



# How promising is it to analyze every single EOS-like failure in depth?

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# Agenda

- What is EOS?
- Challenges related to EOS/EIPD FAR handling and root-cause finding
- Solutions for Dealing with Semiconductor Devices showing a signature of electrical overstress
- Recap and Key Statements, Discussion



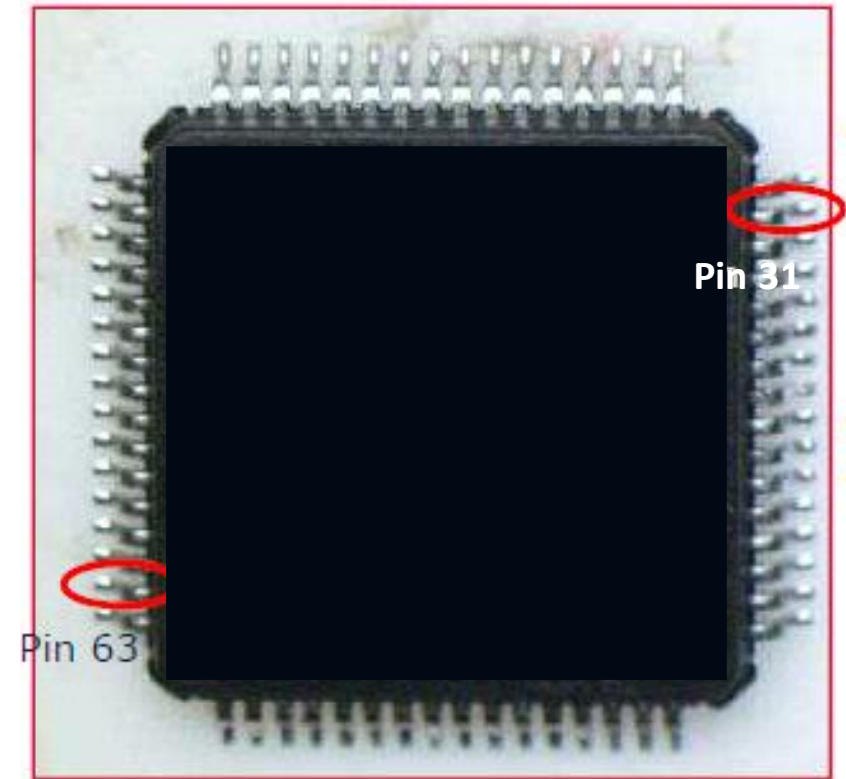
# What is EOS?



# What is EOS?

## EOS – Electrical Overstress

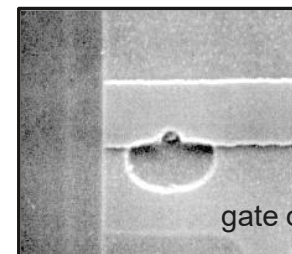
- A (Semiconductor-) component is limited (“AMR” = **A**bsolute **M**aximum **R**atings) with respect to tolerable currents, voltages and dissipated power applied to its individual pins.
- AMR are part of the product datasheet
- Examples for typical Specifications:
  - ESD robustness on component level
  - Protection against reversed battery
  - Repetitive Avalanche



# What is EOS?

## EOS – Electrical Overstress

- If these upper limits are exceeded during the manufacture, assembly or use of the component, this is referred to as "EOS".
- EOS can result in damages inside the device (from small holes in the gate oxide up to massive thermal damages or even evaporation of metal lines).
- Consequence: either an immediate malfunction or a latent damage of the component (causing a reduction of its specified lifetime).



Examples of failure analyses by semiconductor manufacturers



# EOS and AMR – Responsibilities and Duties

- The maximum limit is termed 'Absolute Maximum Rating' (AMR)

## Supplier

- AMR is to be defined by IC supplier
  - IC supplier needs to consider process variations and dependency on parameters such as temperature, humidity etc. in the specification of the AMR levels.
  - The specification of AMR has to provide exact stress conditions like pulse duration or reference to applied stress standards (ISO7637, etc.)

## Customer

- AMR has to be fully adhered to within the system design.
- All electrical stress conditions beyond Operating Conditions of an IC in final system targeting lifetime of the IC must be known!

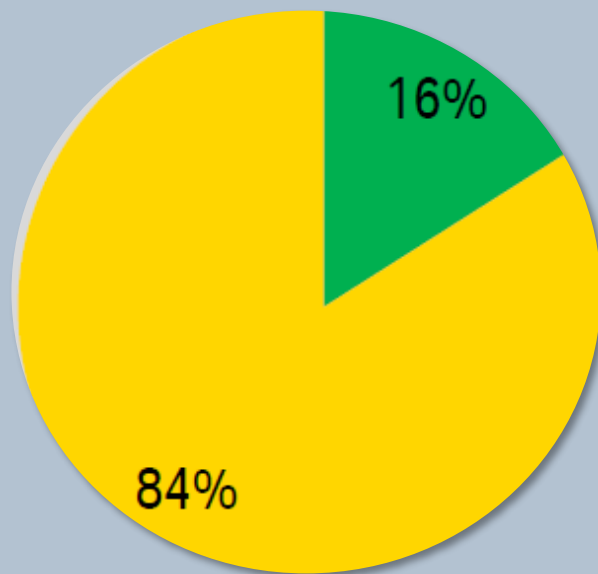


# Challenges related to EOS/EIPD FAR handling



## Why is that a topic for the (automotive) industry?

### Typical distribution for identifying EIPD root cause (e.g. experience OEM)\*



■ Root cause finding successful  
■ Reason unknown

### Further aspects

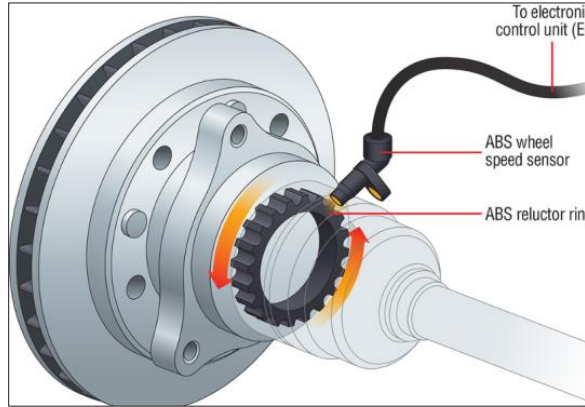
- Above-average effort for the analysis
- 8D Processing times cannot be met

Source: VDA QMC

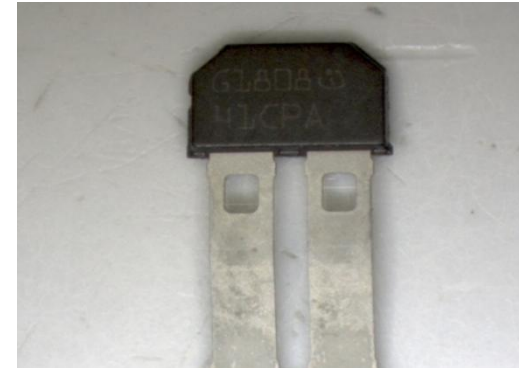
⇒ Challenges posed by EIPD/EOS require a restructuring of the problem-solving process

# EOS complaint: Typical Process, Expectations - why now “EIPD”?

@FIELD or @OEM: Malfunction of an ABS-module or unit

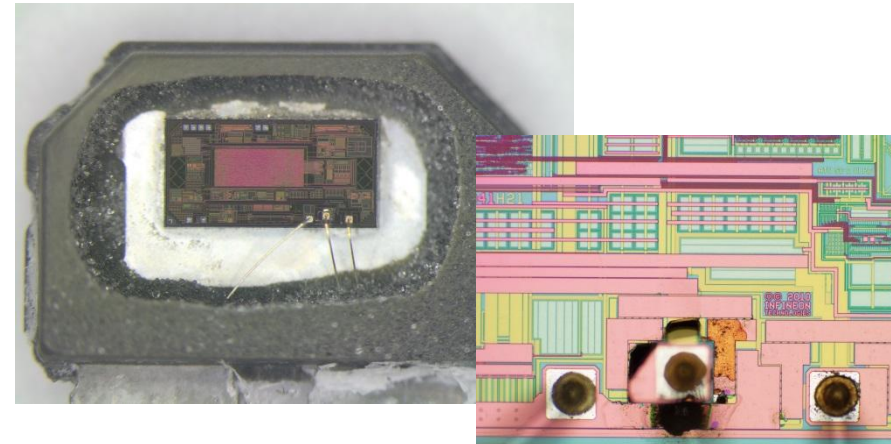


@TIER: Reason for malfunction is a semiconductor component



- SEMI can work out the **failure signature** only!
- TIER/OEM expect to know the **failure mode**!
- **Conflict**: there is no unique relationship between the electric stress and failure signature (see below)
- **Therefore/from now on**: EIPD (Electrically Induced Physical Damage) as feedback to customer

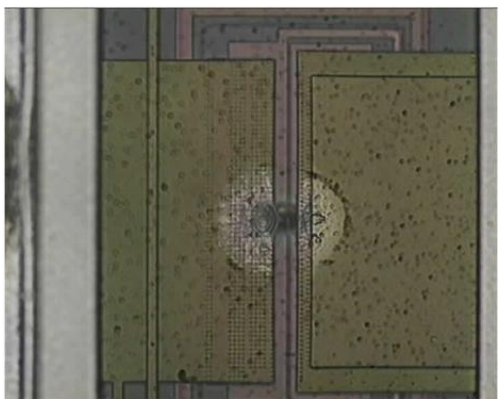
@SEMI: Semiconductor component after decap



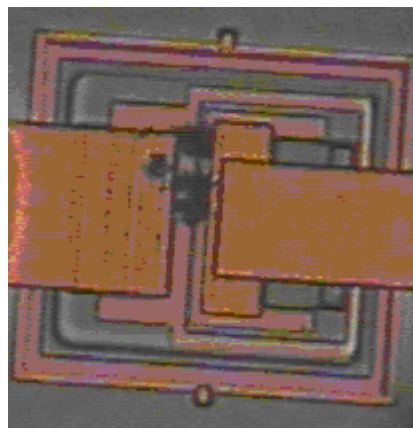
# Ambiguity of failure signature from EOS

## Example for EIPD

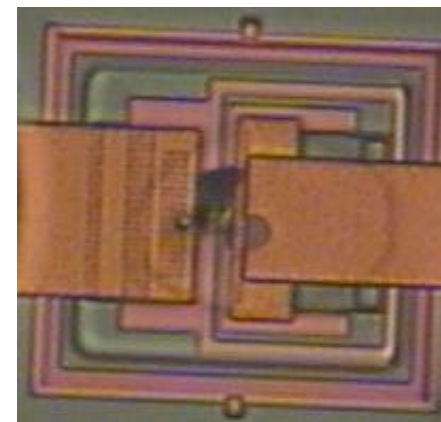
FAR device



Reproduction in LAB



15kV ESD „HBM“  
stress  $\Rightarrow$  10A/150ns



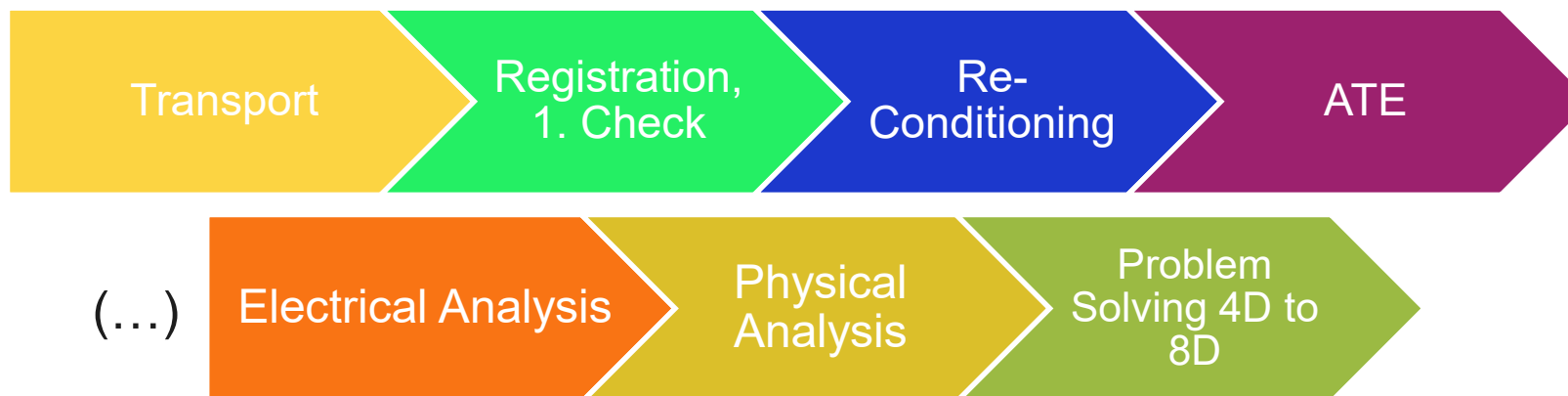
3V above VBD  
 $\Rightarrow$  300mA/“DC” (2x AMR)

- $\Rightarrow$  Limiting yourself to only one of the possible failure scenarios at this point in time increases the risk that the "real" cause will not be eliminated.
- $\Rightarrow$  Further information about the specific situation of the EIPD occurrence is necessary

# EOS complaint

## Effort for the Analysis

- **Typical flow:**



- **Challenge:** The analysis effort, especially the part of the physical failure analysis, is enormous for each individual case!
- **Consequence:** Use available resources sensibly, e.g. by applying VDA flow



# **Solutions for Dealing with Semiconductor Devices showing a signature of electrical overstress**



“Is EOS/EIPD really a relevant problem for the Industry and why?”

“What are solutions to deal with that?”

⇒ Use Consortia Activities to find out!

| Task                                             | Umbrella Organization                  |
|--------------------------------------------------|----------------------------------------|
| Assessment of the situation                      | Industry Council on ESD Target Levels  |
| Automotive Strategies for EOS problem resolution | USCAR <sup>1</sup> , ESDA <sup>2</sup> |
| Process Flow for Cooperation in RootCauseFinding | VDA <sup>3</sup>                       |

<sup>1</sup>USCAR: United State Council on Automotive Research

<sup>2</sup>ESDA: Electrostatic Discharge Association

<sup>3</sup>VDA: Verband der Automobilindustrie (German Association of the Automotive Industry)

## 2. USCAR EOS Initiative

### ”Automotive strategies for EOS problem resolution”

- Project was started within US Automotive Industry
  - (triggered by Infineon and GM)
- Companies from each tier level (OEM, TIER1 and Semiconductor supplier) have met at USCAR and reviewed their struggling points and how to improve them.
  - **OEM’s:** FCA, Ford, GM
  - **Tier1’s:** Bosch, Continental, Nexteer
  - **Semi’s:** Infineon, NXP/Freescale, Renesas



## 2. USCAR EOS Initiative

### Reaction in Automotive Consortia

- Electrical Over Stress (EOS) are the most frequent source of returns sent back to automotive Tier1 and Semi suppliers for failure analysis.
- Root cause finding for EOS
  - Challenging and time-consuming process
  - For single occurrences, the success rate is very low
  - Success depends on information sharing and a close co-operation between the Tier levels and OEM
  - A common expectation and misperception in the industry is to determine the exact EOS event based on the observed damage signature on silicon chip level

## 2. USCAR EOS Initiative

### Reaction in Automotive Consortia

**Different situations/events require different levels of support!**

**“Spend your resources wisely“**

**Focus on the right things to be more efficient in the EOS root cause finding process!**

- ⇒ Group at USCAR wrote document to prioritize EOS type damages (published as ANSI/ESD SP 27-1)
- Two-Level process
  - Cooperation
  - Information Exchange



## 2. USCAR EOS Initiative

### – Definition of Two-Level support

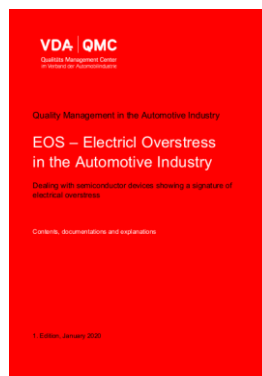
| Level | Definition                                                                                                                                                                                                                                                                                                                                |
|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1A    | <u>Single occurrences in production within a 12-month period</u> that have no evidence of a systemic signature.<br>Most of the EIPD cases fall into this group.                                                                                                                                                                           |
| 1B    | <u>Single occurrences</u> that happen in <ul style="list-style-type: none"> <li>• safety relevant applications</li> <li>• production validation (PV)</li> <li>• design verification (DV)</li> <li>• the safe launch period.</li> </ul>                                                                                                    |
| 2     | <u>Repeat incidents for a particular electronic component</u> that happen in <ul style="list-style-type: none"> <li>• safety relevant applications</li> <li>• production verification (PV)</li> <li>• design verification (DV)</li> <li>• during the safe launch period</li> <li>• normal production within a 12-month period.</li> </ul> |

### – A classification of a case as “1A”, “1B”, or “2” is done independently by each Tier level

### 3. VDA: A standard flow to support root cause finding in EIPD cases

#### Probability of success for finding the root cause

| <i>Incident</i>                      | <i>Total share of all component complaints</i> | <i>How likely is root cause finding successful?</i>                           | <i>Future approach</i>                                                                                                                             |
|--------------------------------------|------------------------------------------------|-------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| Individual cases (single occurrence) | high                                           | low                                                                           | „Level 1“: Cases in which the location of the root cause cannot be located are concluded in a simplified procedure (closed with "EIPD")            |
| Reoccurring, systemic cases          | minor                                          | high<br>with appropriate use of resources, know-how and information exchange! | „Level 2“: Cases that are subject to extended processing in the expert group with the cooperation of at least two participants in the supply chain |

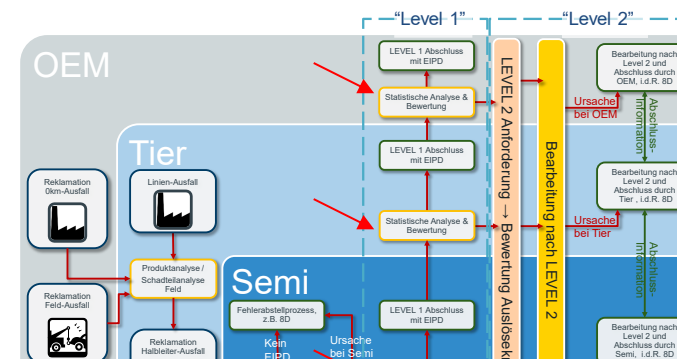


**VDA „EOS“ document defines criteria for single occurrence versus systemic issue!**



### 3. New flow according VDA standard – Level 1

- Details for Level 1:
- Statistical analysis, example Semi



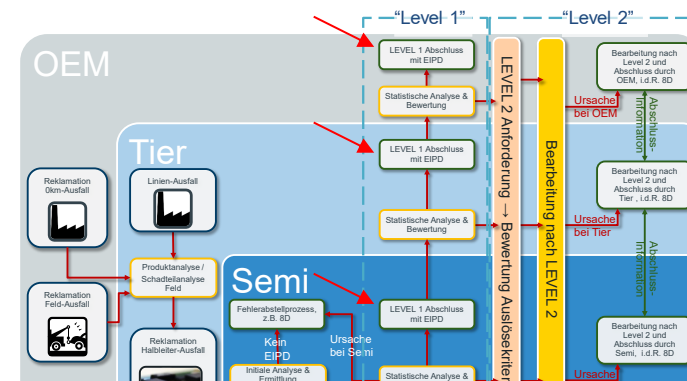
| #   | Question                                                                                                                      | Answer |
|-----|-------------------------------------------------------------------------------------------------------------------------------|--------|
| S1  | Have there been damages with a comparable failure picture from the same production unit (wafer lot) during the last 12 month? | Yes/No |
| S2  | Have there been damages with a comparable failure picture from the same production unit (package) during the last 12 month?   | Yes/No |
| ... | ...                                                                                                                           | ...    |

All answers „No“ ⇒ single case ⇒ close as „EIPD“

Source: VDA QMC

### 3. New flow according VDA standard – Level 1

- Details for Level 1:
- Assessment of situation, example Tier



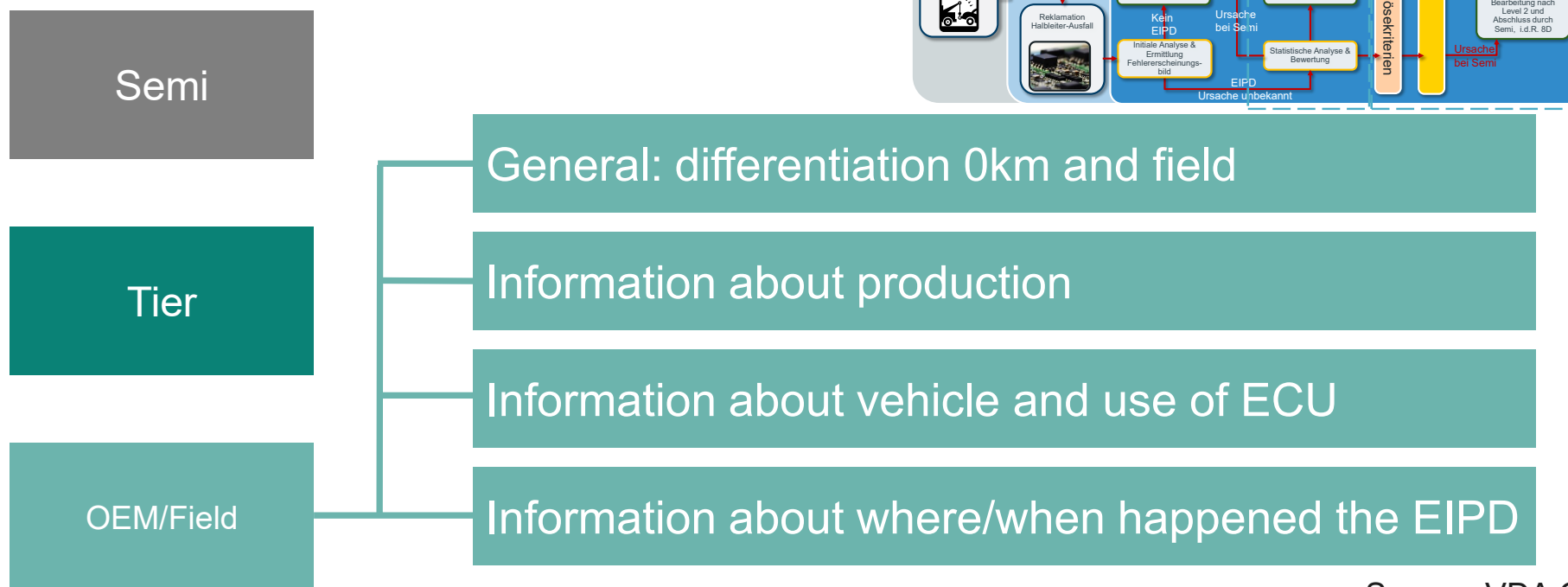
| #   | assessment/criteria                                                       |
|-----|---------------------------------------------------------------------------|
| TA2 | Damage during qualification / validation / requalification                |
| TA3 | Damage during start of production (safe launch for new start and restart) |
| ... | ...                                                                       |

Important: assessment is done individually on all levels!

Source: VDA QMC

### 3. New flow according VDA standard – Level 2 (-Questionnaire)

- Details for Level 2:
  - Cooperation of all partners
  - Information exchange: example OEM



Source: VDA QMC

(For a more detailed insight into the VDA standard & application: see “Rotband” and book a training @VDA QMC)

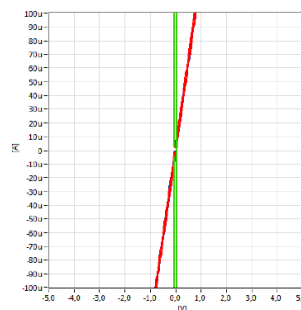
# 3. New flow according VDA standard – examples

- Complaint from OEM via Tier1 to Semi: failure at 0km- product does not meet specification

Initial analysis & determining failure picture

⇒ failure of Power MOS-FET confirmed by Semi

IV characteristic of  
Gate vs. Drain  
and Gate vs. Source



Optical inspection of chip surface  
after partial decapsulation



Statistical analysis & assessment

- S1 Have there been damages with a comparable failure picture from the same production unit (wafer lot) during the last 12 month?
- S2 Have there been damages with a comparable failure picture from the same production unit (package) during the last 12 month?
- S3 Have there been damages with a comparable failure picture above average <sup>1</sup> from the same device during the last 12 month?
- S4 Have there been damages with a comparable failure picture above average in the same technology (wafer technology and package technology) during the last 12 month?
- S5 Have there been damages with a comparable failure picture from other customers during the last 3 month?

**All questions  
answered with NO  
⇒ single case  
⇒ Level 1  
⇒ close as “EIPD”**

### 3. New flow according VDA standard – examples

LEVEL 2

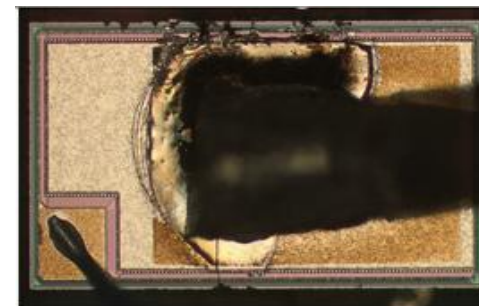
- Complaint from Tier1 to Semi: 15 cases reported by Tier 1 coming from 0 km fails from 3 different OEMs

Initial analysis &  
determining failure  
picture

⇒ Damage confirmed by Semi

burn mark under the bond area pin 3 with cracks  
seen in most cases

⇒ Indication of a huge overcurrent in the on-state



Statistical analysis by Semi

Statistical analysis &  
assessment

⇒ 15 cases from only 1 customer but 3 different OEMS

⇒ 20+ million parts sold

⇒ Affected Tier 1 taking approx. 1/3

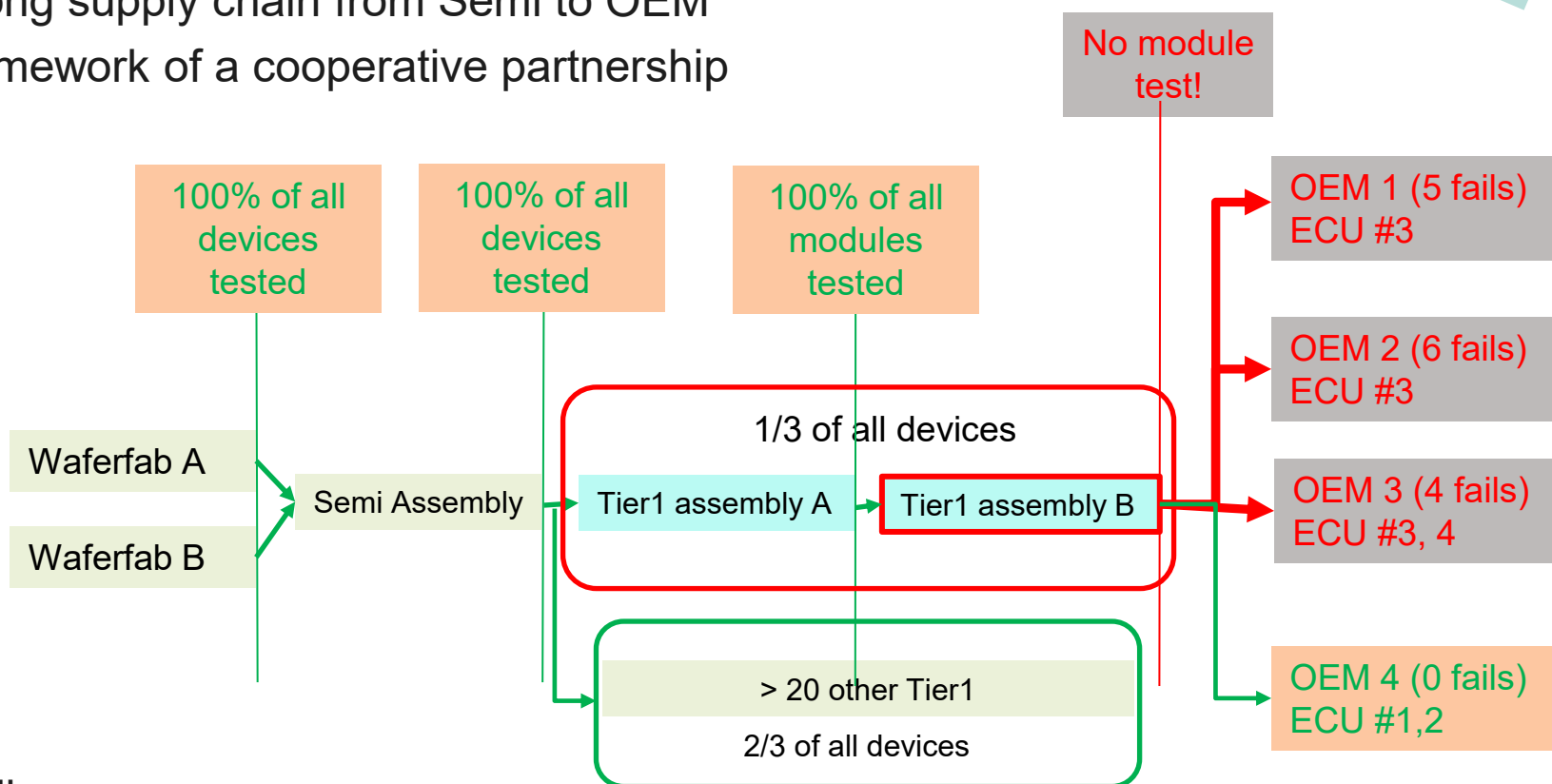


⇒ Statistical analysis now hints to systemic issues (at Tier 1)

⇒ **Conditions for Level 2 support fulfilled**

### 3. New flow according VDA standard – examples

- Process flow along supply chain from Semi to OEM
- Within the framework of a cooperative partnership



#### Findings:

- Damage probably happens in assembly B of Tier1
- Failure is coupled with specific application

Chart can only be created in cooperation with all parties involved (information exchange)!

### 3. Key Techniques applied in root cause finding

#### – Commonality study

- Investigation (machine mapping for failed devices) showed no commonality at Semi (waferfab and assembly)
- Investigation (machine mapping for failed devices) showed no commonality at first assembly site of affected Tier 1, but...

#### – IS / IS Not analysis

- Can give hint regarding location and type of stress

|       | Is                                                                 | Is not                                                |
|-------|--------------------------------------------------------------------|-------------------------------------------------------|
| What  | Power MOSFET Type A                                                | Other Power MOSFETs and other devices in same package |
| Where | Affected Tier1<br>OEM 1, 2 and 3<br>Under bond pad of affected pin | Other Tier 1s<br>OEM 4<br>other areas of the chip     |
| When  | 0 km fails                                                         | Semi production or Tier 1 (plant D) production        |

#### – Fault Tree Analysis

- Can give hint regarding location and type of stress (e.g., excluding ESD stress by looking at failure picture or location, exclusion of production parts due test coverage,...)

VDA process lays foundation to make use of these powerful tools

**Finally** root cause found? Not always disclosed to all partners  
VDA: “share information to all involved partners to avoid problem in the future!”



# Recap and Key Statements, Discussion



## Recap and Key Statements

- EIPD is one of the biggest challenges in electronic industry – happens in all parts of value chain.
- Problem solving and Root cause finding need cooperation between Semi / Tier / OEMs.
- Chances for finding the root cause rises significantly in case of systemic issues, not single events
- Flow and Process by VDA describes how to classify a case according to Level 1/Level 2 and enable cooperation
  - By this:
    - Follow Methodical problem-solving strategy
    - Avoid premature blame
    - Minimize failure analysis and operational expenditures
    - Improve meeting efficiency
  - Foster a strong and sustainable partnership for future growth
  - Learning Curve: Minimize or Eliminate EIPD redundancy

# Discussion

- 
- A large, out-of-focus microphone is positioned in the center-right of the slide, serving as a background element for the discussion points.
- Are you aware of both VDA/USCAR standards?
    - Do you apply them in your company?
    - What is your experience?
  - We could imagine to start an AEC working group to ...
    - exchange on experience wrt EIPD/FAR handling
    - review the process
    - work on improvements
    - compile EIPD cases from each partner and work on a comprehensive fault tree for classifying root causes
  - **Would you like to join such activity?**

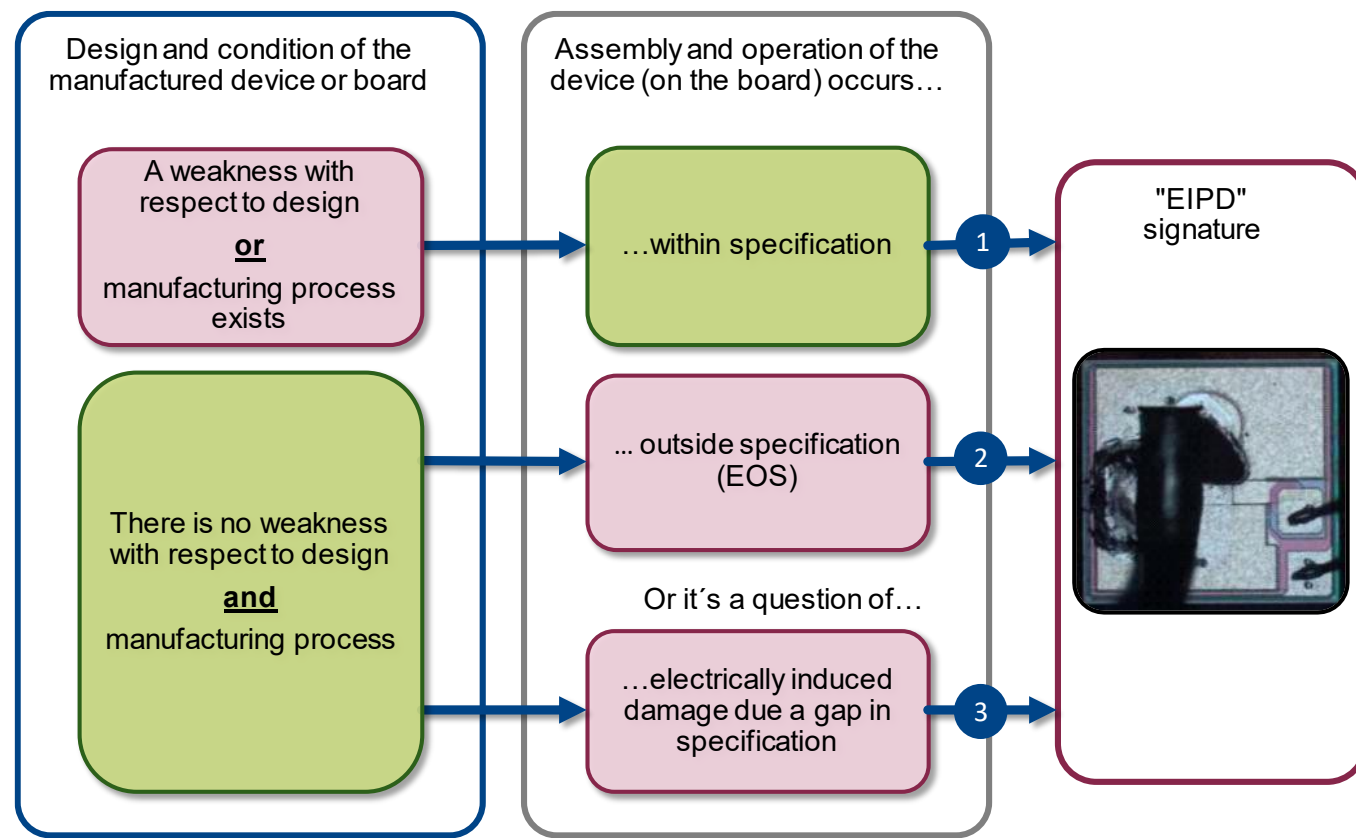


# Backup



# Ambiguity of failure signature, an even more general perspective

- 1) There exist further ways to damage part the same way
- 2) per se it is not clear, where did it happen!



- Causes of EIPD are manifold and cannot be determined for a specific case without further information from the customer/end user
- It makes it more difficult to reliably resolve a critical situation.

## Recap and Key Statements

- **Finally**
  - Be aware of AMR requirement, no violation
  
- Normally easier and cheaper to reduce/avoid electrical overstress than to introduce many new EOS stress pulses/requirements.
  
- IFX Americas, FY25/26:
  - nearly 50% of all repetitive cases have been processed as Level 2
  - almost 90% of them have been closed with root cause identified!

