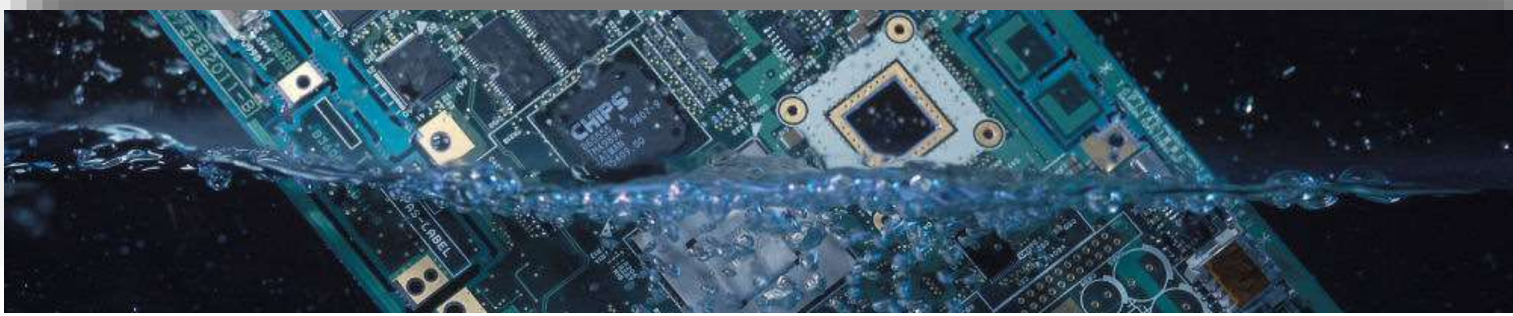
PCB Cleaning



Watch the webinar recording on YouTube: https://youtu.be/_S5eKz7NOQo

You can also watch the video here: http://thor.inemi.org/webdownload/2021/BdAssy-Tech_Topics/Board_Assembly_Tech_Topic-PCB_Cleaning.mp4

Stefan Strixner
Principal Engineer

Agenda

ZESTRON High Precision Cleaning

- Why Cleaning of electronic assemblies?
  - Standards
  - Reliability
  - Subsequent processes
- Cleaning processes
  - Cleaning chemicals
  - Cleaning machines
- Cleaning process monitoring
  - Bath monitoring
  - Result monitoring
- Process cost

Stress on electronic assemblies

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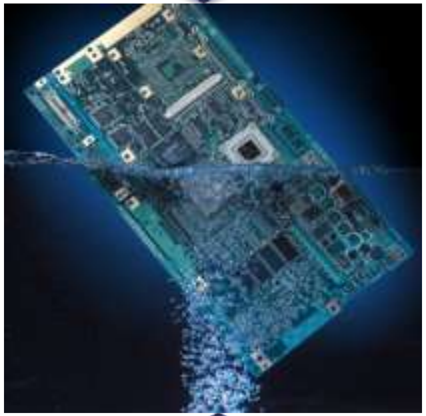
Mechanical

i.e. vibrations, accelaration, crash

Thermal

i.e. temperature changes,

Extremly high/low temperature



Chemical

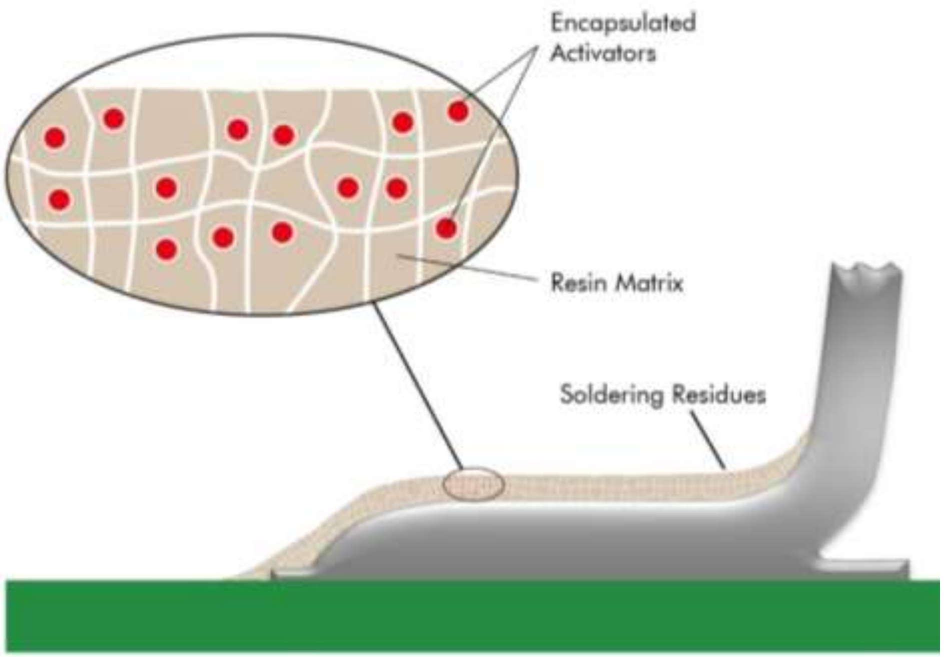
i.e. Humidity, Atmospheric change, Salt spray, Corrosive gas

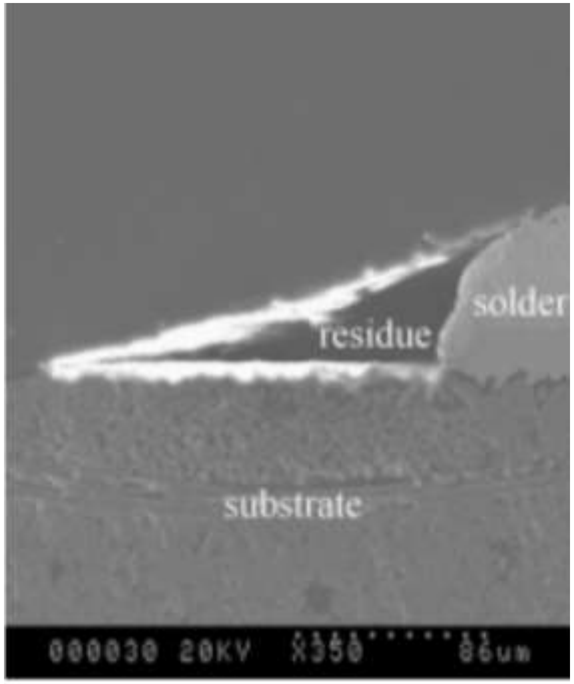
Electrical

i.e. Humidity, fluxes, contaminations, Electrical Overstress (EOS)

NoClean Process

NoClean solder pastes leave small amounts of noncorrosive, resinous residues behind.
As specified by the manufacturers, these flux residues are designed to be left on the boards since the resin component encapsulates detrimental, hygroscopic flux activators and thus ensures electrical reliability.





NoClean Process vs. PCB Cleaning

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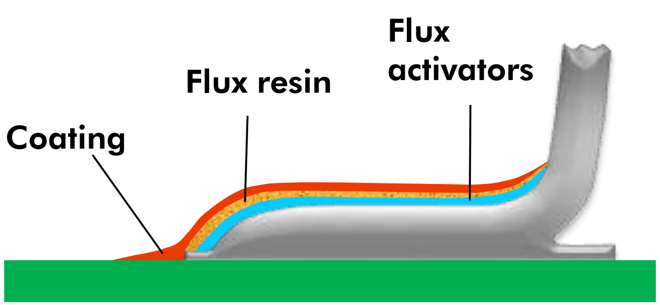
BUT (hands-on experience):

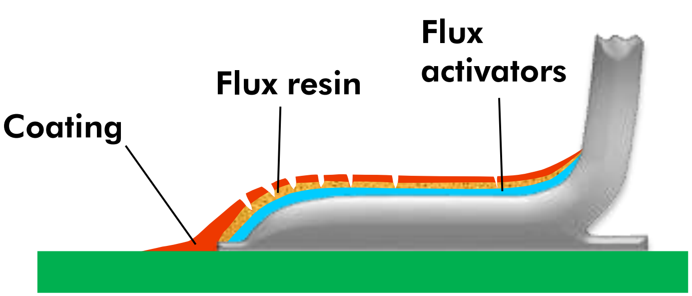
Climatic stress in the field causes (NoClean) resins to become brittle.

- Hygroscopic flux activators become exposed → Consequences: Corrosion, reduced adhesion of coatings (delamination), leakage current,...

After soldering

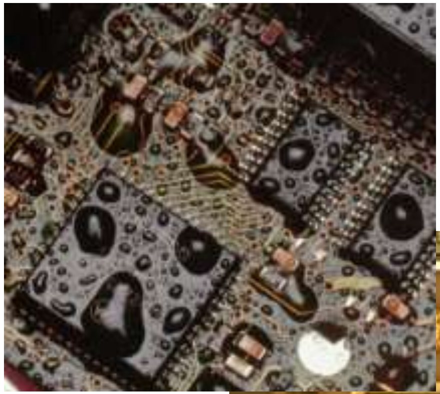


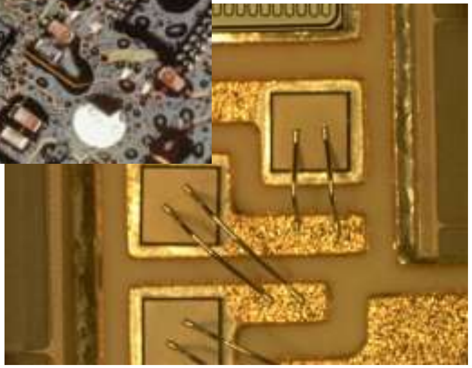
After climatic stressing



Cleanliness Demands and Requirements

Degree of cleanliness and control defined by:



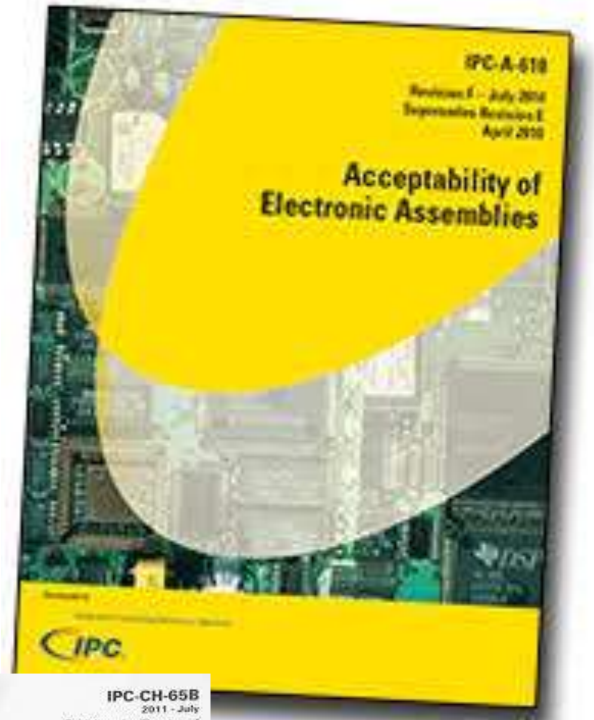


- Customer requirements
- Standards
- Climatic reliabiltiy requirements
- Subsequent processes

Transparency of manufacturing process

Ensure consistent product quality

- J-STD (… tronic
- IPC-A-6 …
- IPC 92(… fication
- IPC-Hd … on of
- IPC 57(… ʼrinted Boards
- IPC-Hd … d Assemblies
- IPC-7526 Stencil and Mi … d Cleaning Handbook
- GfKorr Guideline for … nd handling of protective coa … ronic assemblies

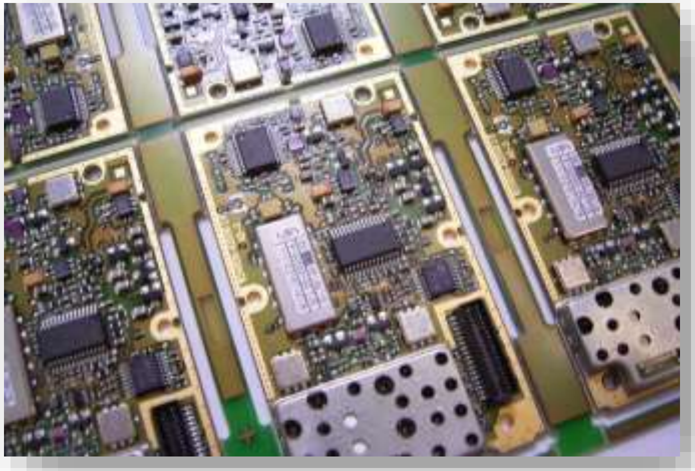


Increasing Climatic Endangerment

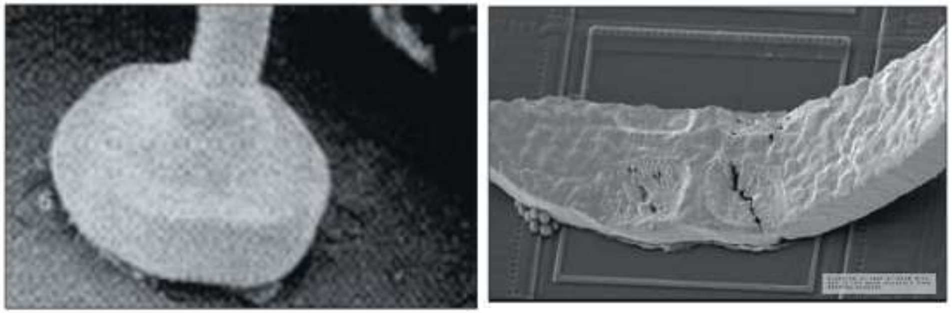
- Big components
- Low density on the assemblies
- Low environmental impact

Trend

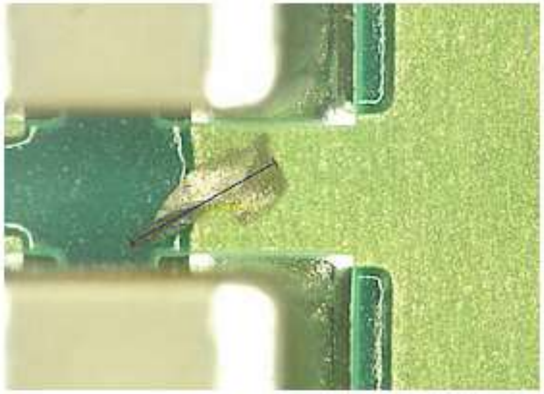
- High packaging density
- Low stand-offs
- Extreme environmental impact



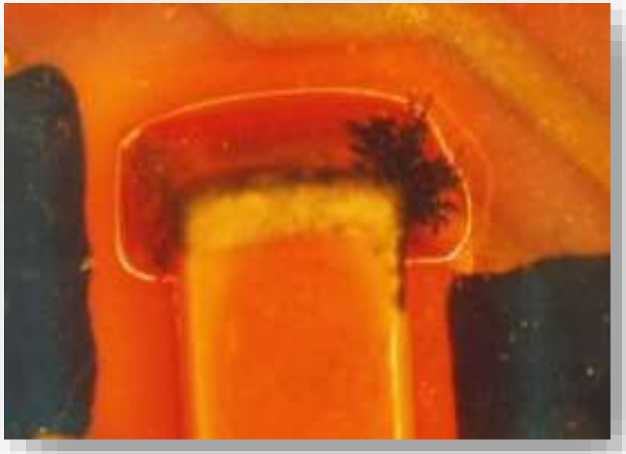
Defects caused by poor surface cleanliness



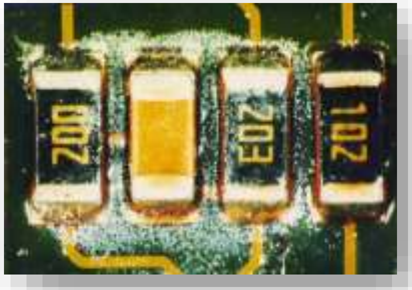
Deficient wire bonds
(e.g. lift-offs and heel cracks)



Particle-related malfunctions
(e.g. risk of short circuits)

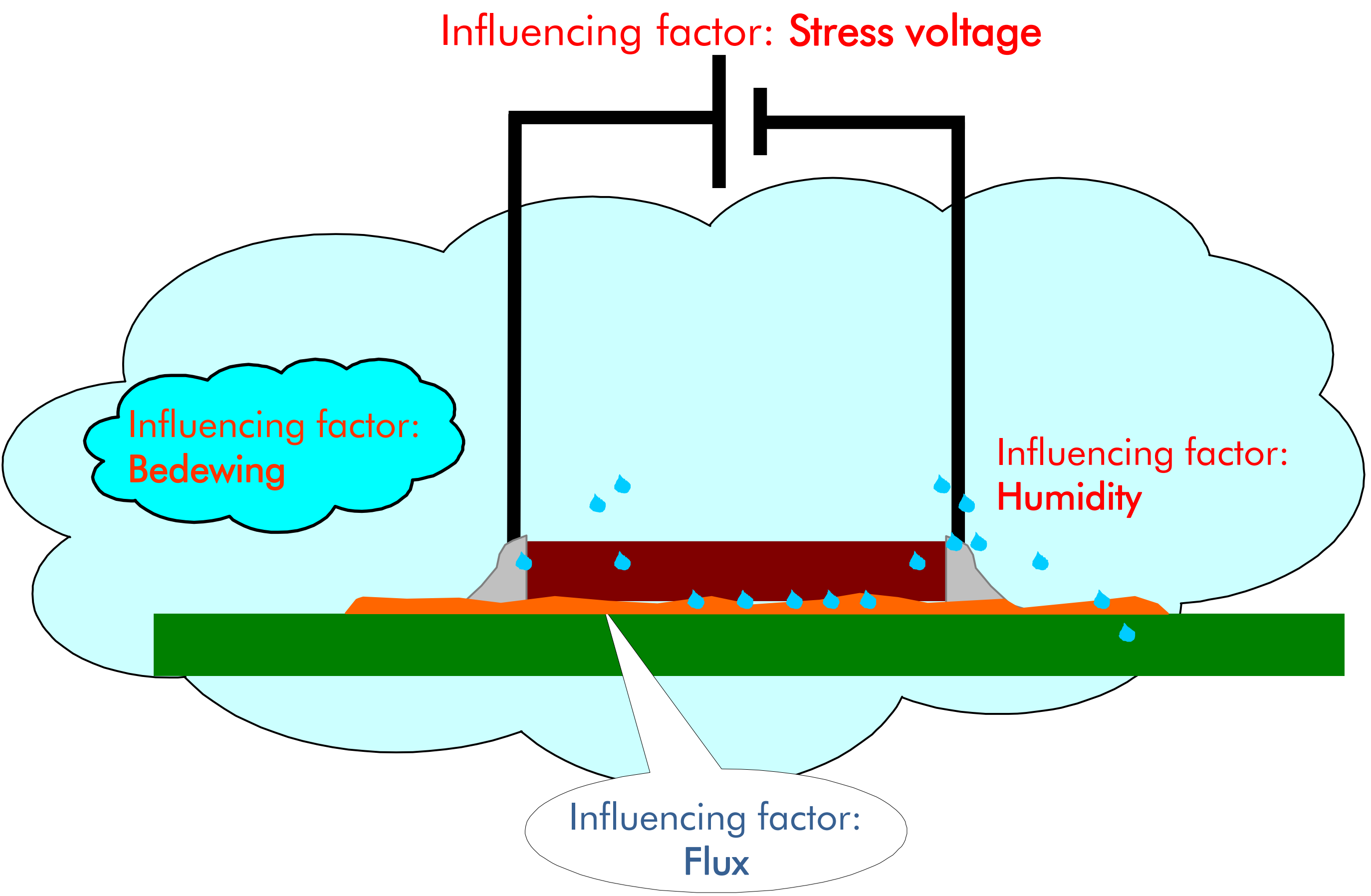


Corrosion
(e.g. dendrite growth/ electrochemical migration)



Coating defects
(e.g. delamination)

Electrochemical Migration



steam/humidity
+
ionic contamination
(salts, flux activators)
=
conductive electrolytes
+
stress voltage
=
Electrochemical Migration

Mechanism of Dendrite Growth

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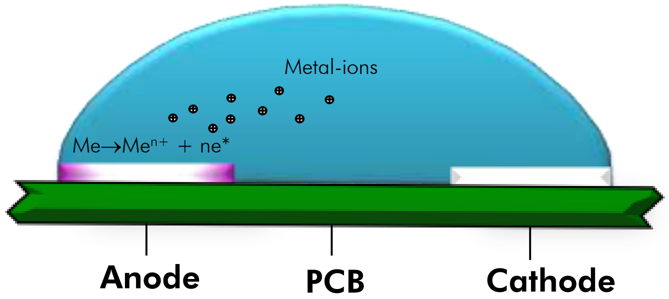
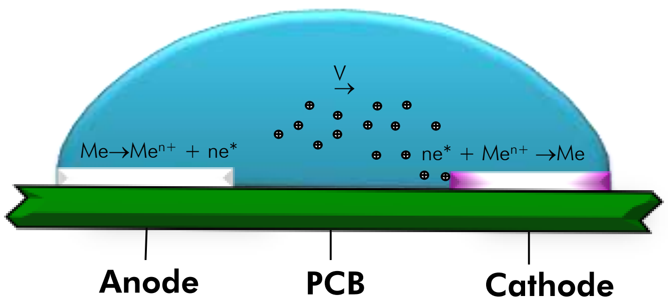
High Precision Cleaning

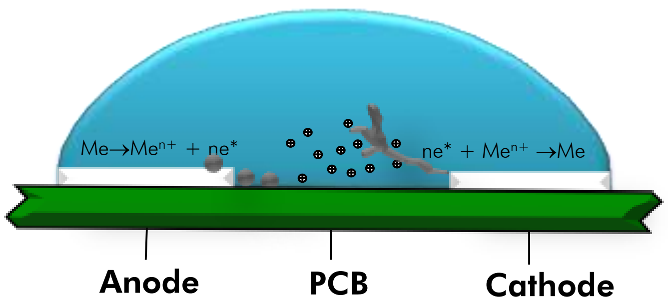
Dissolving

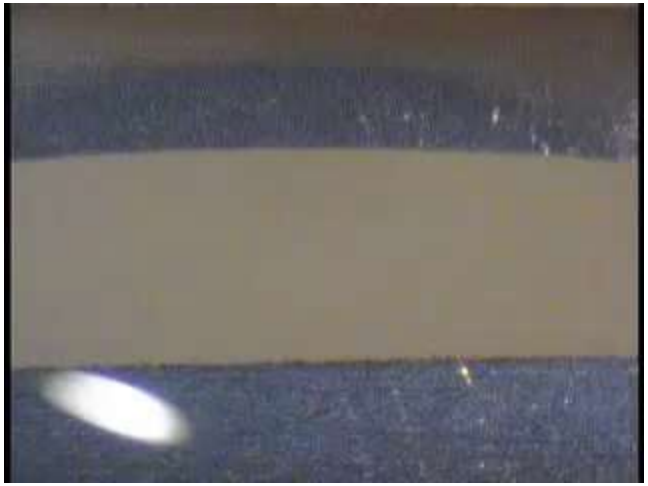


Ion migration



Precipitation





Water Vapour Permeability of Coatings

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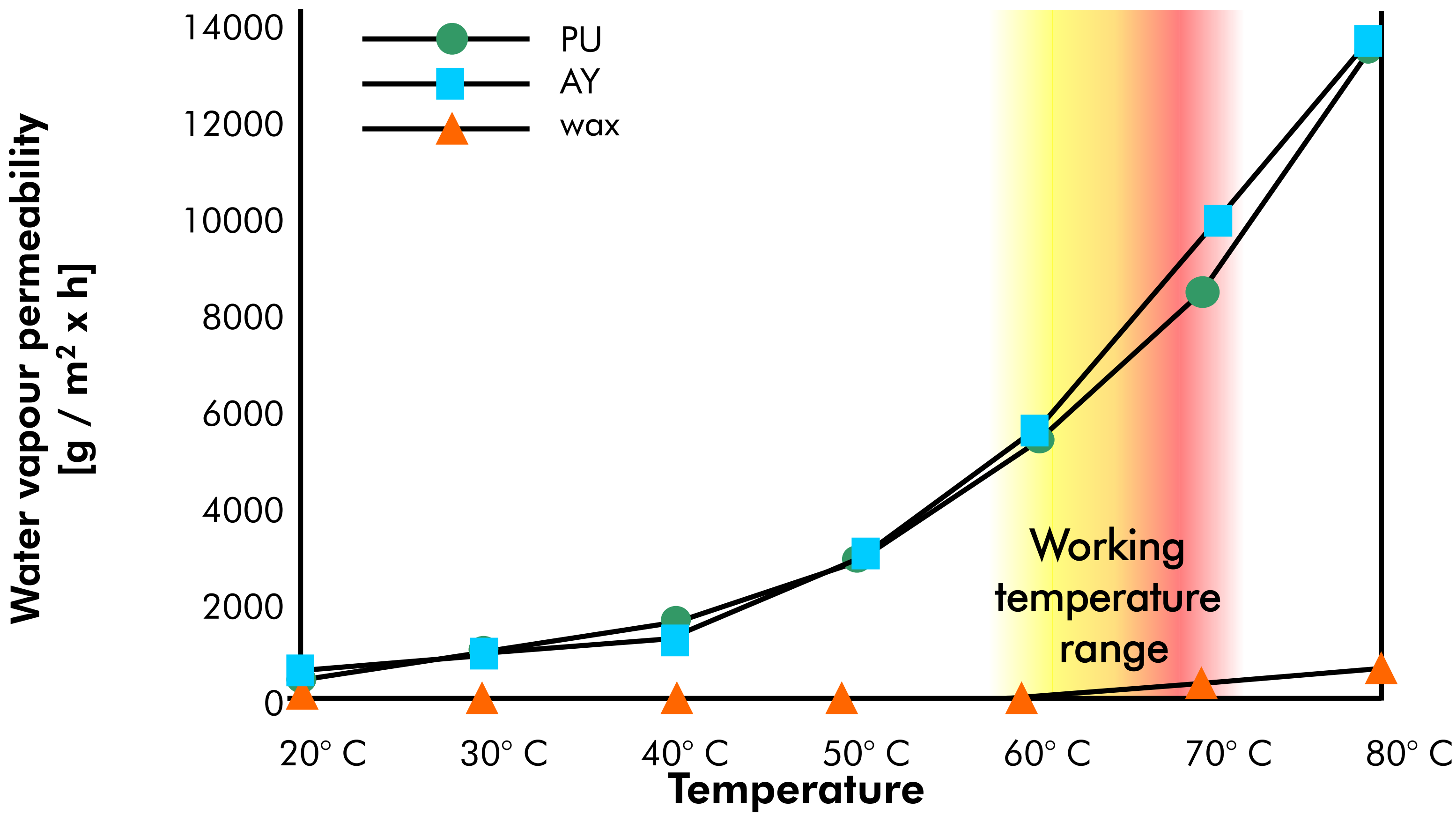

ALL polymer materials, even several centimeter thick pottings are (more or less) vapour permeable!

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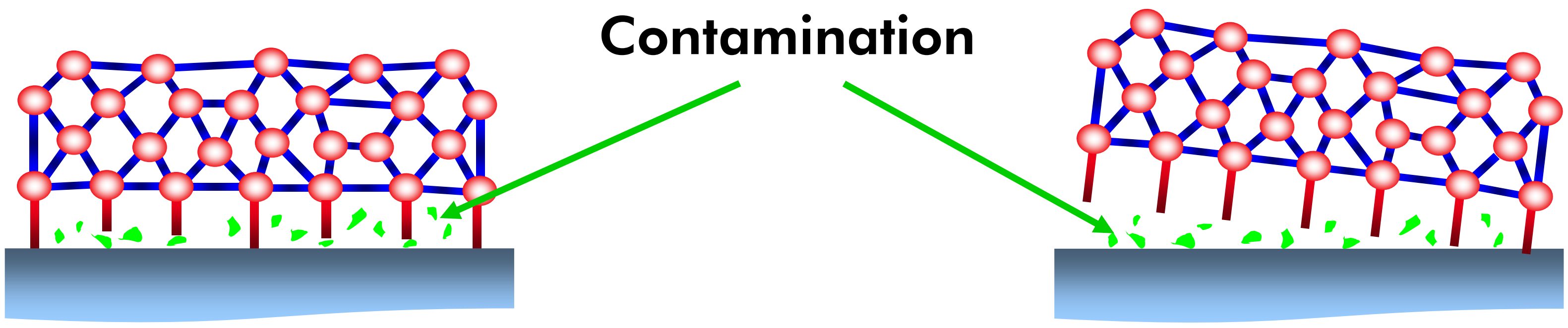
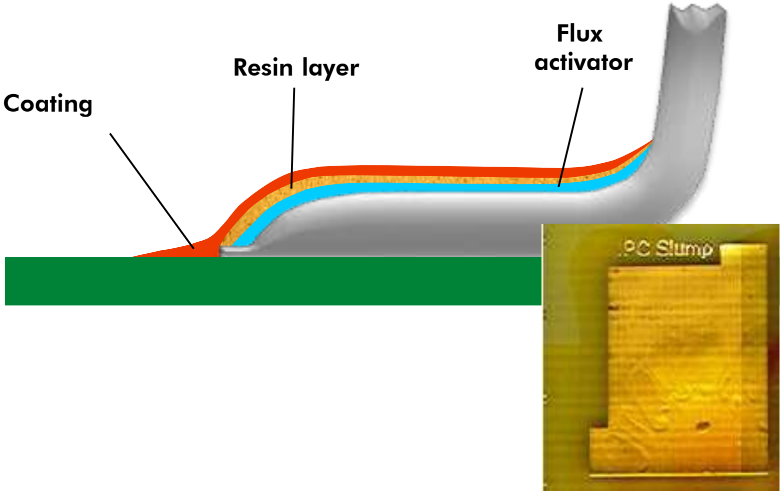


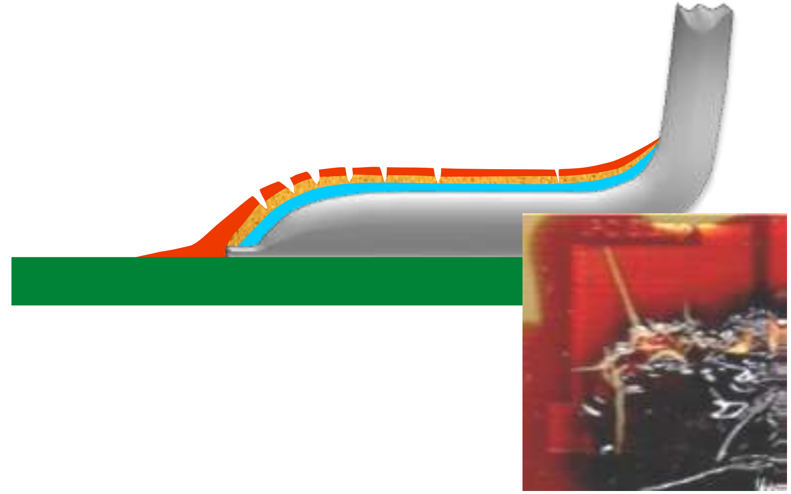
Contamination reduces adhesion forces between substrate and coating → delamination

Contamination effects

No-Clean after coating



After climate change



Resin based residues	▪ subsequent delamination when exposed to climatic changes ▪ Cracks in coatings ▪ Bit failures in HF applications

Coating Defects Caused by Surface Contamination

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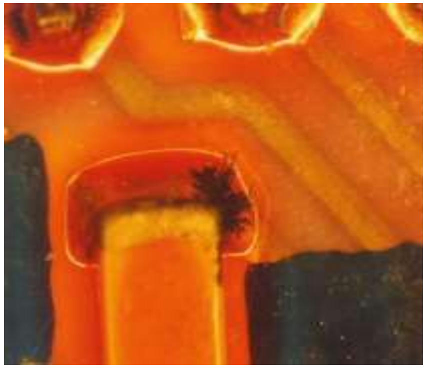
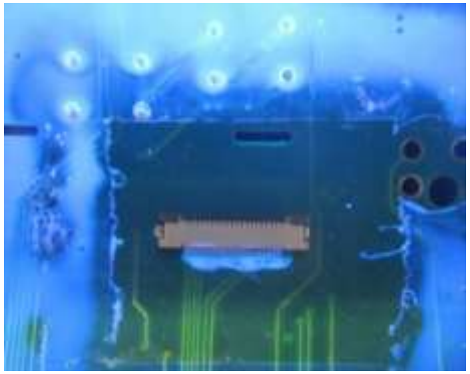
High Precision Cleaning



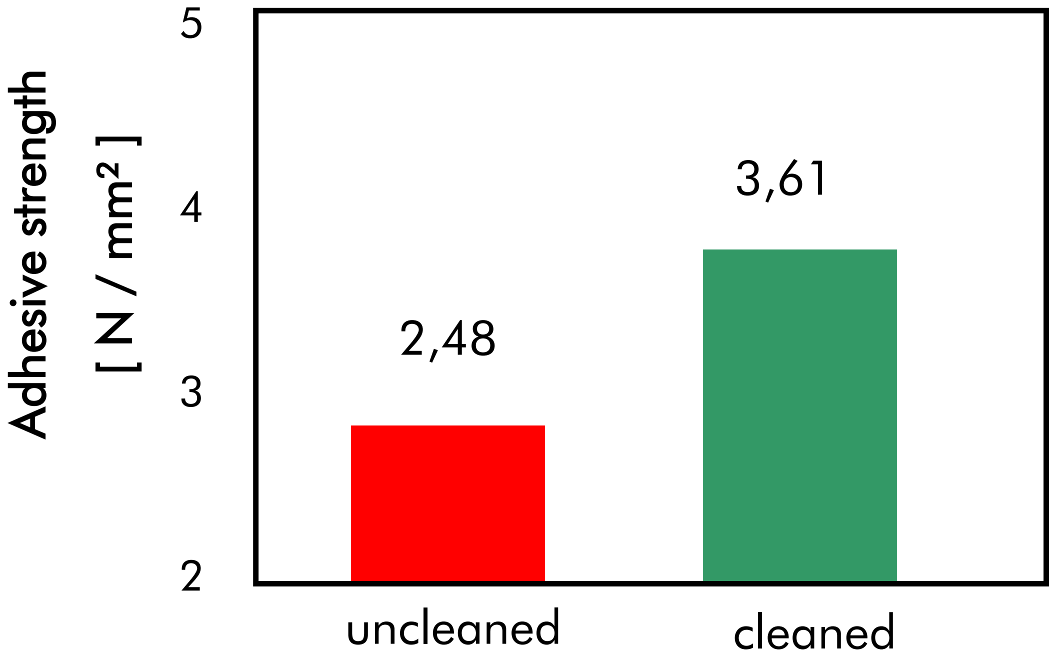
ECM



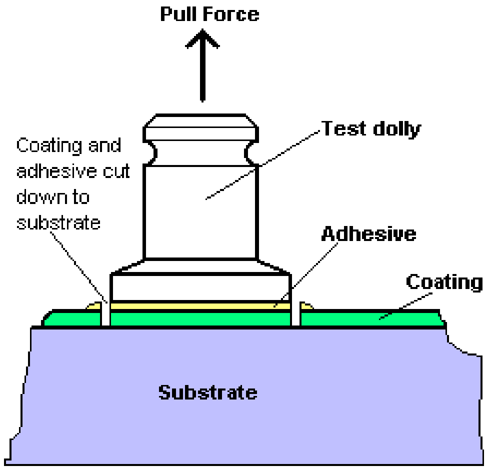
Bleeding

Flux activators	▪ hygroscopic – danger of delamination ▪ Corrosion of connections ▪ Leakage current ▪ Diminished line stability by selective coating

Partially cured PU coating applied to leaded solder (Sn60Pb)



Pull-off test
DIN EN ISO 4624*



*Alternative: „Tape Test“
ASTM D3359 Method B

- 46% increase in adhesive strength after cleaning
- Additional/ alternative methods to increase adhesive strengths between coatings and substrates: Plasma treatment (= surface activation);surface roughening e.g. by etching (= surface area enlargement); primers

Cleaning effect on Conformal coating

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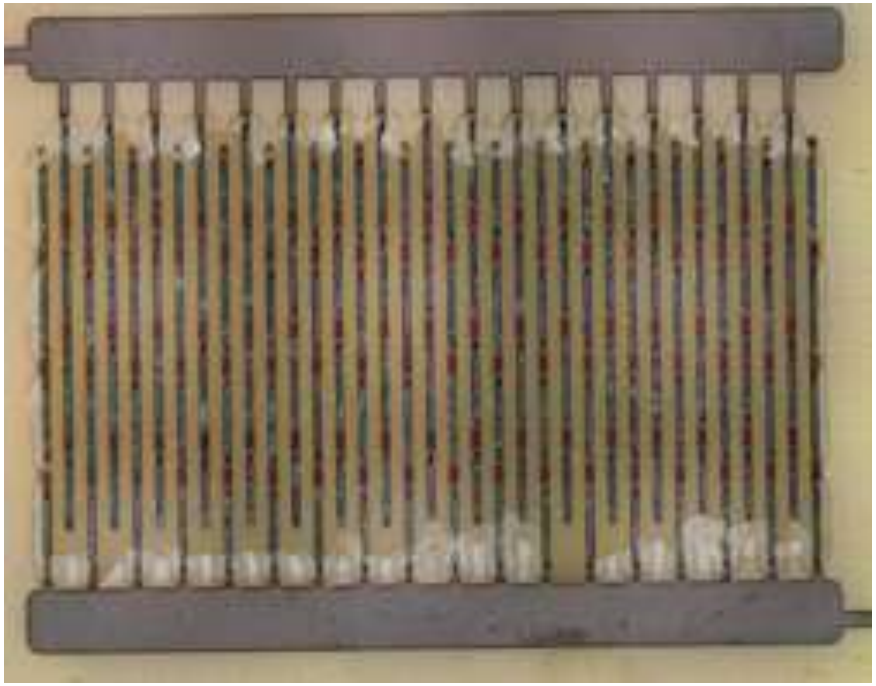
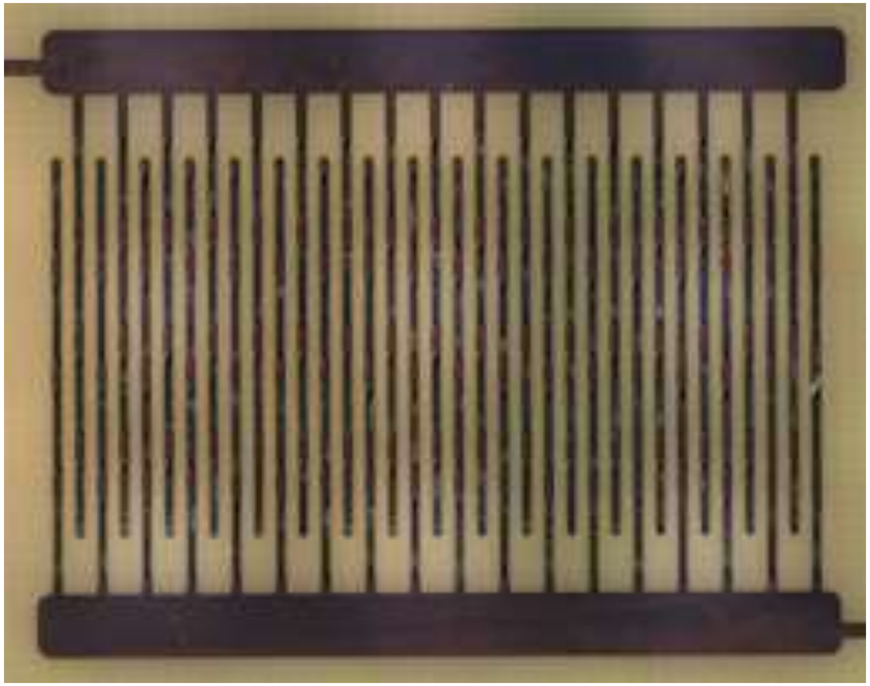
High Precision Cleaning

uncleaned



cleaned



Agenda

- Why Cleaning of electronic assemblies?
  - Standards
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- **Cleaning processes**
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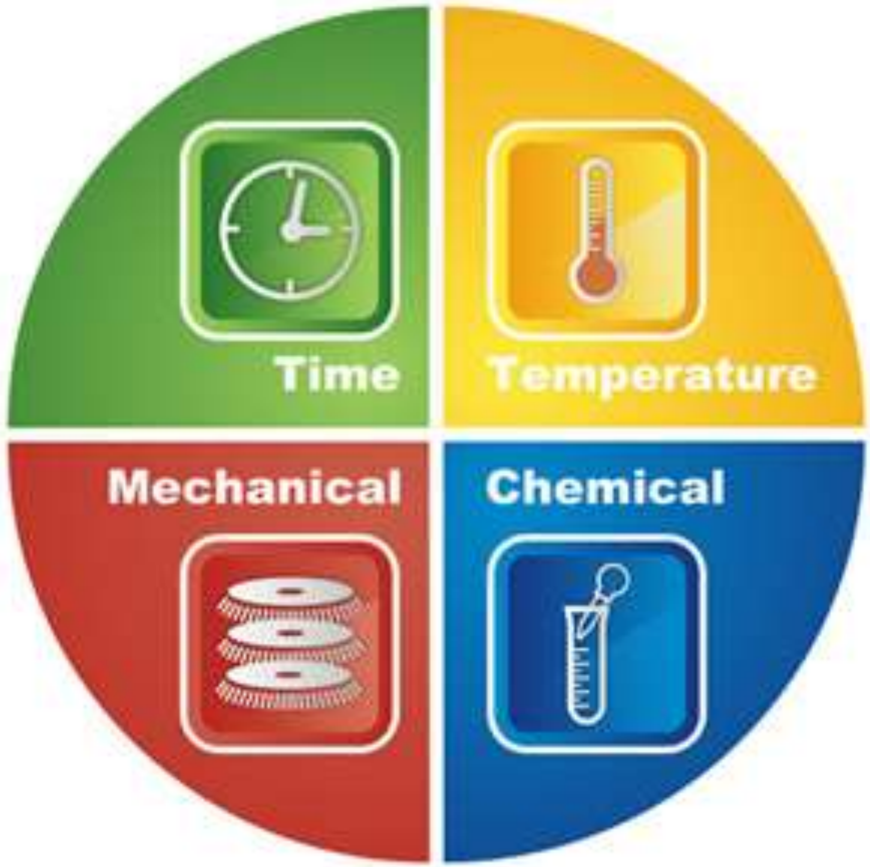
Cleaning – Sinner's circle

Parameters to modify cleaning performance – The Higher The Better!

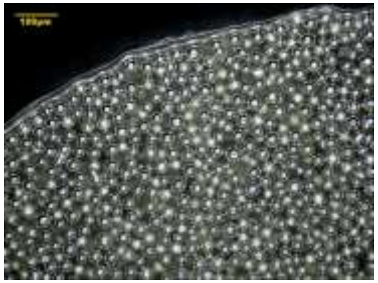


Flux composition and change after soldering

Before soldering

ΔT & Δ t

After soldering

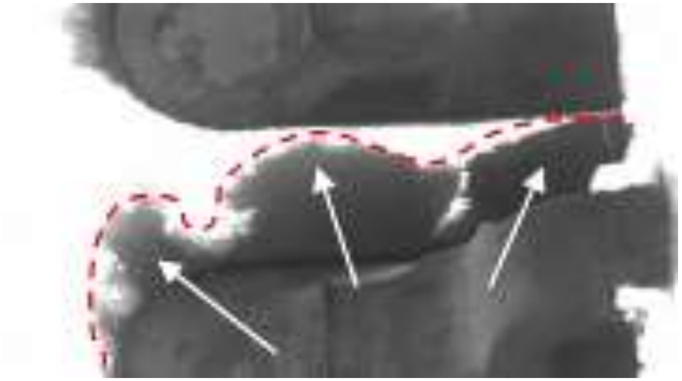


Before soldering:
- Other additives
- Resin
- Activators
- Solvent

After soldering:
- Other additives
- Resin
- Activators

Halogenide-based residues:

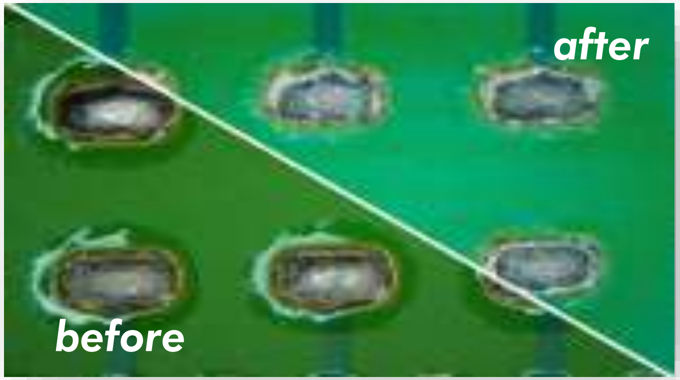
- Organic, hence difficult to remove with DI-water
- Formation of hypo-halogenide-solutions partly ionized → corrosion, electrochemical migration, creeping currents

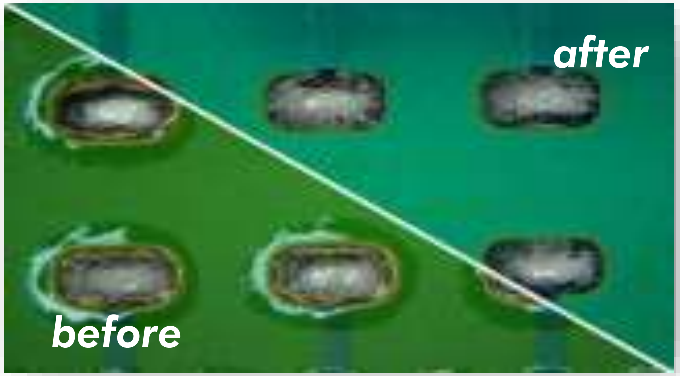


- Creeping currents

Problems with residue removal caused by solubility:

- Low solubility of organics
- Cleaning not possible on RMA, no-clean, synthetic and highly polymerized “3D” flux residues
- DI-water can not remove flux residues





Limits of DI-Water Processes

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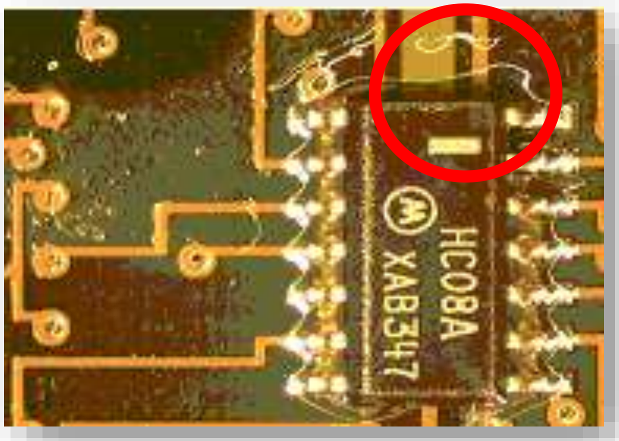
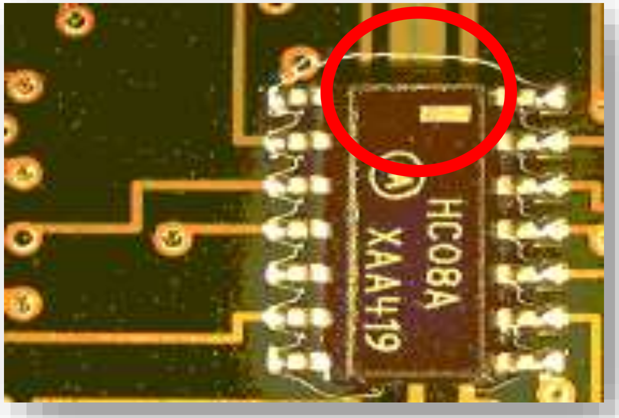
Reduced surface activation:

- Insufficient flux removal is followed by reduced surface activation
- Negative influence on coating and wire bonding processes



- DI-water process



- Process with cleaning medium

Aqueous Cleaning process

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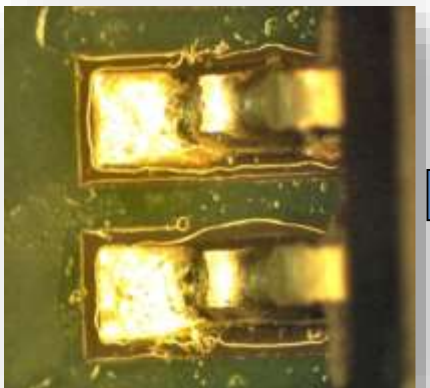
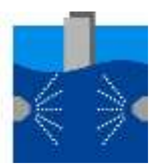


Chemistry +

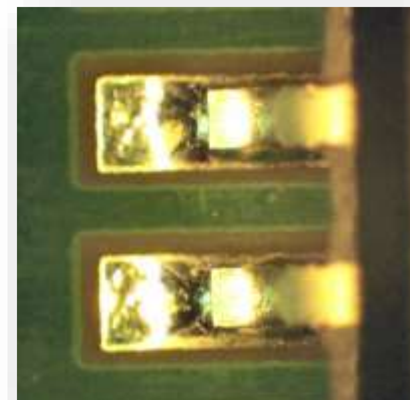
Process

Spray-in-air

Ultrasonic



Spray-under-immersion



Surface free of:
- flux
- Other critical contaminants

Modern Cleaning Systems

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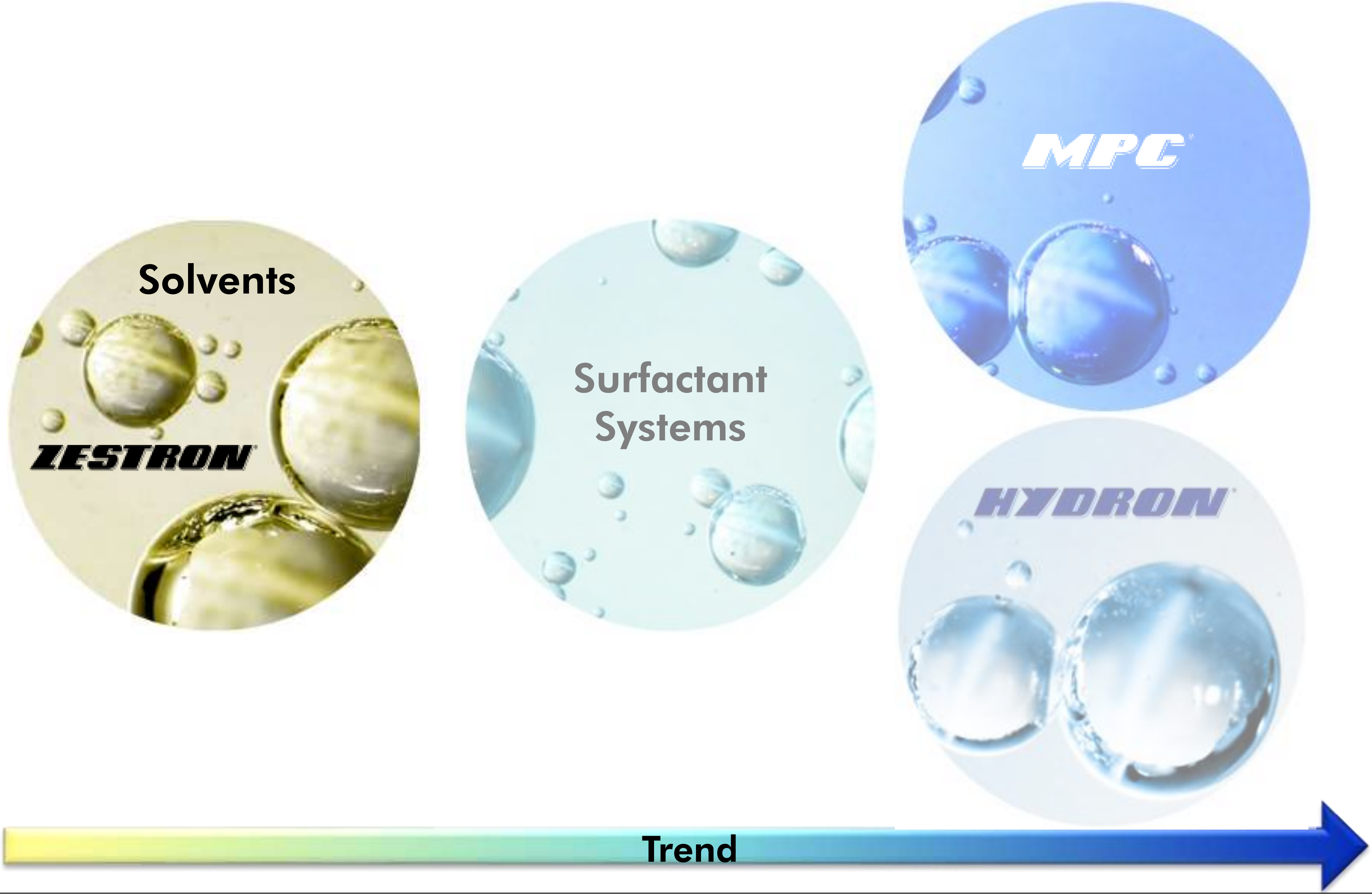
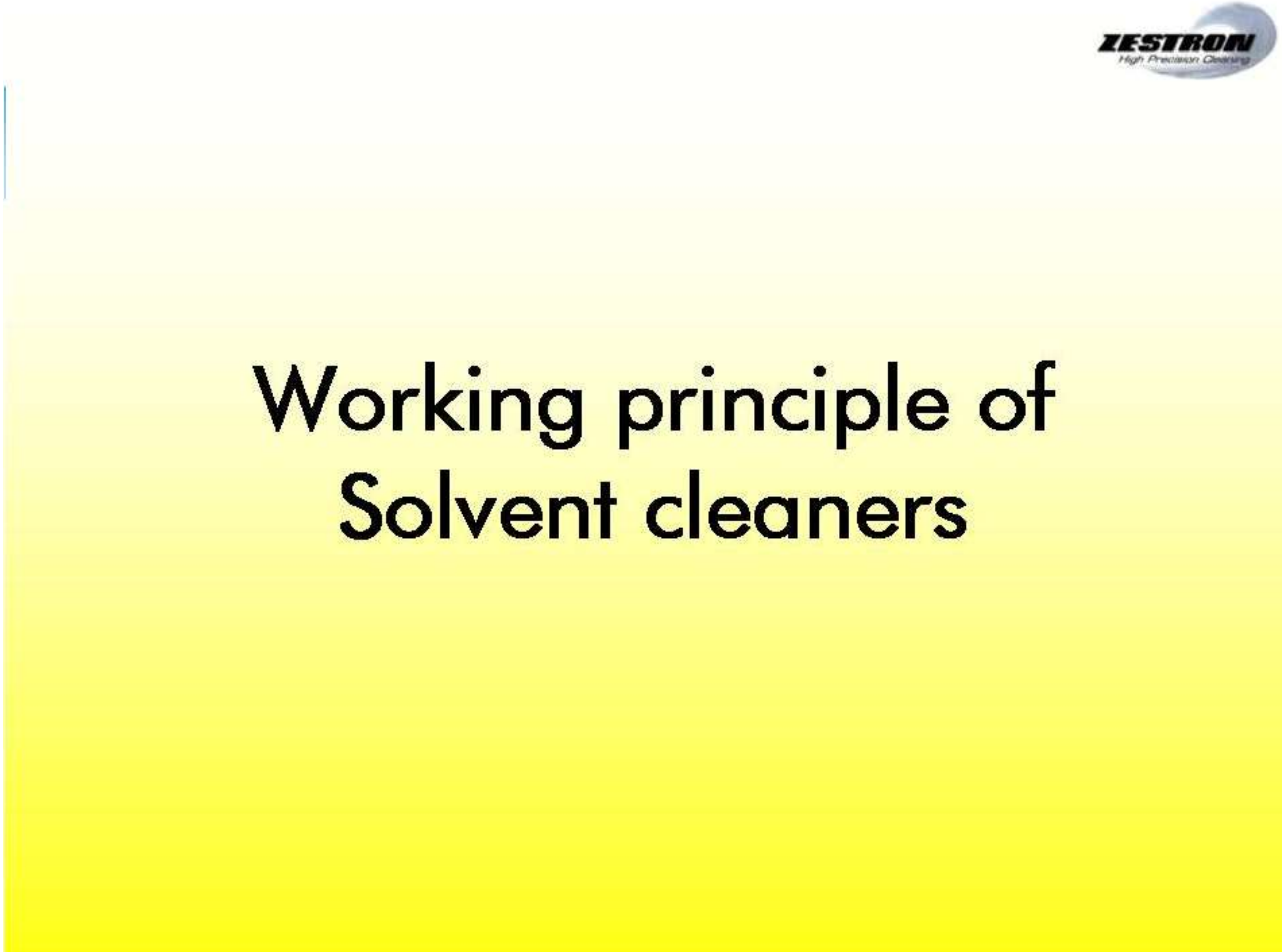
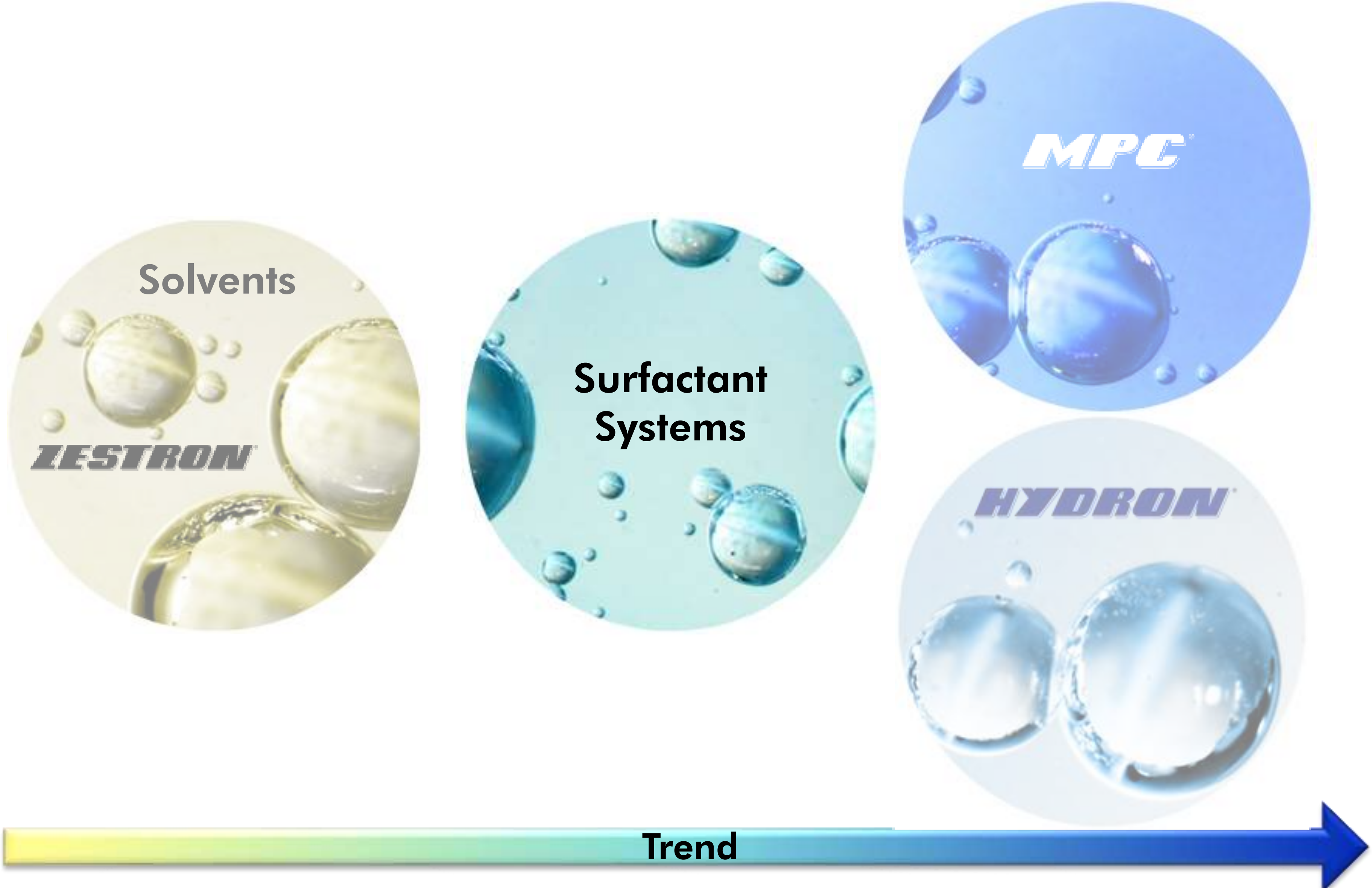
High Precision Cleaning




ZESTRON
High Precision Cleaning
Working principle of
Solvent cleaners

Modern Cleaning Systems



Working principle of surfactant cleaners

Modern Cleaning Systems

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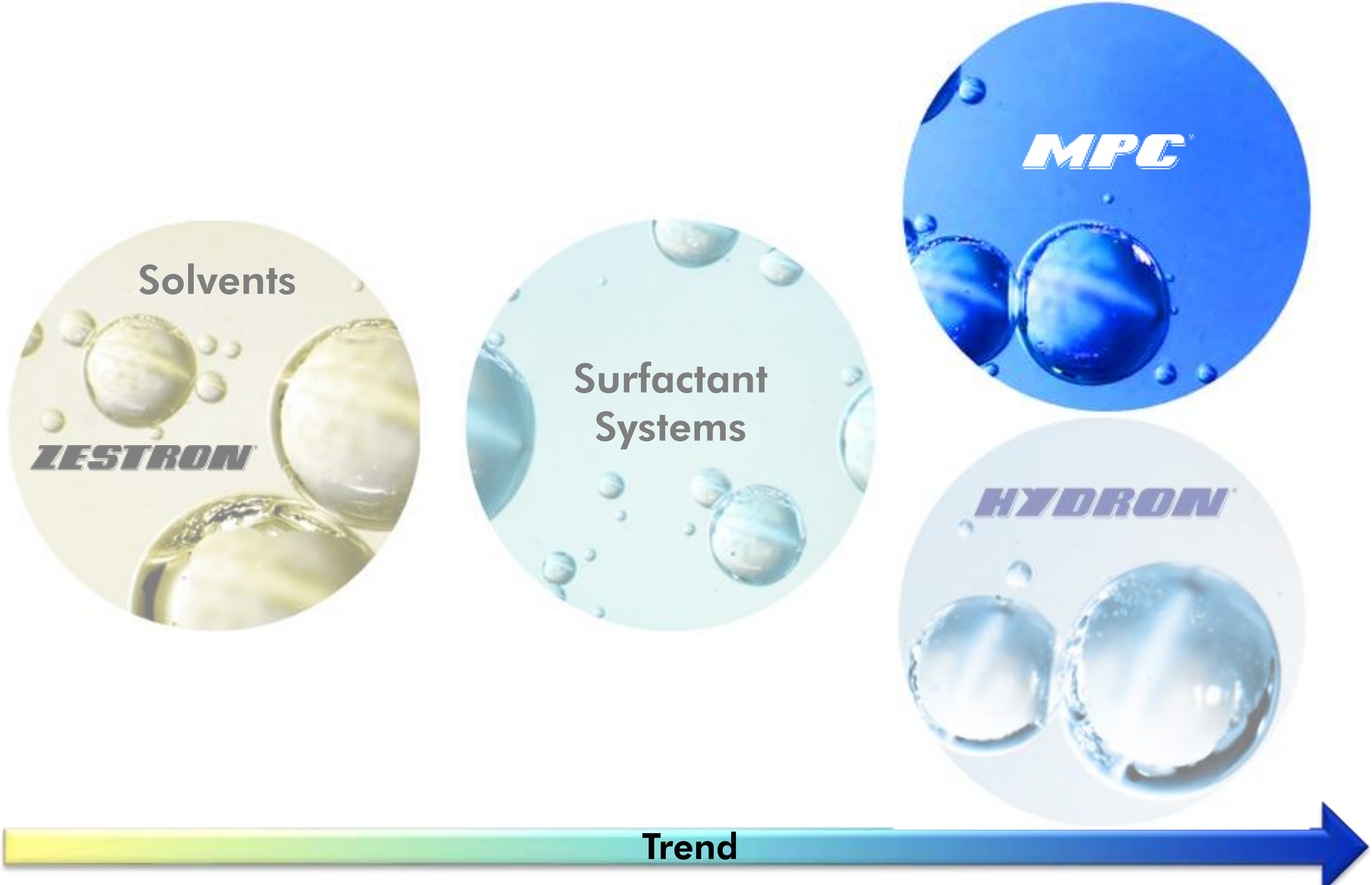
High Precision Cleaning

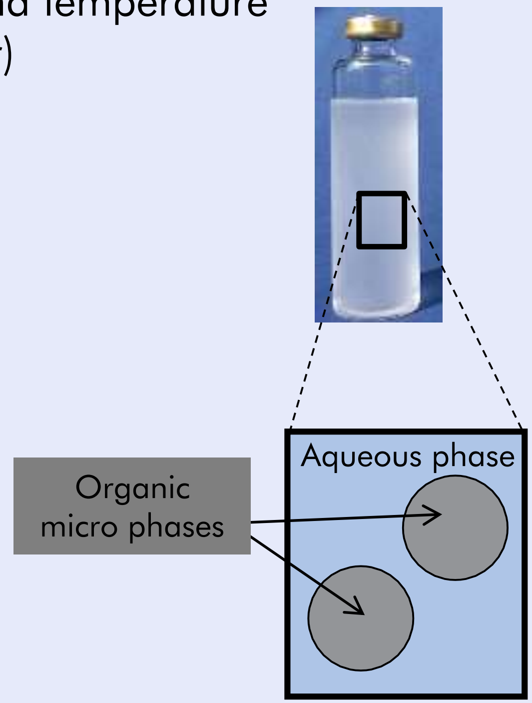


Working principle of MPC®-Technology

ZESTRON
High Precision Cleaning

MPC cleaning agents are <u>two-phase</u> systems that can be filtered for gaining extended bath lifetime

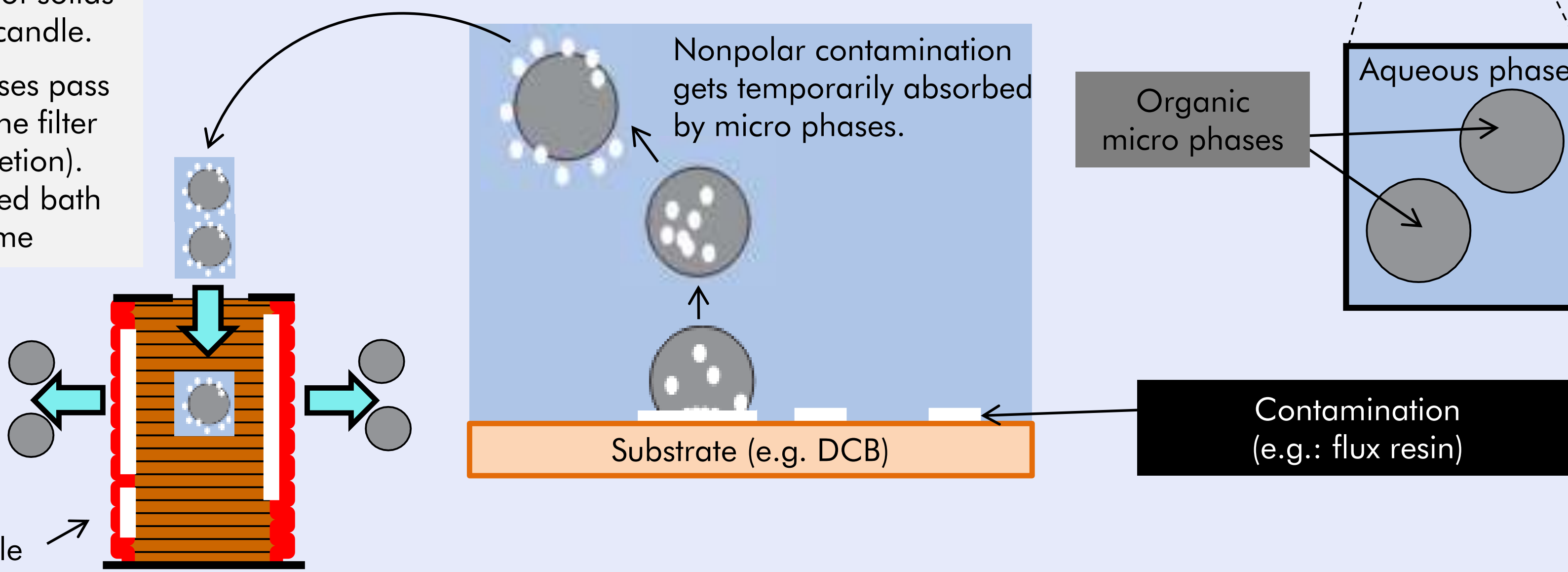
Activation by agitation (spray/ultrasonic/circulation) and temperature (20 - 60° C, depending on the respective MPC cleaner)



Contamination precipitates over time and is transported to a filter candle via cleaner circulation.

Discharge of solids via filter candle.

Micro phases pass through the filter (no depletion).
→ Extended bath lifetime



Working principle of MPC®-cleaners

Separation of Contaminations

Conventional surfactant-/ solvent cleaner

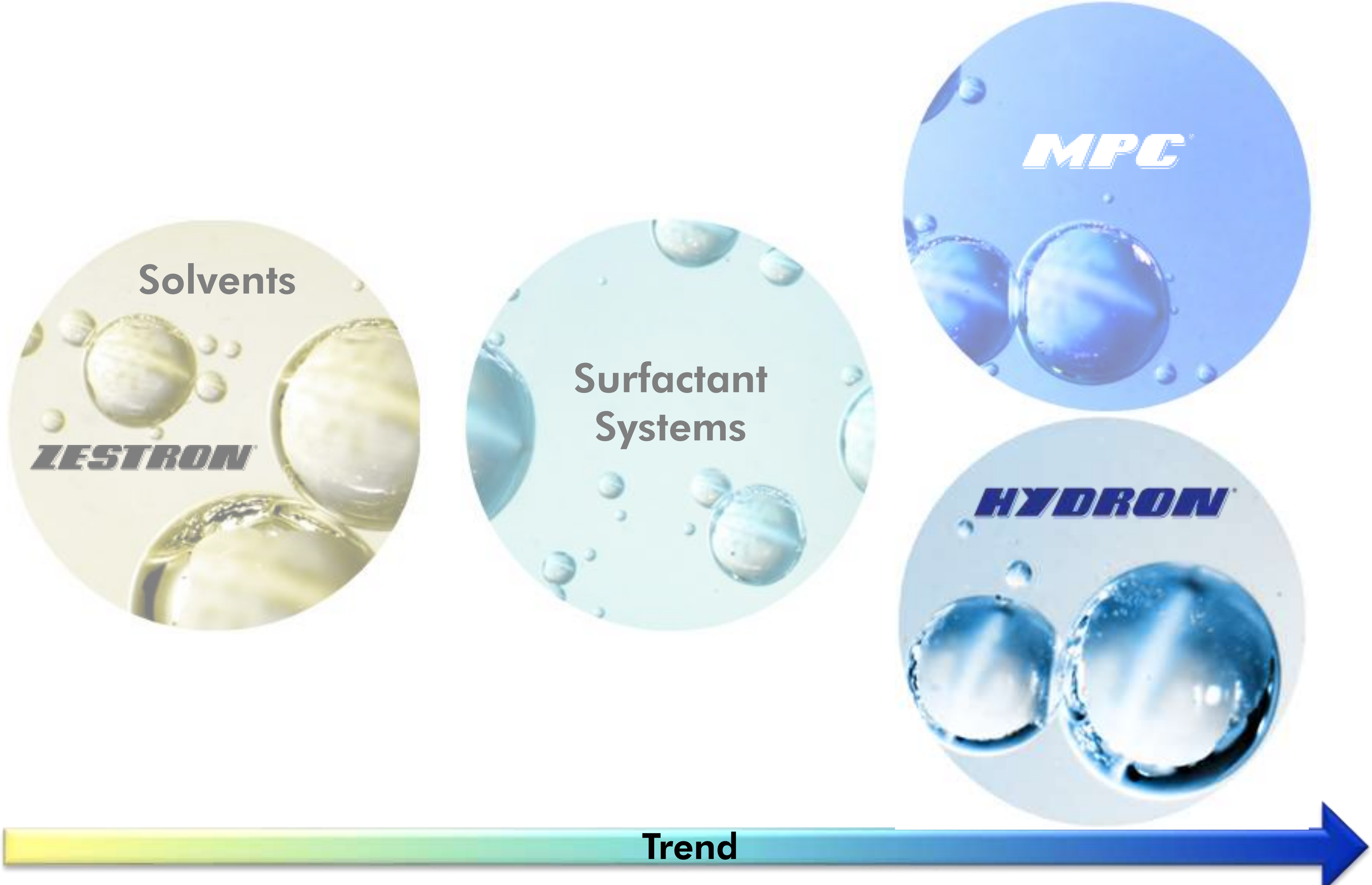
MPC®-Technology

Contamination solved → Filtration not possible

Contamination precipitates → Filtration regenerates cleaner

Modern Cleaning Systems

ZESTRON High Precision Cleaning



Characteristics of HYDRON®

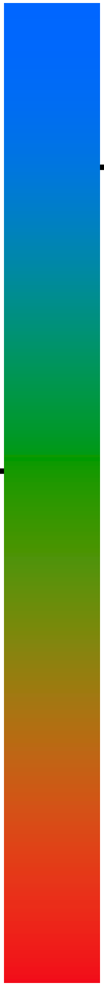
HYDRON® Technology based cleaning agents:

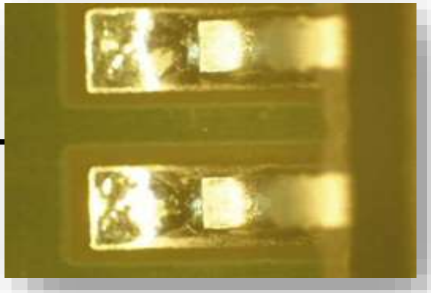
- have a single-phase formulation
  - stable single-phase emulsion
  - Water-clear appearance
- remove inorganic & organic based residues
- provide excellent material compatibility
- Have no flash point & are environmentally friendly

fresh HYDRON®

cleaning agent

Influence of pH-Value





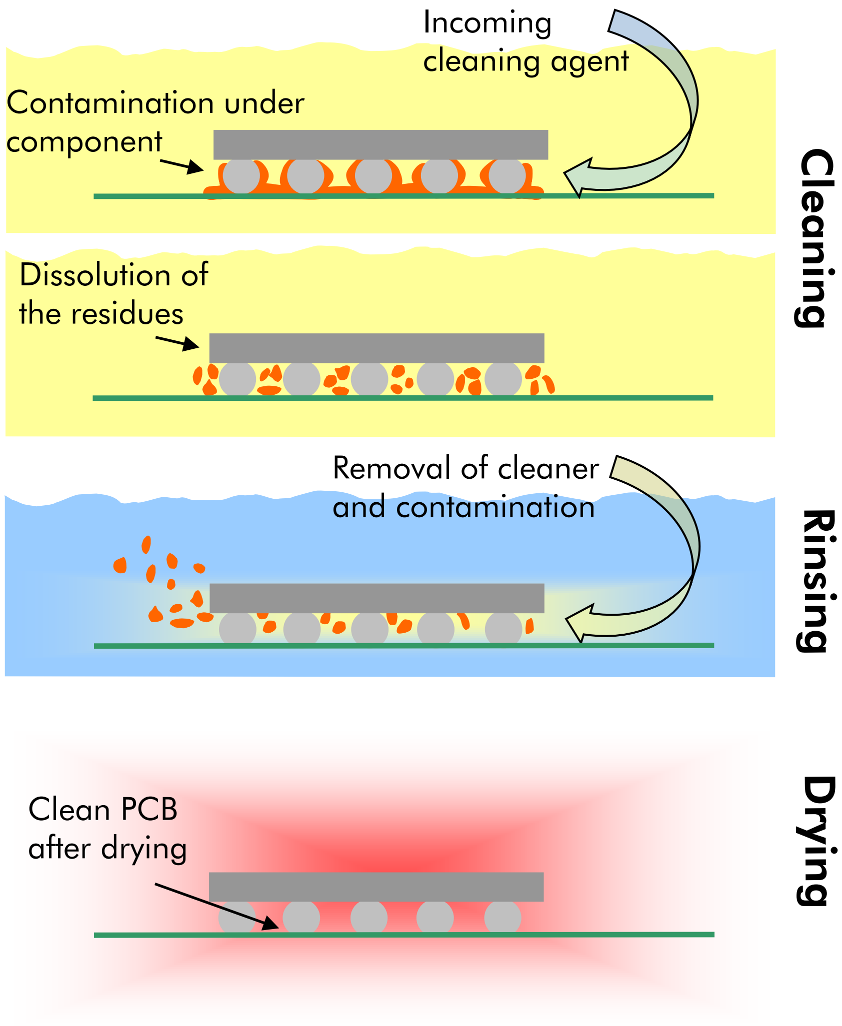
Alkaline pH-value is optimal for flux removal

Neutral pH-value is optimal for material compatibility

The Cleaning Process

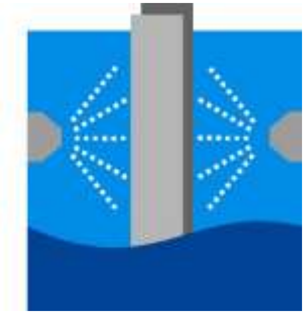
- Requirements to a suitable cleaning process:

- Cleaning equipment and medium have influence on the process



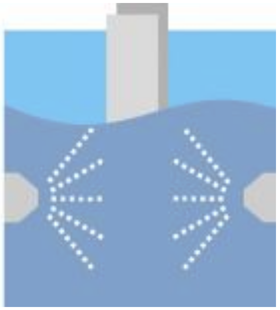
Agitation methods – Water based

ZESTRON High Precision Cleaning

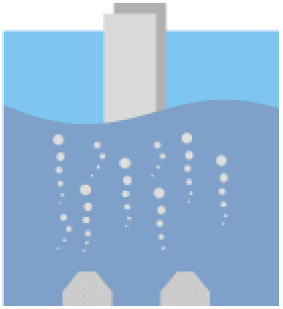


Spray

Ultrasonic



Spray-under-Immersion

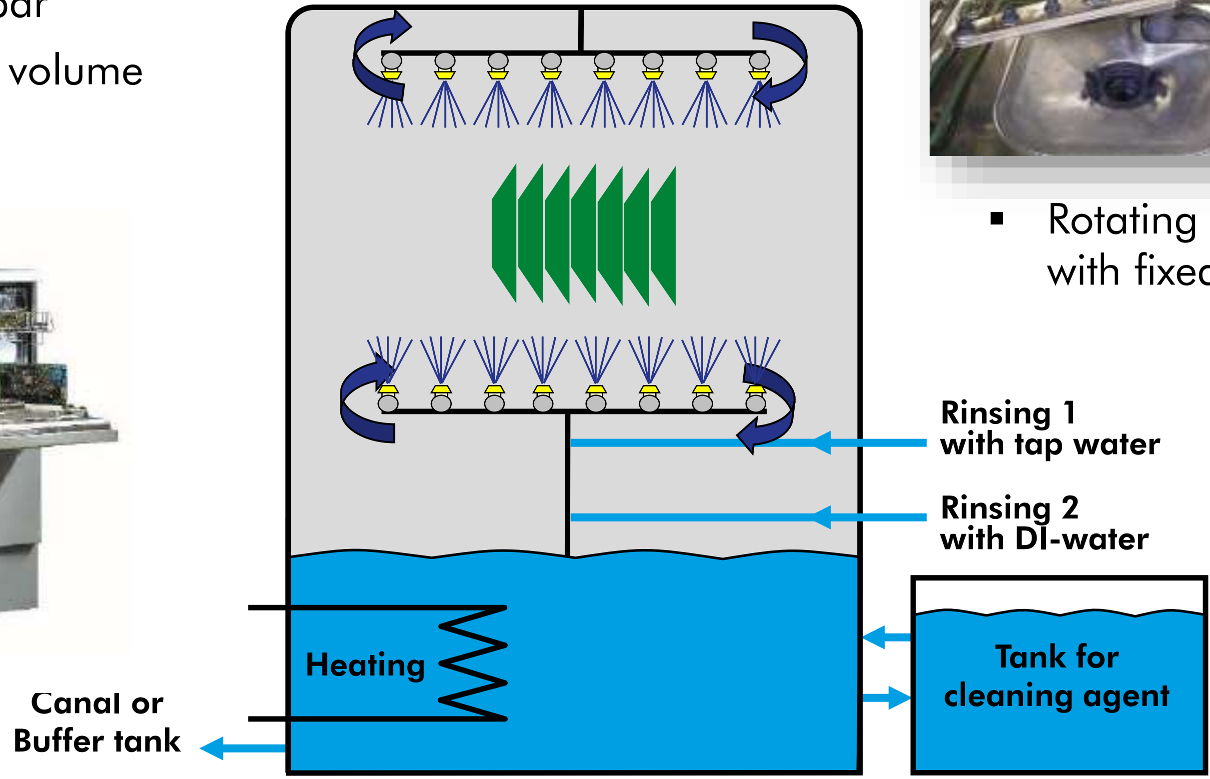


Immersion
Air supported

Spray-in-air / Batch process

Process characteristics:

- For low and medium throughput
- Spray pressure < 1bar
- Low pressure – high volume
- Small footprint



- Rotating arms with fixed nozzles

Spray-in-air / Inline process

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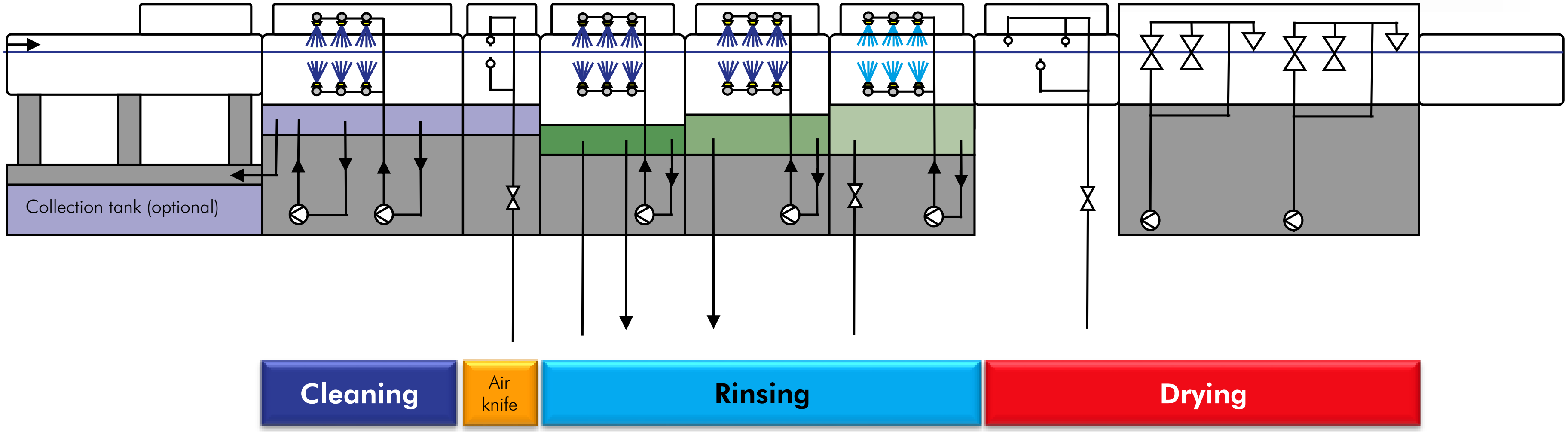
High Precision Cleaning

Process characteristics:

- Medium to high throughput (6-12m²/h)
- High pressure (Spray pressure > 2bar) – low volume
- Large space requirement (>6m length)



Typical Cleaning Systems

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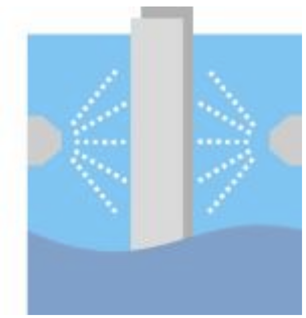
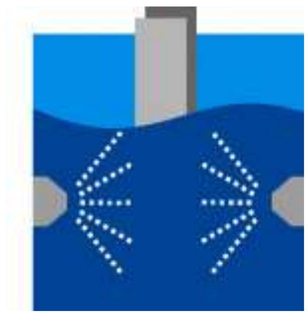
High Precision Cleaning

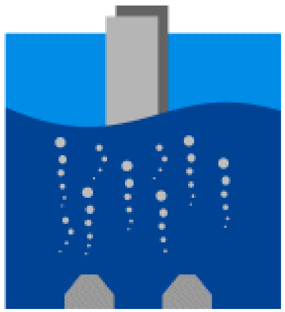


Spray

Ultrasonic

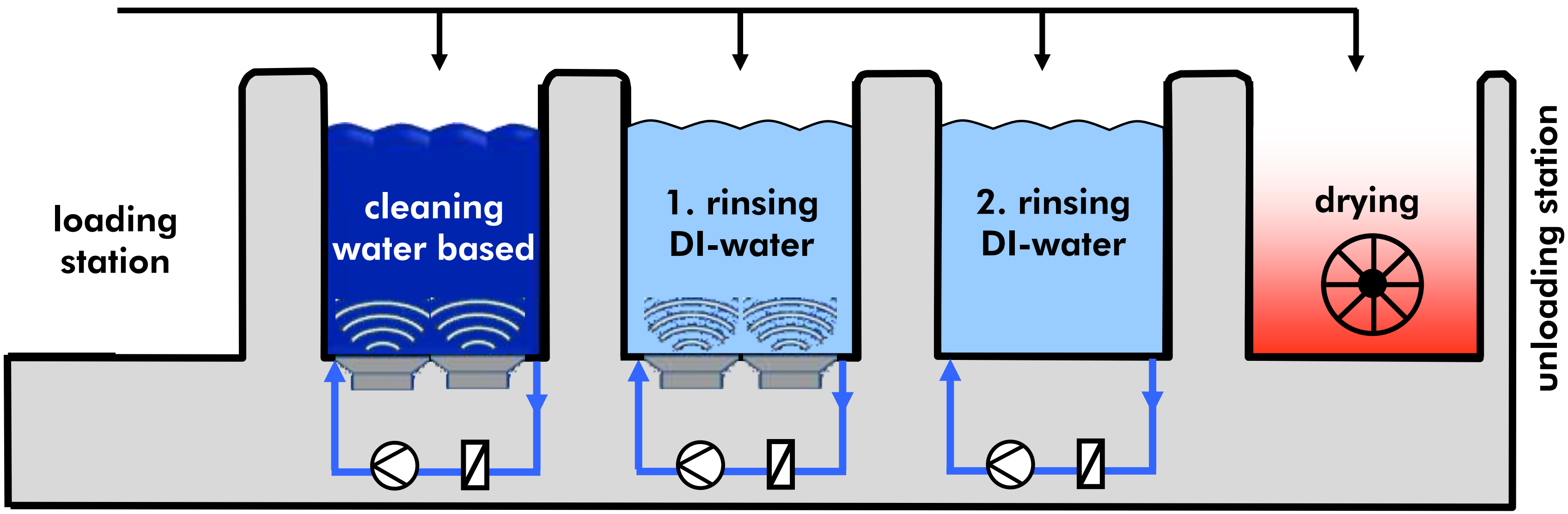


Spray-under-immersion



Immersion
Air supported

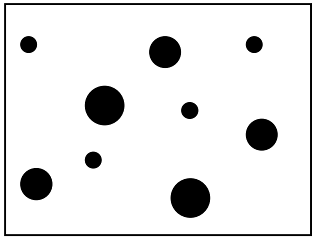
Set-up of a typical ultrasonic process



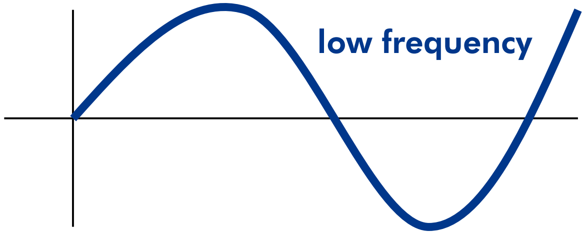
Impact of the frequency:

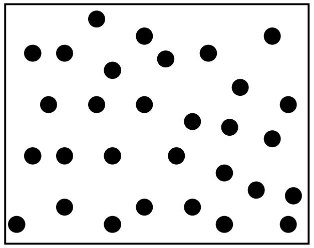
- More energy per bubble at lower frequency
- Higher mechanical effect at lower frequencies
- Better material compatibility at higher frequencies
- Better distribution of the mechanical effect at higher frequencies

→ **Recommendation: 40 kHz according to IPC**

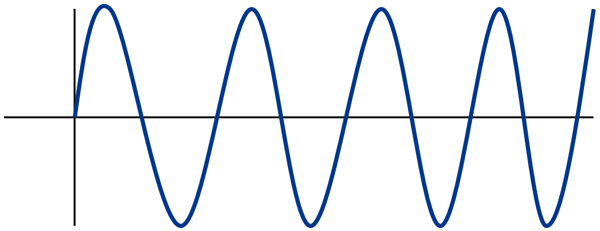


Distribution at 25 kHz



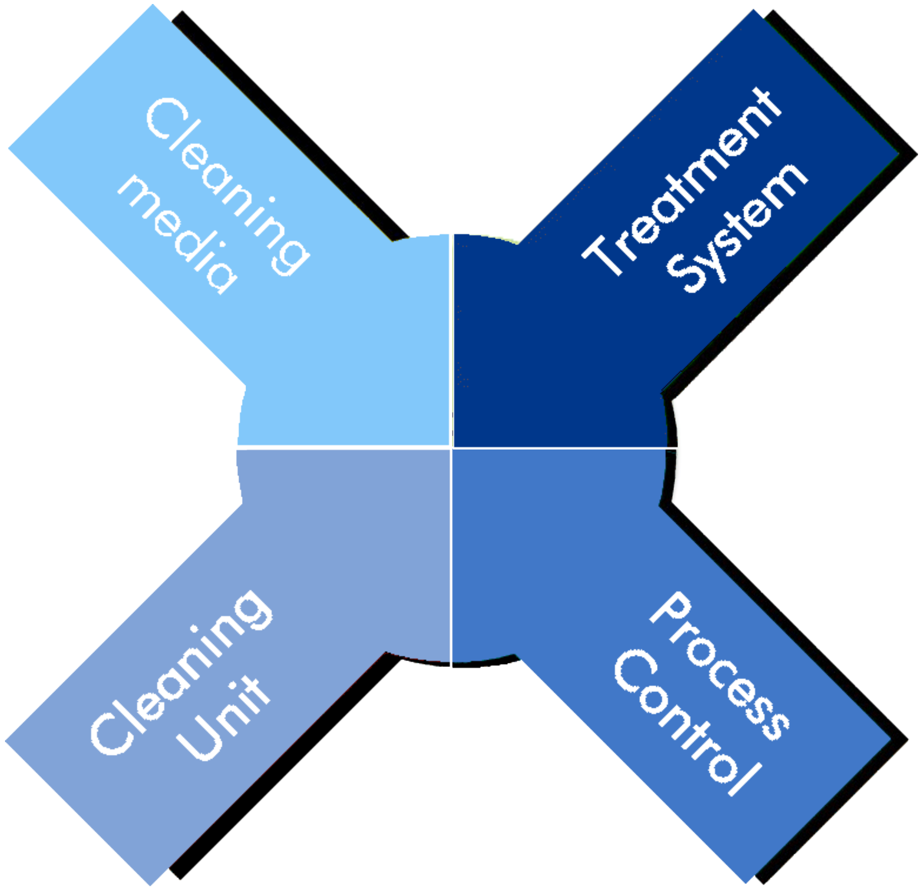


Distribution at 40 kHz



High frequency

All Factors need to be adjusted



Goal: stable running processes

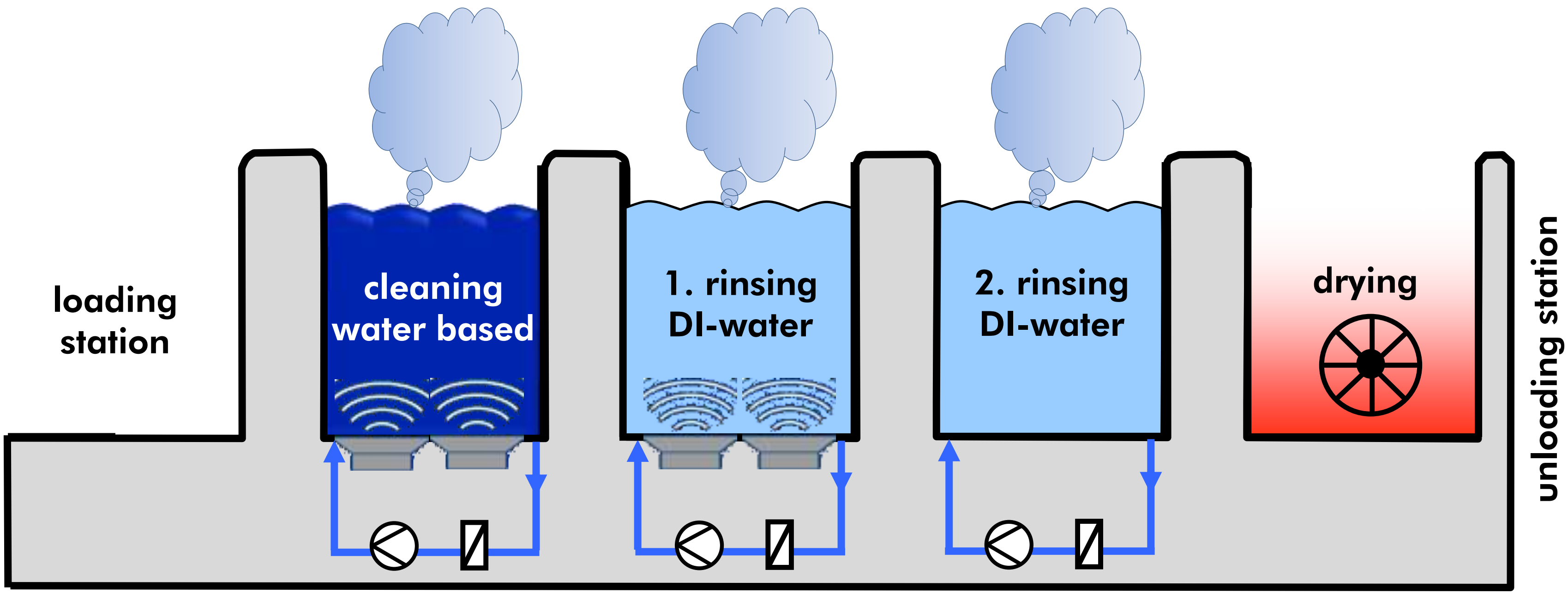
Agenda

ZESTRON
High Precision Cleaning

- Why Cleaning of electronic assemblies?
  - Standards
  - Reliability
  - Subsequent processes
- Cleaning processes
  - Cleaning chemicals
  - Cleaning machines
- **Cleaning process monitoring**
  - **Bath monitoring**
  - **Result monitoring**
- Process cost

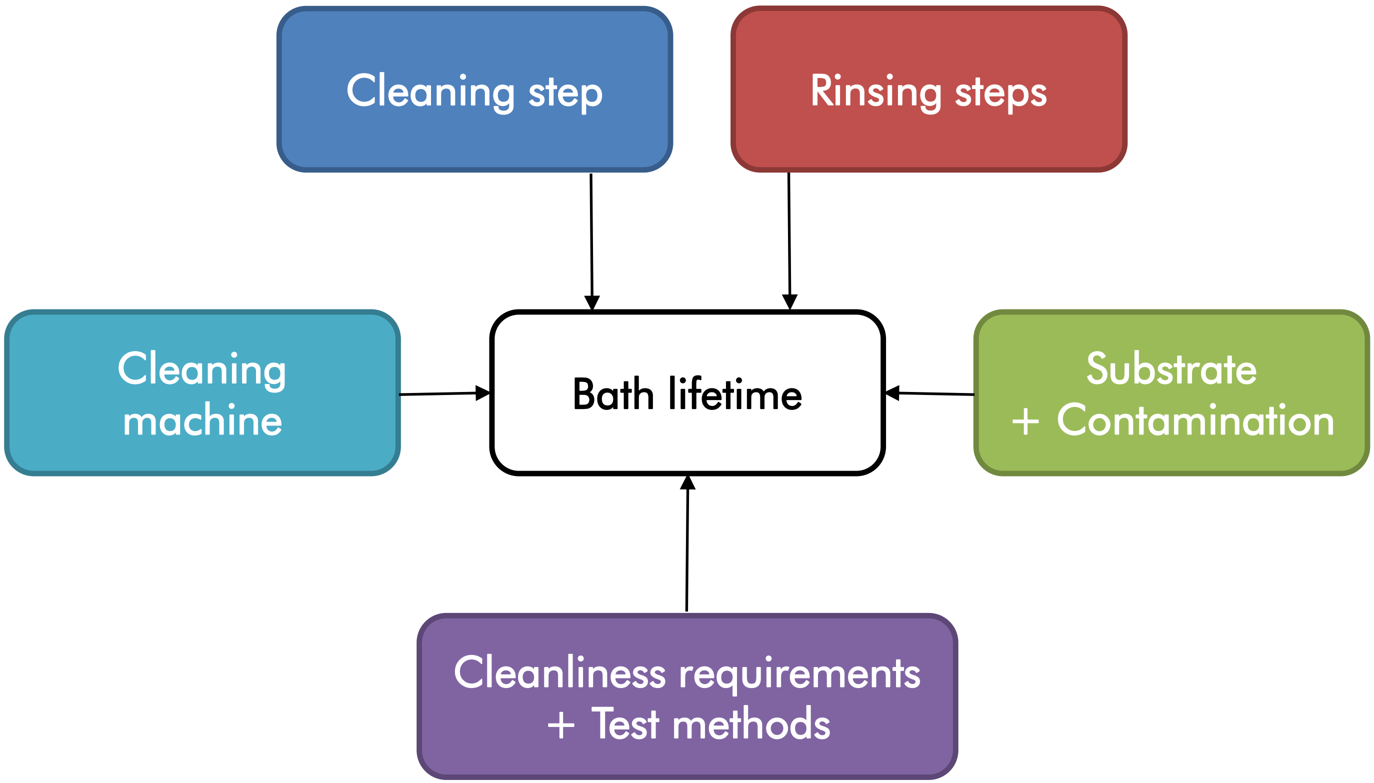
Why is monitoring important

- Evaporation-losses
- Drag-out
- Contamination



Factors influencing the cleaning bath lifetime in spray-in-air processes

When do I have to change my cleaning bath?



Surface Analysis can be used as a tool for process control.

Indirect Assessment

Standardized

Not-Standardized

Direct Assessment

Portfolio Concentration Measurement

ZESTRON High Precision Cleaning

Manual	Manual / digital, real-time	Continuous, inline, real-time

ZESTRON Bath Analyzer 10

ZESTRON Bath Analyzer 20

ZESTRON EYE M Mobile

ZESTRON EYE 3P-Technology

Level of Automation →

Possibilities to monitor contamination
Examples

Conductive measurement

pH-value

Refraction index

ZESTRONs
bath monitoring starter kit

ZESTRON High Precision Cleaning

- **ZESTRON service for evaluating the bath lifetime:**

- You receive six bottles („sixpack“) when the wash tank of your system is first-time filled with a ZESTRON cleaning agent.

- You send bath samples to the ZESTRON laboratory at regular intervals and provide the following feedback:

  1) Substrate surface cleaned so far or current number of cleaning cycles.

  2) Current cleaning results: good / medium / bad (or more detailed information if possible)

- ZESTRON will measure the <u>concentration</u> of the bath sample as well as <u>bath loading parameters</u>: conductivity, solids content, rinsability, pH value, etc.

Aim:

1) **Easy and controlled start-up of your cleaning process.**

2) **Early detection of the time at which you should change the cleaning bath** → We determine an application-specific bath loading parameter with associated limit value, which you can integrate into your routine bath monitoring.

Option no. 1 for measuring the bath loading

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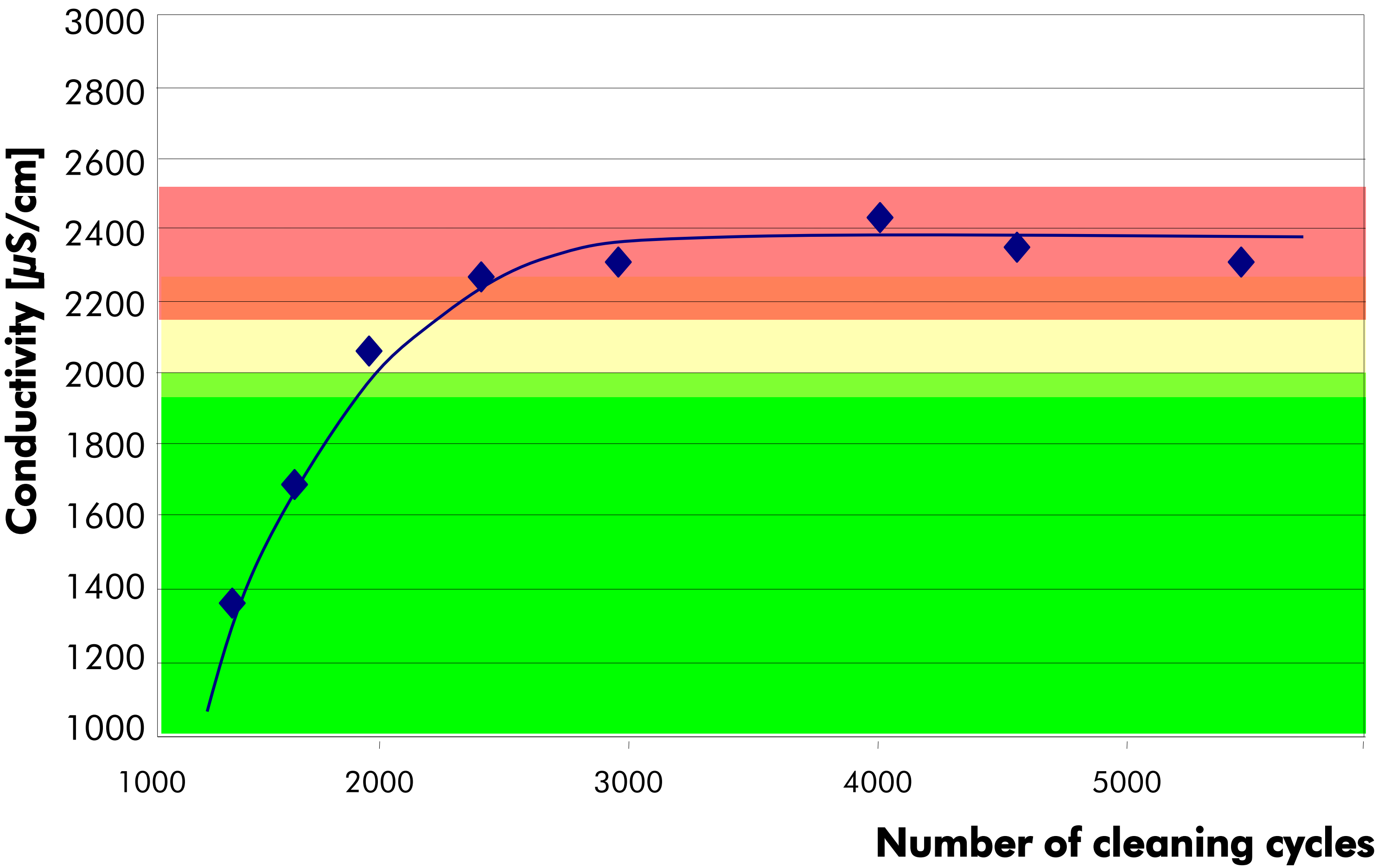
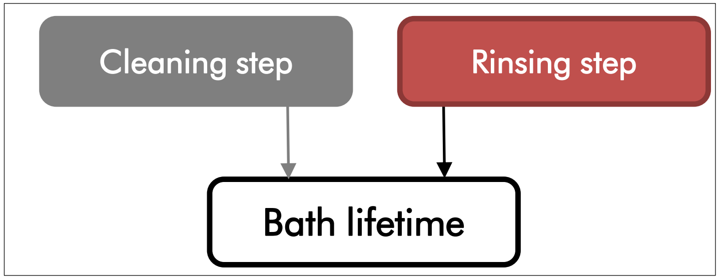
High Precision Cleaning



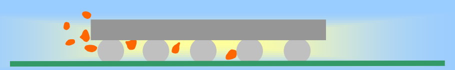
Influencing factors – Rinsing steps

ZESTRON High Precision Cleaning



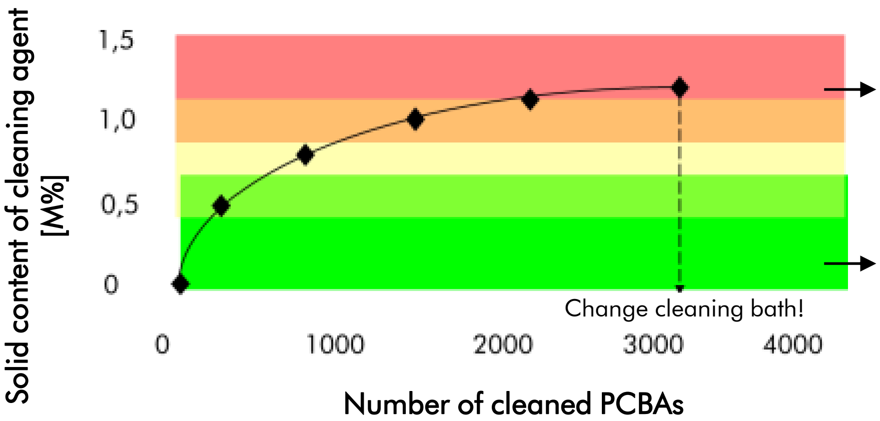
- **Rinsing water quality** (organic and salt content)
- **Rinsing temperature**
- **Rinsing time and number of rinsing steps**
- **Mechanical rinsing performance** (machine-dependent)
- **Drip-off time between cleaning and rinsing**

After cleaning and drip-off: Removal of loaded cleaning agent still adherent to the substrate (and trapped in capillaries)



With increasing wash cyles/ bath loading, the rinsability of cleaning agents decreases.
→ Spotting (redeposition of contaminants on the substrate surface).

Excessive drip-off times (> 60-90 seconds) can cause drying of loaded cleaning agent on the substrate. → Difficult to remove/ rinse off

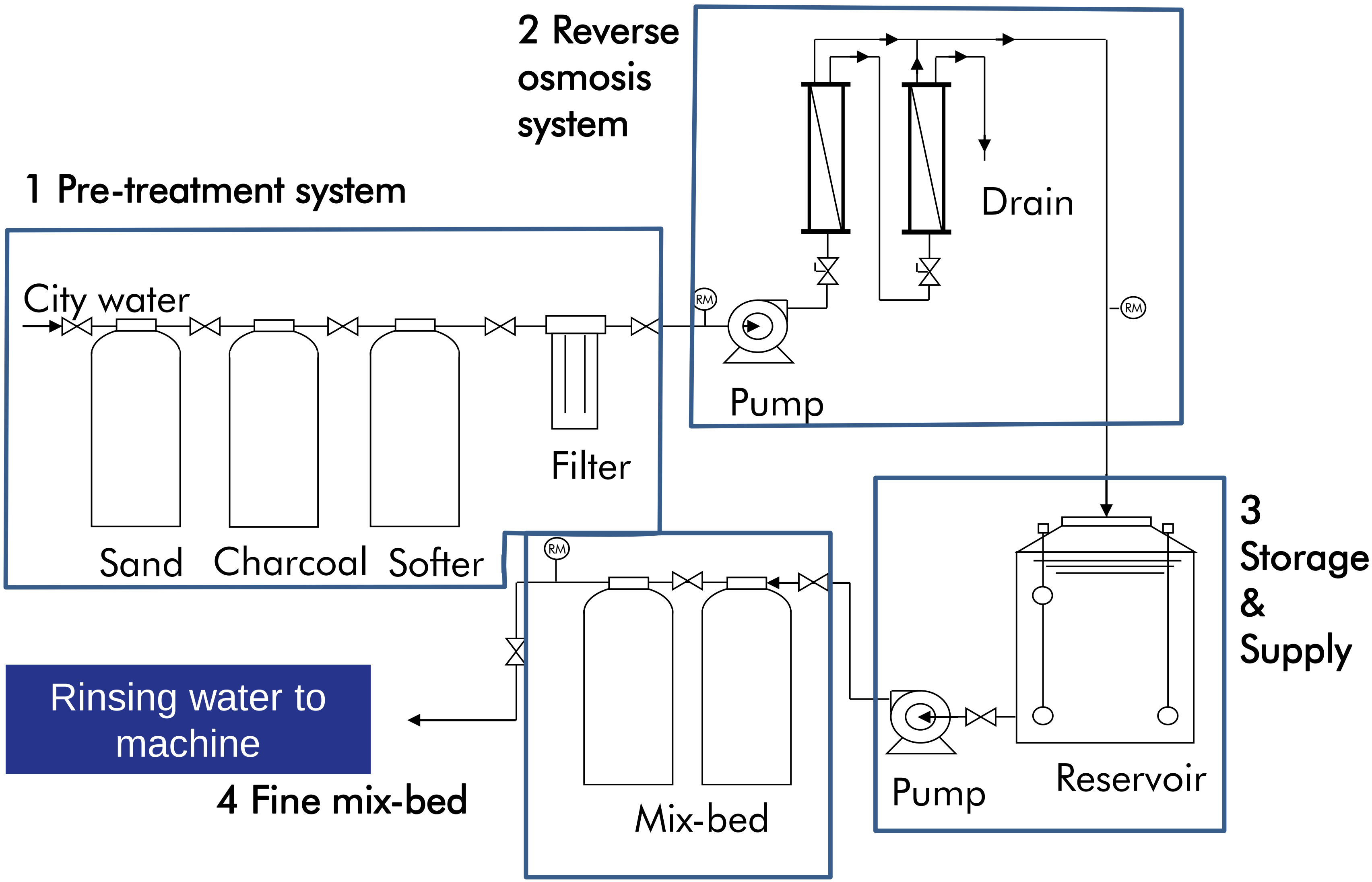


Cleanliness requirements <u>not met</u>

Cleanliness requirements met

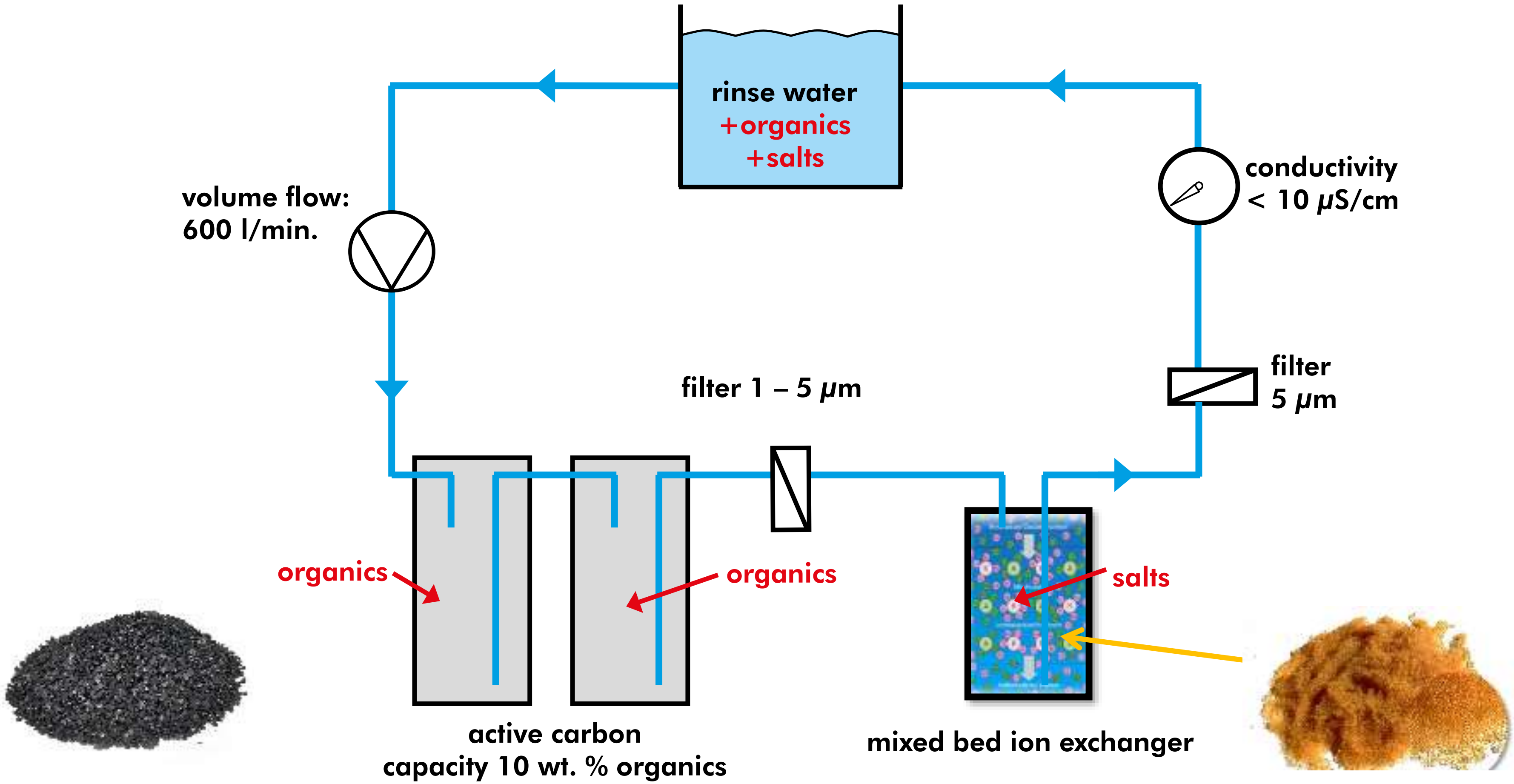
Typical factory water supply for cleaning

ZESTRON High Precision Cleaning



Cloosed Loop Water Treatment

Requirement	Acceptance value
Low organics (last rinse)	nd ≤ 1,333
Low conductivity (last rinse)	1/5/10 µS depending on substrates



Measuring equipment and target values for rinsing water control

ZESTRON
High Precision Cleaning

Conductivity

Offline

or

Inline

(many PCBA cleaning systems have inline conductivity sensors in the rinsing stages as a standard feature)

Refraction index

Usually **Offline**

(only few PCBA cleaning systems are equipped with inline refractometers)

- **Recommended salt content of rinse water** in PCBA cleaning processes:

  Conductivity < 10 µS/cm (at least in the final rinse stage)
  → so called demineralized/ deionized water

- **Recommended organic content** of rinse water in PCBA cleaning processes:
  Refractive index as close as possible to 1.3330 (589nm; 20°C)

  → corresponds to the value for organic-free water (liquid)

Analytic methods: Validation vs. Monitoring

Validation / Risk assessment	Process monitoring
Ionchromatography → IPC 9202	Optical inspection (IPC-A-610)
Infrared-Spectroscopy	Ionic contamination / ROSE-Test
Surface Insulation Resistance (SIR) → IPC 9202	ZESTRON Flux- / Resin-Test
Temperature-Shock-Testing	Test-ink fopr surface energy
	End of Line (electrical test)

ZESTRON® Flux/Resin Test

ZESTRON High Precision Cleaning

- Detection of activator residues originating from flux
- Shows local distribution
- Based on color reaction

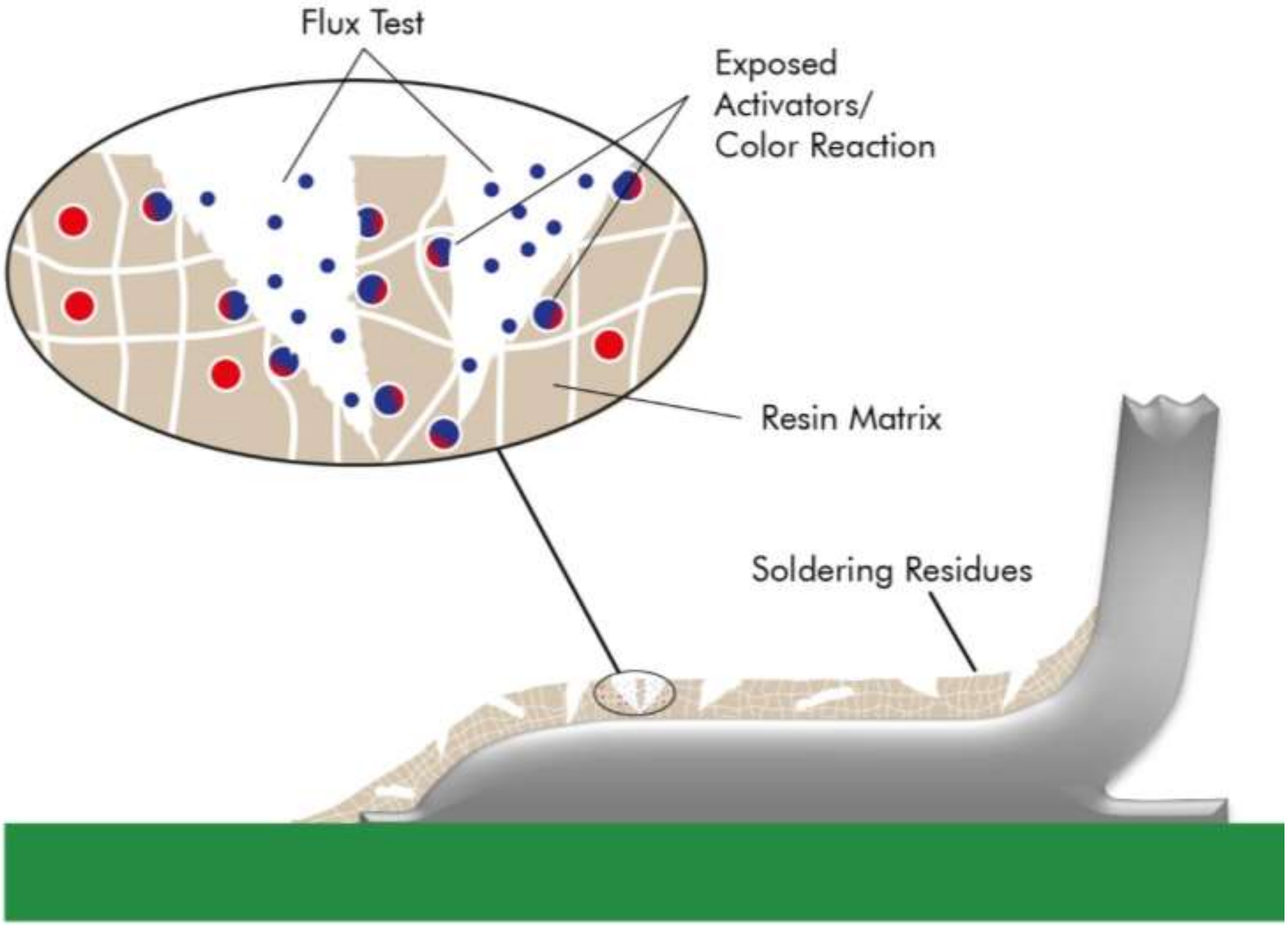
Apply

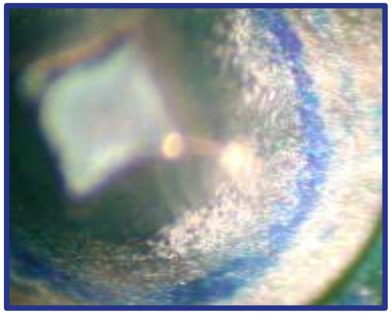
Rinse

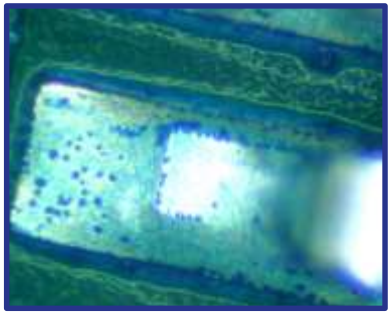
Dry

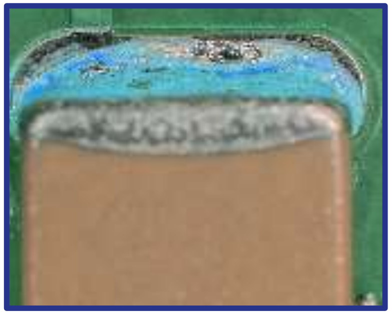
Flux Test

ZESTRON High Precision Cleaning



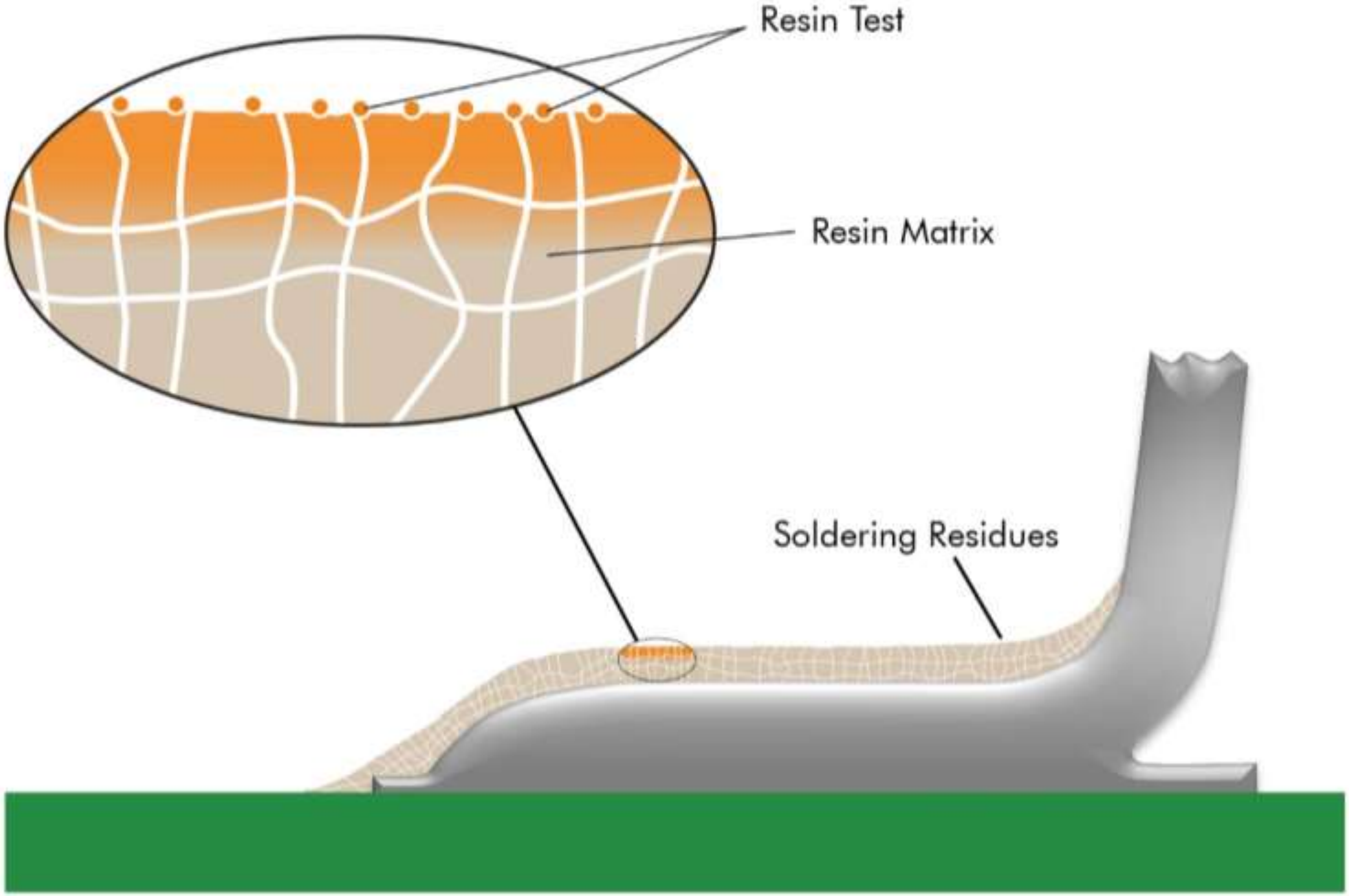


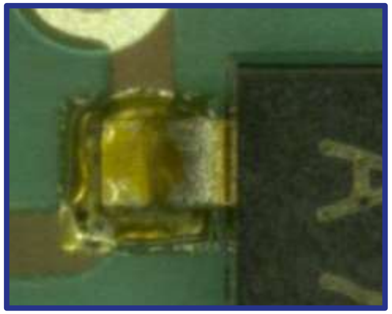


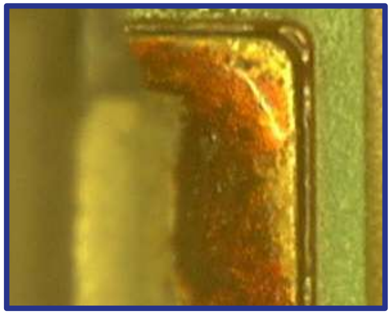


Resin Test

ZESTRON
High Precision Cleaning







Analytic methods: Validation vs. Monitoring

ZESTRON High Precision Cleaning

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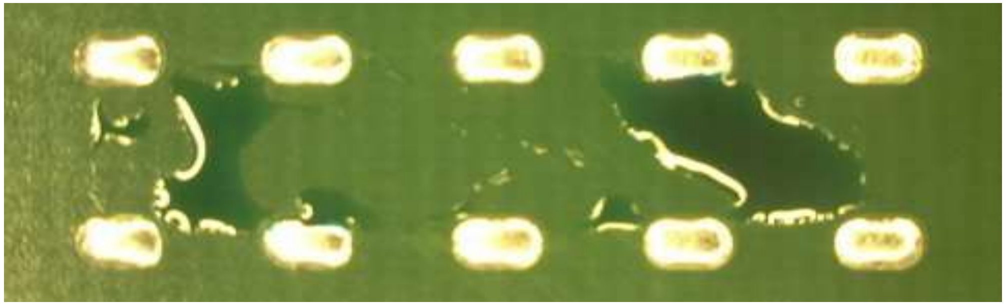
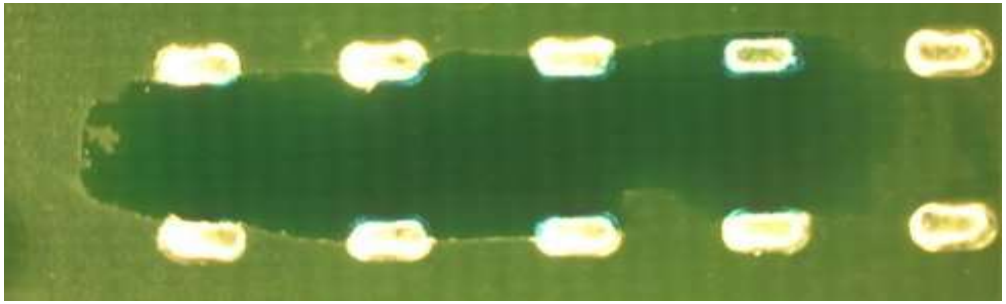
Surface Insulation Resistance (SIR) → IPC 9202	ZESTRON Flux- / Resin-Test
Temperature-Shock-Testing	Test-ink fopr surface energy
	End of Line (electrical test)

ZESTRON
High Precision Cleaning



Bad wetting = unclean surface



Good wetting = clean surface

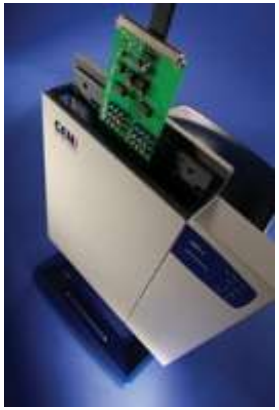
Test Method: Ink Test

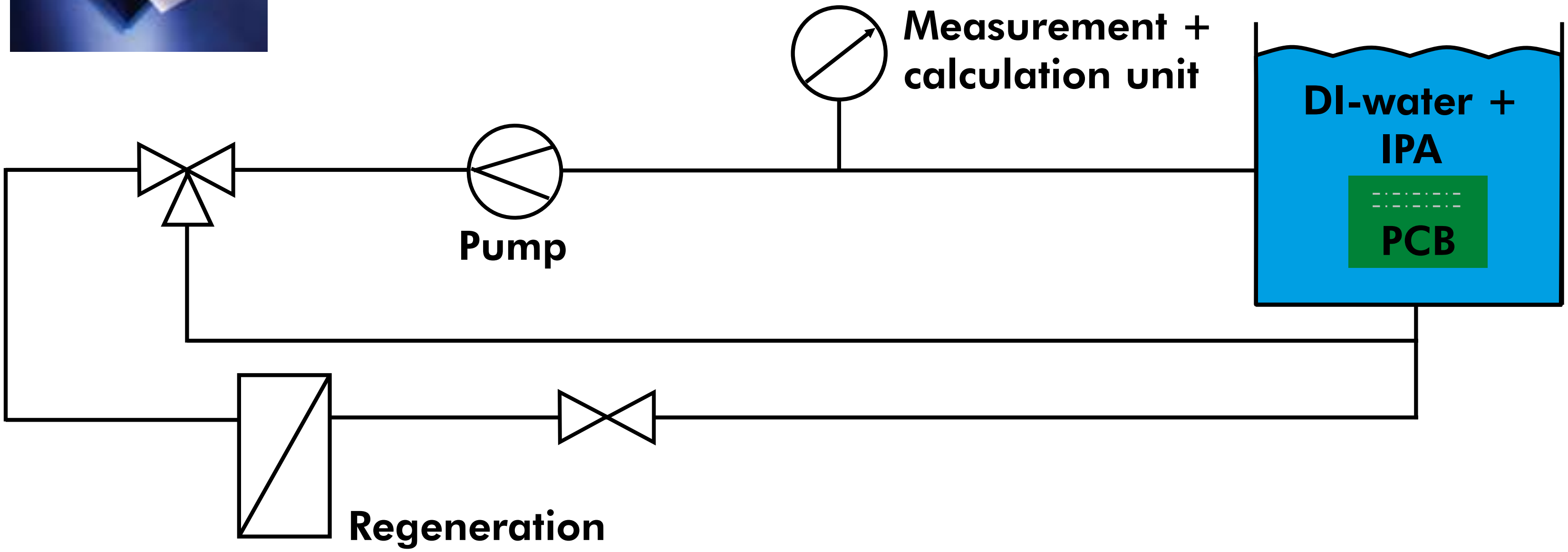
Analytic methods: Validation vs. Monitoring

ZESTRON High Precision Cleaning

Validation / Risk assessment	Process monitoring
Ionchromatography → IPC 9202	Optical incpestion (IPC-A-610)
Infrared-Spectroscopy	Ionic contamination / ROSE-Test
Surface Insulation Resistance (SIR) → IPC 9202	ZESTRON Flux- / Resin-Test
Temperature-Shock-Testing	Test-ink fopr surface energy
	End of Line (electrical test)

Static Measurement Devices





Static Measurement (GEN 3)

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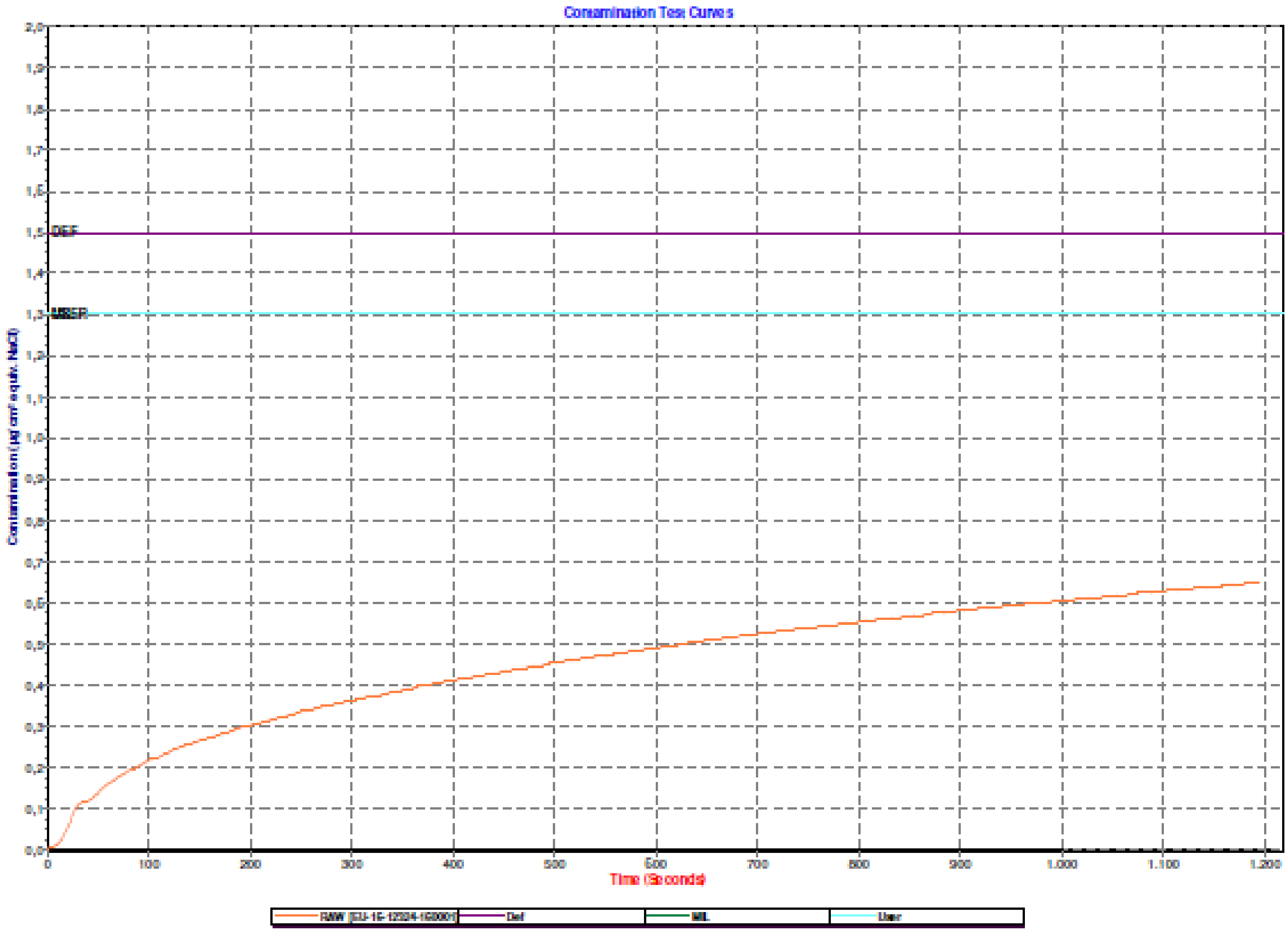

Equivalency Factors for Different Equipment

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High Precision Cleaning

- Every equipment gave different readings for identical test substrates
- Military incorporated „equivalency factors“ MIL-2000A:

Instrument	Equivalency factor cm^2 & in^2	Acceptance limit (μg NaCl eq./in^2)	Acceptance limit (μg NaCl eq./cm^2)
Omegameter	1,39	14	2,2
Ionograph	2,01	20	3,1
Zero Ion	3,83	37	5,7
Original Method	1	10	1,56

IMPORTANT:
This Standard does not exist anymore and is not valid.
This chart should only visualize the difference of different systems.

Analytic methods: Validation vs. Monitoring

ZESTRON High Precision Cleaning

Validation / Risk assessment	Process monitoring
Ionchromatography → IPC 9202	Ionic contamination / ROSE-Test
Infrared-Spectroscopy	ZESTRON Flux- / Resin-Test
Surface Insulation Resistance (SIR) → IPC 9202	Test-ink fopr surface energy
Temperature-Shock-Testing	End of Line (electrical test)

Test Method – Ion Chromatography

- IPC TM 650 2.3.28 (Extraction:1h, 80°C)
- Identifies and quantifies specific ionic species that are present
- Measures cations and anions
- Measures weak organic acids
- Provides a method for process evaluation, characterization and qualification

Demands According to IPC-CH-65B

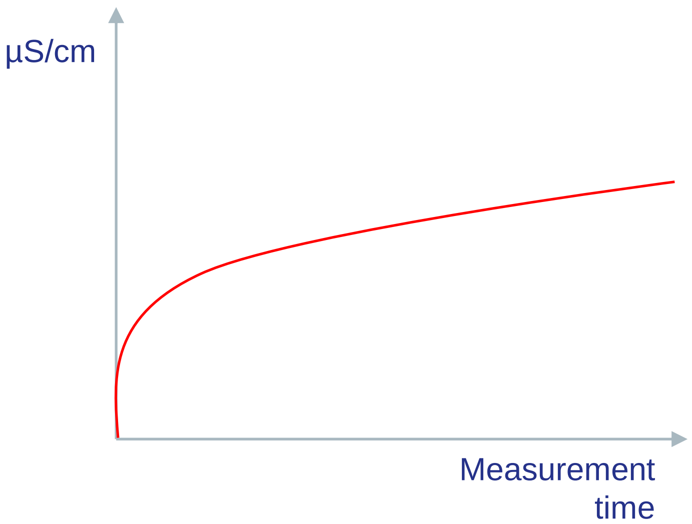
ZESTRON
High Precision Cleaning

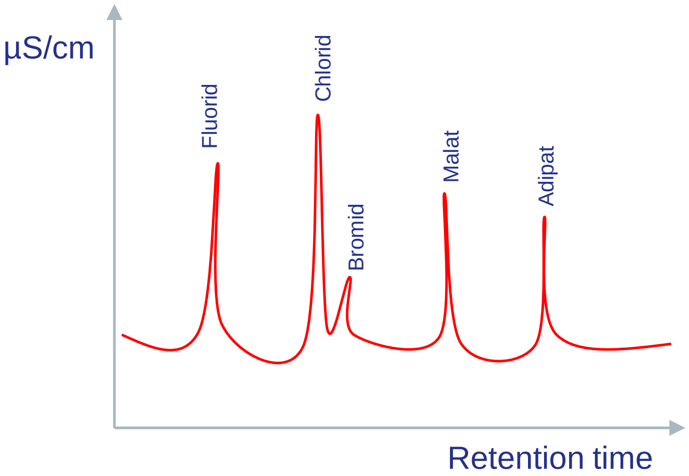
Minimum Ionic Species	µg/cm²
Bromide	< 1,55
Chloride	< 0,93
Fluoride	< 0,47
Sulfate	< 0,47
Phosphate	< 1,09
Nitrates	< 0,47
Weak Organic Acids	< 3,88

Table 1: Contamination Levels per IPC TM-650 2.3.28

Ionenchromatography - IC vs. ROSE-Test

ROSE-Test	Ion Chromatography
Conductivity measurement	Conductivity measurement
Measurement of all ions together	Measurement of single ion species
Total ion content	Ions by type and amount
No risk assessment possible	Risk assessment possible
Time for measurement max. 1 h	Time for measurement > 20 h





Agenda

- Why Cleaning of electronic assemblies?
  - Standards
  - Reliability
  - Subsequent processes
- Cleaning processes
  - Cleaning chemicals
  - Cleaning machines
- Cleaning process monitoring
  - Bath monitoring
  - Result monitoring
- **Process cost**

Factors of process costs

- Equipment invest (amortisation)
- Cleaning medium
- Operating materials (DI-water, etc.)
- General operation costs
- Personnel costs / Maintenance costs
- Environmental costs (disposal)

Cost Comparison of Different Throughputs

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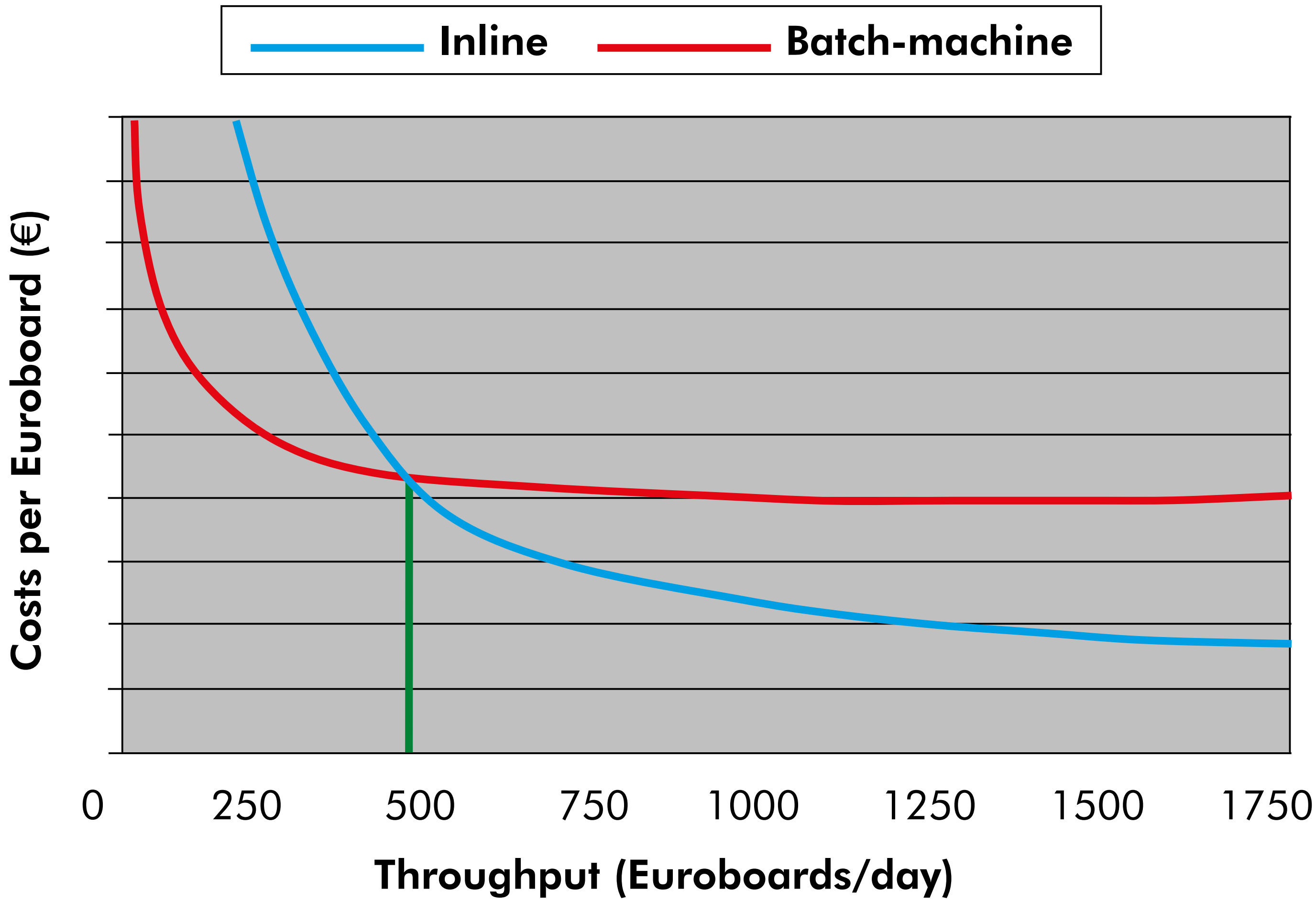
High Precision Cleaning



Costs depend on throughput and equipment

Process costs

Costs of
cleaning medium

Costs per substrate

Costs per m^2

Not the price of the medium, but the costs per cleaned part are relevant

PCB Cleaning

Stefan Strixner

Principal Engineer