Year in Review:

EOS
The Real Challenge or **E**nd **O**f **S**tory (of Communication)?

Reinhold Gaertner, Infineon Technologies

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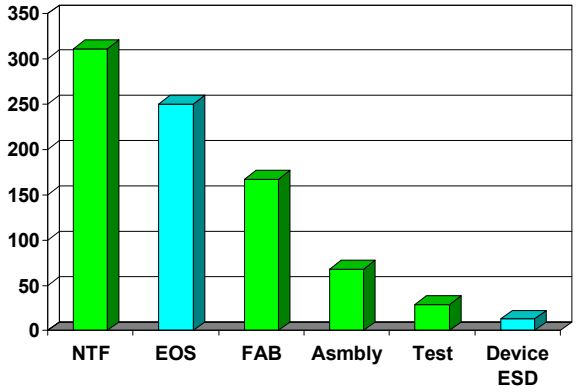
Outline

- Difference between EOS and ESD
- EOS work of Industry Council
  - Key definitions
  - Root causes
  - Case studies
- USCAR project: focus on the right things to be more efficient in the EOS root cause finding process!
  - two-level process for information sharing and support
  - FTA work
- Activities in other areas

Motivation – EOS the real threat?



/Welsher/

- The term “Electrical Overstress” or EOS has been widely used for decades to describe a large class of electrical failures of devices.
- EOS failures are said to account for most of the electrical failures of devices that occur in factories and in the field.

Difference between EOS and ESD (conventional)

ESD: short voltage or current pulses injected from any external charged object into the device (inappropriate handling, charging during automatic handling), resulting in dielectric breakdown or minor thermal damages.

Filaments can appear at random areas of the same device (if concentrated at one spot, usually small)

typically: leakage, increased power consumption, functional fail

EOS: voltage or current pulses of varying length, injected via application, resulting in massive thermal damages inside the device (up to evaporation of the material)
Localized at the same spot as a hole
Spreading into large melting area

typically: short, leakage, open, melted mould compound

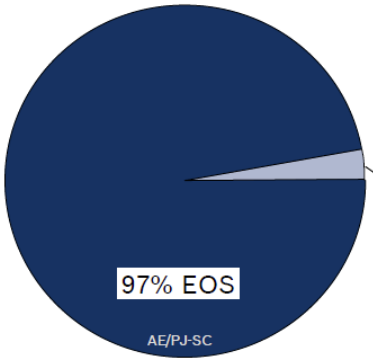
Evaluation of Bosch

/Source: C. Thienel; ZVEI/

ESD versus EOS

Failure Modes of C Failures

Bosch ASIC
C failures - 0-km & field
incoming 2009 - 2010
as at Nov 17th, 2010



ESD (Electrostatic Discharge):
- steep short needle
- very high voltage
- very low energy

3% ESD

EOS (Electrical Overstress):
- low voltage compared to ESD
- voltage out of spec
- sufficient energy to destroy big ASIC area

32 times more EOS failures than ESD failures!

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EOS of Automotive Semiconductors

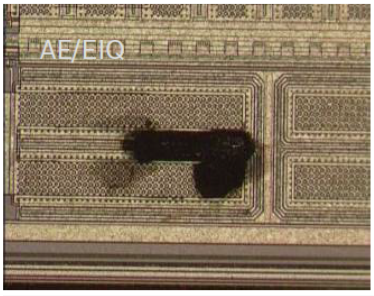
EOS Symposium Korea 2015

EOS Reproduction on IC (more than 2500 trials)

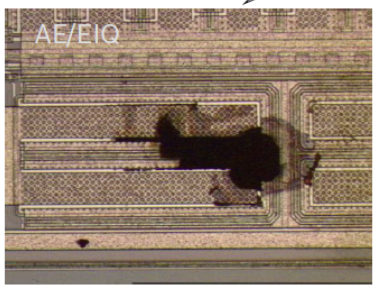
Example: molten protection circuit at pin Batt

0.25mm * 0.2mm

Customer complaint



EOS trial



1. Results only by **out of spec operation**
2. **ESD** was **not a precondition** (no two step processes)
3. Many failures by **hot plugging** and **missing ground**

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Industry Council on ESD Target Levels 2015 Membership

http://www.esdindustrycouncil.org/ic/en/

White Paper on EOS

- Understanding industry views on EOS
  =>EOS Survey
- Absolute Maximum Ratings (AMR) and EOS
- "Fishbone" of Root Causes leading to EOS-like damage
- Case studies
- Opportunity for industry to minimize EOS returns

http://www.esdindustrycouncil.org/ic/en/documents
Also published as JEDEC JEP174: UNDERSTANDING ELECTRICAL OVERSTRESS – EOS

Important Lessons from EOS Survey

- Misapplication stands out as the most widely reported root cause
- Root cause of EOS can vary – sometimes the root cause is not truly electrical in nature
- Not many failures exhibiting EOS-like damage are completely resolved
- Complete information on failure is not often available
- Developing a common information framework is important
- Link to Absolute Maximum Rating (AMR) for EOS is not well understood

It is an industry-wide problem!

Improved Understanding of EOS

Previously	New
Misinterpretation due to vague use of terms: EOS, EOS event, EOS damage etc	An EOS event is clearly defined as an excess of a specified absolute maximum rating (AMR)
Infrequent and insufficient supplier-to-customer and customer-to-supplier communication	A clear communication is demanded based on accurate definition of terms
No common understanding of responsibilities between IC supplier and customer	An EOS analysis procedure with contributions by supplier and customer is described

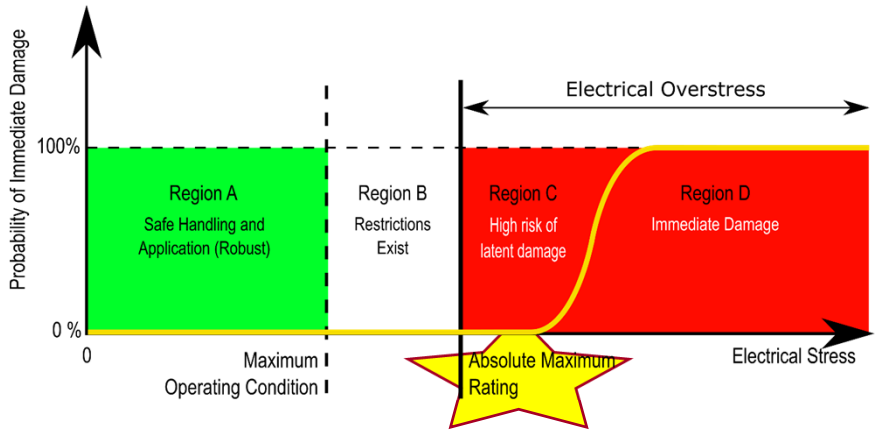
Source: www.esdindustrycouncil.org

WP4 Key Term – Electrical Overstress

EOS – Electrical Overstress

An electrical device suffers electrical overstress when a maximum limit for either the voltage across, the current through, or the power dissipated in the device is exceeded and causes immediate damage or malfunction, or latent damage resulting in an unpredictable reduction of its lifetime.

WP4 Key Definition – Absolute Maximum Rating (AMR)



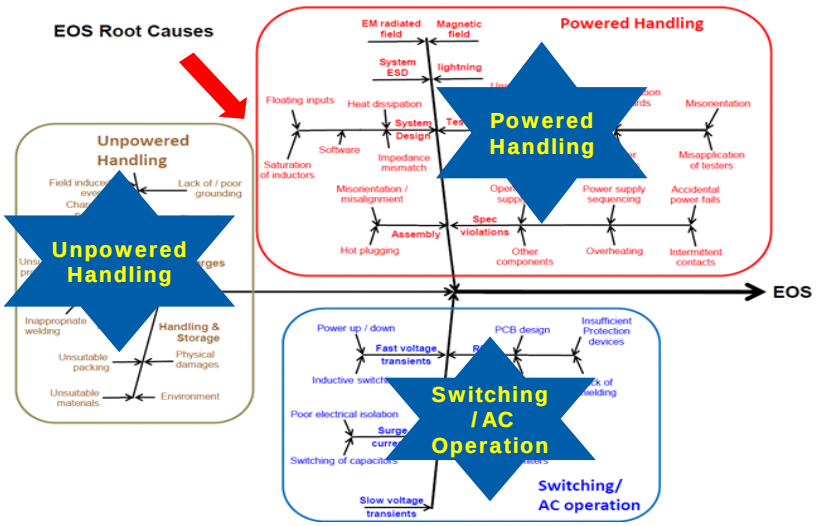
WP4 Key Term – EIPD
Electrically Induced Physical Damage

EIPD – Electrically Induced Physical Damage

Damage to an integrated circuit due to electrical/thermal stress beyond the level which the materials could sustain. This would include melting of silicon, fusing of metal interconnects, thermal damage to package material, fusing of bond wires and other damage caused by excess current or voltage

EIPD to be used during initial FA/FI until a more comprehensive joint analysis between supplier and customer can point to a potential EOS risk

EOS Root Causes

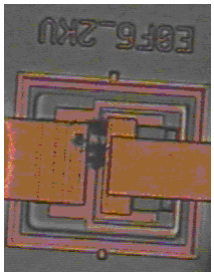


Case studies

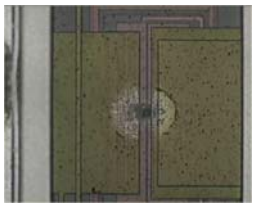
- White paper describes many case studies covering the categories shown in the fishbone diagram, describing
  - Failure occurence
  - Failure signature
  - Analysis and Simulation
  - Solution

Problem – ambiguity of failure picture

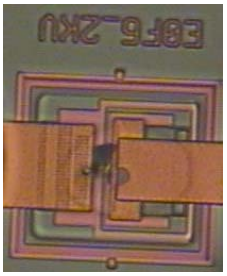
Device stressed with ESD Human Body Model like pulse of **15 kV** resulting in a current of about **10 A**



Field failure



Device stressed with a DC voltage of **3 V above VBD** with a current of 300 mA (**2x AMR**)



It cannot be decided what was the damaging stress
=> further information needed!

Conclusions from the case studies

- Failure analysis only provides a damage signature and does not reveal the true root cause.
- Often the failure signature and damage can be replicated by controlled experiments
- In general, EOS occurs when products are brought outside their specification limits (misapplication, hot-plugging, ground bounces, supply switching, EMI transient surges, or process or product / system assembly issues)
- Adequate solutions to EOS problems are only possible through thorough understanding, which is possible via a root cause analysis where all parties cooperate on the same level.

Conclusions from factory and field return analysis

- EOS damage can occur due to poor grounding methods and can easily be mitigated with established guidelines. A risk analysis often can avoid such problems.
- Learning from field events is also important. Many of the problems could be avoided if the supplier and the board designer practice better communication.
- Automotive applications pose some of the most common risks. Hot plugging is a persistent problem that can be mitigated by practicing the principle of first-mate-last-break.
- EOS by ESD is another cause that can be reduced by avoiding charging/discharging in assembly lines and implementing a balanced ESD protection approach.

Information needed for root cause analysis

- A detailed description of all handling steps the part went through from the time it was received to the time a failure was detected.
- A detailed description of the system and component failure symptoms.
- A description of system functionality after swapping the part with a fresh part (if possible).
- System Datasheet
- System schematics and board layout diagrams
- Power sequence and system initialization timing diagrams.
- A reference functional system if the customer can provide one.
- As much background information as the customer is willing to share. It is hard to provide too much information

Application of WP4

USCAR project

”Automotive strategies for EOS problem resolution”

OEM’s: FCA, Ford, GM
Tier1’s: Bosch, Continental, Nexteer
Semi’s: Infineon, NXP/Freescale, Renesas

Started in September 2015

USCAR EOS Initiative - Introduction

- 3 companies from each of 3 tier levels (OEM, TIER1 and Semiconductor supplier) have met at USCAR and reviewed their struggling points and how to improve them.
- The group saw the need for 2 “projects”:
  - a two-level process for information sharing and support
  - a systematic approach using applicable branches of the Fault Tree, published in the “Industry Council on ESD target levels” Whitepaper 4

Goal: focus on the right things to be more efficient in the EOS root cause finding process!

USCAR EOS Initiative
Definiton of two-level support

Acknowledgement: different situations/events require different levels of support.
“Spend your resources wisely!“

Level	Definition	Support
1A	Single occurrences in production within a 12 month period that have no evidence of a systemic signature. Most of the EIPD cases fall into this group.	Regular support from all parties is needed providing standard information as defined in 4.1 being available in every case
1B	Single occurrences that happen in • safety relevant applications • production validation (PV) • design verification (DV) • the safe launch period.	Extended support from all parties is needed providing additional information as defined in 4.2
2	Repeat incidents for a particular electronic component that happen in • safety relevant applications • production verification (PV) • design verification (DV) • during the safe launch period • normal production within a 12 month period.	Extensive support from all parties is needed providing additional information as defined in 4.3. This additional information is required for a good cooperation between all tiers to support the solving of the problem. This extensive support is limited to cases with more than one damaged device

NOTE: Level 1A, 1B or level 2 could be set/recognized by OEM but could also be upstream i.e. at Semiconductor or Tier 1 level

Level	Definition	Support
1A	Single occurrences in production within a 12 month period that have no evidence of a systemic signature. Most of the EIPD cases fall into this group.	Regular support from all parties is needed providing standard information as defined in 4.1 being available in every case
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Set date

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Up and down stream "Give" info approach

Sharing

Support Level	Info block	OEM	Tier1	Semiconductor
1A	- General - Process data - Look across	- …. - …. - ….	- …. - …. - ….	- …. - …. - ….
1B	- General - Process data - Look across	- …. - …. - ….	- …. - …. - ….	- …. - …. - ….
2	- General - Process data - Look across	- …. - …. - ….	- …. - …. - ….	- …. - …. - ….

Set date

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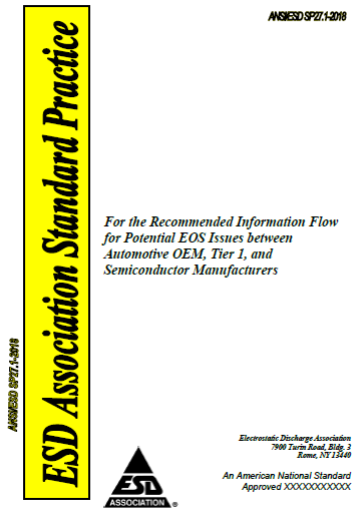
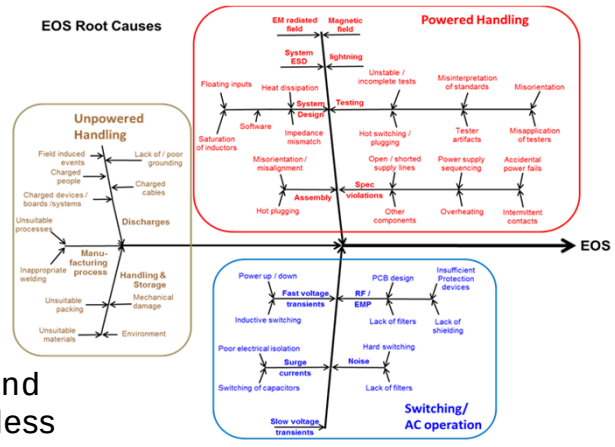
US ESD Association & USCAR

- To reach a wider audience and make the work known in a better way the work was transferred to an ESDA working group
  - ESDA WG27: Automotive strategies for EOS problem resolution
  - Document published as ANSI/ESD SP 27.1



Work on FTA-document

Idea: take the IC WP4 fishbone and apply it to processes of various tiers (fill into an excel sheet)



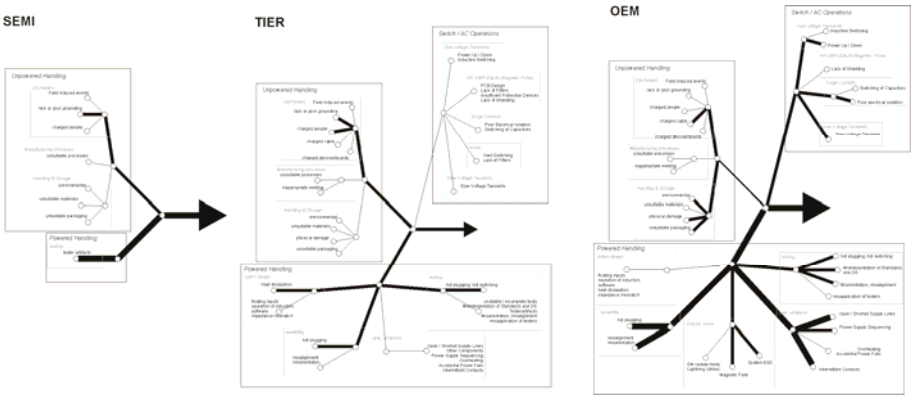
Excel sheet filled and reviewed more or less completely by all tiers

FTA application

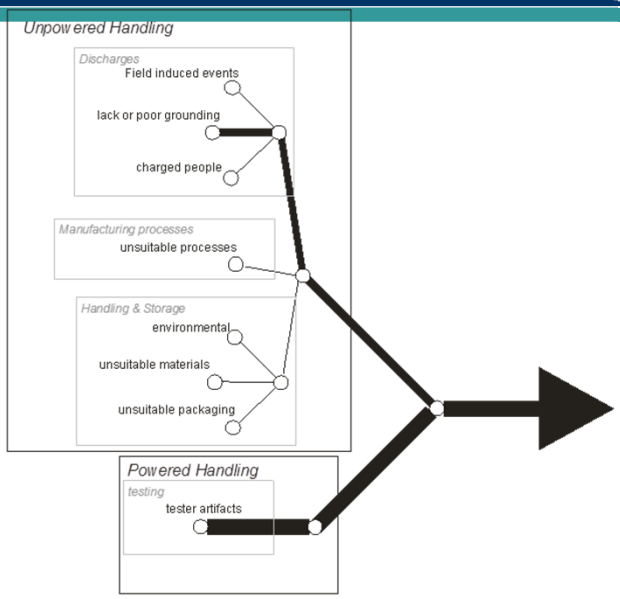
EOS Root Causes cause by ==>			Tier1				
Category	Sub-Category	Branch	Explanation of rating	Historical observed examples	Area to Investigate	Possibility based on history H(high) M(medium) L(Low) NA(not applicable)	E
Unpowered Handling	Discharges	Field Induced Events (ESD CDM event)	Human electrical field event. Historically, not observed within Tier 1, but should be considered.	Human electrical field event. Example - pulling of engine block (under static wallcap) may create electrical field.	Tier 1- Investigate unobserved activities and operations. Tier 1- Provide electrical path to the vehicle interface (Connector pin).	Low	Human observ
		Lack of / Poor Grounding (Equipment)	ICT or EOL Functional testers could have poor ground or improper grounding sequence.	Poor grounds at ICT or EOL testers.	Tier 1- Validate ground paths within the functional testing processes. Tier 1- Provide Tester and PCB ground path circuit.	Low	Test PPTH,
		Charged People	ESD programs in place. Some historical occurrences.	Accessible violations of policy. Intermittent grounding of accessible.	Tier 1- Provide recent ESD audit results. Req historical data across other divisions.	Low	No ESD Search Not ka histori
		Charged Cables - Plugged/Unplugged Harness	ICT and EOL Functional testers could have some observe charged capacitor	Typically, known occurrences are not used within the Tier 1 manufacturing process.	Tier 1- Review and validate functional testing processes.	Med	Cables produ issues
		Charged Devices / Boards / Systems Covered above FIE	Process normally in conjunction with poor grounding.	1) Measured of PCBA revealing charge. 2) Discharge of components in unapproved packaging. 3) Airflow (holistic during reflow operations) causing charged device.	Tier 1- Provide recent ESD audit results. Req historical data across other divisions. Reflow process review. Tier 1- Provide specification of packaging material and shipping methods.	Low	Human observ
	Manufacuring Processes	Unsuitable Processes	Use reviews during the PPAP signoff process fails. However, opportunities for unreliable process may exist.		Tier 1- Use walk of Tier 1 manufacturing line for any major process handling outside the standard process flow.	Low	Out of
		Inappropriate Welding	Human electrical welding. Not a typical process at the Tier 1.	None.	1) Review any external welding operations. 2) Support OEM investigation of OEM facility of welding operations.	Low	Human at the C
			ESD packaging is part of the standard process, but deviations can occur.	1) Components returned to warehouse without being placed back in ESD bags.	Tier 1- Provide specification of packaging materials, shipping, and in process transport.		ESD p bad de

FTA application

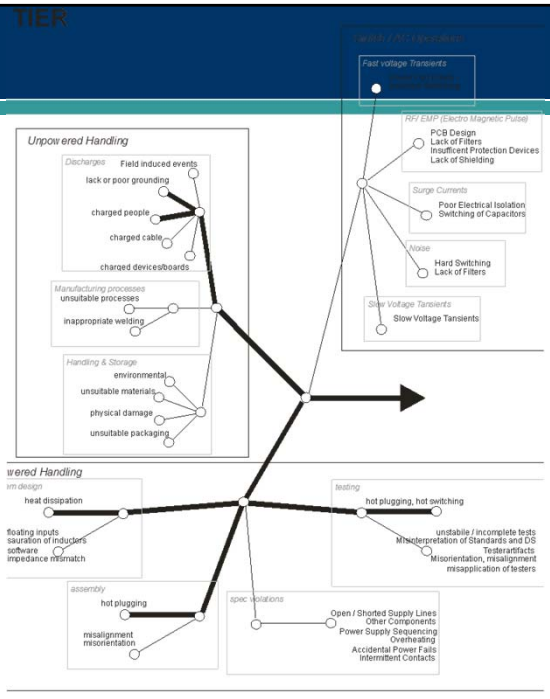
Weighing Most Common Cause Area



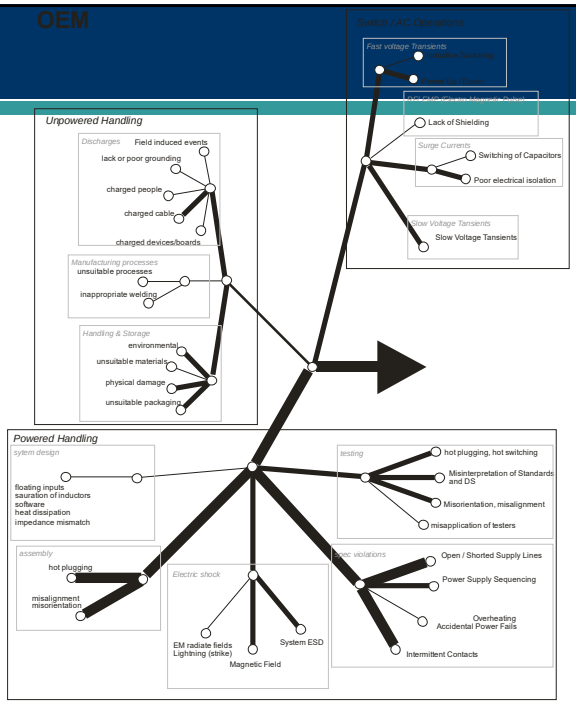
Semiconductor Manufacturer



Tier 1



OEM



Case studies

- A number of **anonymous** case studies should be added to underline/explain the excel sheet with the following structure:
  - Problem statement/failure occurence
  - Failure signature/mode
  - Analysis and Simulation
  - Root cause explanation
  - Solution
- To be stored in a database

More activities

- Germany => VDA – Verband der Automobilindustrie
  - WG with members from OEM, Tier1, and Semiconductor Manufacturer formed to adapt topic to VDA framework
- Workshop during the AEC meeting in April 2018
- Tutorial during EOS/ESD Manufacturing Symposium in Seoul/Korea in March 2018
- Tutorial during EOS/ESD Symposium 2018 in Reno
- Tutorial during EOS/ESD Manufacturing Symposium in Dresden/Germany in November 2018
- Online tutorial planned

Literature

- *ANSI/ESD SP27.1-2018 : „Standard Practice for the Recommended Information Flow Regarding Potential EOS Issues between Automotive OEM, Tier 1, and Semiconductor Manufacturers", 2018*
- *Industry Council on ESD Target Values: White Paper 4 - Understanding Electrical Overstress – EOS*
- *JEDEC JEP174: UNDERSTANDING ELECTRICAL OVERSTRESS – EOS, 2016*
- *K.T. Kaschani, R. Gärtner, „The Impact of Electrical Overstress on the Design, Handling and Application of Intergrated Circuits"; EOS/ESD Symposium, 2011*
- *C. Thienel, „Electrical Overstress of Automotive Semiconductors", Euroforum, 2010*