

Simulation of the Destruction Effects in CMOS- Devices after Impact of Fast Transient Electromagnetic Pulses

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Overview

- Motivation
- Threats
- Disturbing Signals
- Microscopical Analysis
- Simulation of Breakdown
- Simulation of Melting Process
- Time Behavior of Electric Field and Temperature
- Summary

A problem has been detected and windows has been shut down to prevent damage to your computer.

If this is the first time you've seen this Stop error screen, restart your computer. If this screen appears again, follow these steps:

check to be sure you have adequate disk space. If a driver is identified in the Stop message, disable the driver or check with the manufacturer for driver updates. Try changing video adapters.

check with your hardware vendor for any BIOS updates. Disable BIOS memory options such as caching or shadowing. If you need to use Safe Mode to remove or disable components, restart your computer, press F8 to select Advanced Startup options, and then select Safe Mode.

Technical information:

*** STOP: 0x0000007E (0xC0000005, 0xAF811695, 0xF7C3EAAA, 0xF7C3E7A0)

What do you think at this moment, when these error message appears on your screen ?

What does a flight controller think about ?

...or a pilot?

And which consequences will it have, if this happens on an intensive care unit ?

Motivation

Meaning of electronic systems for the world in the 21st century

- *safety systems*
- medicine
- economy
- traffic
- forces



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Motivation

Meaning of electronic systems for the world in the 21st century

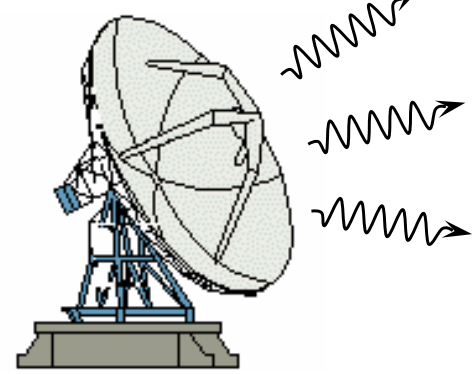
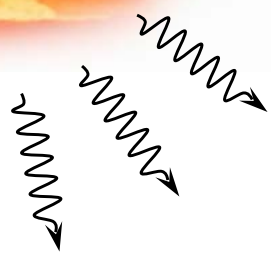
- safety systems
- medicine
- economy
- traffic
- *forces*



Threats

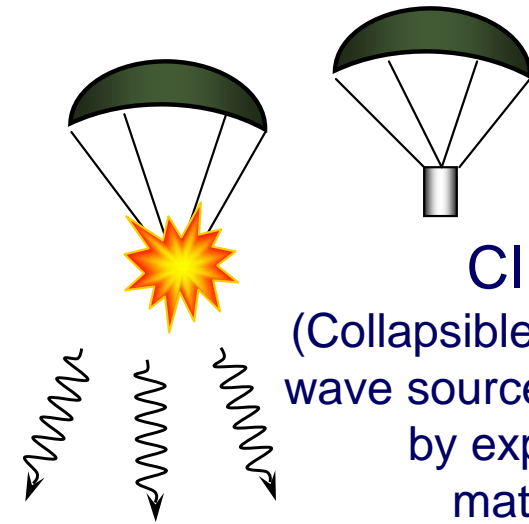
NEMP

(Nuclear electromagnetic pulse)



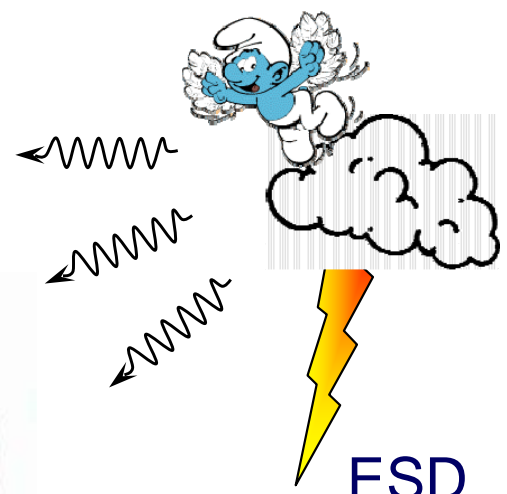
IRA

(Impulse radiating antenna)



CIRA

(Collapsible IRA; microwave source embossed by explosive material)

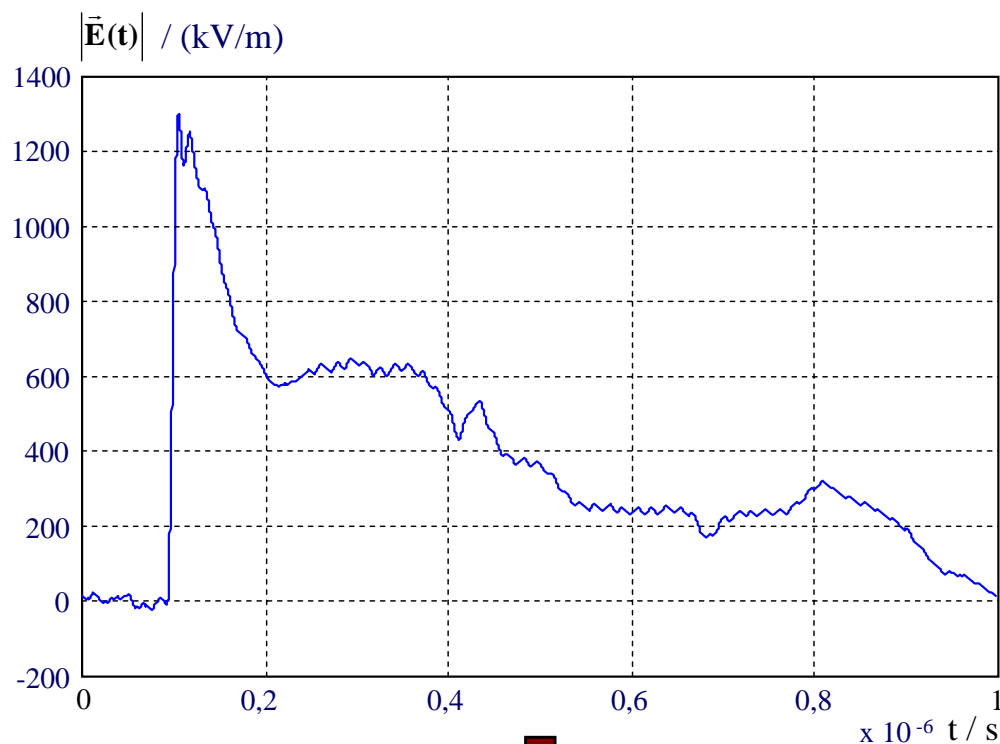


ESD

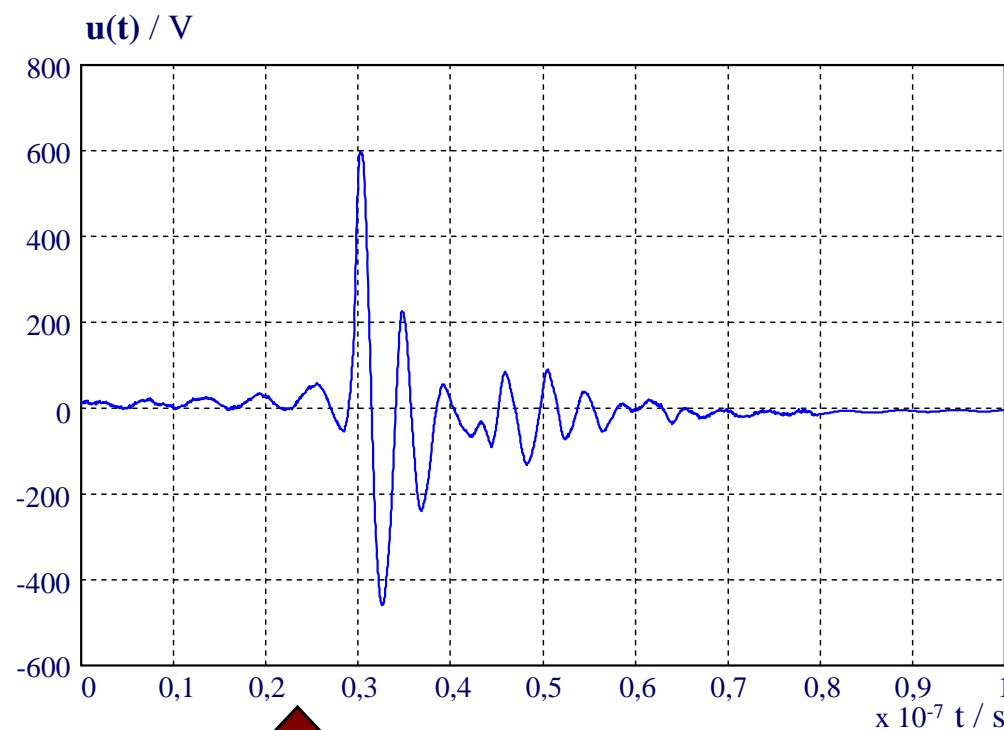
(Electrostatic discharge)

Disturbing Signals

Electromagnetic pulse



Voltage on connecting line



Primary coupling path:
Connecting lines

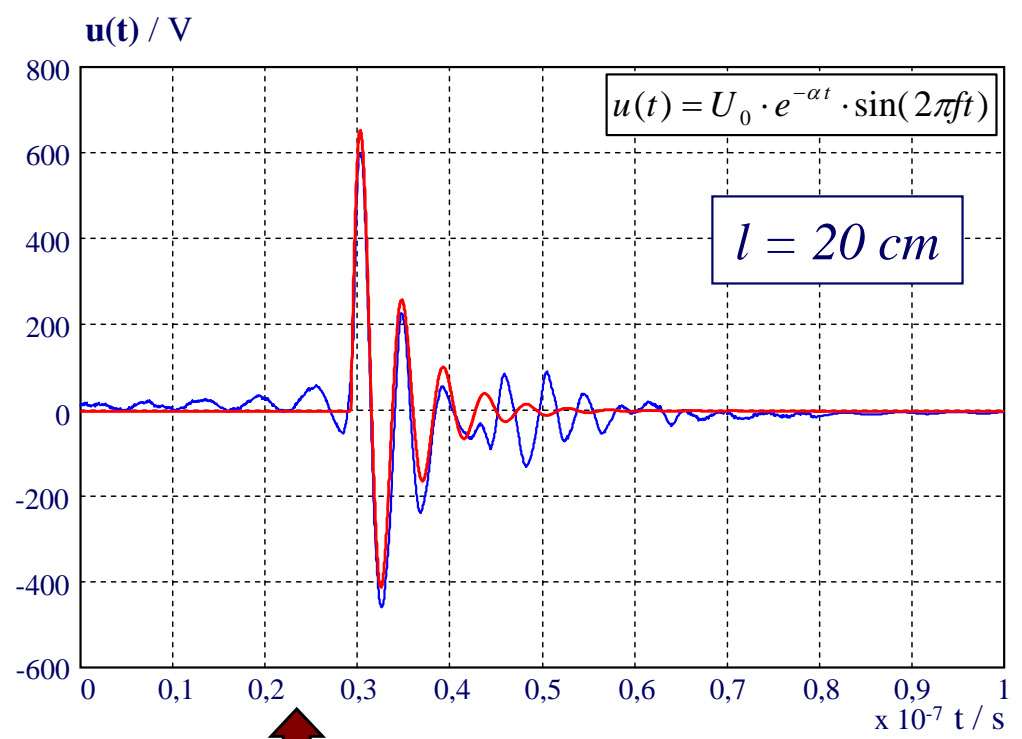
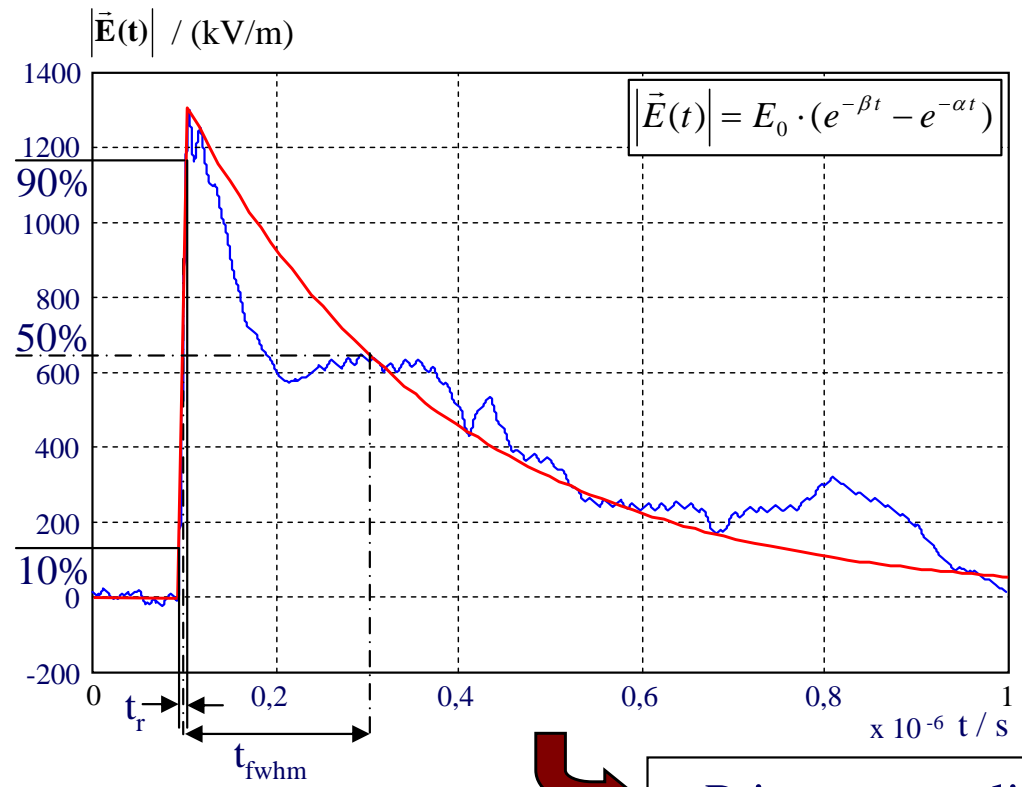
Disturbing Signals

Electromagnetic pulse

Voltage on connecting lines

→ double-exponential form

→ damped harmonic oscillation

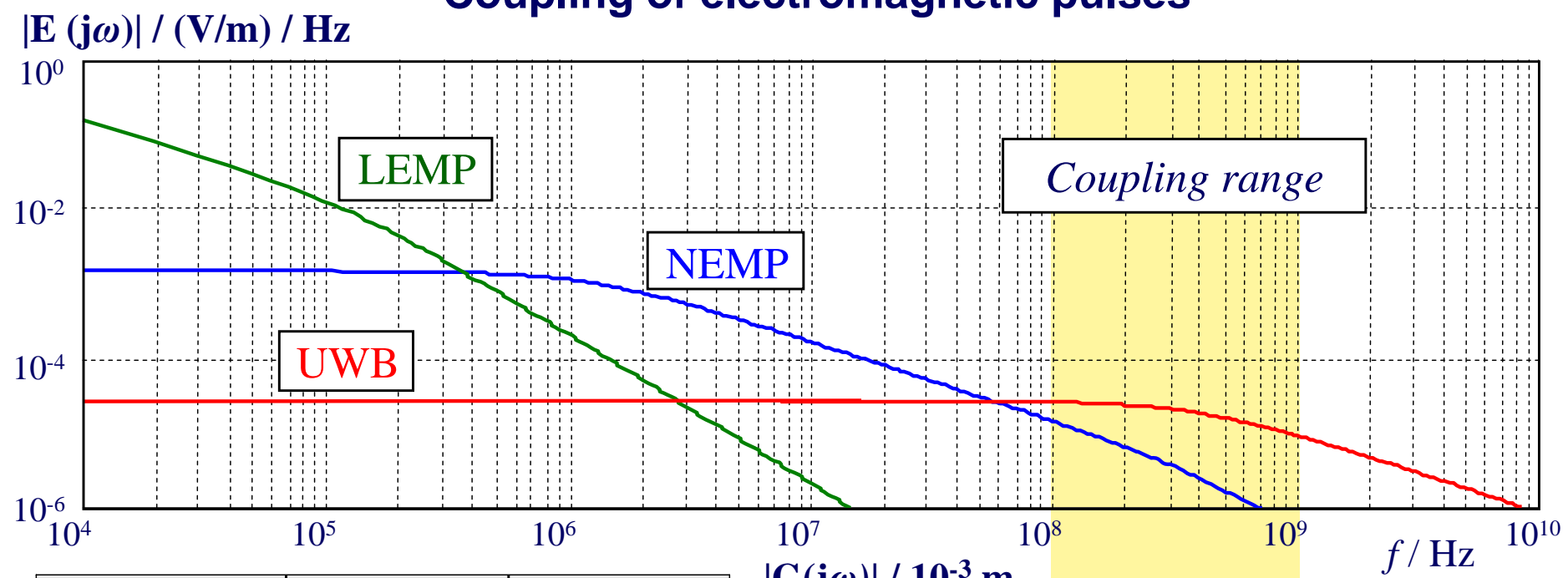


Pulse parameter:
 $t_r = 7,5 \text{ ns}$
 $t_{fwhm} = 180 \text{ ns}$
 $E_{max} = 1290 \text{ kV/m}$

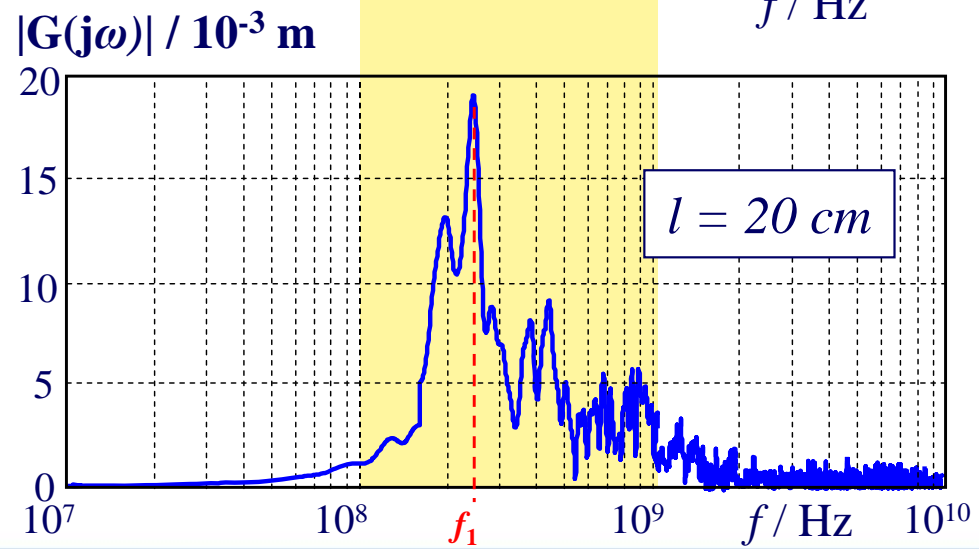
Primary coupling path:
Connecting lines

Parameter of the coupled-in signal:
 $\alpha = 2,1 \cdot 10^8 \text{ s}^{-1}$
 $f_1 = 230 \text{ MHz}$
 $U_0 = 821 \text{ V}$

Coupling of electromagnetic pulses

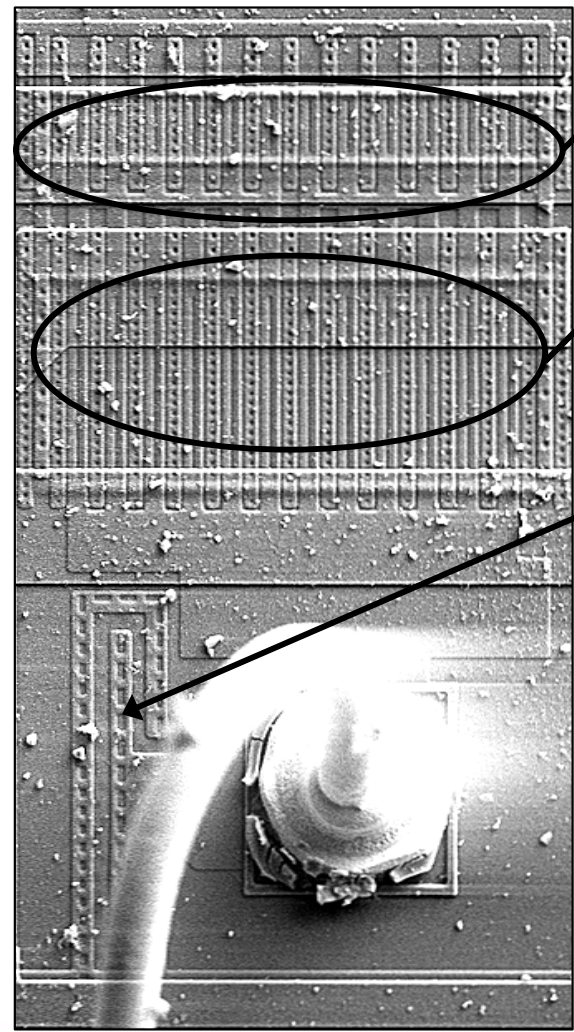


Source	Rise time	Pulse duration
UWB	$t_r = 100$ ps	$t_{fwhm} = 2.5$ ns
EMP (fast)	$t_r = 1.5$ ns	$t_{fwhm} = 80$ ns
Nuclear explosion (NEMP)	$t_r = 1$ ns - 5 ns	$t_{fwhm} > 100$ ns
EMP (middle)	$t_r = 5$ ns	$t_{fwhm} = 300$ ns
EMP (slow)	$t_r > 10$ ns	$t_{fwhm} = 500$ ns
Lightning (LEMP)	$t_r = 1$ μ s - 2 μ s	$t_{fwhm} \approx 50$ μ s



Microscopical Analysis

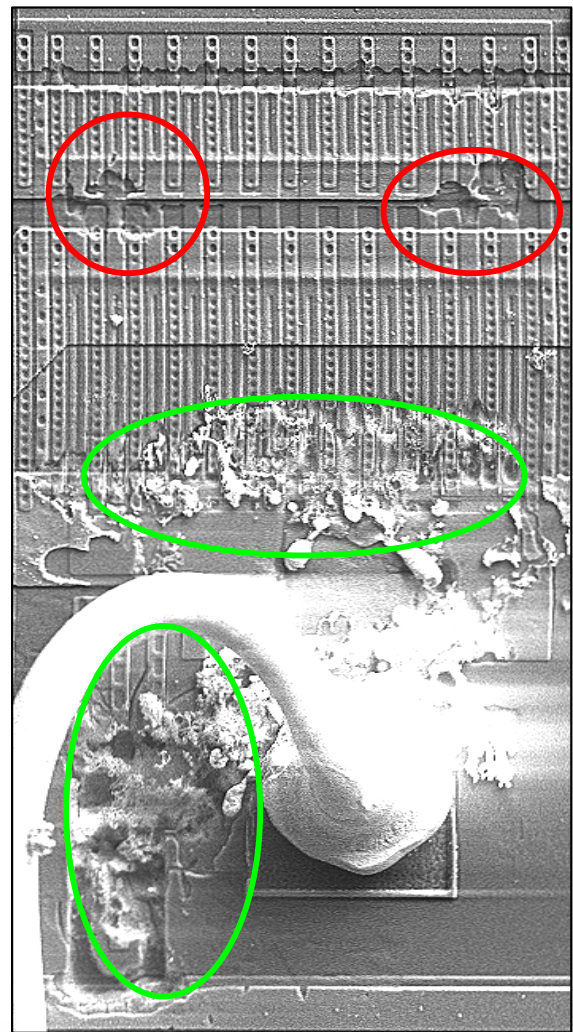
(rear section of an AC-/ACT-Inverter)



N-Channel-MOSFET

P-Channel-MOSFET

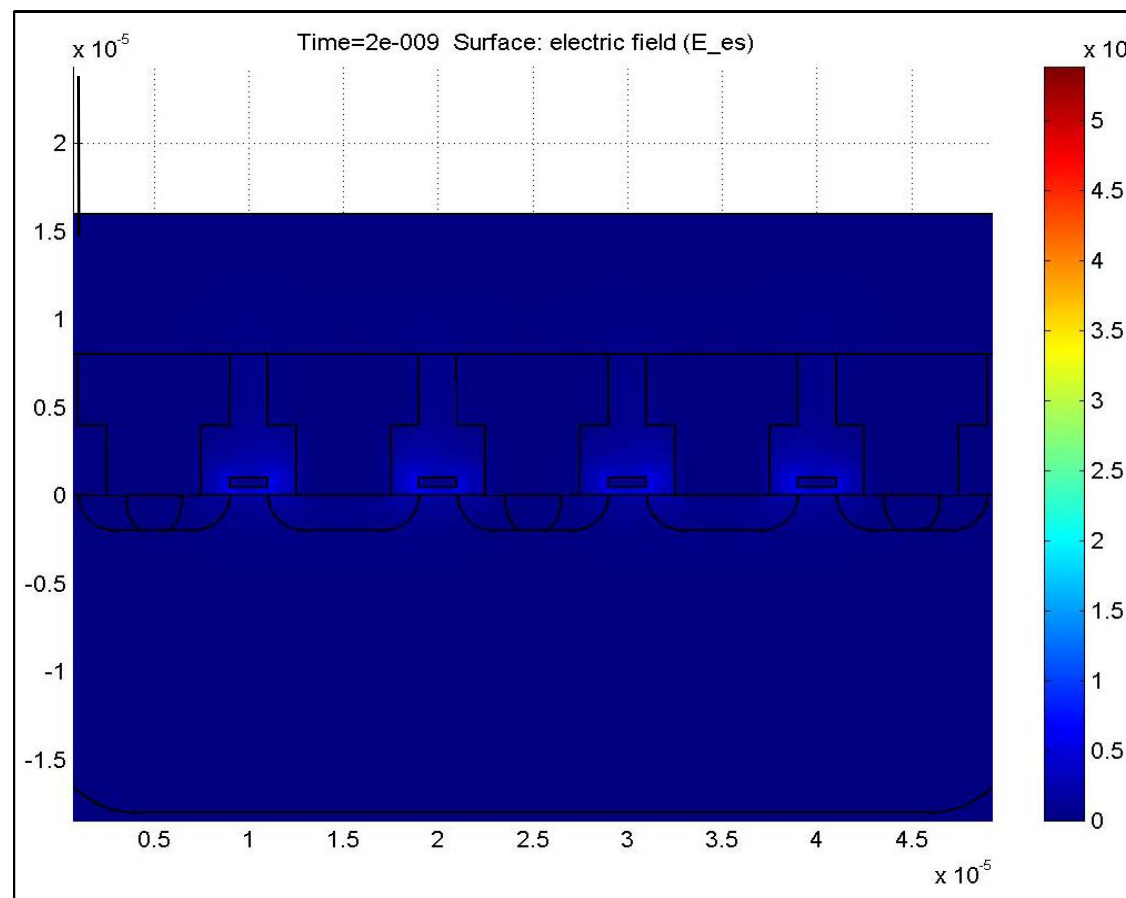
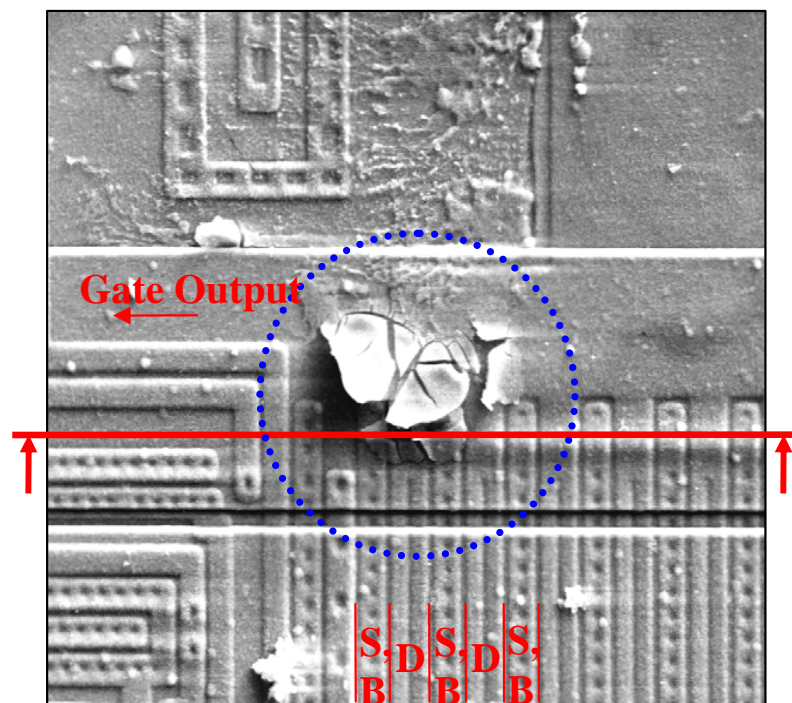
Diode



— Breakthrough

— Melting Process

Simulation of Breakthrough (CMOS)



Criterion of breakthrough:

$$E_{BR,SiO_2} \approx 10^8 \text{ V/m}$$

$$E_{BR,Si} \approx 2 \cdot 10^7 \text{ V/m}$$

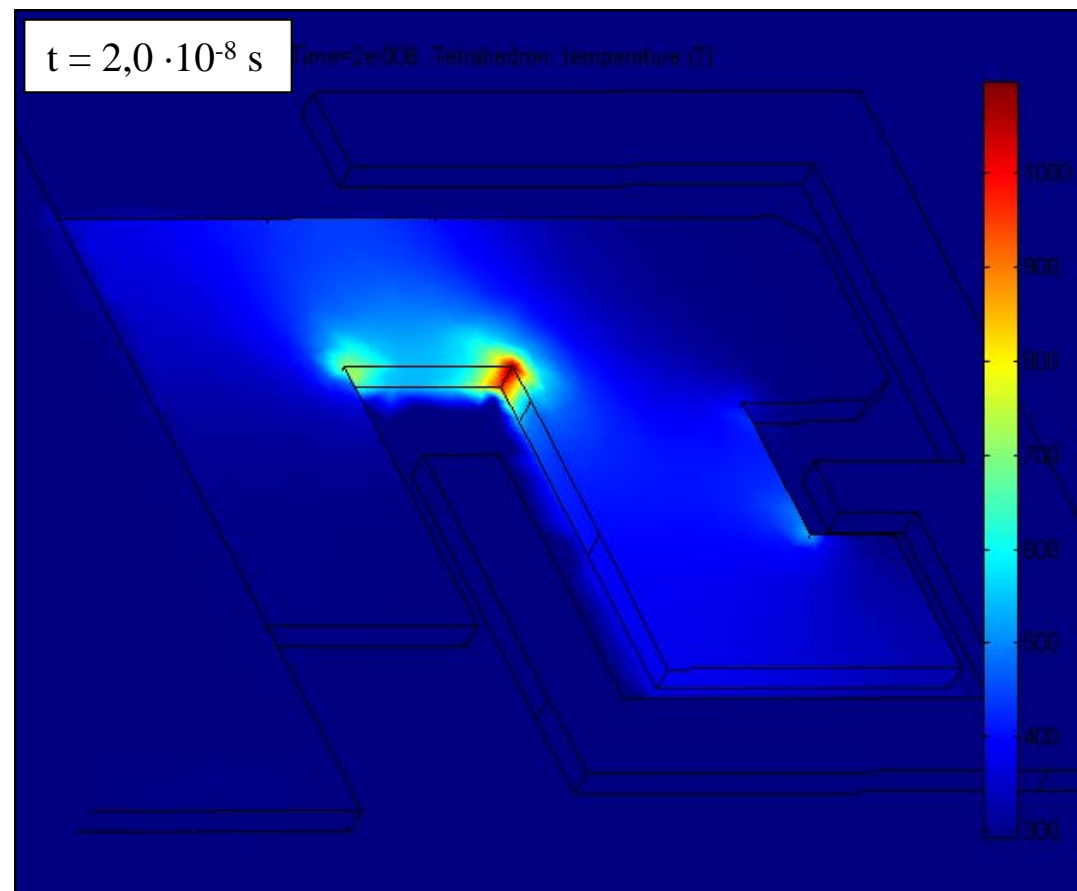
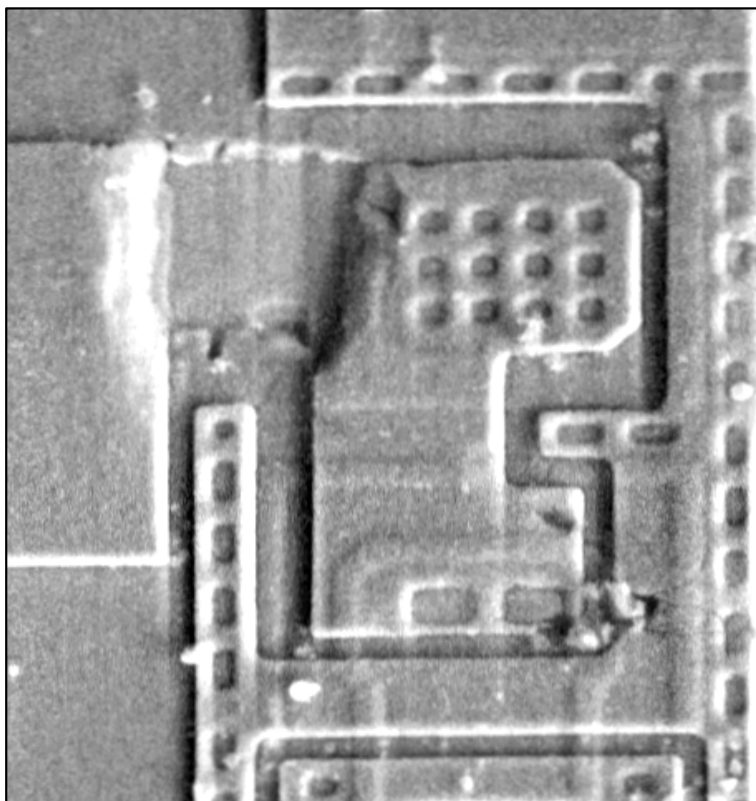
Simulation of the field strength characteristic:

$$E_{\max} = 5,38 \cdot 10^7 \text{ V/m} < E_{BR,SiO_2} \Rightarrow \text{no breakthrough over the whole period of time}$$

$$E_{\max,Si} = 2,04 \cdot 10^7 \text{ V/m} > E_{BR,Si} \Rightarrow \text{Drain-Gate-Breakthrough at time } t = 1 \cdot 10^{-9} \text{ s}$$

- but note, that there is no information about the depth → faulty simulation results

Simulation of Melting Process



Criterion of melting:

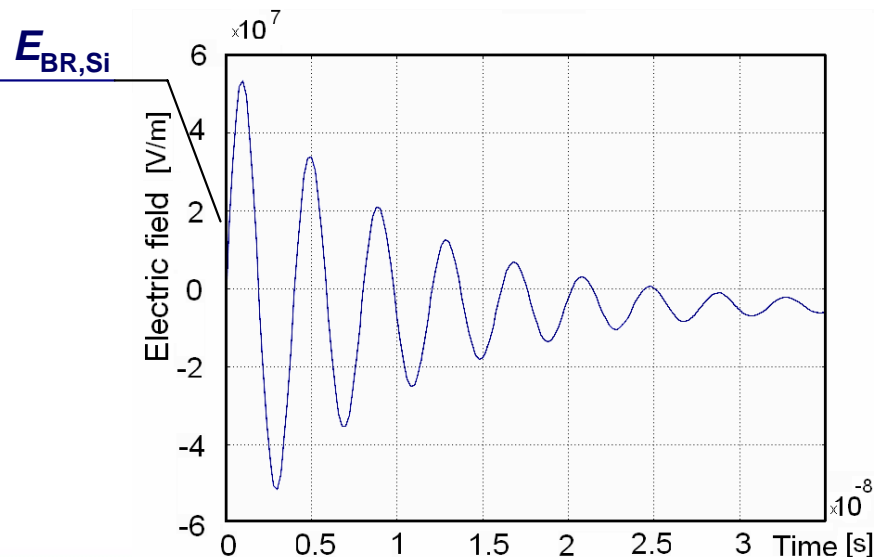
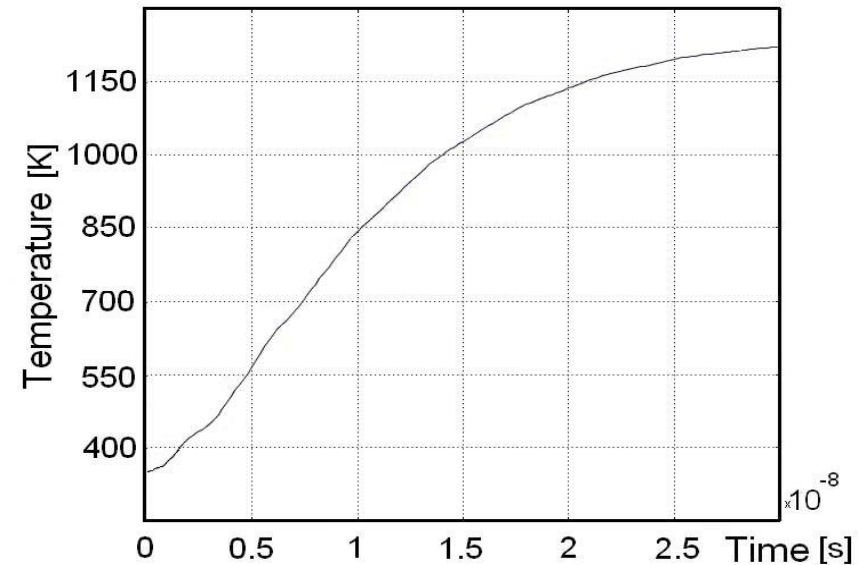
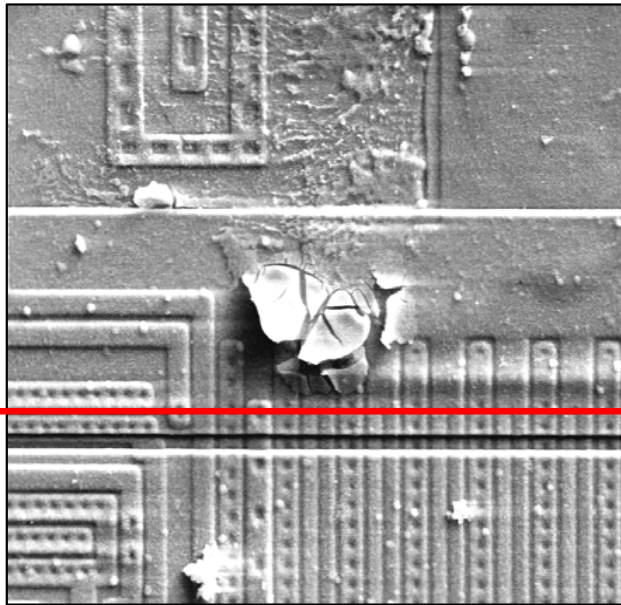
$$T_{Melting,AlSiCu} = 933 \text{ K}$$

Simulation of the temperature characteristic:

$$T_1 = 720 \text{ K} < T_{Melting,AlSiCu} \Rightarrow \text{no destruction}$$

$$T_{max} = 1092 \text{ K} > T_{Melting,AlSiCu} \Rightarrow \text{melting of the conductor line at time } t \approx 0,8 \cdot 10^{-8} \text{ s}$$

Time behavior of electric field strength and temperature

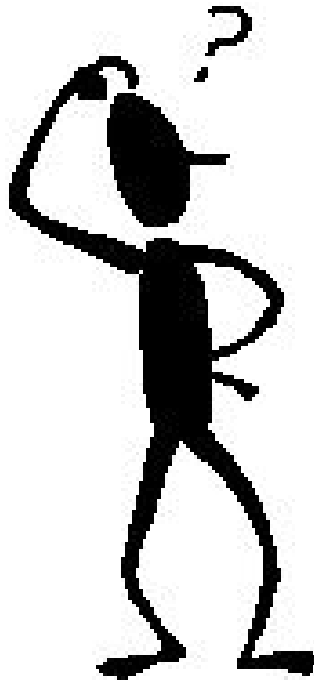


- determination of the time of breakthrough is possible
- the destruction field strength can be determined \rightarrow modifying the input variable until $E_{\max} = E_{BR}$
- determination of the time of melting process is possible

Summary

- Microscopical analysis shows breakthroughs and melting processes → both processes can be simulated
- Information got by the simulations:
 - * time of breakdown
 - * location of the position of the destruction
 - * field strength required for destruction
- Simulation reproduces the measured results
- Problems:
 - * only a part of the whole structure could be simulated, because the models are very complex
 - * thin and large structures → problems with mesh

Thank you for your attention!



Questions?