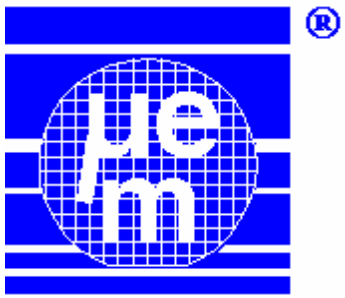
Introduction into ESD Challenges

P. Jacob, Empa and

EM Microelectronic Marin



THE SWATCH GROUP LTD

EMPA

Materials Science & Technology

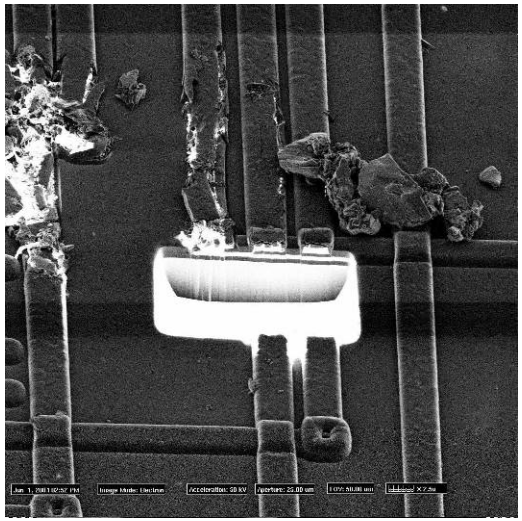
Present Concepts and Accepted Assumptions

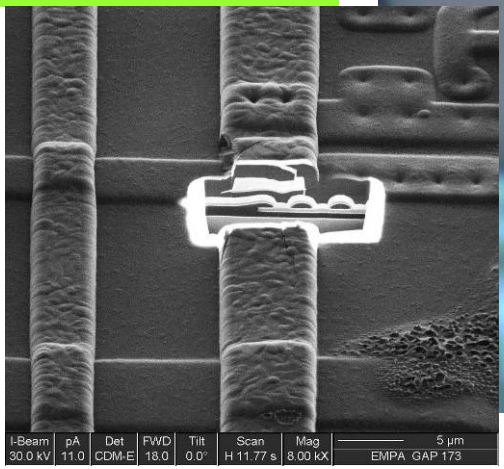
- **ESD is generally known as a problem of capsulated devices** if they are handled incorrectly: Touching by elektrostatically charged persons, non-ESD-safe mailing etc. generates high-voltage pulse introduction into device pins
- Therefore, device **pins are protected** against ESD **by special protection structures**.
- Using standardized **ESD tests**, based on generally accepted models (human-body-model, charged-device-model, machine-model) the chips should be **tested on their ESD-robustness**, which is basically limited by the quality and area of their pin-protective structures.
- **ESD influence by operators** should **be avoided by suitable protection concepts** (floor, shoes, hand discharge setup etc.)

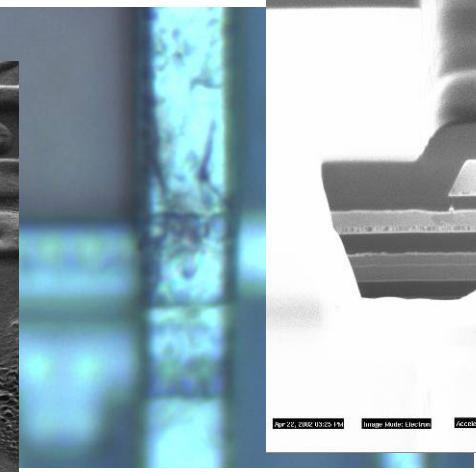
Considerations

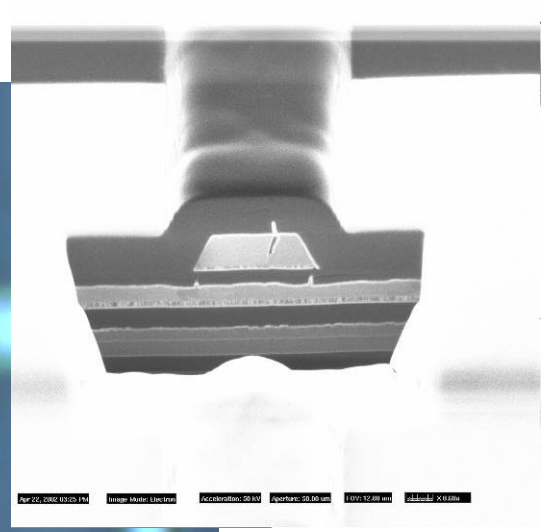
- **ESDFOS (Electrostatic Discharge From Outside to Surface)-related failures are often mixed up with mechanical damage**
- **No specific ESDFOS examinations related to copper metallizations have been done, yet**
- **We punish non ESD-conformal behaviour of line staff, but still accept kV‘s of device surface charging by tool robotics !!!???**

ESDFOS History



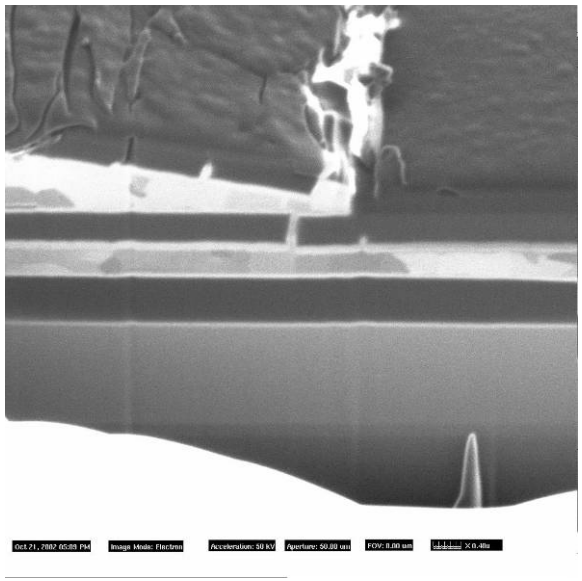


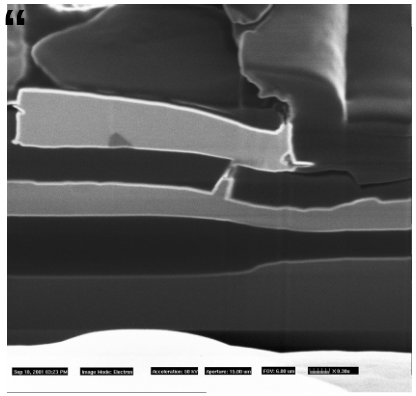




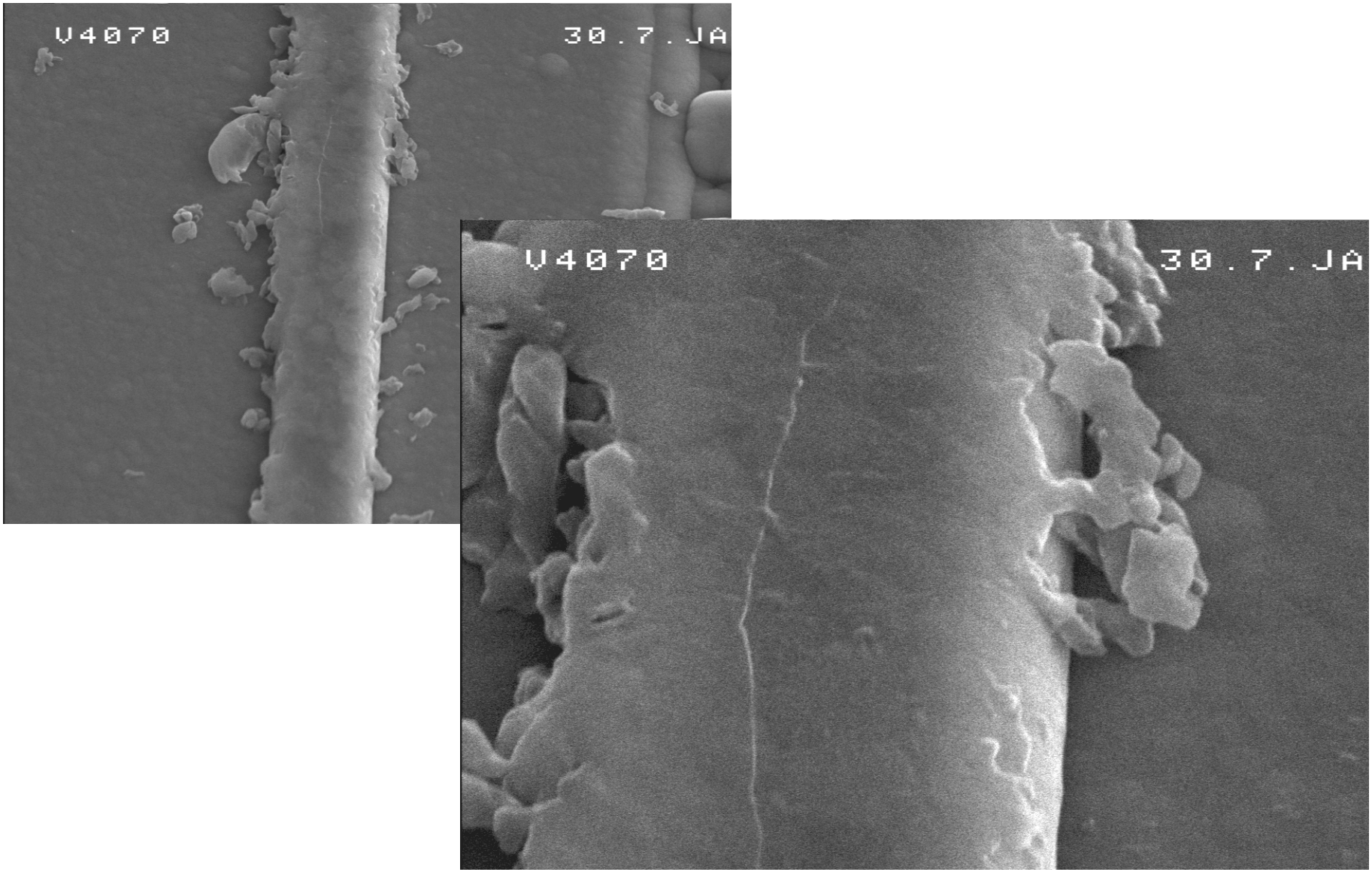
Such failures were proven as typical ESDFOS failures

Often they have been wrongly taken into the category of „mechanical damage“

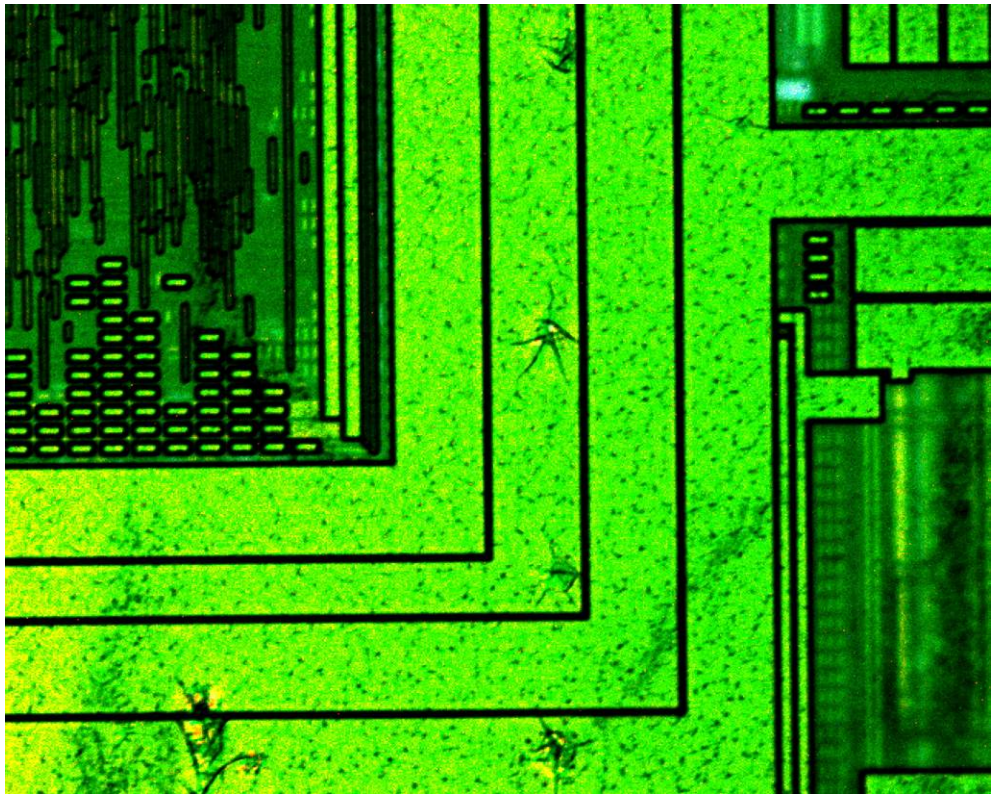


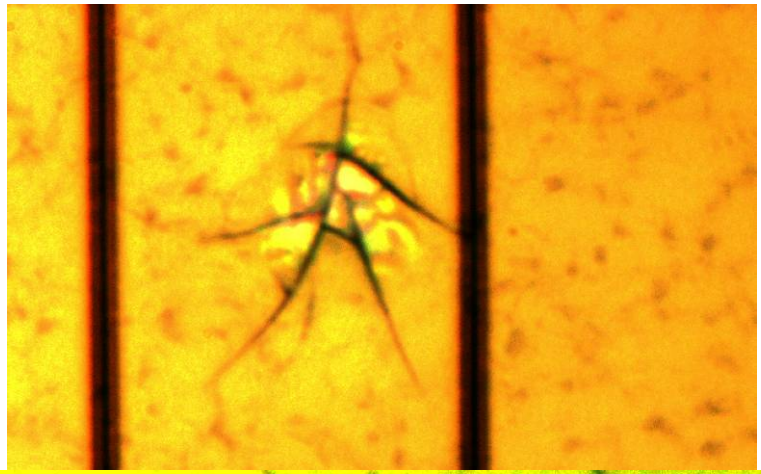


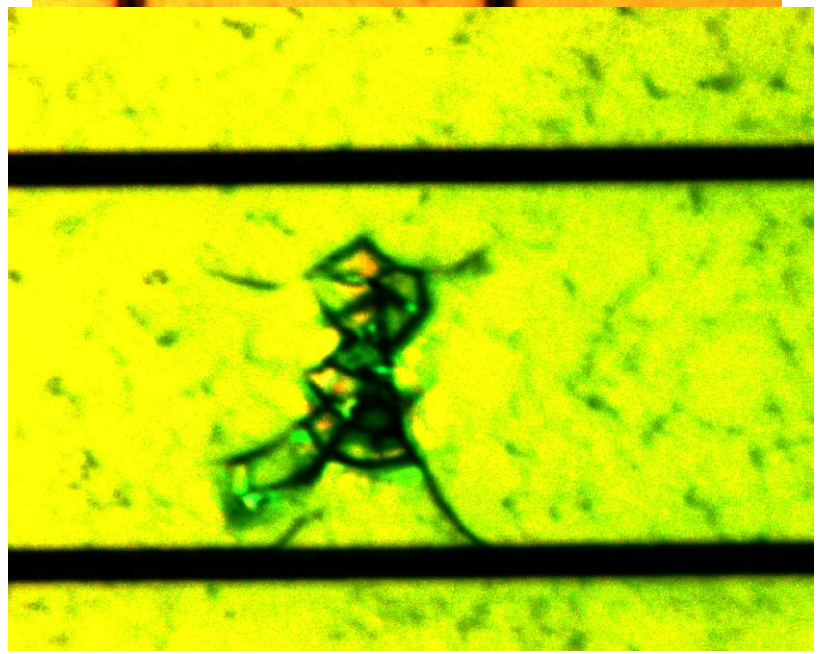
Crack length and SEM appearance



ESDFOS by ultrasonic cleaning

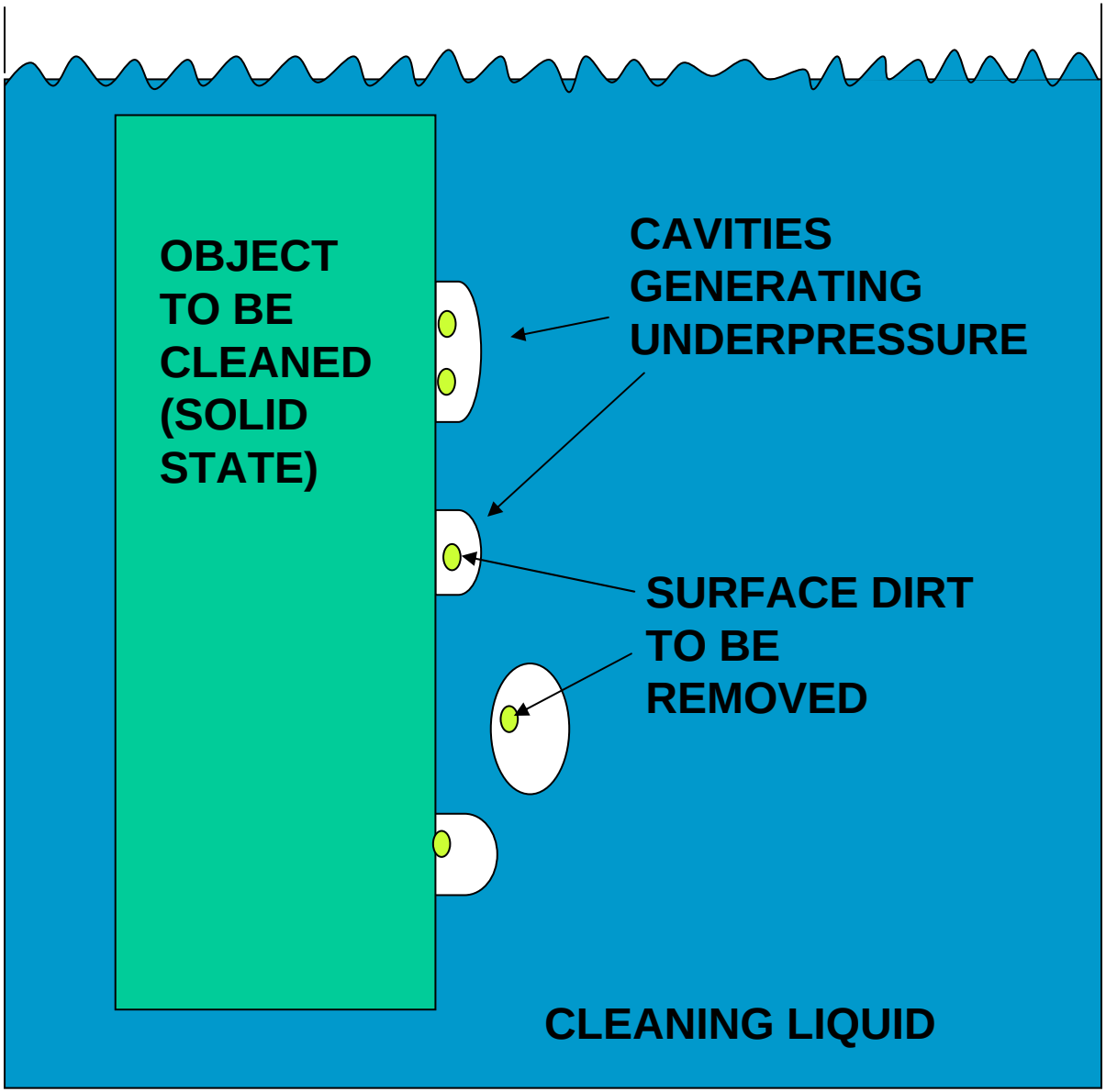






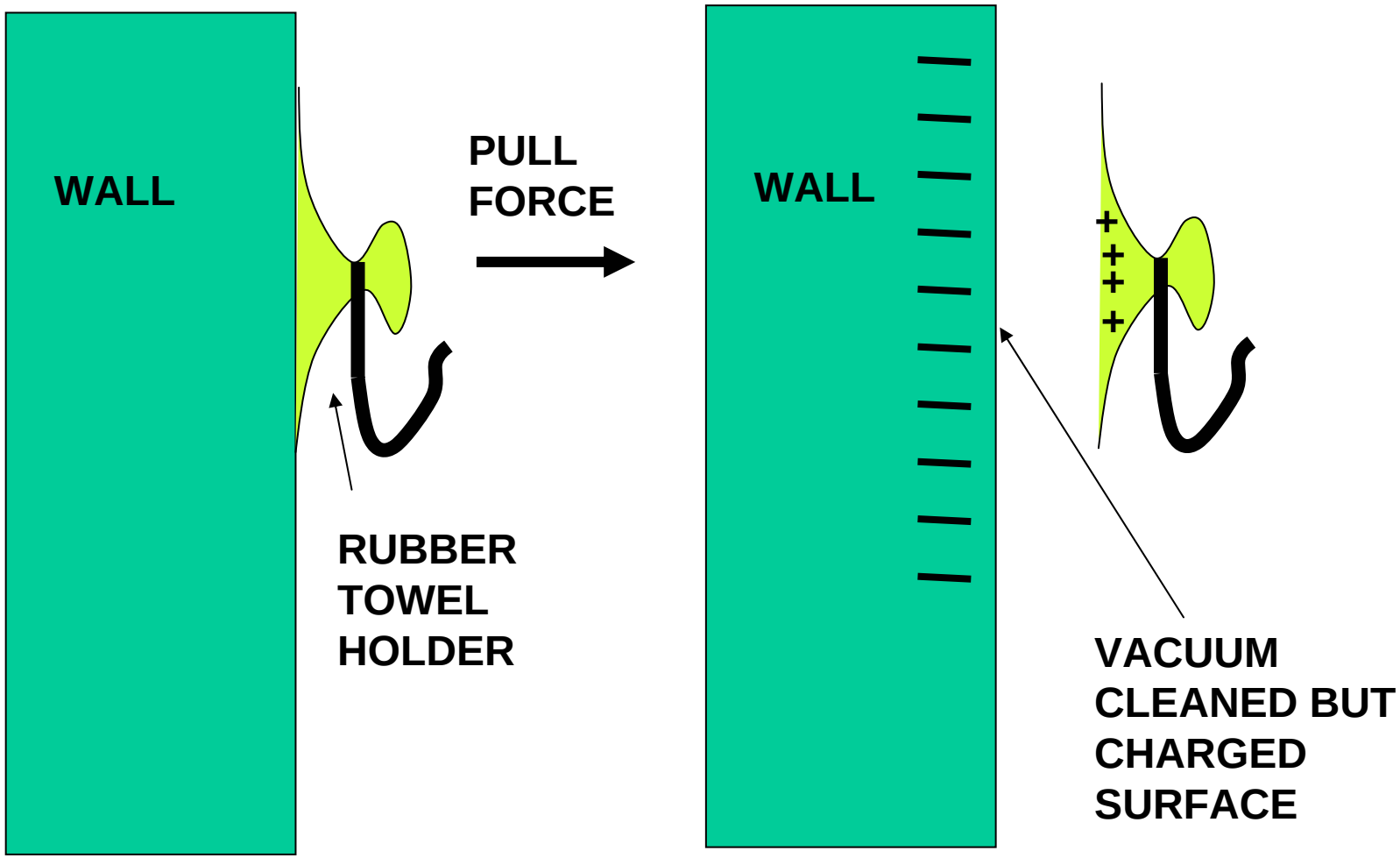
This example shows US-cleaning-induced ESDFOS, using some days old DI-water. After replacing the water by new DI water, the effect disappeared.

Ultrasonic Cleaning Principle by Cavities

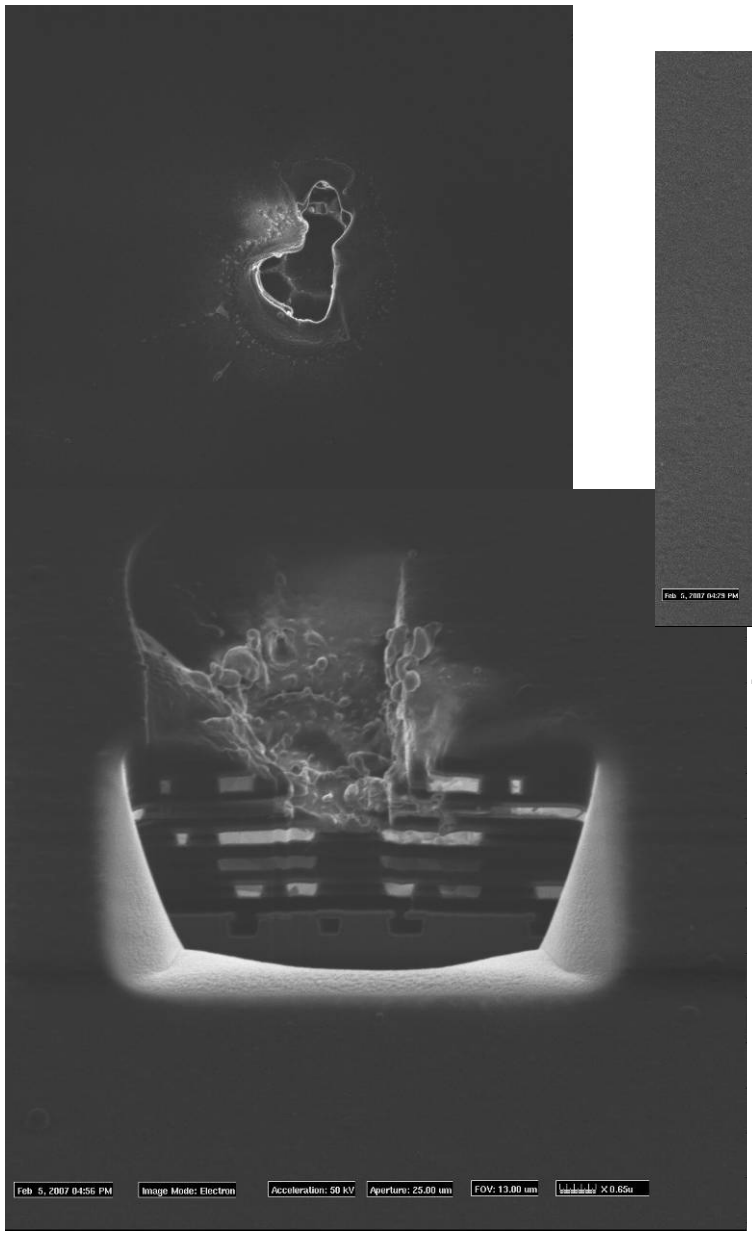


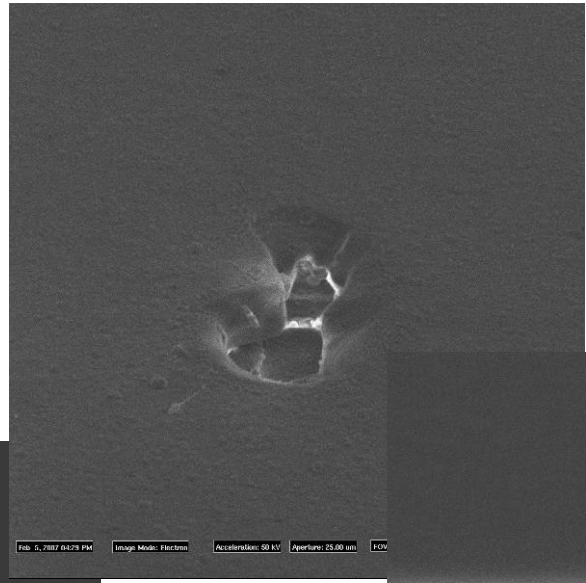
Ultrasonic bath, frequency approximately 42 kHz, often using isolating cleaning liquids

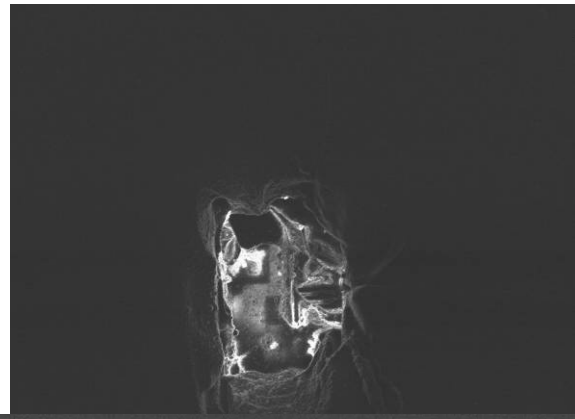
Model for Cavity Ultrasonic Cleaning Effect

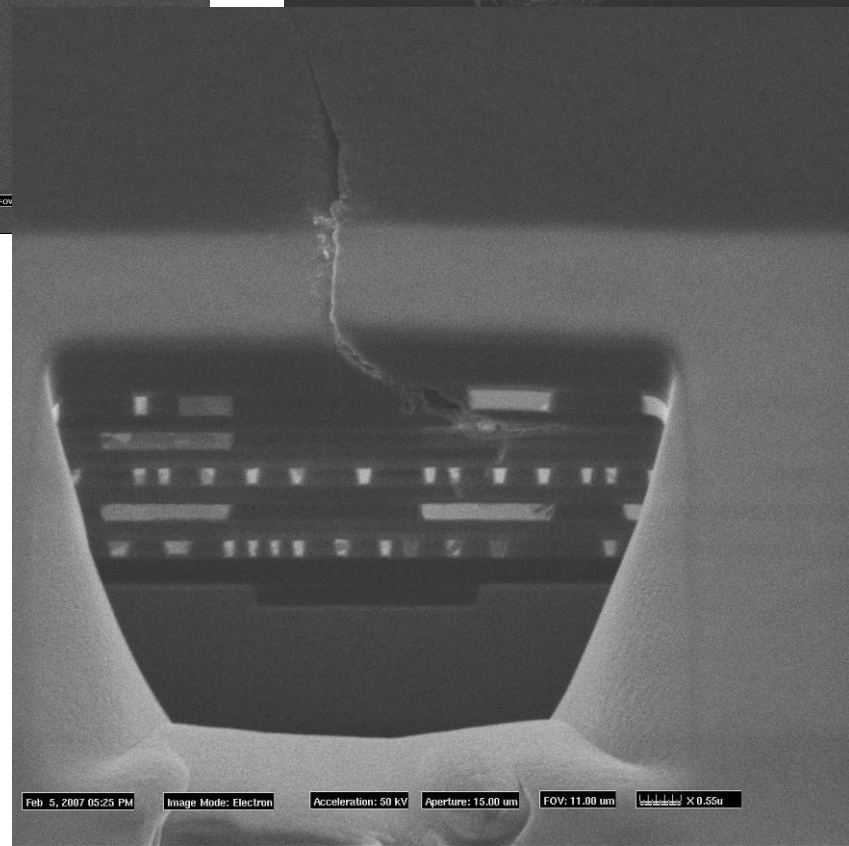


Cu-ESDFOS



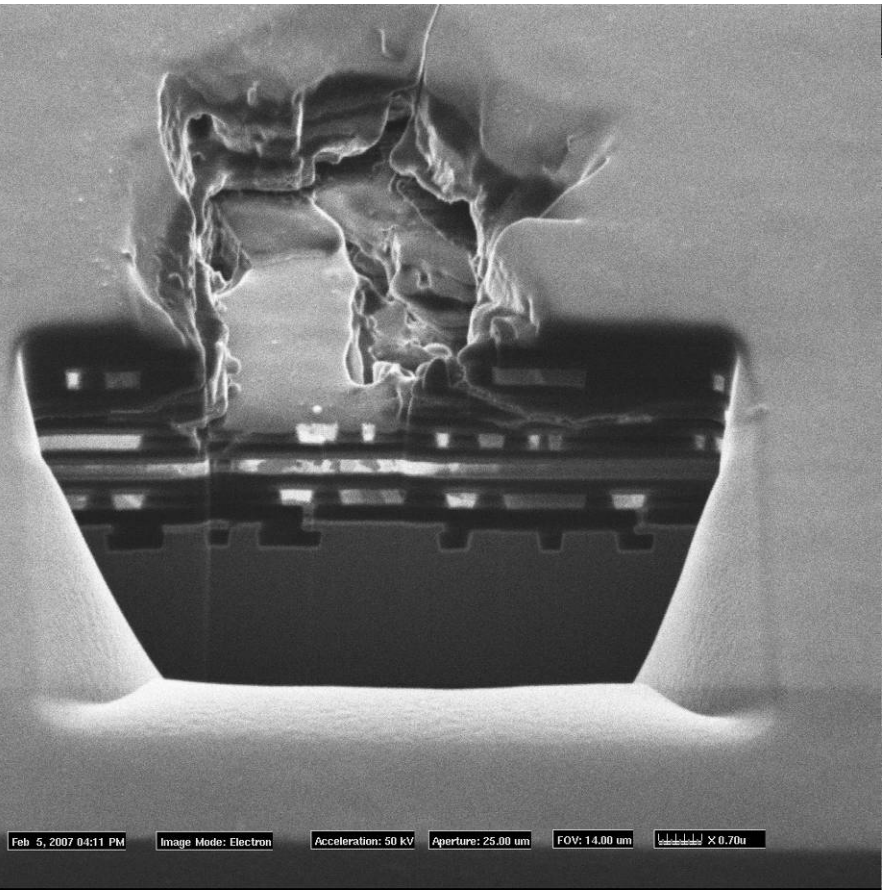


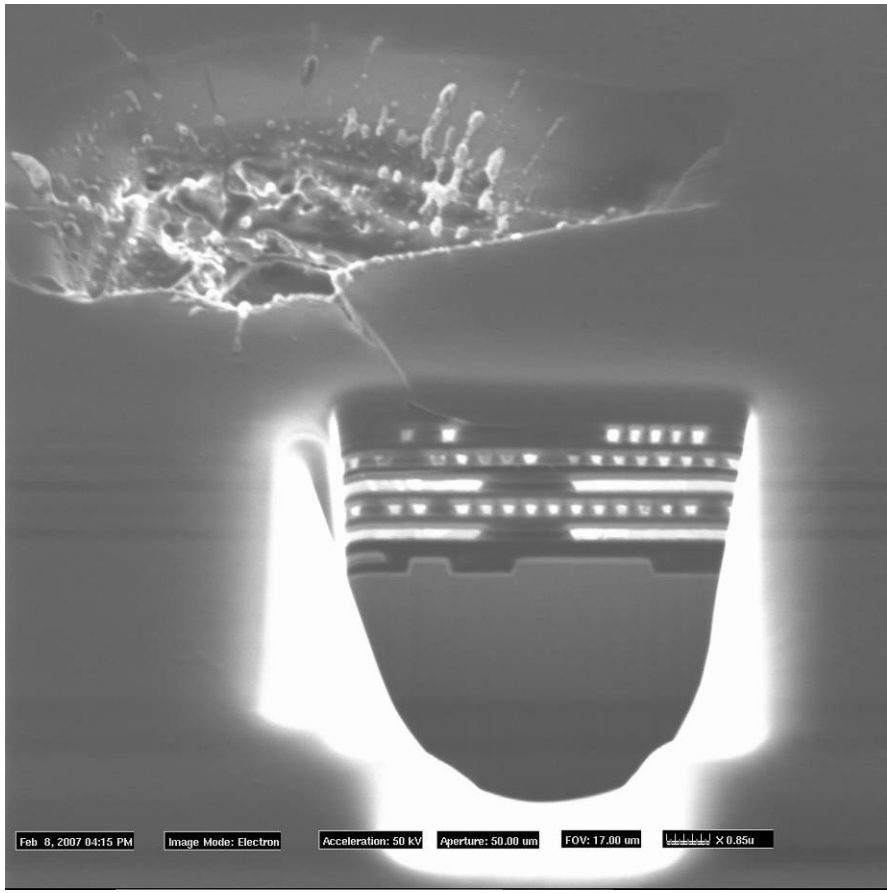




The top 1-2 metal layers are damaged

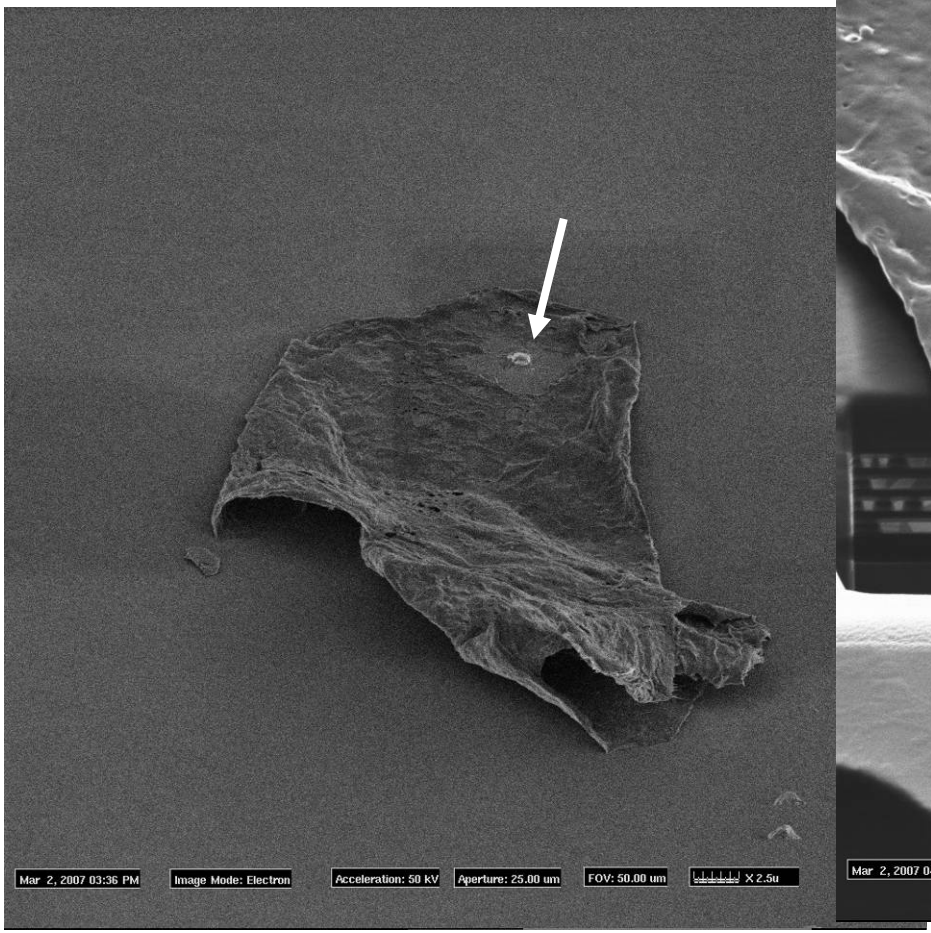
Cu: High Severeness





Damage into deep metal layers, cracking interlevel dielectrics in-between

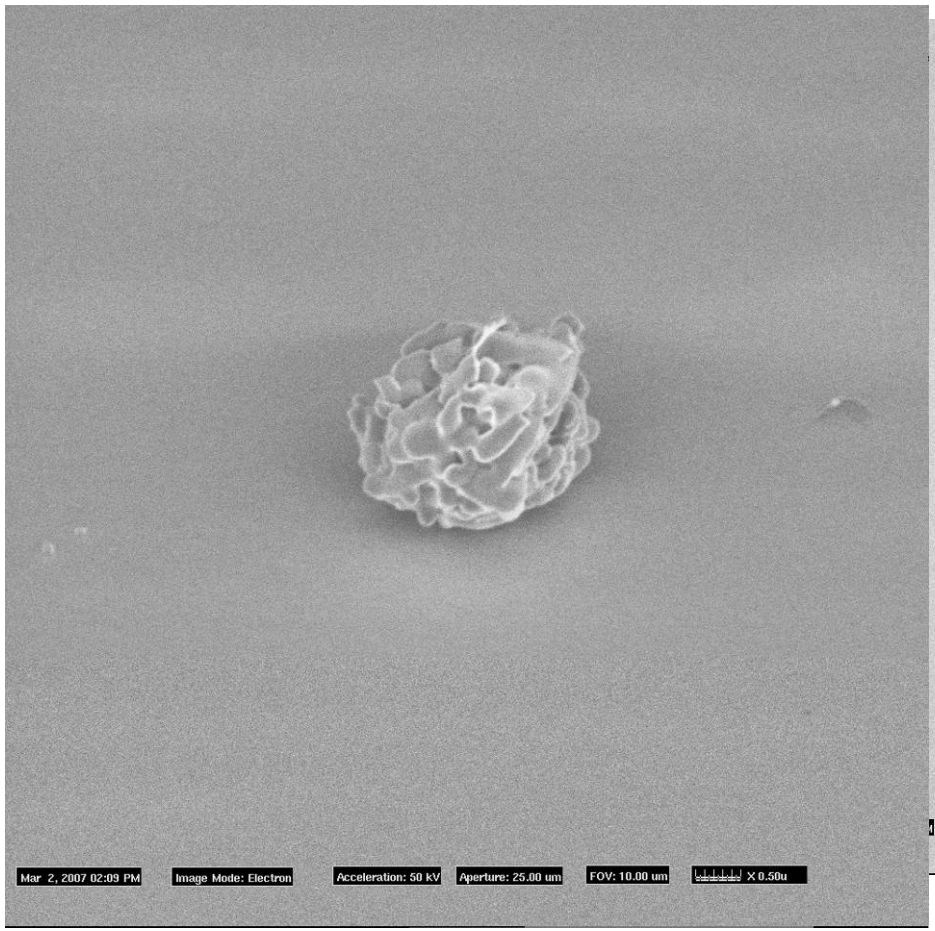
ESDFOS on Cu-metallized devices (6)

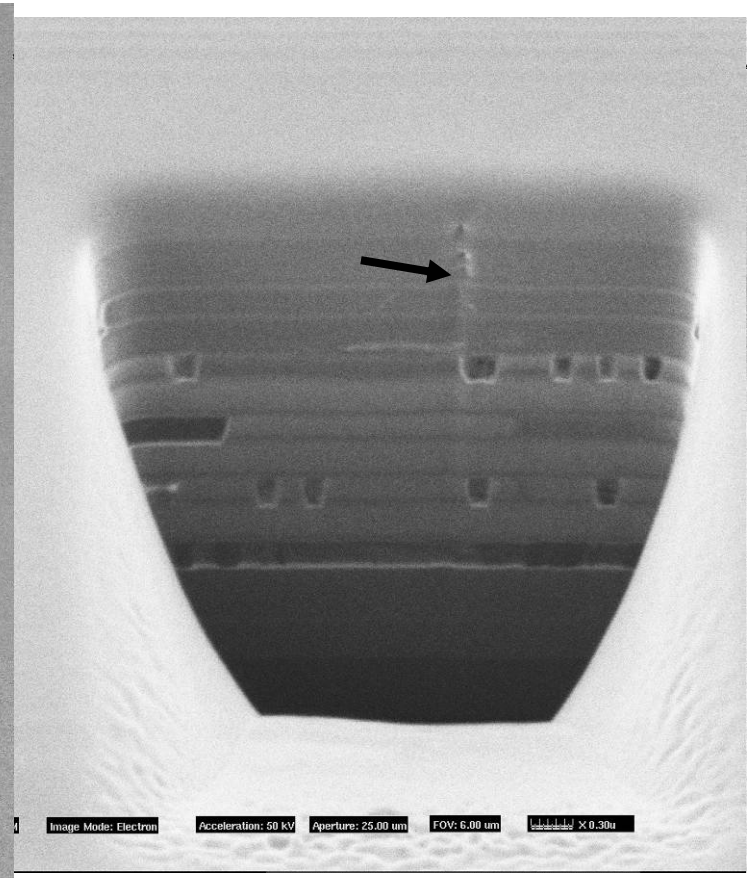


No one would imagine this particle to be ESDFOS-caused

...but the FIB cross section proves exactly this (180° rotated cut thru hole)

ESDFOS on Cu-metallized devices (8)





In some cases, ESDFOS is accompagnied by small, „collected-material“- particles, which disappear after the FIB cross section

Conclusions for Charge Generation: Where Do We Have ESD-Risks ?

- Touching or disconnecting isolating materials
- Rolling movements of isolating materials
- Fast movement of DI-water, powders, sand etc.…
- Mechanical friction

Usually it is sufficient, if *one* of the participating materials is an isolator

Tool ESD Risk Assessment Preparations

- Measurement of humidity and temperature
- Electrostatic activity measurement by an electrophorous: spark length should be 5mm or more vs GND.
- Measurement of the air ionization degree (in prep)
- Should the electrophorous test indicate insufficient electrostatic activity, the audit cannot be made.

Visual check of material selection/ setup/ media

- Where are triboelectric materials very close to DIPs (devices in process)
- Triboelectric medis involved in process sequence ? (DI-water w/o CO2-bubbling, gas flows, non-antistatic plexiglass-covers etc...)
- Are toothbelts, transmission/ transportation belts etc made from dissipative materials ?
- Setups existing, which remember to electrostatic generators ?

Charge separation by water spraying in wafer sawing

Using a new developed Trek measurement head for humid environment measurements, it was found, that the surface voltage of water drops may reach some hundreds of volts

How to Fight Against Tool-ESDFOS ?

- Performing of a ("smooth") potential discharge (using copper GND belts etc)
- Use of antistatic or conductive materials
- Local discharging using ionizers
- Employee´s training
- Chip-design-specific measures for device-internal soft discharge
- Periodical ESD checks of process equipment using suitable measurement setups

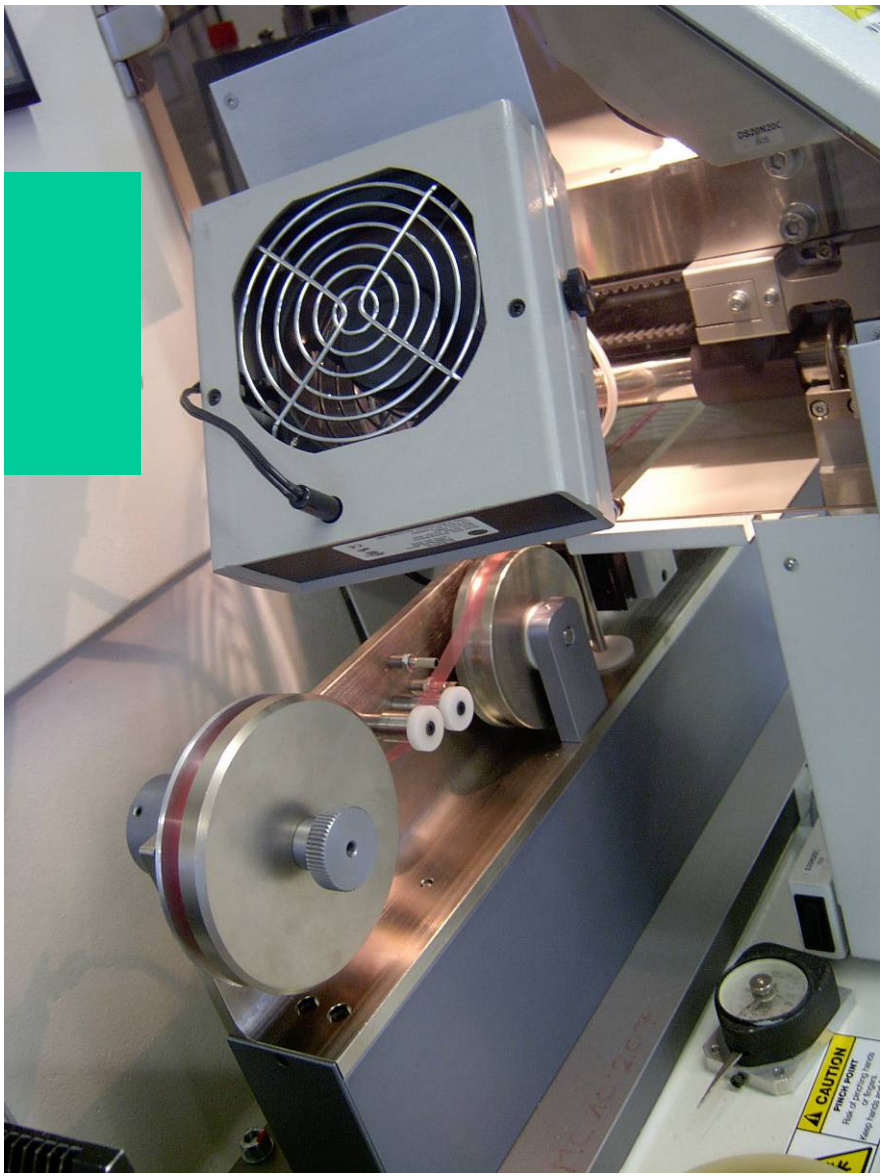
Charge measurements at critical positions

- Robitics must be programmed/ supervised by the tool engineer
- Make measurements if possible during movements; use field meter or Trek voltmeter.
- Charging > 300 Volt is critical to ESDFOS. In case of bad electrostatic conditions (Elektrophorous <5mm) at least 100% safety margin should be added to the results. Breakdown of usual oxinitride passivation is at about 500V

Ionizer check

- Use charged-plate measurement setup
- If not available, use a charged metal ball and measure its discharging after exposing to the ionizer
- Ionizer PWR-supply: is it directly wired to the process equipment or is it switched separately ? – Risk of bewing switched-off when the process is running
- Periodic check at least quarterly

Protection of the chip placing onto the tape

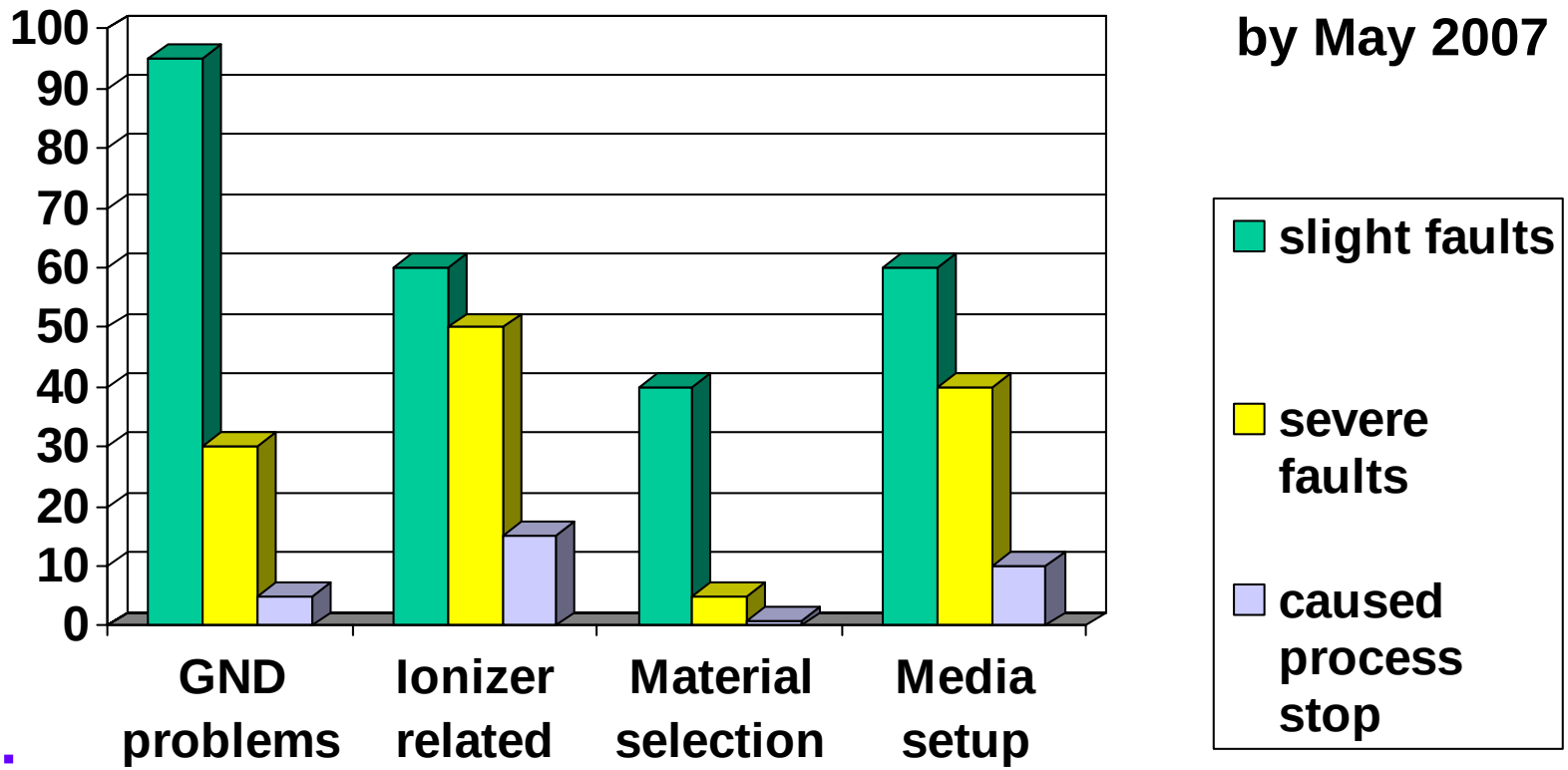


When electrostatic charging cannot be avoided, air ioniozers make the air locally conductive. This allows a controlled, smooth discharge of charged bodies and dies. However,mounting instructions must be carefully considered. The range and direction of an ionizer is very limited, depending from its construction

GND connections/ resistances

- Visual check of process sequences
- Measurements of metallic parts to GND: Resistance should be < 1MOhm. Attention: No scratching with measurement needle: Lacquered or anodised surfaces are isolating and chargeable !
- GND-concept (GND-star, defined potential, etc.)
- If necessary, scope measurements on critical pulses, coupled for example by internal RF or sparking (e.g. wireball-bonders)

Failures in assembly tools by Failure type



HITS:

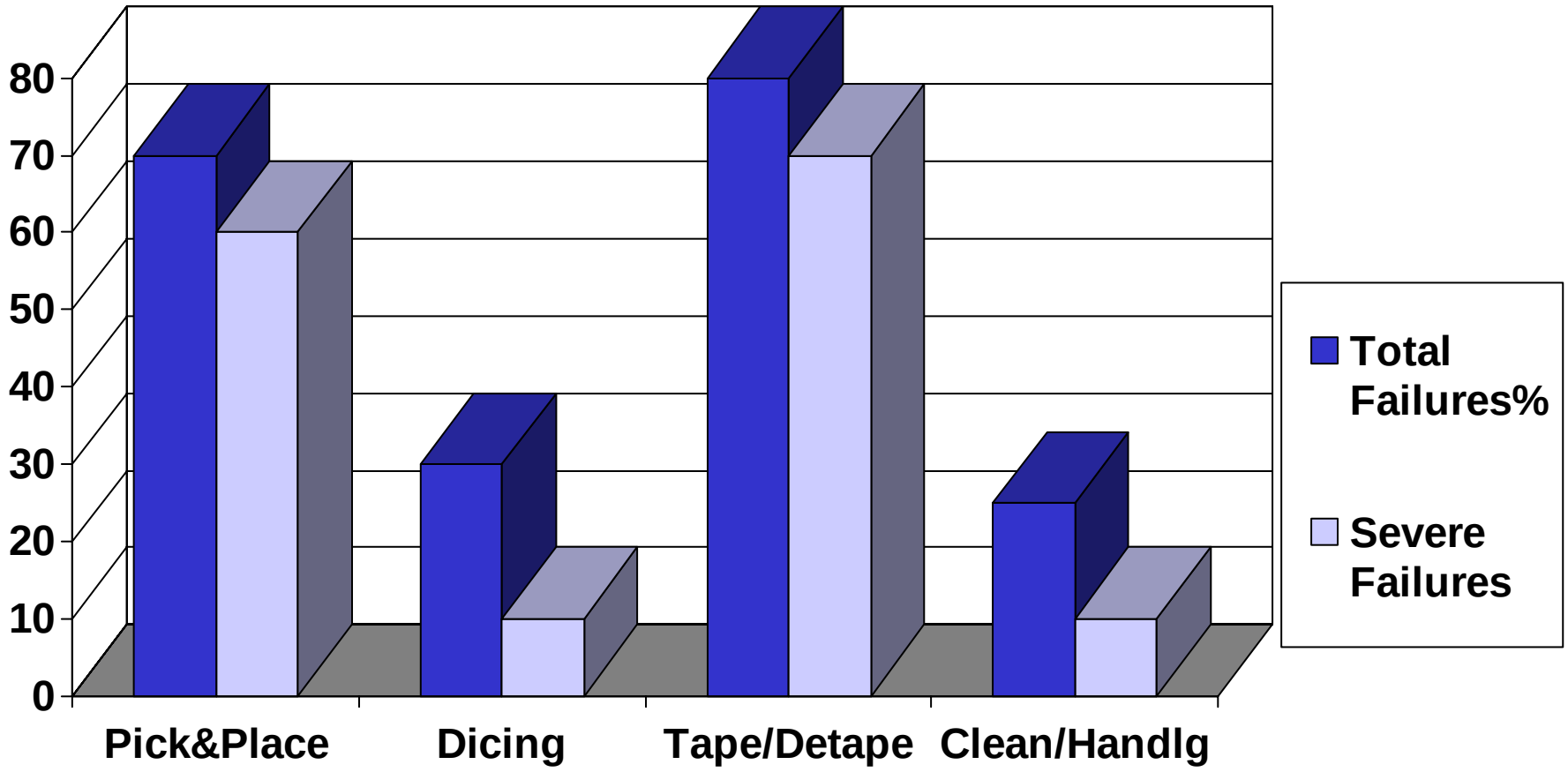
-GND: floating, anodised material, no GND concept, metal on plastics

-Ionizer: missing, no function, out-of-range, inst.localisation; sw.off

-Material: Teflon rails and wheels, triboelectr. transmission-/tooth-belts

-Media/ Setup: foils/ carrier tapes, Water, gas/ airstreams

Audit results by assembly processes



Space availability for ESD protection

- Devices become more sensitive due to structure miniaturization
- Shrinking success must not be eaten by requesting more ESD protection

New thinking in ESDFOS

- Process equipment needs to be ESD certified
- Should we approach to standardized or engineering solutions ?
- Ban of triboelectric process media, especially taping foils

ESD ideas entering into...

- System ESD protection
- Other branches (hospital, textile industry...) more and more involved
- Machine construction
- MEMS/ MOEMS (specific failure modes)

High speed circuitry

- ESD pulses do not obey „what they should“: HBM, CDM, MM are only virtual approaches; frequently, they don‘t match with field reality
- Reality requires new test strategies: VFTLP, PCB-CDM....? (Leadership of FhG-IZM)

F/A Diagnosis on ESD-related problems

- ESD often masked by subsequent EOS
- ESDFOS specific to technologies
- Non-destructive ESD and ESDFOS problems (memory delete, reset etc)
- ESDFOS on power semiconductors, causing border passivation problems

Conclusion: are our efforts in ESD protection on the right focus ?

- ESD-protected workplace setup
- ESD robotic tool protection
- ESD-useful design
- ESD-test strategies
- Understand electrostatic activity
- System-ESD-protection
- Training/ Education
- ESD-related F/A diagnosis

Today‘s focus	Future need
++	↓
O	↑
+	↑
+	↑
--	↑
--	↑
+	→
--	↑