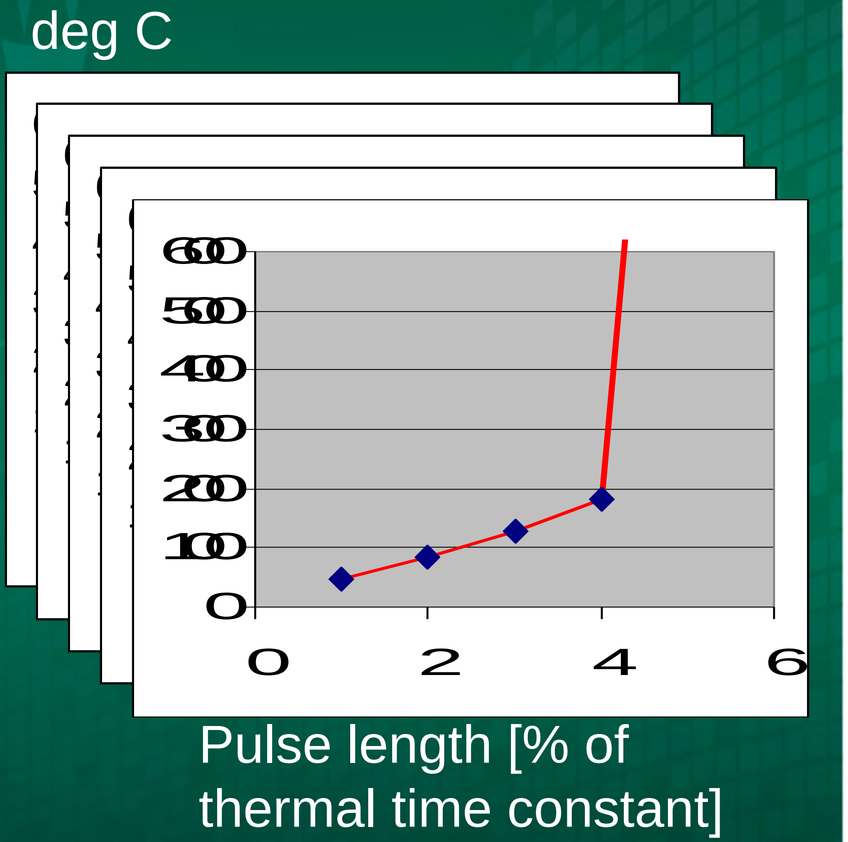
Current

Temperature rise does not increase linearly with pulse length as current levels increase

Temperature distribution

Visualization of temperature rise
during pulse loading

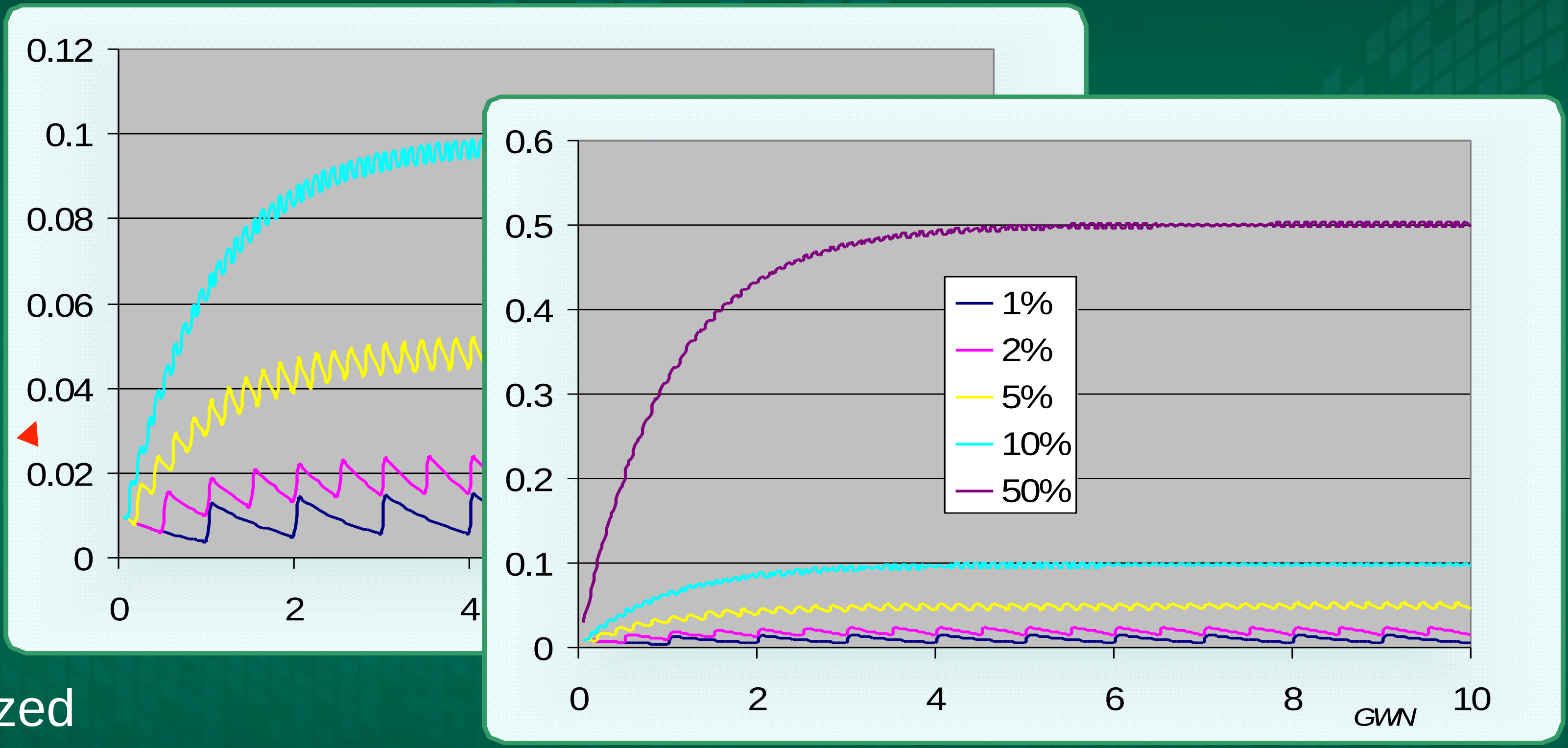




Color gradient is normalized to maximum temperature in each individual image

Duty cycle dependence of Tr

Pulse length = 10% of thermal time constant



Normalized
to peak DC
temperature

Time axis

Temperature as a function of time*

(*linear electrical model)

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Material options

Improvements should be available from engineered materials:

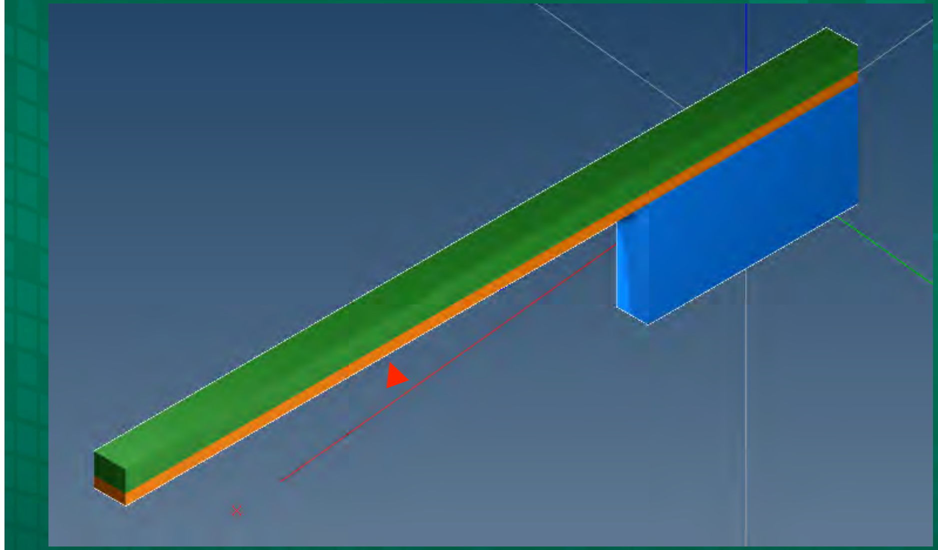
- Higher melting point of materials at hot spot
- Less dependence of electrical resistance R(T)
- Lower temperature coefficient of thermal conductivity
- Layered structure with temperature insensitive materials

Design options

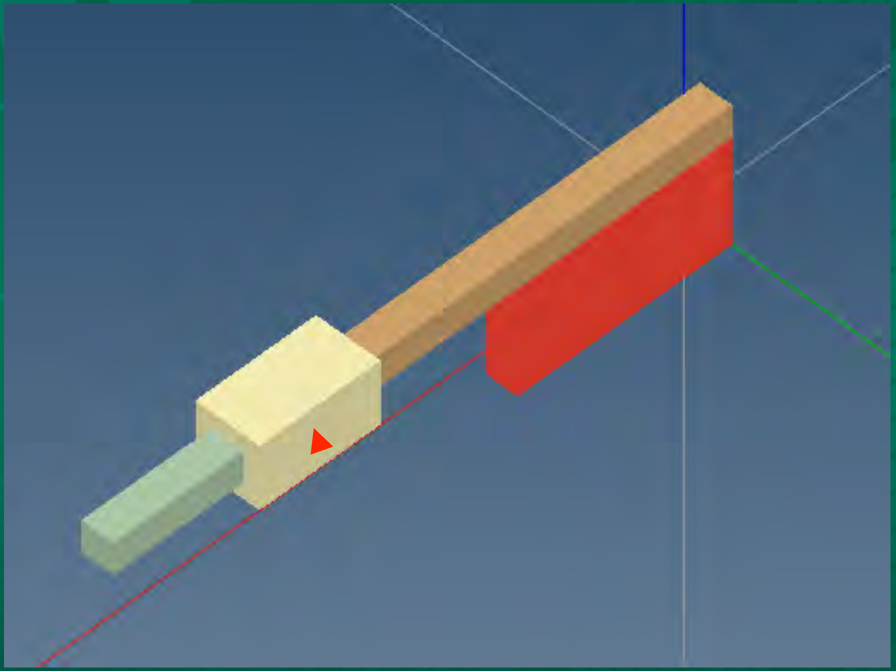
Improvements should be available from geometry:

- Forced (air) cooling
- Better heat sinking at ends, in particular tip
- Shorter contacts
- More bulk at hot spot

Examples

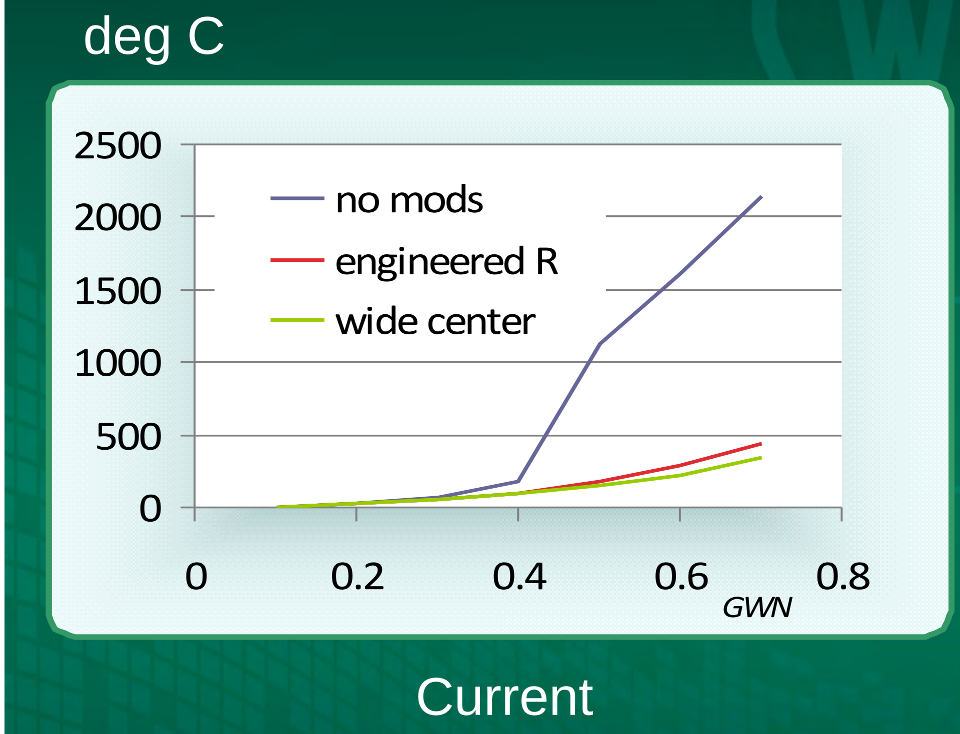


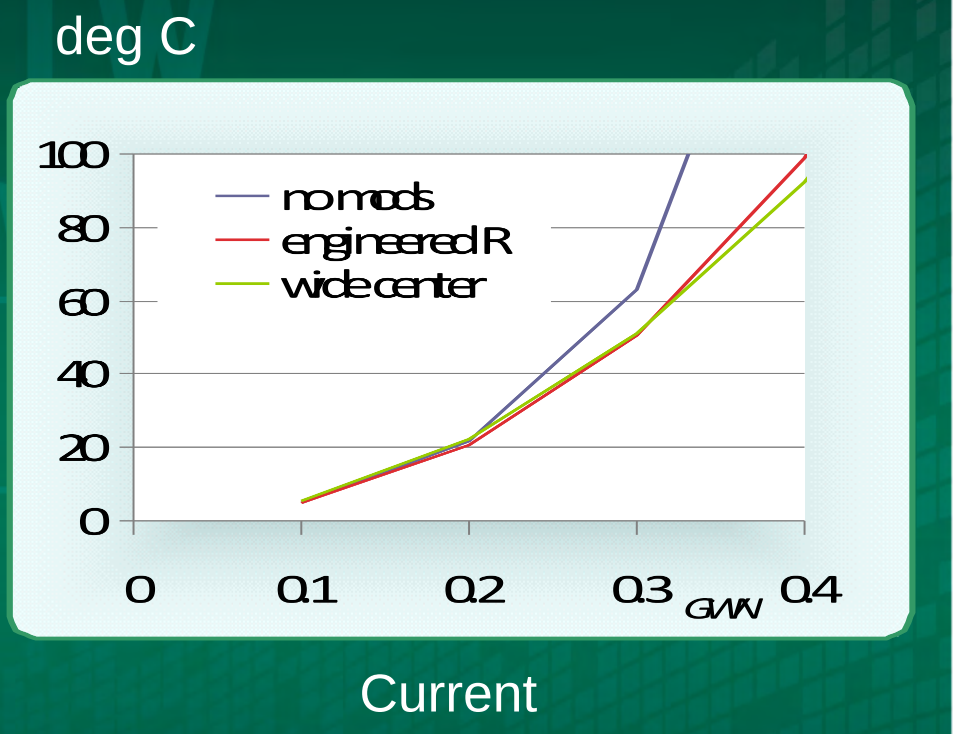
Engineered materials



More bulk at hot spot

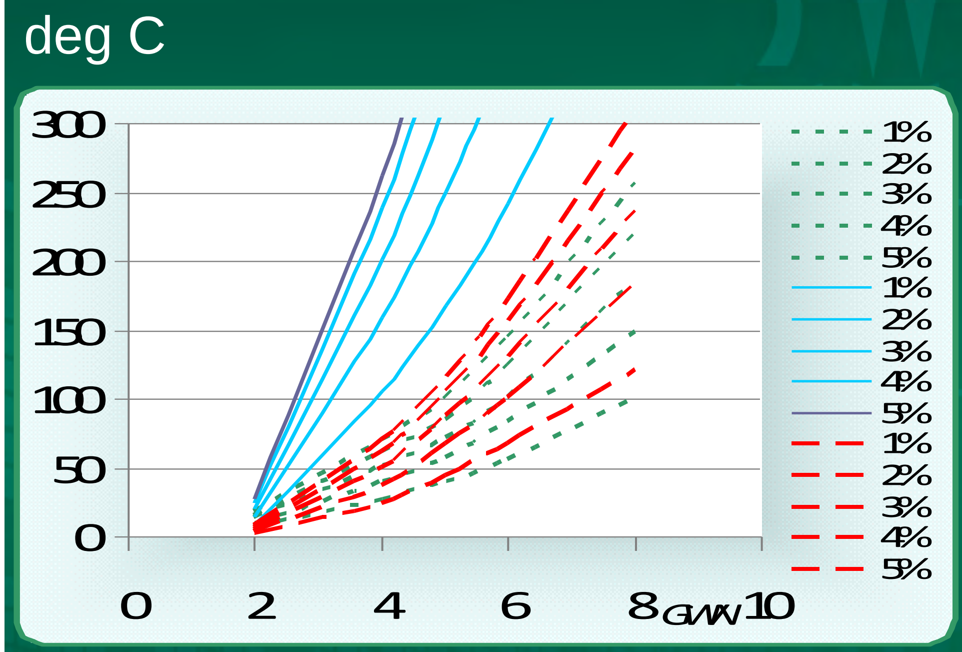
Temperature rise Tr, DC current

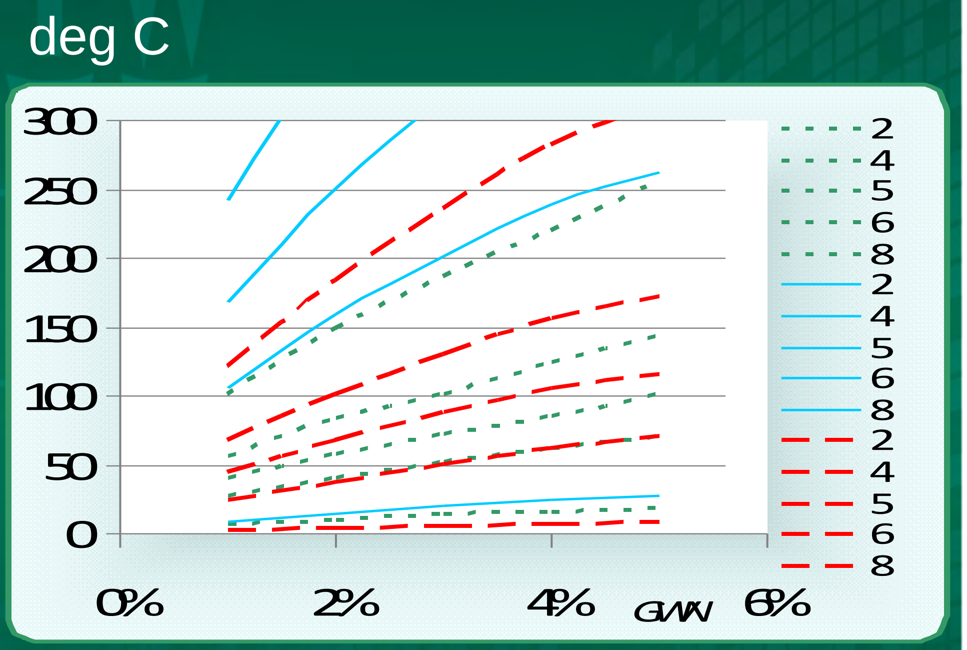




Shape as well as materials engineering can improve maximum DC current handling performance

Temperature rise, pulse current



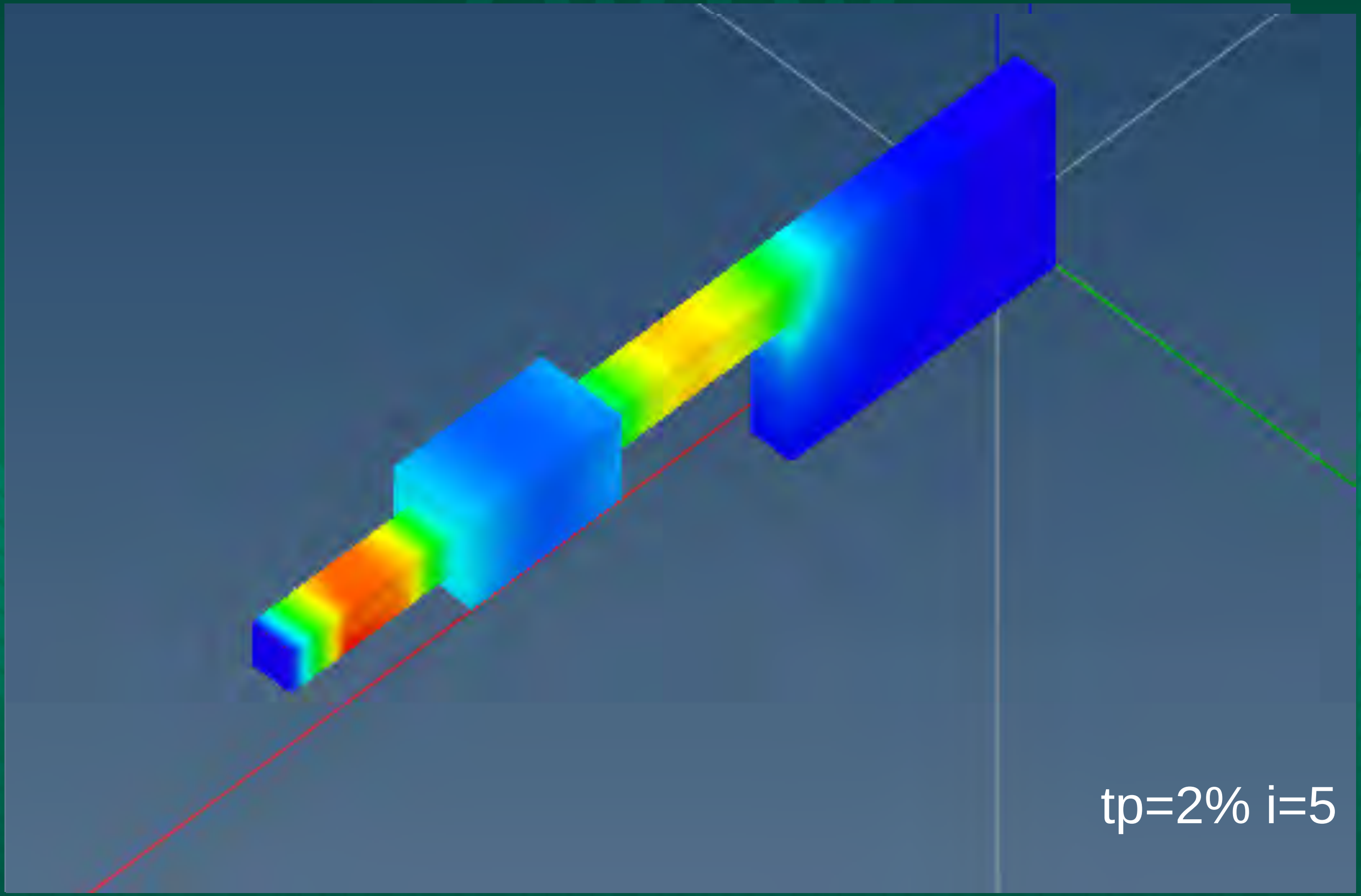


Current

Pulse length [% of thermal time constant]

Shape as well as materials engineering can improve performance especially for short, high current pulses

DC and pulse temperature distributions

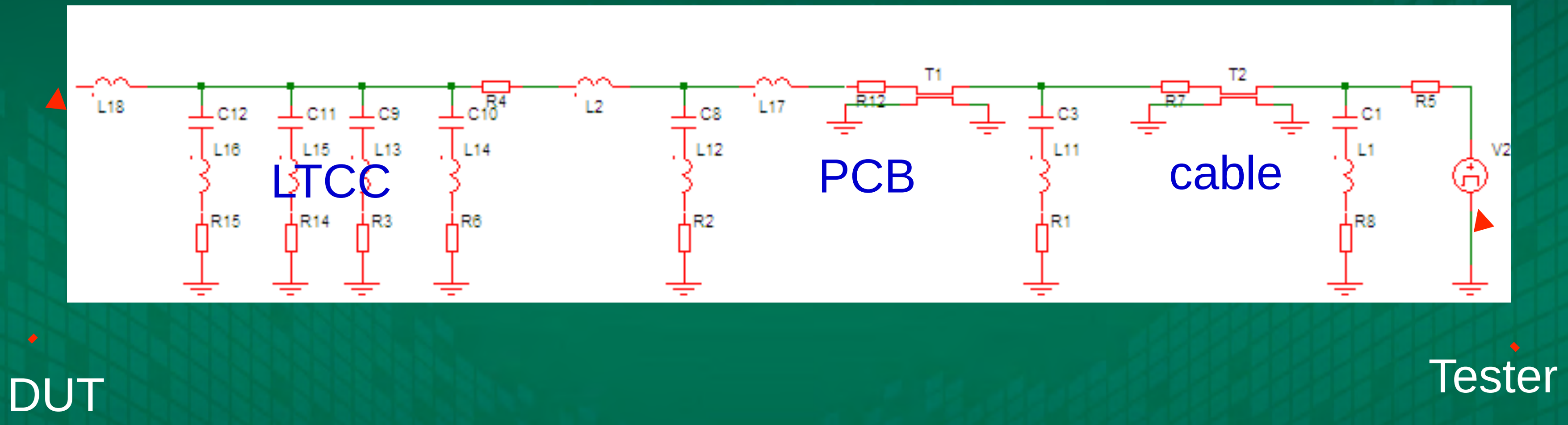


The presence of additional mass delays heating up of the center portion

What about the impact of ever improving power delivery networks?

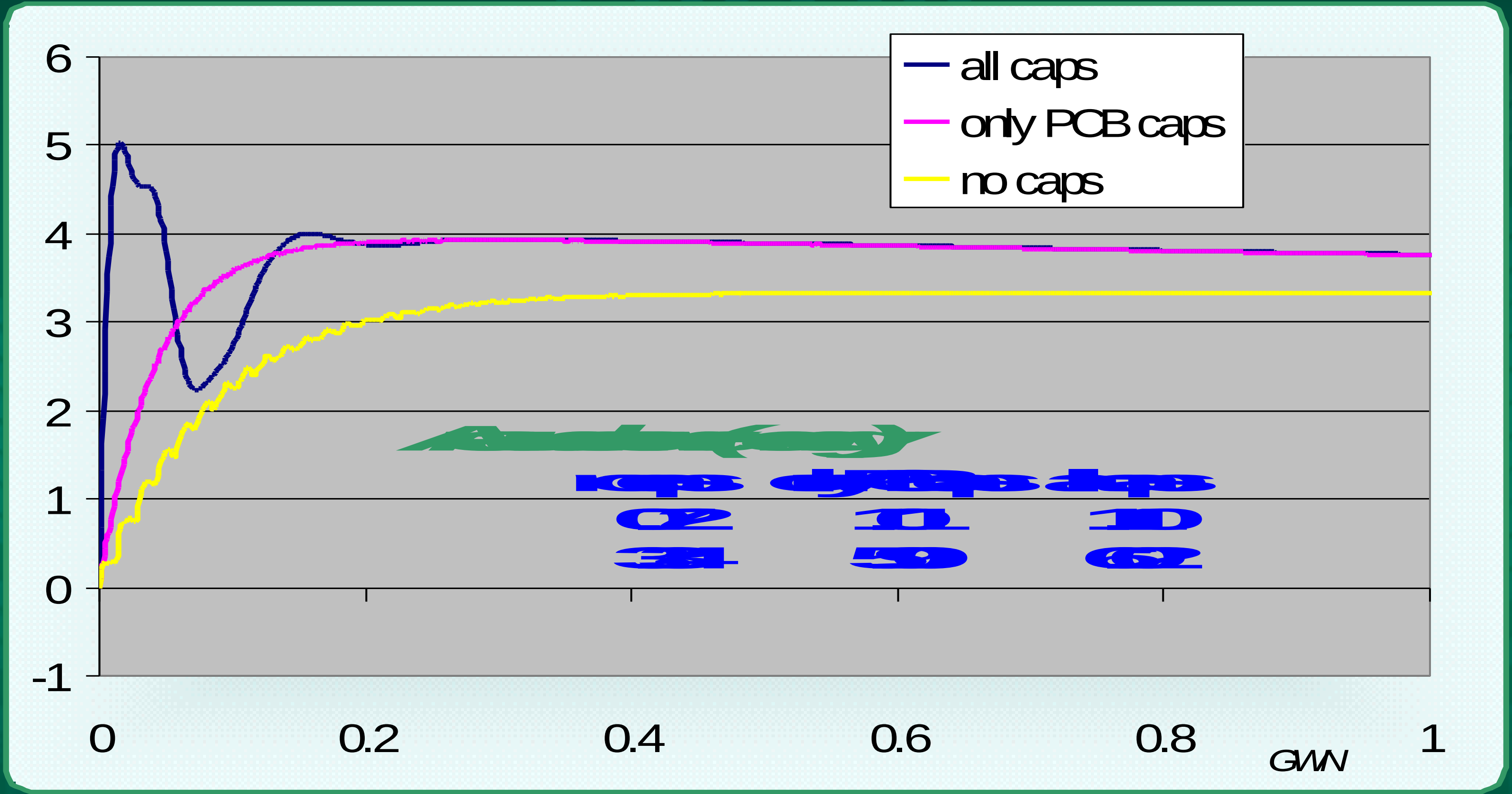
- Low series resistance
- More capacitors near device under test (DUT)
- On-board regulators

PDN schematic example



Simplified power delivery network equivalent circuit

Current pulse from a short circuit at DUT



Examples for a short circuit at DUT condition are

‘hot’ touchdown and device failure during test

Conclusions

- Contact material and shape can have a significant impact on pulse current handling capabilities.
- Simulations have to be set up and monitored very carefully in order not to overlook divergences
- Energy storage in bypass capacitors near the contacts does not appear to be a major concern