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ZERO "0" CONTAMINATION CLEANROOMS

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Abstract
From various points of views zero contamination cleanrooms will be necessary in the next 5 years latest.
Not only for the coming semiconductor production environments, but also for the nanotechnology and biotechnology as well as bio-safety new requirements have to be defined.
This affects not only cleanroom and clean air but also all other aspects of contamination control from ultrapure media to ultrapure surfaces to the measurements and monitoring of the contaminants and last but not least the control of the contaminations.

1. Introduction

The today regulations the German VDI 2083 (6) and the international ISO 14644 (7) already address the requirements of the tomorrow applications. So it is discussed in the very moment to use even the wording nano-particles in the guidelines.
Especially in the VDI 2083 all kinds of clean media are defined and described and even the ISO 14644, part 9, deals with clean surfaces.
If one looks to the other predominant applications which need contamination control like:

- Semiconductor industries
  We have reached now mass production on minimum structure widths of 30 nm and below. From the roadmap it is clear that we have to control contamination on the nano-scale and in the zero contamination regime

- Pharmaceutical and medical device industries
  The drug particles get smaller and smaller to achieve more effective drug delivery and pharmaco dynamics. Medical devices must be nano and micro structured for their functional use in our body.
  More and more pharmaceutical and medical devices get joined for the better drug application. Stem cells play an important role and will play a vital role for our future life and prevent of death. The stem cells must be handled on even single molecular bases and from this view the requirements for the living environment are even higher than for the today microelectronics.

- Biosafety
  The highest probably for the humankind to die out is coming from epidemic and pandemic risks.
  For the one or other disease only one or a very few species can create illness and death. Also in the high containment fields to deal with these creatures and understanding of Zero Cleanliness is vital for all of us.

Zero Contamination – Classification

Besides the fact that measuring zero is not that easy with statistical significance – which will be addressed later – here it shall be derived the definition of zero "0" contamination.

For the start we will work with the definition of ISO 14644 class 0 for the particles from the particle size spectrum > 0.01 µm upwards. For the AMC we will work to the level of < 10 ppt for the relevant tracer and killer gases and molecules, see figure 1.

For the other parameters we will orientate on the guidance requirements in the semiconductor roadmap (1), if not superseded by microbiological biohazard demands.

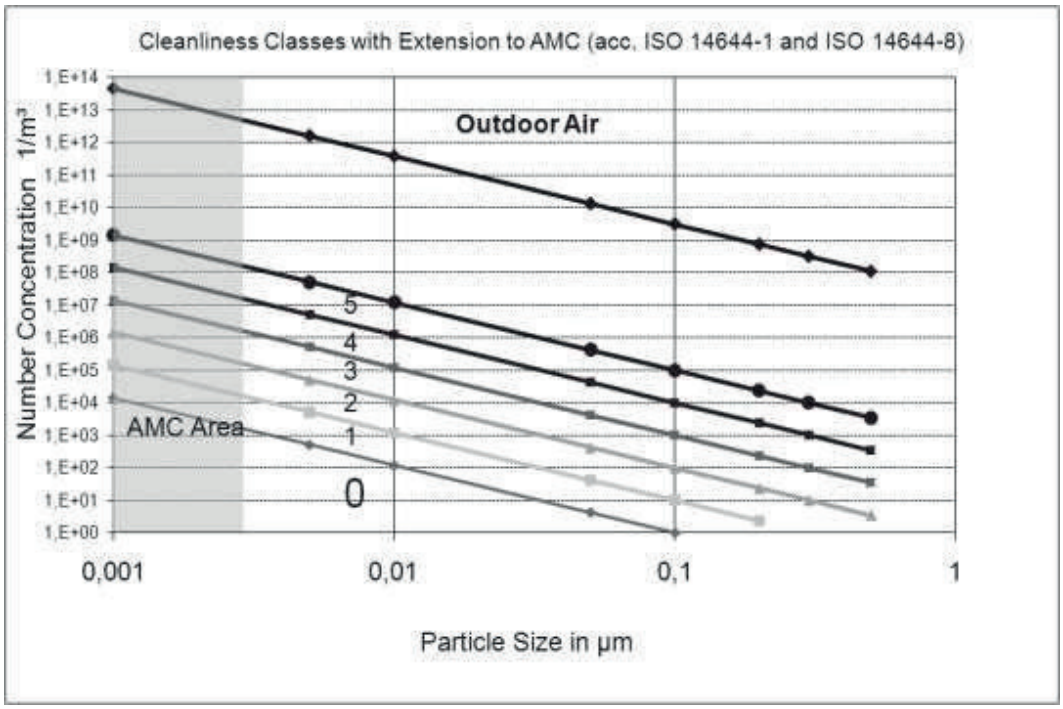


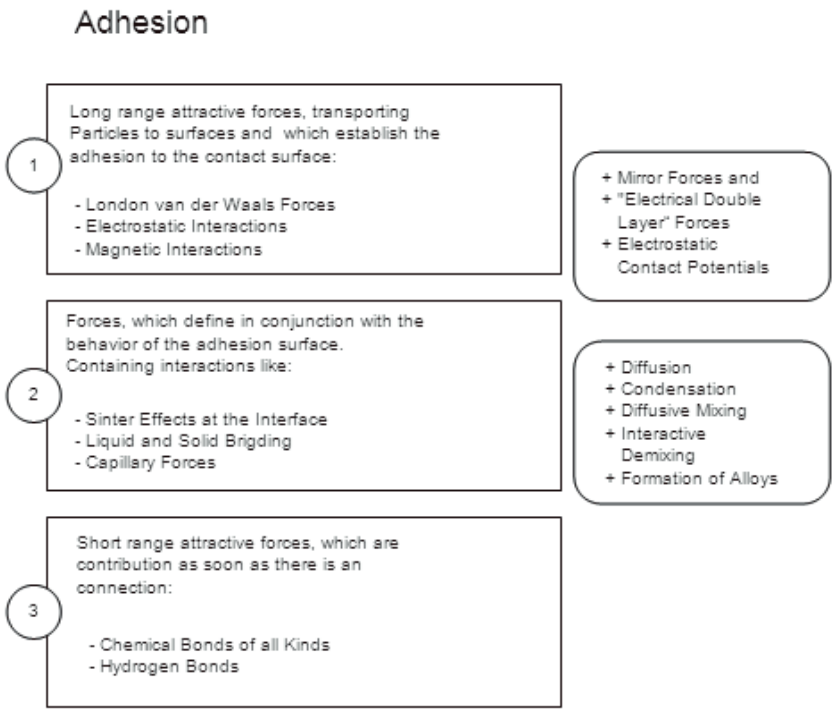
Figure 1: Extension of Cleanliness Classification to the Molecular Regime to harmonize Particles, Nano-Particles and Molecules (2) also with the Reference to the Class "0"

The Zero "O" Contamination Cleanroom

The basic technologies are today given to achieve these cleanliness grades on room levels of some 100 m² area.
The physics of adhesion, see schematics 1, as well as absorption and chemi-sorption are needed for controlling any kind of contamination. From the field of understanding the air flow patterns in and around machinery must be developed. We currently work with flow simulation programs and computer parks as for the car and aerospace research for the one or other problem.

The zero cleanroom is going to be established in the Fraunhofer Research Institute IZM-M in Munich.
Very important for any ideas into the low or zero contamination regimes are the dynamics of arrival and settling from the airborne phase to the surface and interaction of surfaces for example for the contamination control compatibility of machinery and equipment. The special advantage of this location is, that not only a complete 6"/partially 8" CMOS line is available to test each and every step in lowering the contamination as well as the access to a Polytronic line, allowing also the understanding in the non-silicon applications.

Besides the filtration and establishing the surface cleanliness partially with high aggressive solvents or even plasma cleaning it is necessary to actively monitor and control the clean environment. It shall be never underestimated that we leave the phase of continuum physics and approach molecular and quantum physics and effects as soon as we are approaching the Zero contamination regime.



Schematics 1: Adhesion – important in contamination control.

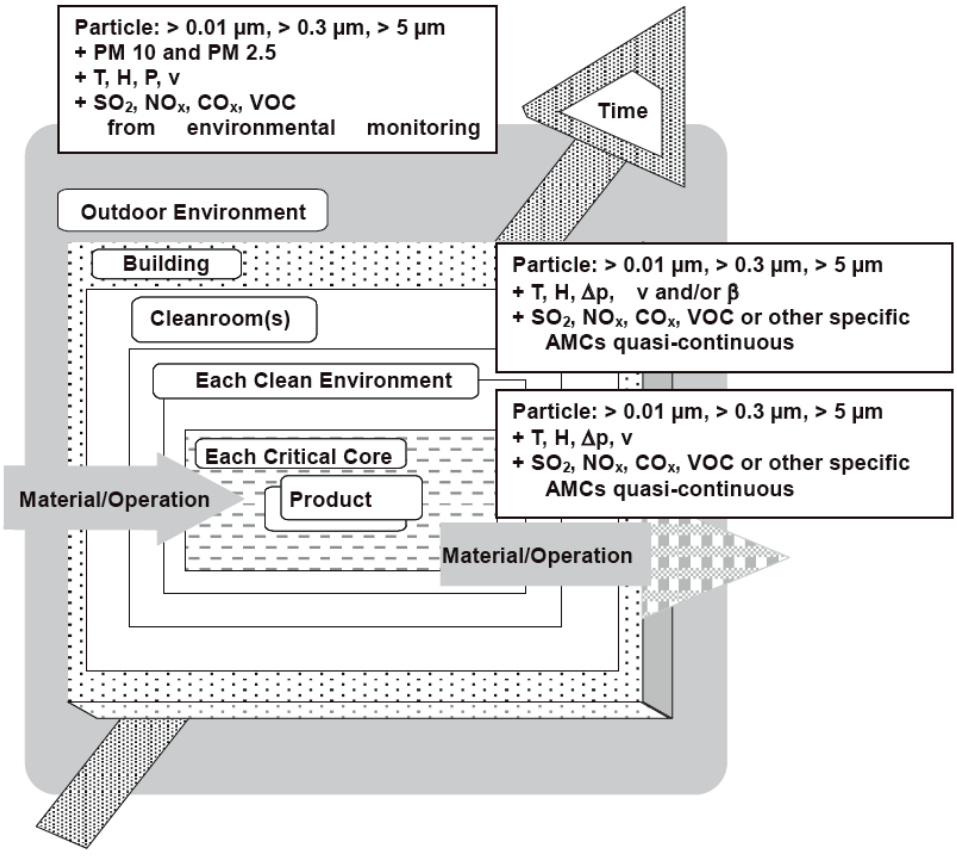


Figure 2: Parameters to be monitored for the air cleanliness

The Active Control of Zero Contamination

Not only that the continuum physics may no longer apply in the zero contamination regime. The normal descriptive statistics is also no longer valid as soon as we approach the zero contamination counting.

This is not only due to the lower and lowest concentrations to be monitoring and analysed but also to the fact, that the cleanroom is a chaotic environment in all physical meaning and background. We have fractal surfaces and non-linear dynamic equations for the particle motion interacting which each other.

In on-going research activities (2-5) it has be shown that for a statistical significant cleanliness measurement a period of more than 3 month is needed for cleanliness classes around ISO 2 or 3. For even higher cleanliness classes as for the Zero contamination measurement devices are needed which allow to measure in this regime without false counts. The monitoring, see figure 2, has to be established to understand the dynamics between the different contaminants and sources of contamination. The fractal analysis, see figure 3 and 4, has proven to be statistically relevant for the analysis of very low counts.

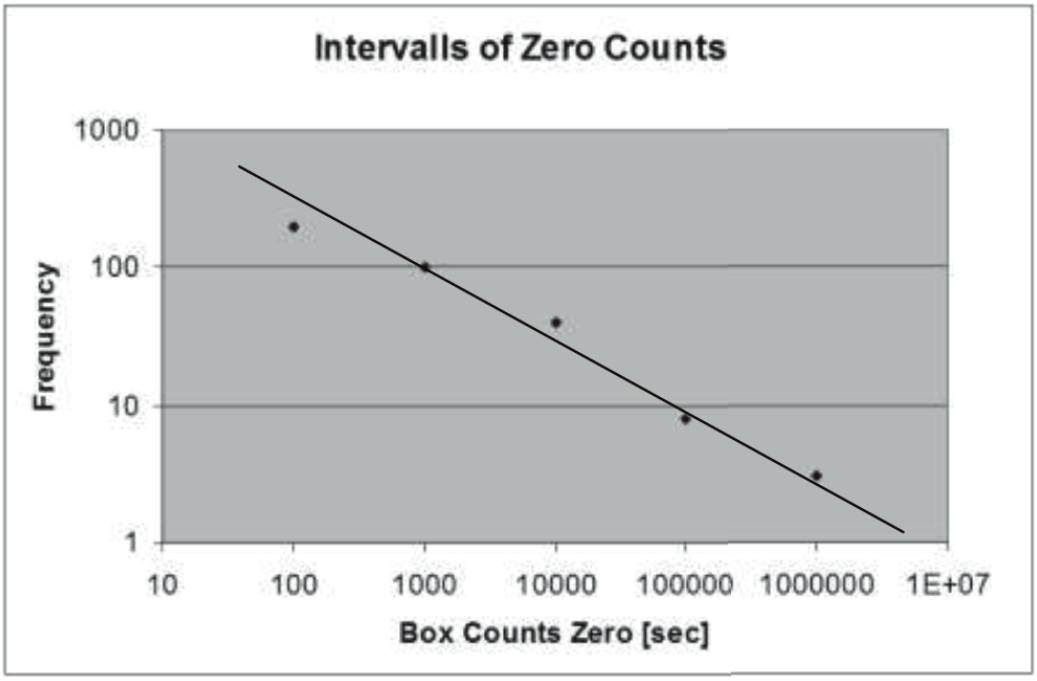


Figure 3: Fractal Analysis with box count methodology for measuring Zero "O" particles (2-5) in a very clean cleanroom over a period of 60 days.

Figure 3 gives an example where the time intervals of counting zero particles, or the time intervals between particle occurrence, in a very clean cleanroom have been grouped over the frequency of the occurrence following the box count methodology of fractal analysis. For example the time interval of 50 to 500 seconds of counting any particles has been found in an observation period of 60 days around 200 times.
The same methodology is used in an operational pharmaceutical manufacturing environment to analyse the nominal ISO 5 areas for a laminar flow (LF1 R262) and an enclosed filling machine (Machine R262) area, see figure 4. Monitoring time has been again 60 days. It can be seen that the time intervals of measuring zero particles between particle events are also correlated in this typical manufacturing environment.

Summary and Conclusion

Today there is no Zero contamination cleanroom in the world with a size compatible to test equipment for zero contamination compatibility of machinery and equipment.

Currently this type of cleanroom is built up at the Fraunhofer Research facility IZM-M.
The background of measuring and controlling this low concentration is parallel installed and improved.

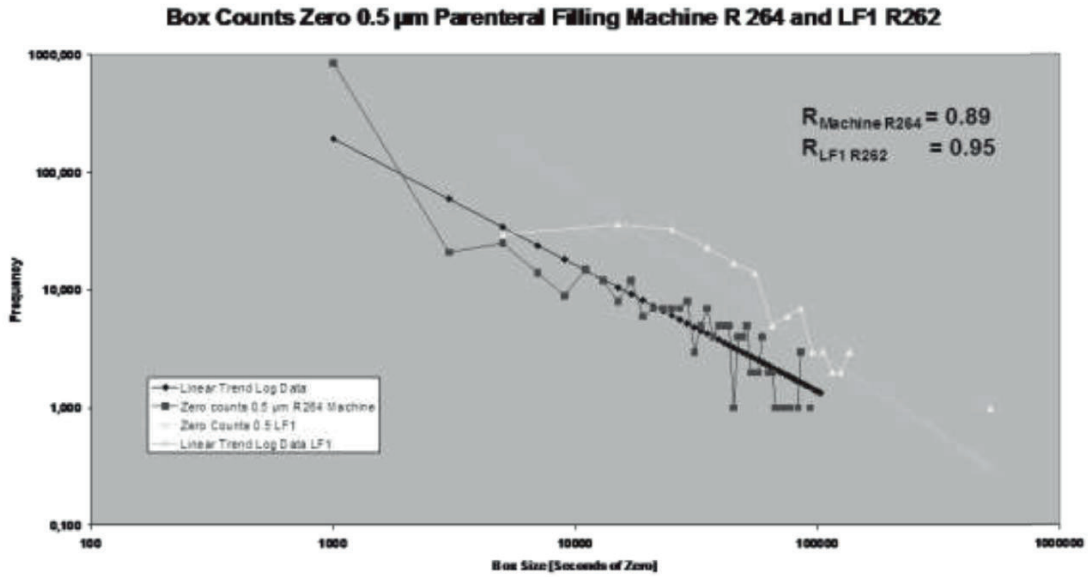


Figure 4: Practical results for measuring Zero "O" in a pharmaceutical sterile environment (2-5) following box count methodology.

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