MOISTURE IN PCBS
DEVELOPMENT OF AN EFFICIENT DRYING PROCESS

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

AGENDA

Moisture in printed circuit boards - development of an efficient drying process

1. When is moisture in printed circuit boards critical?
   - Thermal stress
   - Fault images
2. Documents in customer communication
3. Moisture content - a balance
4. Moisture content - influencing factors
5. Drying - but how?
   - Oven technologies and drying time
   - Developing an efficient drying process
6. And the logistics?
7. Drying and solderability
8. Further reading

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WHEN IS MOISTURE IN PRINTED CIRCUIT BOARDS CRITICAL?

Humidity and thermal loads simultaneously

Effects on the PCB-material

- Moisture leads to swelling of polymers
- Moisture reduces adhesion forces at boundary layers, for example due to hydrolysis
- "Moisture reduces the critical fracture toughness" and the Young's modulus of polymers → Crack propagation is favored

(see Fraunhofer IZM, Dr. Hans Walter, Einfluss von Feuchte und Temperatur auf die Zuverlässigkeit von Packaging Materialien, 14. Europäisches Elektroniktechnologie-Kolleg, März 2011)

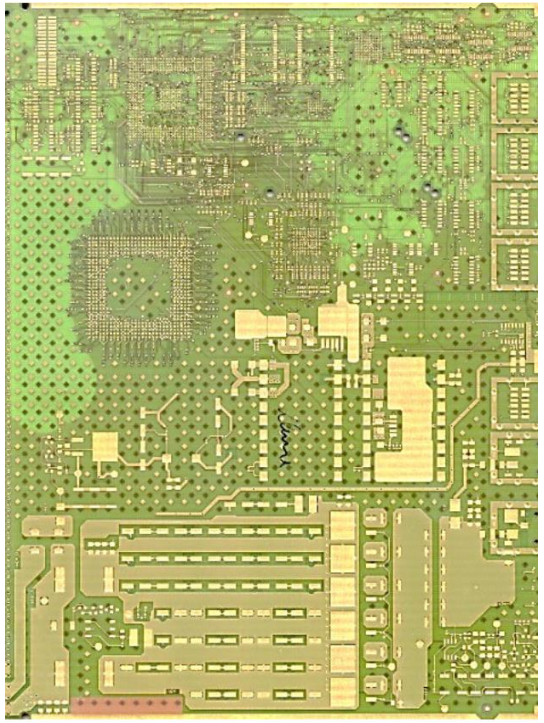
Thermal loads of a printed circuit board

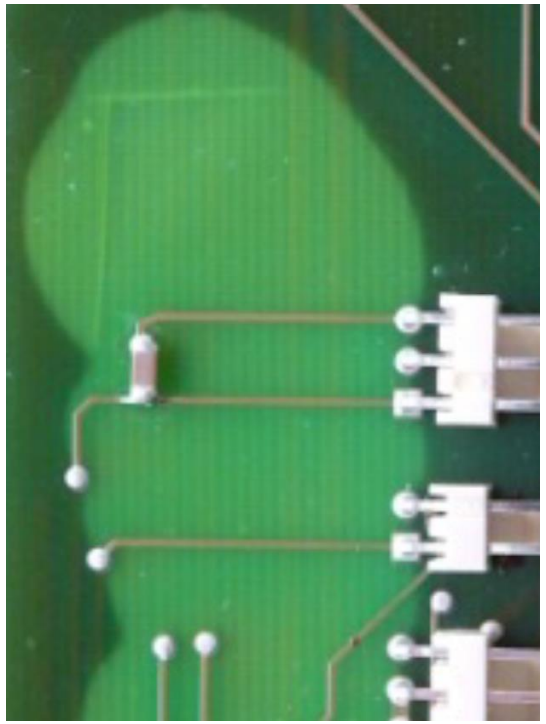
- Drying processes
- Preheating before the soldering process
- Adhesive curing for 2-sided SMD assembly
- Wave soldering
- Reflow soldering
- Selective soldering
- Rework (possibly manual soldering!)
- Repair soldering (possibly manual soldering!)

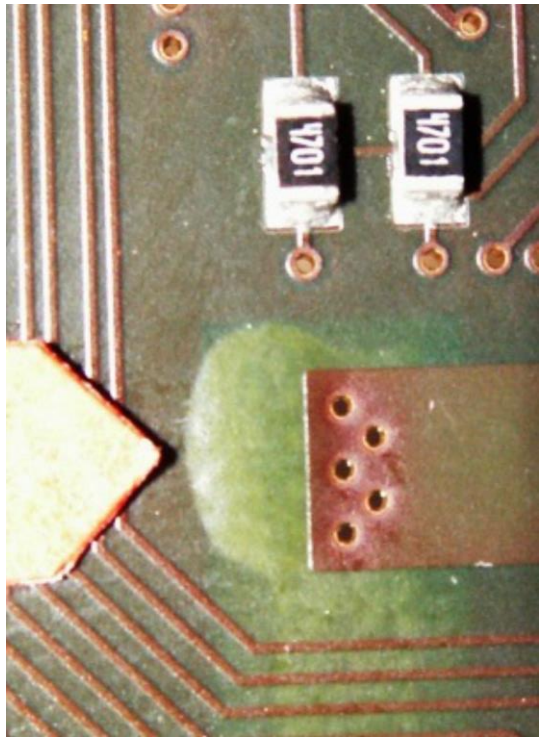
WHEN IS MOISTURE IN PRINTED CIRCUIT BOARDS CRITICAL?

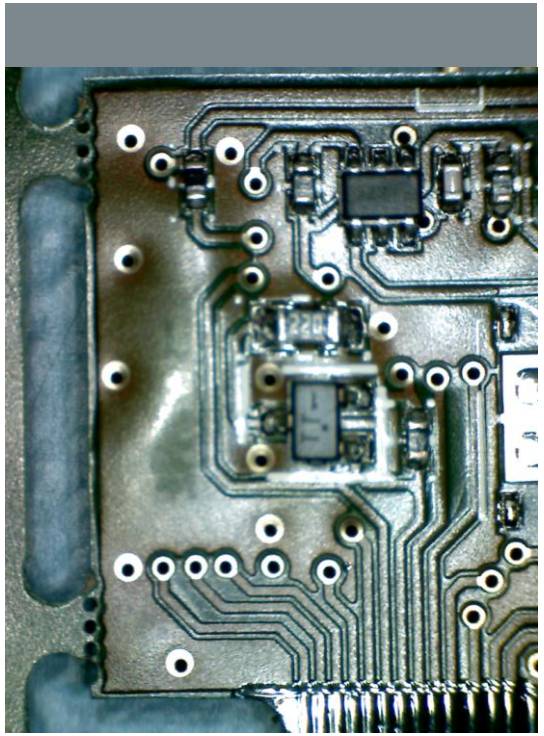
Typical error patterns after soldering

- Bright spots large area
- Bubbles without copper
- Bubbles with copper
- Bubbles under copper









POLL

Multiple-Choice

When are PCBs completely dry?

- Before the washing process before electrical test
- On delivery
- On picking from the stock
- After the first reflow process
- Never

DOCUMENTS IN CUSTOMER COMMUNICATION

ZVEI-Guide values/ Recommendations

- „Trocknen von Leiterplatten vor Löten“
- „Lagerbedingungen für unbestückte Leiterplatten“

Richtwerte/ Empfehlung „Trocknen von Leiterplatten vor Löten“

ZVEI: Die Elektroindustrie

(Parametersetzung obliegt anwenderspezifischem Verarbeitungsprozess)

Zielstellung:

- Trocknung = Verminderung Feuchtigkeit im Basismaterial vor Lötverfahren
- Vorbeugung Delamination durch thermische Beanspruchung nach Feuchteaufnahme

Methoden:

- Trocknung durch Konvektion bzw. in Vakuumtrockenofen
- Parameter* in Abhängigkeit von Materialtyp, Lötoberfläche, Lagenanzahl, Zeitspanne bis Löten, Layout (Cu-Flächen)

Parameterempfehlung:

- Trocknung in Konvektion-/ Umluftofen bzw. in Vakuumtrockenofen, nicht im Stapel

	Material	Parameter	Zeit bis Lötprozess
Trocknung	FR4 (Tg 135 °C)	120 °C, ≥ 120 min	maximal 24 h
	FR4 (Tg > 135 °C)	130 - 150 °C, ≥ 120 min	maximal 8 h
	Starr-Flex, Flex ML ≥ 6 Lagen	130 - 150 °C, ≥ 120 min	maximal 8 h
		130 - 150 °C, ≥ 120 min	maximal 8 h

- Vakuumtrocknen bei 50 mbar erlaubt 20 K niedrigere Temp. und 60 Minuten kürzere Zeit
- Vakuumtrocknen bei thermisch sensiblen Oberflächen (z.B. chem. Zinn) empfohlen

(siehe auch Richtwerte/ Empfehlung „Lagerbedingungen für unbestückte Leiterplatten“)

Fachverband PCB and Electronic Systems im ZVEI e.V. , AK Qualität 28.02.2008

Richtwerte/ Empfehlung „Lagerbedingungen für unbestückte Leiterplatten“

ZVEI: Die Elektroindustrie

(Anforderungsumsetzung obliegt anwenderspezifischem Lager/Verarbeitungsprozess)

Zielstellung:

- Handlungsanweisung zur Erhaltung der Lötbarkeit unbestückter Leiterplatten
- Vorbeugung mechanischer Beschädigung und Lötbarkeitsreduzierung

Methoden:

- Definition Lagertemperatur und -luftfeuchtigkeit
- Lagerung in definierter Verpackungsart/Verpackungsfolie

Parameterempfehlung:

- Lagertemperatur max. 30 °C; Luftfeuchtigkeit max. 70 % r. F.
- Verpackung:
  - genadelte Schrumpffolie (PE-Folie)
  - beschichtete Vakuumfolie (Vakuumbeu
  - antistatisch
- optional Feuchtigkeitsindikator, Trockenmittel bei Vakuumverpackung
- optional mechanische Unterstützungsplatte (einseitig, beidseitig)

(siehe auch Richtwerte/ Empfehlung „Trocknen von Leiterplatten vor Löten“)

Fachverband PCB and Electronic Systems im ZVEI e.V. , AK Qualität 28.02.2008

DOCUMENTS IN CUSTOMER COMMUNICATION

Drying specification

- Drying instruction "Offer" as an attachment for offers for flex solutions
- Drying instruction "Shipment" as a delivery provision for flex solutions

- Important difference: copper design

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

DESIGN- AND DRYING SPECIFICATION FOR FLEX SOLUTIONS

Flexible and rigid-flexible PCBs must be dried before soldering, the copper layout must be modified for this purpose!

WHY? Strictly speaking, PCBs are never completely dry, i.e. without moisture. That is why the original packaging is marked with this label:

Caution! Moisture Sensitive

This is equivalent to MSL6 for components according to IPC/JEDEC J-STD-033, drying before the soldering process is mandatory. Despite packaging, the PCBs may have a critical moisture content!

WHAT CAN HAPPEN? Typical defects are delaminations as shown in the picture on the right. *We would like to point out that any liability for delamination and its consequential damages is excluded if these recommendations are not followed and documented.*

WHAT DO YOU HAVE TO PAY ATTENTION TO? To avoid damage, the following points must be checked and observed:

1. Copper layout with openings
2. Storage
3. Sufficient drying
4. Adapted logistics

1 COPPER LAYOUT THAT ALLOWS DRYING

Copper traps moisture, large copper surfaces prevent sufficient drying in reasonable drying times. Therefore, it is necessary to provide openings on copper surfaces **on all layers** to allow moisture to diffuse to the surface over a short distance. This applies to both the flexible and the rigid areas in the case of a rigid-flexible PCB!

Our recommendation for the design: copper openings with at least 0.3 mm of 1 mm copper length (up to 70 µm base copper thickness).

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DESIGN- AND DRYING SPECIFICATION FOR FLEX SOLUTIONS

2 SHORT AND AS DRY AS POSSIBLE STORAGE

Long storage periods, for example over several months, lead to ever higher moisture absorption and make extended drying times necessary to avoid damage during soldering. Printed circuit boards should always be stored in their original packaging.

Ideal storage for Flex and Rigidflex is in a dry storage cabinet 5 % RH at room temperature.

3 SUFFICIENT DRYING

Drying must take place in a suitable process. Article-specific drying parameters can be determined by establishing drying curves. This also applies especially to repairs, e.g. when replacing components. An impairment of the soldering behaviour due to the drying process must be taken into account if necessary. With our standard surface ENIG there are no problems in this respect.

General drying parameters from PCB manufacturers can only be understood as reference values or rough recommendations and must be verified by the processor on a product-specific basis. Both the design influences and the specific ambient, storage, drying and soldering conditions with the associated logistics play a major role.

- An efficient drying temperature is 120 °C.
- The drying time should be at least 4 hours, up to 24 hours may be required.
- If the copper layout is not suitable, sufficient drying can require massively extended drying times or, in extreme cases, be impossible. A long storage period then has a very negative effect ("worst case").

4 ADAPTED AND MONITORED LOGISTICS

Assembly and soldering must take place immediately after the drying process (within 2 hours), as the hygroscopic properties of the PCBs remain. In case of waiting times after drying or between several soldering processes, storage in a drying storage cabinet is recommended. Thus, another drying process can be saved.

A detailed elaboration „Physics of moisture & process of drying printed circuit boards – a collection" can be found here: www.we-online.com/dryingprocess

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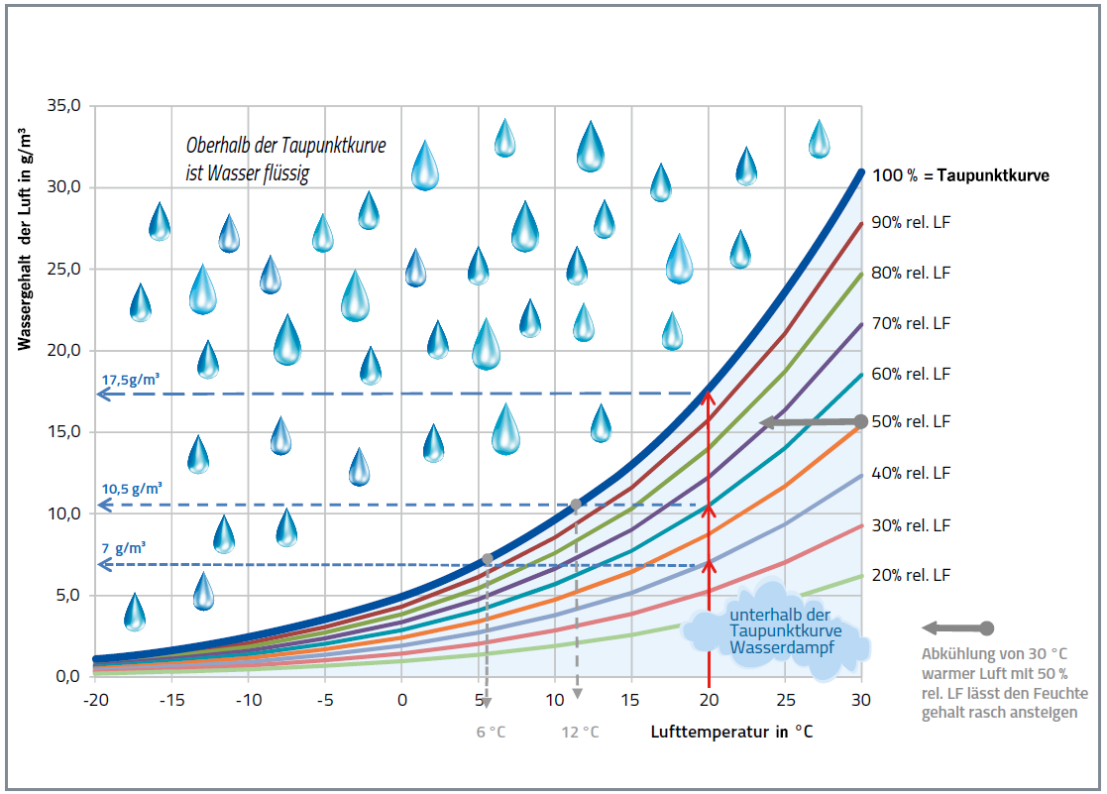
MOISTURE IN PRINTED CIRCUIT BOARDS

Moisture content - an equilibrium

- Humidity is water in molecularly dissolved form
- Experiences with humidity:
  - Cold glasses fog up
  - Fog and cloud formation

- **Achieving equilibrium requires sufficient time**
- **A new equilibrium is established through targeted changes in conditions.**
- **Absorption and release of moisture are reversible processes.**



Source: Fa. SANCO, 2012 (nach DIN 4108-3,

MOISTURE IN PRINTED CIRCUIT BOARDS

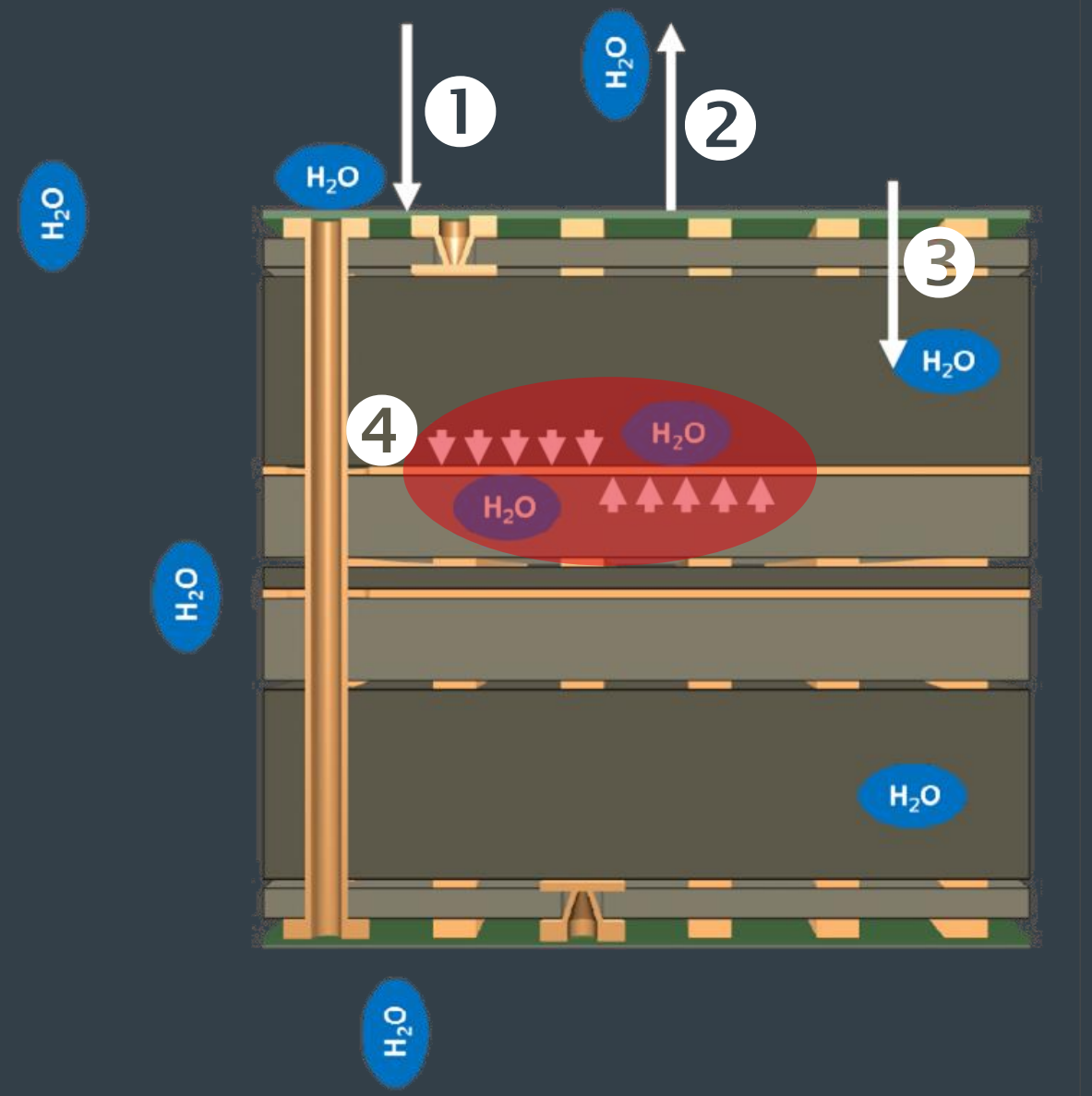
Moisture content - an equilibrium

1. Adsorption on the surface
2. Desorption from the surface
3. Absorption and diffusion into the PCB
4. Copper area as a barrier

A printed circuit board always contains moisture in equilibrium according to the ambient conditions.

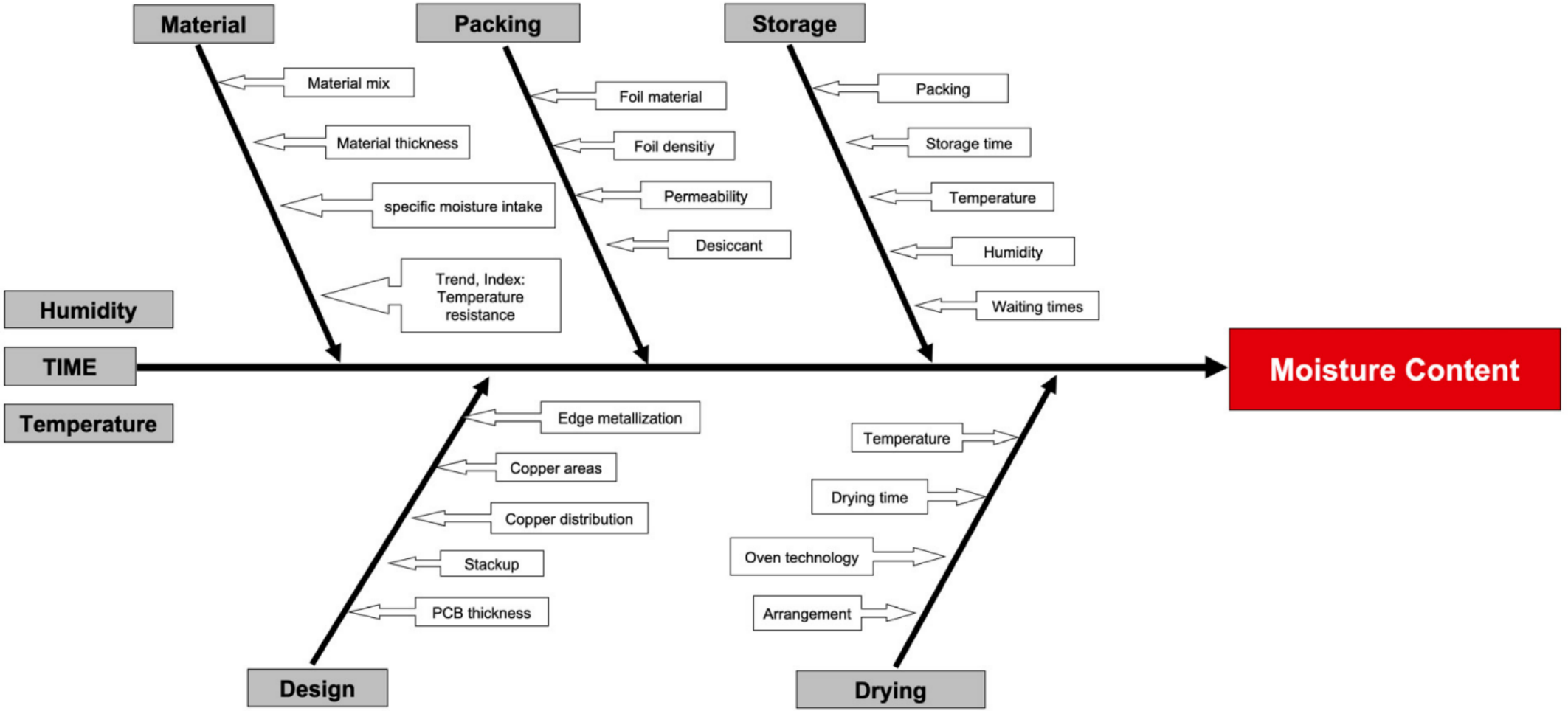
The adjustment of the equilibrium takes time.

Moisture accumulates preferentially at boundary layers.



MOISTURE IN PRINTED CIRCUIT BOARDS

Influencing factors



POLL

Multiple-Choice

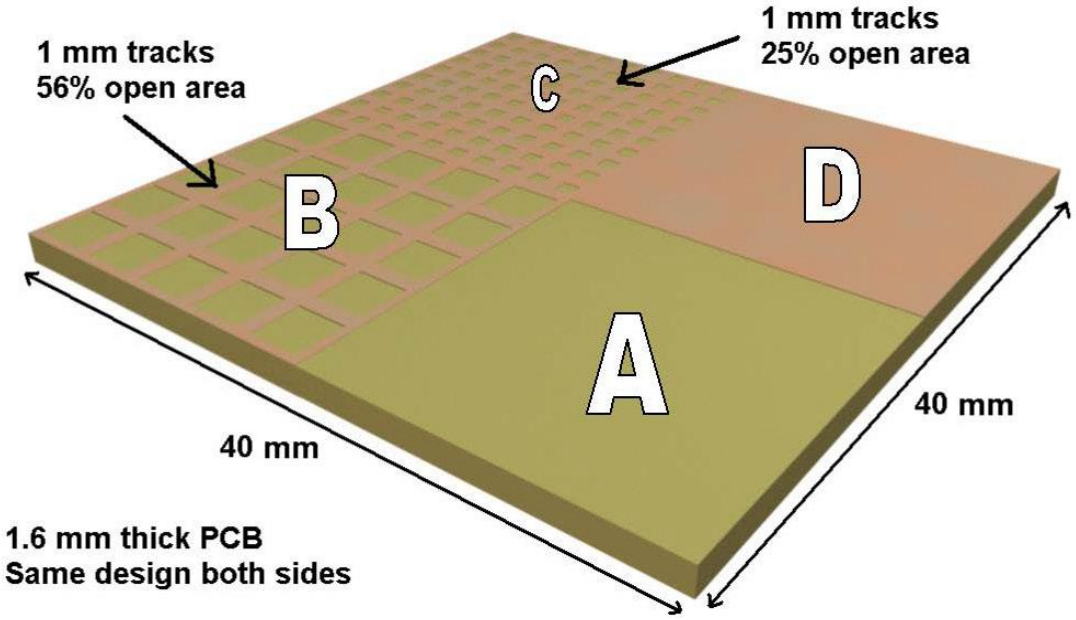
Which cause has the greatest influence on moisture loss during drying?

- Base material
- Copper design
- Oven temperature
- Pressure / Vacuum
- Drying time

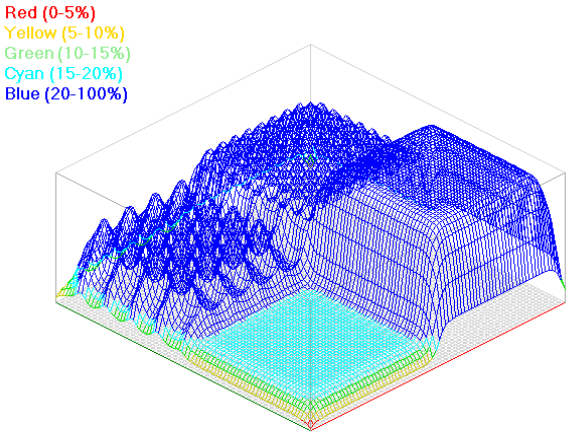
MOISTURE IN PRINTED CIRCUIT BOARDS

Drying time

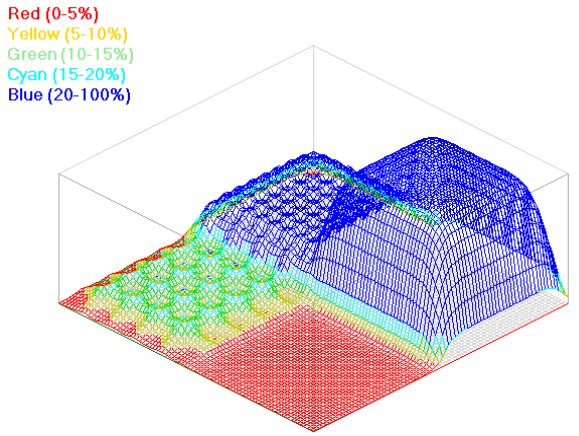
- Test layout with different copper coatings
- Maximum moisture loading / Drying @125°C
- Measurement of residual moisture at 0.6mm depth



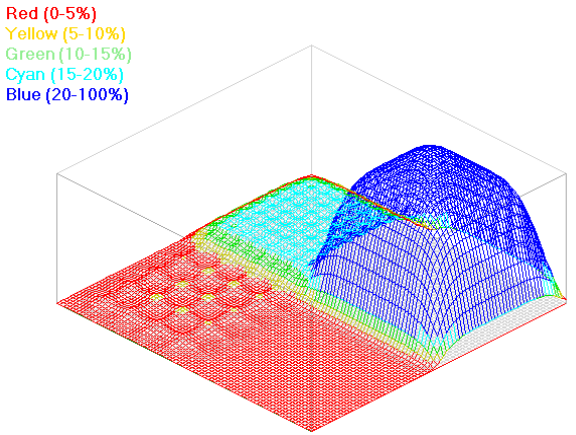
Source: Moisture Measurements in PCBs and Impact of Design on Desorption Behavior, Christopher Hunt, Owen Thomas, Martin Wickham, ISBN: 978-1-61782-845-4, IPC APEX EXPO Technical Conference 2011



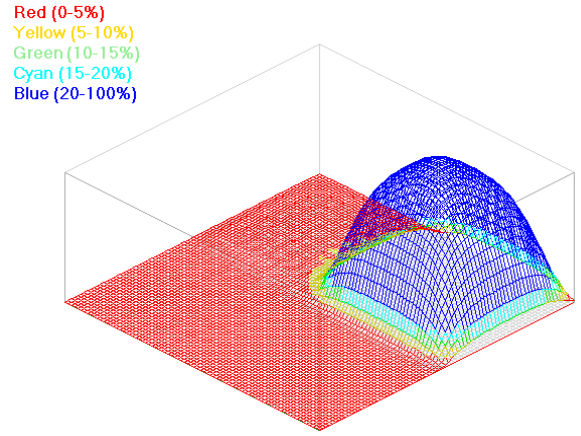
Elapsed Time: 6 hours



Elapsed Time: 15 hours



Elapsed Time: 25 hours



Elapsed Time: 45 hours

MOISTURE IN PRINTED CIRCUIT BOARDS

Design-for-Drying

- The largest contiguous copper area is the critical dimension for drying.
- Full copper layers without openings should be avoided, even on inner layers.
- In the area of critical signals that require an undisturbed return flow path on the reference layer, the openings can be removed accordingly or shifted by the necessary amount.
- Even small openings in the copper represent diffusion channels for drying.

MOISTURE IN PRINTED CIRCUIT BOARDS

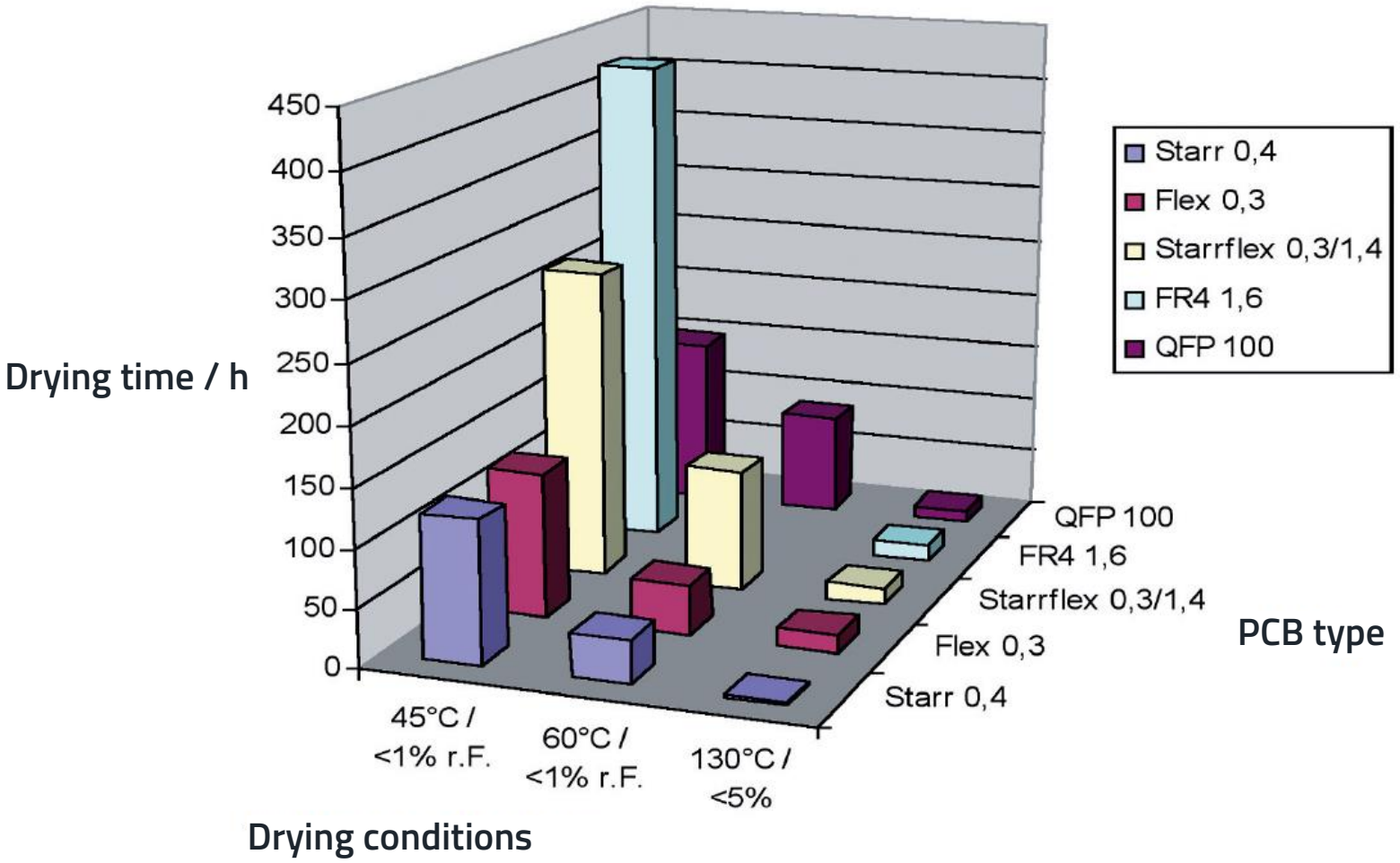
Oven technologies

Relevant for drying

- Temperature
  → Diffusion rate
- Heat transfer
  → Time
- Humidity content in the oven
  → Desorption rate

Practise

- Circulating air drying cabinet 120°C
- Vacuum not effective inside the PCB
- Drying storage cabinet suitable, longer drying times.



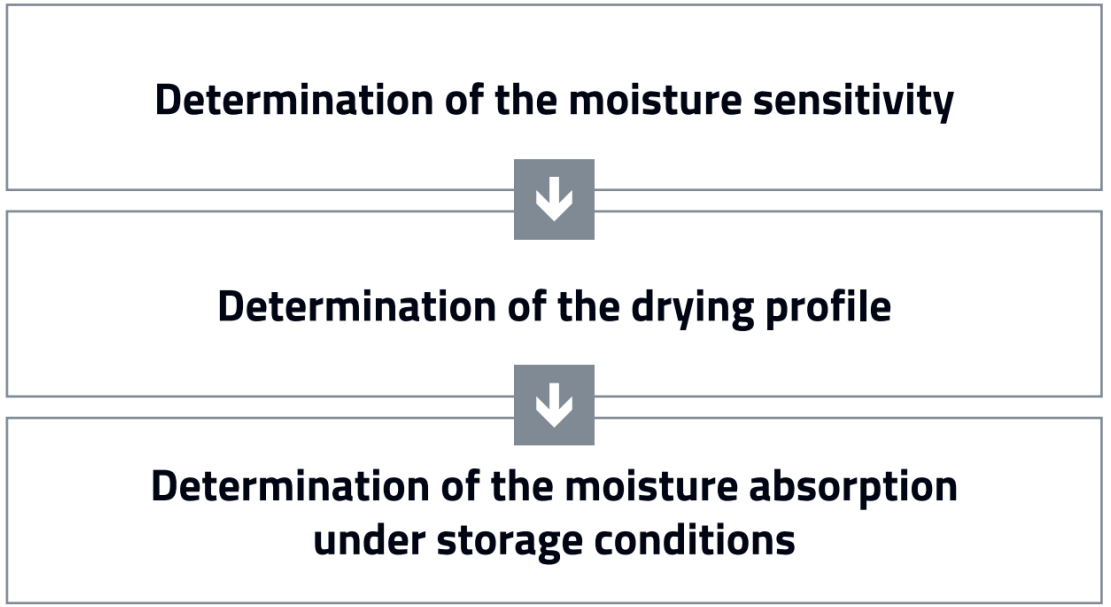
MOISTURE IN PRINTED CIRCUIT BOARDS

Development of an efficient drying process

Clarifications

- How much moisture has the PCB absorbed?
- What dehumidification is sufficient for the subsequent temperature stress?
- What moisture absorption does the base material or material mix show?
- Design-for-Drying ok?
  - PCB thickness
  - Copper surfaces
  - Supply and reference layers
  - Edge metallization
  - Heatsink
  - etc.
- What time without moisture protection must be allowed?

Process:



MOISTURE IN PRINTED CIRCUIT BOARDS

And the logistics?

- Fan or stack drying?
  - Risk of bending in the fan
  - Ensure drying in the stack
  - Check „transfer pressure“
  - Labels? Bleeding?
  - Protect surface from damage, scratches
- Maximum two hours unprotected
- Documentation, drying log?

- Production control, Kanban?

MOISTURE IN PRINTED CIRCUIT BOARDS

Drying and solderability

- Drying at 120°C
  - Ageing
  - Sure solderability
    - Wetting tests
    - Spreading tests
  - ENIG
    - robust
    - can be dried several times

Further reading


THANK YOU
FOR YOUR
ATTENTION