1

Introduction

1.1 What is a Cleanroom?

It is clear that a cleanroom is a room that is clean. However, a cleanroom has a special meaning and it is defined in the International Organization for Standarization (ISO) standard 14644-1 as:

room in which the concentration of airborne particles is controlled, and which is constructed and used in a manner to minimise the introduction, generation, and retention of particles inside the room and in which other relevant parameters, e.g. temperature, humidity, and pressure, are controlled as necessary

The first two-thirds of the definition is, in essence, what a cleanroom is. It is a room that minimises the introduction, generation and retention of particles. This is achieved, firstly, by supplying it with an exceptionally large quantity of air that has been filtered with high efficiency filters. This air is used (1) to dilute and remove the particles, bacteria and chemicals dispersed from personnel, machinery and other sources within the room and, (2) to pressurise the room and ensure that no dirty air flows into the cleanroom. Secondly, a cleanroom is built with materials that do not generate particles or 'outgas' airborne chemical contamination and can be easily cleaned. Finally, cleanroom personnel use clothing that envelops them and minimises their dispersion of particles and micro-organisms.

Cleanroom Technology, Second Edition. W. Whyte

Figure 1.1 A cleanroom with personnel wearing cleanroom clothing

These and other similar measures that minimise the introduction, generation and retention of contamination in a cleanroom are discussed in this book. Cleanrooms can also control the temperature, humidity, sound, lighting, and vibration. However, these parameters are not exclusive to cleanrooms, and are therefore not discussed in any detail in this book.

1.2 The Need for Cleanrooms

The cleanroom is a modern phenomenon. Although the origins of cleanroom design and management go back for more than 150 years and are rooted in the control of bacterial infection in hospitals, the need for a clean environment for industrial manufacturing led to the modern cleanroom in the 1950s. Cleanrooms are needed because people, production machinery and the building structure all generate contamination. As will be discussed later in this

book, people and machinery produce millions of particles, and conventional building materials can break up as well as 'outgas' chemical contamination. A cleanroom controls the dispersion of all this potential contamination to allow manufacturing to be carried out in a clean environment so that the correct quality and reliability of the product is achieved, and, in the case of healthcare products, the patient is not harmed.

The uses of cleanrooms are diverse and shown in Table 1.1 is a selection of products that are now being made in cleanrooms.

Table 1.1 Some cleanroom applications

Industry	Product
Electronics	Computers, flat screens
Semiconductor	Integrated circuits used in computer memory and control
Micromechanics	Miniature bearings, compact-disc players
Optics	Lenses, photographic film, laser equipment
Nanotechnology	A wide variety of products at nanometre size

Biotechnology	Antibiotics, genetically modified organisms (GMOs)
Pharmaceutical	Sterile pharmaceuticals
Medical Devices	Heart valves, cardiac by-pass systems, stents, catheters
Food and Drink	Brewery products, unsterilised food and drink

It may be seen in Table 1.1 that cleanroom applications can be broadly divided into two. Given in the top section of Table 1.1 are those industries where dust particles are a problem, and their presence, even in submicrometre size, may prevent a product functioning, or reduce its useful life.

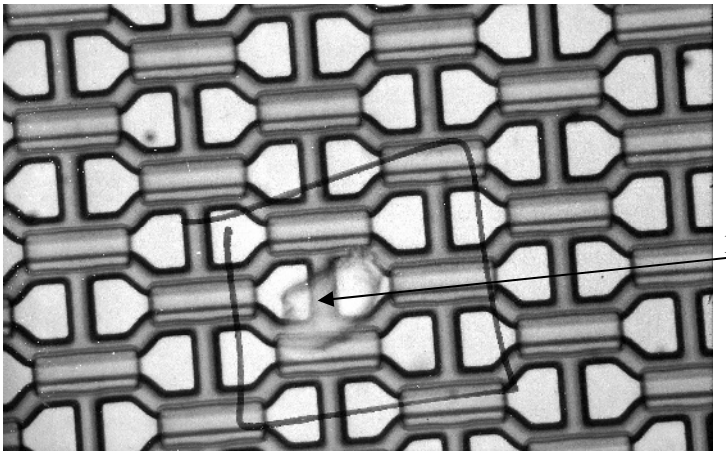

Figure 1.2 Contaminating particle on a semiconductor

A major user of cleanrooms is the semiconductor fabrication industry, where microprocessors are produced for use in computers, cars and other machines. Figure 1.2 shows a photomicrograph of a semiconductor with a particle on it. Such particles can cause an electrical short circuit and ruin the semiconductor. To minimise contamination problems, semiconductors are manufactured in cleanrooms with very high standards of cleanliness.

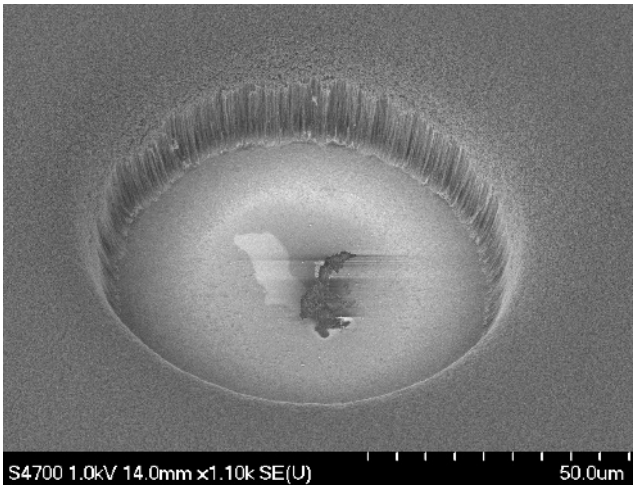

Figure 1.3 Contaminating particle inhibiting carbon nanotube growth

Shown in Figure 1.3 is a contamination problem in a nanotechnology application. The photograph shows a particle sitting in the centre of a field of carbon nanotubes that are growing upwards. The growth of nanotubes around the particle is inhibited by chemical contamination diffusing from the particle. Nanotubes beyond the edge of the area of inhibition are seen to have grown normally. In the photograph, the particle is approximately 10 μm micrometres across and the area of inhibition 70 μm in diameter. The nanotubes are only 2 to 3 nanometres in diameter, so are difficult to distinguish one from another. 1 nanometre (nm) = 1/1000 micrometre (μm).

The bottom section of Table 1.1 shows manufacturers that require the absence of micro-organisms, as their growth in a product could lead to human infection. The healthcare industry is a major user of cleanrooms, as micro-organisms or dirt must not be injected or infused into patients through their products. Hospital operating rooms also use cleanroom technology to minimise wound infection (Figure 1.4).

Figure 1.4 Unidirectional airflow system and occlusive clothing used in an operating room

It may also be seen from Table 1.1 that many of the examples are recent developments and this list will certainly be added to in the future, there being a considerable and expanding demand for this type of room.

1.3 Types of Cleanrooms

Cleanrooms have evolved into two major types and they are differentiated by their method of ventilation. These are *non-unidirectional* and *unidirectional airflow cleanrooms*. Unidirectional airflow cleanrooms were originally known as 'laminar flow' cleanrooms and non-unidirectional flow cleanrooms as 'turbulently ventilated'. The use of the term 'laminar flow' was a mistake, as laminar flow has a meaning in physics and engineering that does not apply to the airflow in a cleanroom. Unidirectional airflow is the correct way of describing the airflow and is the term used in the ISO standards. Unidirectional airflow cleanrooms use very much more air than non-unidirectional airflow cleanrooms, and give superior cleanliness.

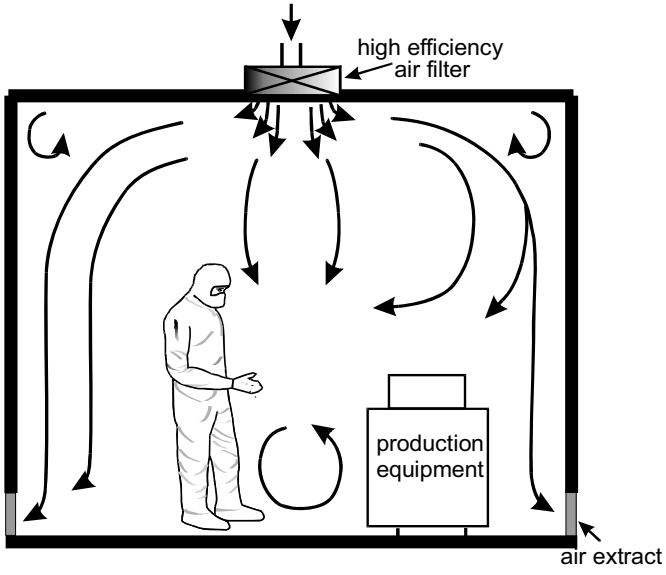

Figure 1.5 Non-unidirectional airflow type of cleanroom

The two major types of cleanroom are shown diagrammatically in Figures 1.5 and 1.6. Figure 1.5 shows a non-unidirectional airflow cleanroom receiving clean filtered air through a high efficiency air filter and air diffuser in the ceiling. This air mixes with the room air and removes airborne contamination through air extracts at the bottom of the walls. The air change rates are normally equal to, or more than, 20 per hour, this being much greater than in ordinary rooms, such as in offices. In this non-unidirectional style of cleanroom, the contamination generated by people and machinery is mixed with and diluted by the supply air, and then removed.

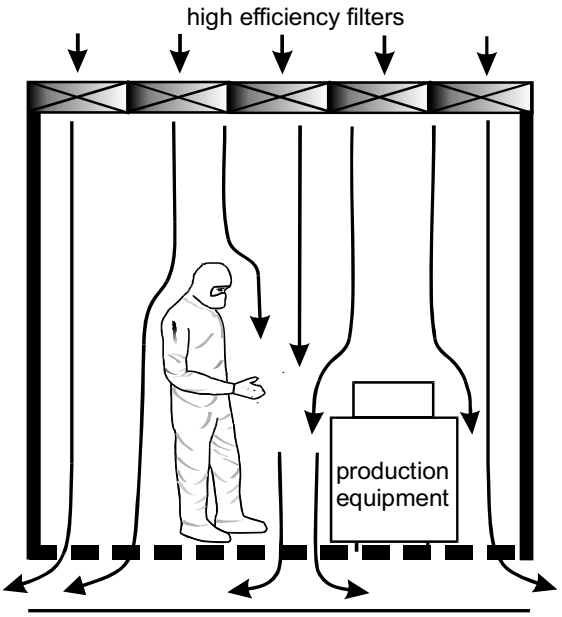

Figure 1.6 Unidirectional airflow type of cleanroom

Figure 1.6 shows the basic principles of a unidirectional airflow room. High efficiency filters are installed across the whole ceiling and the air to the room is supplied through these. This air sweeps down through the room in a unidirectional way at a velocity generally between 0.3 m/s (60 ft/min) and 0.5 m/s (100 ft/min) and exits through the floor, thus removing the airborne contamination from the room. This system uses much more air than the non-

unidirectional airflow cleanroom but, because of the directed air movement, it minimises the spread of contamination about the room and sweeps it out through grilles in the floor. An alternative configuration has the high efficiency filters installed across the whole of one wall with the air being removed at the opposite wall.

Separative devices, such as unidirectional airflow benches or isolators, are used in both non-unidirectional and unidirectional airflow cleanrooms. These give a localised supply of filtered air and enhanced air conditions where required, e.g. at the area where the product is open to contamination.

1.4 What is Cleanroom Technology?

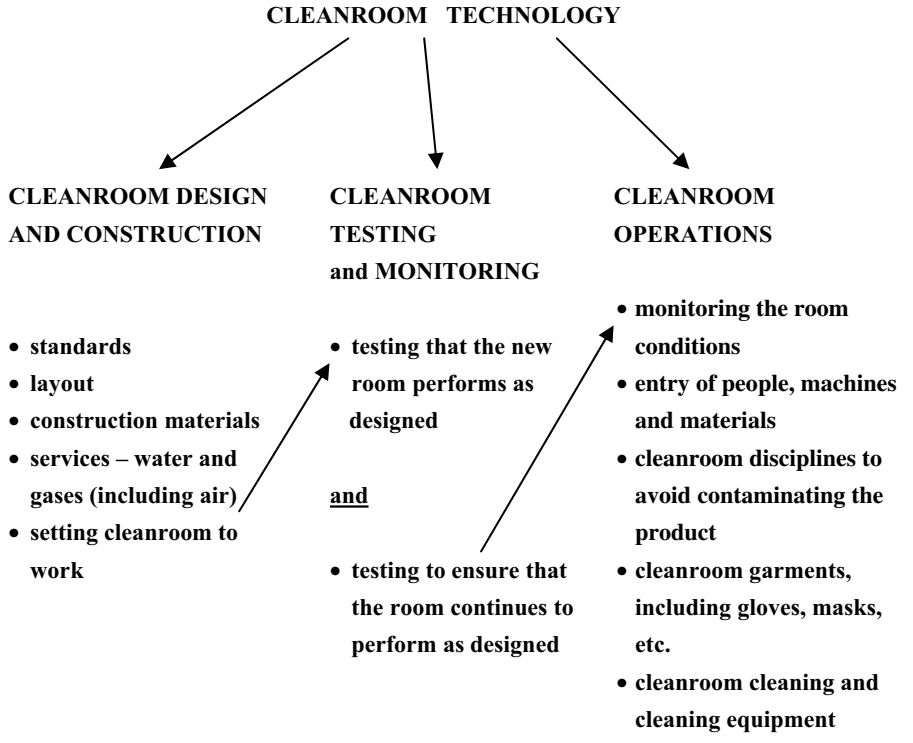

Figure 1.7 Various parts of cleanroom technology and their interconnections

As can be seen in Figure 1.7, cleanroom technology can be divided into three broad areas. These areas can also be seen to parallel the application of the technology as the cleanroom user moves from firstly deciding to purchase a room to finally operating it.

Firstly, it is necessary to *design and construct* the room. To do this one must consider (1) the design standards that should be used, (2) what design layout and construction materials can be used, and (3) how services should be supplied to the cleanroom.

Secondly, after the cleanroom has been constructed it must be *tested* to check that it conforms to the stipulated design. During the life of the cleanroom, the room must also be *tested and monitored* to ensure that it continually achieves the standards that are required.

Finally, it is necessary to *operate* the cleanroom correctly so that the manufactured products are not contaminated. This requires that entry of people and materials, garment selection, cleanroom disciplines and cleaning of the room are all correctly carried out.

These three fundamental elements of Cleanroom Technology are covered in this book.

Acknowledgements

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