Cleaning alone is no longer enough

In the manufacture of microscale products, the requirements for technical cleanliness are increasing. The defined level of cleanliness on difficult to reach surfaces also plays an increasingly important role. This is a challenge for the **ENTIRE PROCESS** and the associated cleaning method.

Figure 1. Because of their complex geometric shape and surface structure, combined with the purity requirements in the high purity sector, additively produced implants represent a significant challenge for the overall process and for cleaning technologies

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Whether medical implants from a 3D printer, highly sensitive lasers or sensors, the production of microscale products is becoming more and more complex. At the same time this impacts the industrial cleaning of these components and on the design of the associated systems. LPW Reinigungssysteme GmbH from Riederich in Germany has conducted two years of intensive research in this field and carried out an extensive series of tests with users from the relevant industries at LPW's in-house testing and service centre. This article explains why cleaning alone is no longer enough, what is new in terms of technical cleanliness and which processes are crucial for successful production.

Technical cleanliness is not solely the result of a ›quality gate‹ approach to cleaning. Of relevance here are the upstream process and its influences on cleanability, the actual cleaning process and its direct internal parameters, as well as the downstream process with its quality-related factors en route to the 'ready to use' status (physical and chronological) of the cleaned product.

Two new trends have emerged across the entire field of microscale products. The first is the ever more stringent requirements for the technical cleanliness, for example, in high vacuum, sensor

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Figure 2. The higher quality requirements in terms of technical cleanliness affect not only small and precisely manufactured precision mechanical components. Large and complex metallic components weighing several hundred kilograms as found in materials processing applications are also affected by the criteria that apply to microproduction. For example, chambers with a capacity of over 3000 litres are produced for pulsing vacuum cleaning processes for high vacuum technology components in the semiconductor industry

technology or the manufacture of analytical equipment, i.e. in terms of films, pigment or biological, toxic and even atomic contamination levels. Secondly, the increasingly relevant aspect regarding the cleanliness of difficult to reach surfaces, for example in complex geometric shapes on additively manufactured components or capillary structures **(Figure 1)**.

Both trends present a major challenge to a quality gate cleaning approach, and to the process chain as a whole. The benchmark for individual cleanliness specifications correlated to the component geometry and the environmental and more general parameters now calls for modified overall planning and execution concepts – as well as appropriate awareness and training of all associated employees.

Influences on processes

From the raw material to the individual assembly and production operations, every sub-process has to be assessed in terms of whether it has positive or negative consequences for the required level of technical cleanliness. Factors ranging from the handling operations, the operating supplies used and the environmental parameters have to be defined in terms of their nature and occurrence, assessed in terms of their impact on subsequent processes, and specified along with their permitted limiting values. These factors provide the foundation for cleanability and have a direct influence on the feasibility and the cost of a qualified cleaning process.

This is well illustrated with the example of forming, grinding and polishing tasks. Here, filmy and ultra-fine particulate impurities are present directly on metallic surfaces **(Figure 2)**, some of which having been actively worked into the surface and thus playing a significant role during the actual cleaning process. With high cleanliness requirements (for example in high vacuum technology), this has to be adapted to the upstream process **(Figure 3)**. Unscheduled changes, for example a change of operating materials or tools, geometric variations to components, or waiting times, have a negative influence on cleaning and can even mean that the relevant quality level cannot be met.

If there is a defined and verifiable level of cleanability, the cleaning process has to address the issue of reaching the contamination with the mechanical (and chemical) cleaning method used and ensure that it is reliably removed. While this is in theory straightforward, these new requirements have their own profile:

- Filmy, pigment-like or biological, toxic or atomic contamination are hidden in the laminar boundary layer, directly on the component surface, and (due to upstream processes) can also occur within the formed boundary layer. Depending on the cleaning task, this can present a genuine challenge.
- When it comes to a complex, in some cases capillary geometry or a tightly packed arrangement of the item to be cleaned, many established cleaning processes and media (aqueous or gas-borne) are only of limited effectiveness – that is, if they can actually be used at all **(Figure 4)**.
- We also have to consider influences from the environmental conditions (for example, cross-contamination from handling), the risk of contamination by the cleaning system itself (e.g. mechanical movement or unwanted accumulation of dirt in the ▶

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Figure 3. In laser processing and high vacuum technology, cleaning methods are faced with sensitive and very precisely machined surfaces

Figure 4. Capillary structures, for example in fine cannulas and tubes, are subject to the very highest cleanliness criteria. Because of their aspect ratio (ratio of internal diameter to length) these components rule out the use of most familiar cleaning methods and additionally are a real challenge to rinsing and drying processes. Here we see a 300 mm long glass capillary with an internal diameter of around 70 µm

drying systems, in particular for air circulation drying) and due to the use of unsuitable media such as liquids, chemicals, and ambient or compressed air **(Figure 5)**.

The downstream process is often underestimated. It is frequently the most critical point in terms of technical cleanliness and is characterised by the fact that it represents both the chronological and physical separation between achievement of a required cleanliness level and the point at which it is required. This is itself subject to a large number of risks and variables, for example damage or contamination due to incorrect handling, unsuitable packaging or unsuitable environmental parameters, as well as ageing/alteration influences caused by excessively long storage and stand-by times.

Practical example – additively produced implants

Additively produced implants for medical technology represent a classic scenario of a present-day cleaning task. They combine all the high purity requirements discussed (for example, in terms of cytotoxicity, bioburden) with a complex geometry. In everyday operations, the situation is as described in the following passage.

The additive production process results in an open-pored geometric form that is contaminated with powder residues from this initial process. In

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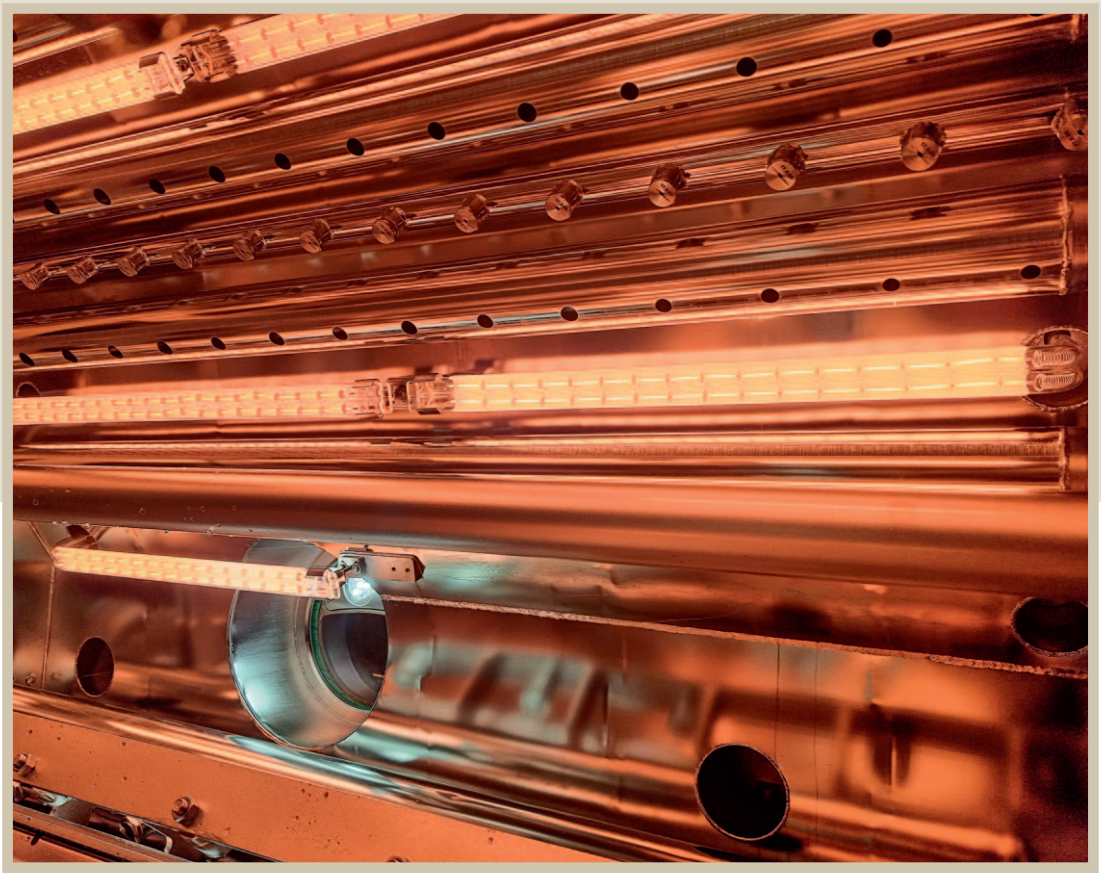

Figure 5. The influence of drying on the level of technical cleanliness is frequently underestimated. Energy-efficient circulating air drying systems tend to result in an accumulation of ultra-fine contamination and, as a result, in recontamination of the components. This is why LPW utilises ambient isolated infrared systems

subsequent stages, contamination can occur in the internal geometry due to mechanical rework for example. As a result, two cleaning processes are necessary. The first comes after 3D printing to remove the powder residues, and the second immediately after final machining before packing. The nature of the unwanted contamination (filmy and ultra-fine particulates) in the laminar boundary layer combined with the geometric structure poses a real difficulty for the cleaning process in terms of removing the initial contamination and applying the cleaning chemicals in the rinsing processes. The same applies to drying. Many methods (for example most spray and flooding processes) are unsuitable. They are frequently unable to reach the contaminated surfaces or only able to do so inadequately. It also pushes the limits of the capabilities of tried and tested ultrasonic methods. This is also true of cleanliness analytics, as the geometric design makes non-destructive extraction of the remaining contamination in the component just as difficult as the cleaning process itself.

System for new high purity requirements

Based on their research and test series with users from different high purity sectors, LPW has developed a modular system concept for fine and ultra-fine cleaning, which meets the stringent requirements for process control and the desired end result at all levels. In addition to well-known ultrasonic and cyclic nucleation cleaning methods, the ›PowerJet Ultra‹ system also provides the required drying for tougher demands. The concept is intended to be a technology platform for a wide range of different wet chemical cleaning and rinsing processes, and includes ambient-air-free drying systems with the option of an integrated deionised or high purity water supply. The media flows can be monitored using a large number of application-specific sensors, providing a key basis for industry-related validation processes. The system can be linked directly to a cleanroom (up to ISO 5) or installed in the cleanroom as an integrated component. A further significant company strategic step involved process digitalisation and the creation of LPW Application Engineering as a completely new division.

Technical cleanliness is ultimately not just a technical issue. It is an issue that requires understanding, a new way of thinking and learning in terms of requirements in interdisciplinary functions. This is why the experts from LPW are providing their high purity customers with extensive support in implementing and optimising appropriate methods and processes, and training their own application engineers and technicians to use them. ■

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