Customized Cleanliness Suitable Cleanrooms and Manufacturing Equipment

VCCN Annual Cleanroom Symposium/15th Exhibition Contamination Control: What determines the suitability of a material for / in a cleanroom?
23rd May 2012, Nijmegen, The Netherlands

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Fraunhofer IPA, Ultraclean Technology and Micromanufacturing

Cleanroom® Suitable Materials

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Outline of the Presentation

- **Fraunhofer IPA and Industrial Alliance CSM at a Glance**
- **Relevancy of Cleanroom Suitable Materials**
- **Methods to determine the Cleanroom Suitability of Materials**
  - Particle Emission
  - Cleanability
  - Chemical resistance
  - Biological Resistance and Microbicidity
  - Outgassing
- **Benefit for CSM Partners: Certification & Database**
- **Summary**

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Fraunhofer IPA and Industrial Alliance CSM at a Glance

- Fraunhofer IPA, Ultraclean Technology and Micromanufacturing
  - more than 25 years of experience and know-how in the field of production processes conducted under cleanroom conditions
  - development of measuring equipment
  - certification of cleanliness suitability
  - initiator of **Industrial Alliance CSM**

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  - more than 25 years of experience and know-how in the field of production processes conducted under cleanroom conditions
  - development of measuring equipment
  - certification of cleanliness suitability
  - initiator of **Industrial Alliance CSM**
- our customers:
  - manufacturers of contamination critical products
  - manufacturers of cleanroom equipment
  - cleanroom planners/production suppliers

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CSM Participants
– Partners of Phase 1, 2 and 3

- AMD Saxony Manufacturing GmbH
- Carl Zeiss Semiconductor Manufacturing Technologies AG
- COLANDIS GmbH
- DESY-Deutsches Elektron-Synchrotron
- Festo AG & Co. KG
- Forbo Flooring GmbH
- Gerflor Mipolam GmbH
- Grenzebach Maschinenbau GmbH
- INA-Schaeffler AG
- Infineon Technologies AG
- Qimonda AG, Dresden
- KARDEX Organisationssysteme GmbH
- Klüber Lubrication München KG
- KUKA Roboter GmbH
- Océ-Technologies B.V.
- Parker Hannifin GmbH, EMD HAUSER
- Philips Semiconductors GmbH
- rap.ID Particle Systems GmbH
- Schott AG
- Schunk GmbH & Co. KG
- Sto AG
- Sieghard Schiller GmbH & Co. KG
- Siltronic
- Sika Deutschland GmbH
- SKF Linearsysteme GmbH
- Uhlmann Pac-Systeme GmbH & Co. KG
- Unaxis Balzers AG
- M+W Zander Holding AG
- VAT Vakuumventile AG

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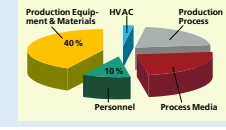
Production Equipment and Materials

today's situation
- **production equipment and materials: ~ 40 % influence upon the products' cleanliness**



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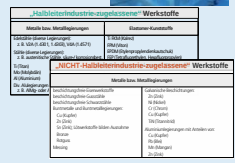
problem
- worldwide **hardly any specifications available:** most times: mere demand for cleanroom suitability



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method used up till now
- selection of materials determined by: **empirics, previous experience, hearsay, appearance**

→ wrong material selection: **loss of production**

aids

→ development of a test standard to determine the **cleanliness suitability of materials**

→ **aim: material data base**

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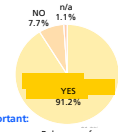
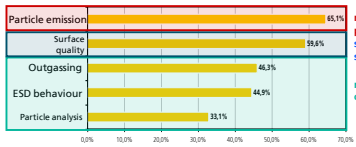
Relevance for the Industry?

- **market analysis of Fraunhofer IPA »Cleanrooms suitable materials« (2003):**
  - Survey with **2700 companies, quota of return: 11 %**
- **main results:**
  - **Very high relevance** of "cleanroom suitability"
  - Prioritisation of different **contamination factors**





most important: particle emisson
second most important: surface quality

next prioritisation: outgassing, ESD, …

→ **panel of experts**: establishment of an **industrial consortium CSM®**

→ **aim: industrially applicable method** to determine the cleanroom suitability of materials

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Methods to determine the Cleanroom Suitability

Particle emission

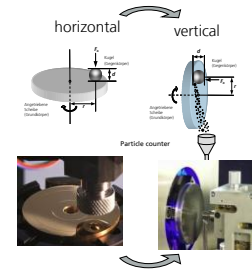
Innovative, creative method for the assessment of materials:

→ small-scale test according to tribological „Pin-on-disk"-technique

→ **turning of the test arrangement**

→ **measurement of emitted particles** with particle counter

test rig: Material Inspec



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Methods to determine the Cleanroom Suitability

Particle Analysis

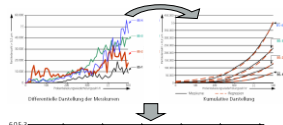
New innovative analysis for the **assessment**:

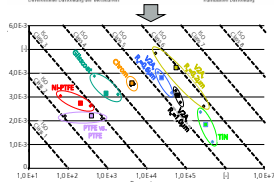
→ **conventional view** of particle emission: differentiell

→ **mathematical change of view**:
- cumulation
- non-linear regression
- coordinate transformation

Résumé from these new conceptions:

→ **explicit classification of the cleanroom suitability of materials**





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Methods to determine the Cleanroom Suitability

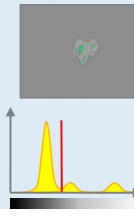
Cleanability of Surfaces

Efficiency regarding removal of particles:

Procedure:
- Defined contamination of test pieces with silver particles 0.5µm and larger
- Automated full-surface SEM particle count (approx. 9 hours)
- Automated CO_2 cleaning
- Renewed count and determination of cleaning efficiency

	Particle size		
	1-5µm	5-10µm	10-50µm
Before	47023	9427	3063
After	66	0	0
Efficiency	46957	9427	3062
Efficiency %	99.9%	100%	100%

Requirement:
Adequate material contrast between particles and surface



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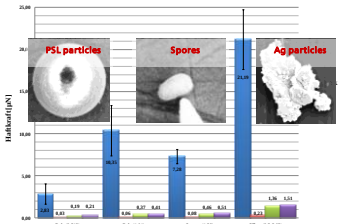
Methods to determine the Cleanroom Suitability

Cleanability of Surfaces

»Adhesive forces are the cause of all surface effects leading to contamination and influencing cleaning«

Hauser G. (2008). Hygienic Manufacturing Technology Weinheim: WILEY-VCH Verlag GmbH & Co. KGaA



Are the results with silver transferrable to other particles

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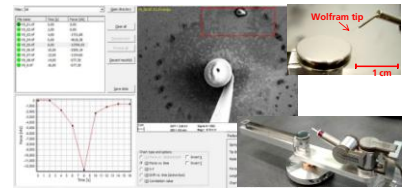
Methods to determine the Cleanroom Suitability

Cleanability of Surfaces

But: is it possible to measure the adhesive forces of micrometer-sized particles?



Conclusion: by comparing the adhesive forces of different particles, the results from cleaning tests on model particles can be transferred to real particles.

Test set-up:
- SEM with serial image function
- Micromanipulator
- Force spring table
- Data processing

Advantages:
- Direct test method (no complex sample preparation required)
- Adhesive forces measurable from **50nN** upwards

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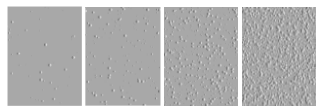
Methods to determine the Cleanroom Suitability

Chemical Resistance

- Surfaces have to be resistant against reagents used to clean, process or sanitize.
- Test method according to
  - ISO 2812-1: Immersion in Liquids other than water
  - ISO 2812-4: Spotting method



N = 2 N = 3 N = 4 N = 5

Value	Amount of damage (N)	Size of damage (S)	Intensity (I)
0	No recognizable damage	Not visible by 10x magnification	No alteration observable
1	Very little, i.e. small, just recognizable amounts of damage	Only visible by 10x magnification	Marginal- just visible alteration
2	Little, but significant amounts of damage	Just visible by normal eyesight	Minor - Clearly visible alteration
3	Average amount of damage	Clearly visible by normal eyesight up to 0,5 mm	Medium - Very clearly visible alteration
4	Severe amounts of damage	0,5 – 5 mm	Strong – distinct alteration
5	Extreme amounts of damage	>5 mm	Very strong - major alteration

Chemical	after 24h
formalin (37 %)	2
ammoniac (25 %)	3
hydrogen peroxide (30 %)	4
sulfuric acid (5 %)	1
phosphoric acid (30 %)	1
peracetic acid (15 %)	3
hydrochloric acid (5%)	3
isopropanol (100%)	1
sodium hydroxide solution (5 %)	2
sodium hypochlorite (15 %)	4

Rounded mean value = 1

Chemical resistance	CSM-Classification
0	excellent
1	**very good**
2	good
3	weak
4	very weak
5	none

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Methods to determine the Cleanroom Suitability

Biological Resistance

- test method according to ISO 846
  Method A: fungi
  Method C: bacteria
- incubation of test samples (approx. 50 x 50 mm) with appropriate inoculum placed on a carbon-free agar-media
- visual and microscopic growth inspection after incubation for 4 weeks at 24 °C for fungi and bacteria
- CSM-Classification is the inferior value of the biological resistance results of method A and method C

Biological resistance	CSM-Classification	Assessment
0	excellent	not visible by 10x magnification
1	very good	only visible by 10x magnification
2	good	visible by normal eyesight, up to 25 of sample surface covered
3	weak	visible by normal eyesight, up to 50 % of sample surface covered
4	very weak	considerable growth, over 50 % of sample surface covered
5	none	strong growth, whole sample surface covered

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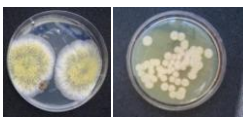
Methods to determine the Cleanroom Suitability

Microbicidity

- test method according to ISO 22196
- incubation of test sample with antibacterial property and blank sample of the same material but without antibacterial property
- covering with appropriate lid
- incubation for 24 hours at 35 °C
- recovery of the bacteria from the test samples and determination of the CFU (colony forming units).
- calculation of the R-value
- final CSM-Classification is the achieved R-value after 24 hours incubation



Mikrobicidity R-value	CSM-classification
>= 4	excellent
< 4	very good
< 3	good
< 2	weak
<1	very weak
0	none

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Methods to determine the Cleanroom Suitability

Outgassing Behaviour of Equipment Materials

To find out about the **suitability of equipments** to be used in **AMC-controlled environments**:
➔ emission behaviour of equipment has to be determined

critical components for clean applications:
Amines, Phthalates, Organophosphates, Siloxanes, Dopants, Total VOC and others

materials used in robot systems with possible outgassing behaviour to be monitored:

- lubricants and sealants
- surface treatments, coatings and paints
- plastics and elastomers

ISO-AMC Class	Concentration [g/m³]
0	10^{0}
-1	10^{-1}
-2	10^{-2}
-3	10^{-3}
-4	10^{-4}
-5	10^{-5}
-6	10^{-6}
-7	10^{-7}
-8	10^{-8}
-9	10^{-9}
-10	10^{-10}
-11	10^{-11}
-12	10^{-12}

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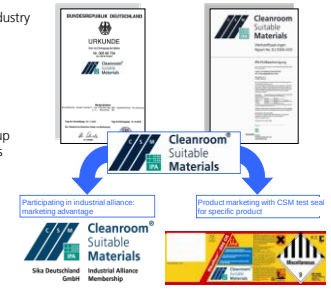
CSM Certification

- **Registered trademark** of the industry consortium
- **Certification** of tested materials

➔ **Benefit for Industry:**

- **Enduser:**
  Tool for planning and setting up cleanroom suitable equipments
- **suppliers:**
  marketing support for their products



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Benefit for Industry Partners

- optimization of equipment
  ➔ reduced contamination
  ➔ **reduced scrap**
- standardized tests with defined parameters
  ➔ **comparable results**
  (between companies and industry branches)
- national & international acceptance in guidelines and standards (VDI 2083-17 and ISO 14644-8/-9)
- test results in **certificates, test reports, test seals** results can be made **"publicly available"** in internet-databases
  ➔ **Strong marketing support**

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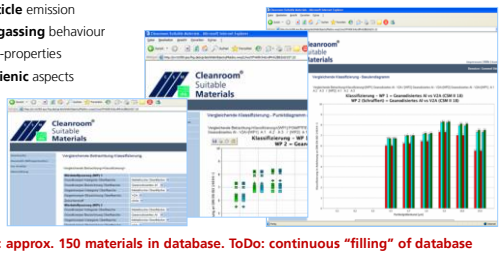
Knowledge-based Expert System: Internet Database

- **particle** emission
- **outgassing** behaviour
- **ESD**-properties
- **hygienic** aspects



So far: approx. 150 materials in database. ToDo: continuous "filling" of database
Benefit for companies:
Tool for planning and setting up cleanroom suitable equipments

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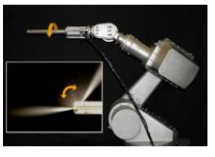
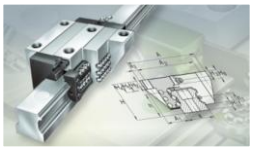
Realization Examples of Equipment with CSM Know-how

Pre-assessment and selection of possible materials for equipments and components

- **FESTO:** pneumatic cylinder
- **KUKA:** cleaning lance for a robot system
- **INA Schaeffler:** linear unit





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Summary

- **Procedure for the assessment** of the cleanroom suitability must be **exactly standardized** to achieve **comparability**.
- factors to be considered:
  - Low contamination patterns regarding **particle** generation
  - Minimal **outgassing** behaviour and **ESD-properties**
  - **Cleanable**, **chemical resistant**, **biological resistant** surfaces
  - Avoiding contamination by usage of appropriate **materials**
- material classification is a help
  - for **users**: to find the appropriate equipment
  - for **equipment manufacturer**: to optimize their equipment
  - for a **consistent system**: cleanroom environment/equipment

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