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Cleanroom Disciplines

Cleanroom personnel are an important source of cleanroom contamination. Almost all micro-organisms found in a cleanroom come from personnel, and they are also a major source of particles and fibres. It is therefore necessary to ensure the minimum of contamination is generated and transferred by personnel activities. By observing certain disciplines, contamination of the product can be minimised. These are discussed in this chapter.

When a cleanroom is about to be opened, management is faced with the task of employing people to work in the room, and determining what disciplines personnel (including maintenance and service technicians) should adhere to within the cleanroom. It is hoped that this chapter will assist in this task.

It should be noted that products manufactured in a cleanroom vary in their sensitivity to contamination, and cleanroom disciplines should reflect this. The information given in this chapter are options from which the user can choose methods that best reflect the degree of risk associated with their cleanroom.

16.1 People Allowed into Cleanrooms

People can, when walking, produce about 1 000 000 particles $\geq 0.5 \mu\text{m}$ and several thousand microbe-carrying particles per minute. The more people, the higher the dispersion within the cleanroom. It is therefore important that the minimum of people, i.e. only the essential personnel are allowed into cleanrooms, and management should ensure that this is so.

Because many contamination problems are caused by lack of knowledge, only people trained to work in a cleanroom should be allowed within the cleanroom. Personnel should therefore be formally trained in the various aspects of contamination control. Visitors should be discouraged and only allowed in under the control of a supervisor; if a cleanroom is designed with windows for visitors to look into the cleanroom, this will usually suffice. Special care should be taken with service and maintenance technicians, and their tools and materials; this is discussed at the end of this chapter.

People who enter the cleanroom should not disperse significantly greater amounts of contamination than the normal population. Given below are examples of conditions that can cause more contamination than normal, and may therefore be unacceptable. Acceptability will depend on the risk, e.g.

whether micro-organisms are a hazard, and whether the product is highly susceptible to contamination or not. It will therefore be up to management to decide which conditions are important.

The following suggestions contain criteria that can discriminate against some personnel. It should be ensured that any discrimination is neither illegal nor unfair. The list also contains a number of temporary conditions. These are included as they may be a reason for temporarily assigning personnel to a job outside the cleanroom.

- Skin conditions where unusually large amounts of skin cells are dispersed, such as dermatitis, sunburn or bad dandruff.
- Respiratory conditions such as coughing or sneezing caused by colds, flu or chronic lung disease.
- In a biocleanroom, it may be necessary to screen personnel for the carriage of micro-organisms that could grow in the product and cause spoilage or disease. Their suitability for work in a cleanroom should be considered with respect to the susceptibility of the product to specific types of microbial growth.
- People with allergic conditions, which cause sneezing, itching, scratching, or a running nose, may not be suitable for employment in a cleanroom. Sufferers from hay fever are likely to find relief in a cleanroom because the air filtration system will filter out the allergens responsible. Some people may be allergic to materials used in the cleanroom, such as (a) garments made from polyester, (b) plastic or latex gloves, (c) chemicals such as acids, solvents, cleaning agents and disinfectants, and (d) products manufactured in the room, e.g. antibiotics and hormones.

Depending on the contamination risk within the cleanroom, some or all of the following suggestions should be brought to the attention of the staff so that contamination within the room may be minimised:

- Personnel should have a good level of personal hygiene. They should shower regularly and keep dandruff at bay. They should wash their hair after a haircut to prevent hair landing on the product. In the case of dry skin, they should use skin lotion to replace skin oil that is lacking; this should reduce dispersion.
- Materials such as cosmetics, talcum powder, hair sprays, nail polish, or similar materials are not normally allowed in a cleanrooms. Anything added on to the body should generally be considered a contaminant. Cosmetics are a particular problem in semiconductor manufacturing as they contain a large amount of inorganic ions such as titanium, iron, aluminium, calcium, barium, sodium and magnesium. In the photographic industry, iron and iodine ions give problems. Other industries, which do not have a problem with specific chemicals, may still experience problems as each application will deposit large numbers of particles (up to 10^9 for particles $\geq 0.5 \mu\text{m}$) on the skin. Some of these will detach in the cleanroom.
- Watches and jewellery are normally not allowed in a cleanroom. If jewellery is allowed, it must be under the clothing and gloves. Rings can puncture gloves and harbour contamination under them. Personnel may be reluctant, for sentimental reasons, to remove their wedding or engagement rings. They may be allowed to keep them on if the skin under the rings, as well as the rings, is washed. Where the rings are liable to puncture the glove they should be taped over.
- Smokers are said to produce more particles from their mouth than the normal population and out-gas chemicals from their body. It may be necessary to ensure that they have not smoked for several hours before entering the cleanroom. It has been reported that taking a drink of water before entering the cleanroom reduces the number of particles given off from the mouth.

16.2 Personal Items Not Allowed into the Cleanroom.

As a general rule, nothing should be allowed into the cleanroom that is not required for production within the room. However, it is up to the management of the cleanroom to decide what items could cause contamination of the product. Items that should be considered for inclusion in a list of prohibited items are:

- food, drink, sweets and chewing gum
- cans or bottles
- smoking materials
- radios, CD players, Walkmans, cell phones, pagers, etc.
- newspapers, magazines, books and paper handkerchiefs
- pencils and erasers
- wallets, purses and other similar items.

Given in Section 18.2 of this book is a list of materials that may be required for manufacturing, and be sources of contamination. Some of the items from that list may be added to the above list.

16.3 Disciplines within the Cleanroom

Within a cleanroom, many rules-of-conduct must be followed to ensure that products are not contaminated. The management must produce a set of written procedures suitable for their room. It may be useful to have these 'does and don'ts' posted in the change or production area. Commonly used procedures that may be adopted are given below. These procedures do not consider the choice of cleanroom garments, masks, gloves and similar clothing items. Information about items of attire is given in Chapter 19.

16.3.1 Air transfer

To ensure that air is not transferred from an area of high contamination to one of lower contamination (e.g. the outside corridor to the production room) the following disciplines should be adhered to:

1. Personnel must always come in and out of the cleanroom through change areas. The change area is used not only to change clothing, but as a buffer zone between the outer dirty corridor and the inner clean production area. Personnel should not use any entrance, such as an emergency exit, which leads directly from the production area to the corridor; this will allow contamination to enter directly into the cleanroom, and their garments may also become contaminated.

2. Doors should not be left open. If they are, air will be transferred between the two adjoining areas because of general air turbulence as well as air transfer caused by a temperature difference between the two areas (Figure 16.1).

Figure 16.1 Doors should not be left open

3. Doors should not be opened or closed quickly, or air will be pumped from one area to the other.

4. Doors usually open inwards into the production room and are held shut by the higher pressure. However, to aid the movement of personnel who are carrying materials, some doors open outwards. Doors should then be fitted with door-closing devices to ensure that the doors are kept closed, and shut slowly to reduce the air transfer (Figure 16.2). Doors without handles will assist in preventing contamination of gloves.

16.2 Door closing device may be used

5. When passing through the doors in an airlock, personnel should ensure the first door is closed before going through the next one. Electrical interlocks between entry and exit doors achieve this, but care must be taken to ensure that there is no danger in the case of fire. Indicator lights, which show if the doors are shut, are also used. Pass-through hatches should be used in a similar way.

16.3.2 Personnel behaviour

The following suggestions should be considered to ensure that personnel do not contribute to the contamination within the room:

1. Silly behaviour should not be allowed. The generation of contamination is proportional to *activity* (Figure 16.3). A motionless person can generate about 100 000 particles $\geq 0.5 \mu\text{m}/\text{min}$. A person with head, arms and body moving can generate about 1 000 000 particles $\geq 0.5 \mu\text{m}/\text{min}$. A person who is walking can generate about 5 000 000 particles $\geq 0.5 \mu\text{m}/\text{min}$. Personnel who move quickly passed products may cause a disturbance of the air that leads to contamination.

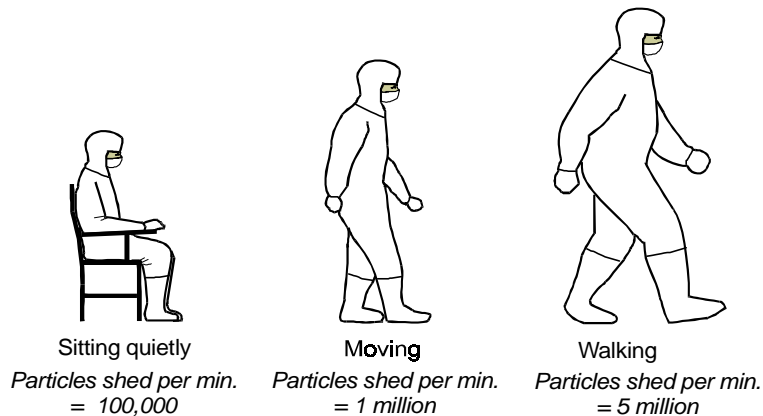


Figure 16.3 Particle dispersion in relation to movement

2. Personnel should position themselves correctly with respect to the product, so that contamination does not land on it (Figure 16.4). They should not lean over the product in such a way that particles, fibres or microbe-carrying particles, fall from personnel onto the product. If personnel are working in a flow of unidirectional air, they should make sure that they are not between the product and the source of the clean air, i.e. the air filter. If they are, a shower of particles could deposit on the product. Methods of working should be pre-planned to minimise this type of contamination.

3. Consideration must be given as to how products are moved or manipulated. 'No-touch' techniques should be devised to prevent contamination getting from the gloved hand onto the product. Although gloves are worn in cleanrooms, they are still likely to be a source of contamination (although a reduced one). An example of this 'no touch' technique is the use of long forceps rather than hands to grip materials (Figure 16.5).

Figure 16.4 Do not lean over and contaminate the product

Figure 16.5 Forceps reduce contact contamination

Each cleanroom should have its own 'no-touch' rules to ensure that the product is not contaminated. Shown in Figures 16.6–16.9 are examples of how silicon wafers can be handled in semiconductor areas. These photographs were staged, as it would not be normal practice in a microfabrication facility to handle a silicon wafer except by a vacuum wand, or by robotic means. Figure 16.6 shows the wafer being held by the ungloved hand with the thumb touching the surface.

Figure 16.6 Handling with no gloves

Oil and skin particles would contaminate the wafer with catastrophic results. If the wafer is held around the edge of the wafer (Figure 16.7) then contamination is reduced, but can still get onto the surface.

Figure 16.7 Handling at edge without gloves

Use of a glove (Figure 16.8) will reduce contamination yet further, and this technique is still used where the line widths are large and a lower yield acceptable.

Figure 16.8 Handling with gloved hand

In semiconductor facilities, wafers will be handled with a vacuum wand which attaches itself to the back of the wafer (Figure 16.9). Robotic manipulation can also minimise contamination.

Figure 16.9 Handling with vacuum wand

Figure 16.10 Do not support materials next to the body

4. Personnel should not support material against their body (Figure 16.10). Although they will be wearing cleanroom clothing, which is much cleaner than indoor or factory clothing, it is not contamination free. Particles, fibres and micro-organisms can be transferred onto the items carried.

5. Personnel should not talk when working over the product, or spittle from the mouth will pass round the imperfect seal between the mask and the skin and contaminate the product (Figure 16.11). Talking, coughing or sneezing can release contamination from the mask surface. If personnel cough or sneeze, they must turn their head away from the product. Masks are often replaced after sneezing. Masks must not be worn below the nose but over the nose as large particles can be released from the nose when snorting.

Figure 16.11 Care should be taken to ensure that mask is used correctly

Figure 16.12 Do not touch work surfaces

6. It is generally not good practice for personnel to touch cleanroom surfaces. Although cleanroom surfaces are very much cleaner than those outside the cleanroom, its surfaces, and that of the machinery in the room, will have particles, fibres and bacteria on them. If personnel touch their garments or mask, they also will pick up contamination on their gloves, which may be transferred to the product. Hands grasped together in front of the personnel, in the style of a hospital surgeon, will help to ensure that they do not inadvertently touch surfaces.

7. Personal handkerchiefs should not be brought into cleanrooms (Figure 16.13). These are clearly a major source of contamination and will transfer particles and microbe-carrying particles into the air and onto gloves. Noses should not be blown inside a cleanroom. The change area may be an acceptable alternative.

8. Washing, or disinfection when required, of gloves during use should be considered. Glove washing can be used in cleanrooms where products are handled and there are particular difficulties in keeping gloves clean. For example, in aseptic pharmaceutical production areas, gloved hands are rinsed with a suitable disinfectant (70% ethanol or iso-propanol) at regular intervals and prior to starting a critical operation. Alcohols are particularly useful, as they do not leave a residue on the glove.

Figure 16.13 Do not use personal handkerchief

16.3.3 Handling materials

The following suggestions, which refer to the materials used in the cleanroom, should be considered:

- Cleanroom wipers that have low concentration of contamination should be used. The exact type of wiper that is selected will depend on the financial budget and what is being produced in the cleanroom. It will also be necessary to decide how often a wipe should be used before being discarded. Some additional information is given in Section 20.3.3 of this book.
- The movement of materials between the inside and outside of a cleanroom should be minimised. Every time a product moves out of the cleanroom there is a high possibility of it being contaminated in the less-clean area, and this contamination being brought back when it re-enters. It is best to store products in a suitable clean area within the cleanroom, or in an adjoining clean area.
- It is normal to find that great care has been taken to ensure that a product is not contaminated during its manipulation stages. However, after that, it can often be forgotten and left out in the cleanroom to gather dust. Products that are susceptible to contamination should therefore be kept in closed cabinets, containers, unidirectional flow benches, or isolators. If the airflow in the cleanroom is unidirectional, storage racks of the type that allow air to flow through are a good choice. Materials should not be left standing on the floor.
- Waste material should be collected frequently into easily identified containers and removed frequently from the cleanroom.
- Cleanrooms should be correctly cleaned (and disinfected if required). This major topic is discussed in Chapter 21.
- The cleanroom must be kept neat and tidy. If it is not tidy, it cannot be kept clean.

16.4 Maintenance and Service Personnel

Through lack of training or supervision, people who enter a cleanroom to maintain or service machinery can be a considerable hazard. The maintenance technician, unless instructed otherwise, will apply the same techniques as they do outside the cleanroom. Service personnel from outside firms may be completely untrained in cleanroom contamination control techniques. The following is a list of procedures that should be considered for maintenance and service personnel:

- Maintenance and service technicians should only enter a cleanroom with permission.
- Maintenance and service technicians should be trained in cleanroom techniques, or closely supervised when they are within the cleanroom.
- Technicians must wear the same, or equally efficient, cleanroom clothing as cleanroom personnel, and use the same techniques to change into cleanroom clothing when entering and exiting clean-

rooms. They should never enter the cleanrooms (especially at weekends, or when no one else is around) without changing into cleanroom clothing.

- Technicians should ensure they remove dirty boiler suits, etc. and wash their hands before changing into cleanroom clothing.
- Tools that are used routinely for maintaining the cleanroom should be cleaned (and sterilised, if required) and kept stored for sole use within the cleanroom. Tools should be made from materials that do not corrode. For example, stainless steel is much preferred to mild steel tools, which may rust.
- If a service engineer or contractor brings tools into the cleanroom (especially those from outside the cleanroom organisation), then they must be cleaned. A wipe-down with a cleanroom wiper moistened with isopropyl alcohol (often 70%, in water) is a suitable method. Only the tools or instruments needed within the room should be selected, decontaminated, and put into a cleanroom compatible bag or container. This has the advantage of leaving behind cases or briefcases, with their associated scraps of paper, fluff etc., which are potential sources of contamination; these should not be allowed into the room.
- Spare parts or items, like fluorescent light tubes, which have wrappings, should have the wrappings removed outside the manufacturing area and the parts wiped down. Information on this topic is given in Sections 18.3 and 18.4.
- Written methods should be kept for each activity, so that contamination control techniques can be incorporated within a specification. These should be adhered to.
- Any instructions or drawings on non-cleanroom paper must not be taken into the cleanroom. They can be photocopied onto cleanroom paper, or laminated within plastic sheets, or placed in sealed plastic bags.
- Particle generating operations such as drilling holes, or repairing ceilings and floors should be isolated from the rest of the area. A localised extract or vacuum can also be used to remove any dust generated.
- Technicians should not bring any materials into a cleanroom that are given on a list of 'contaminating material', similar to that in the list in Section 18.1 of this book.
- Technicians must tidy up when they are finished and ensure that the area is then 'cleanroom cleaned' by a person with suitable knowledge. Only cleaning agents, materials and equipment that has been approved for use in the cleanroom should be used.

Acknowledgement

I would like to thank Lynn Morrison for posing for the photographs contained within this chapter.

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