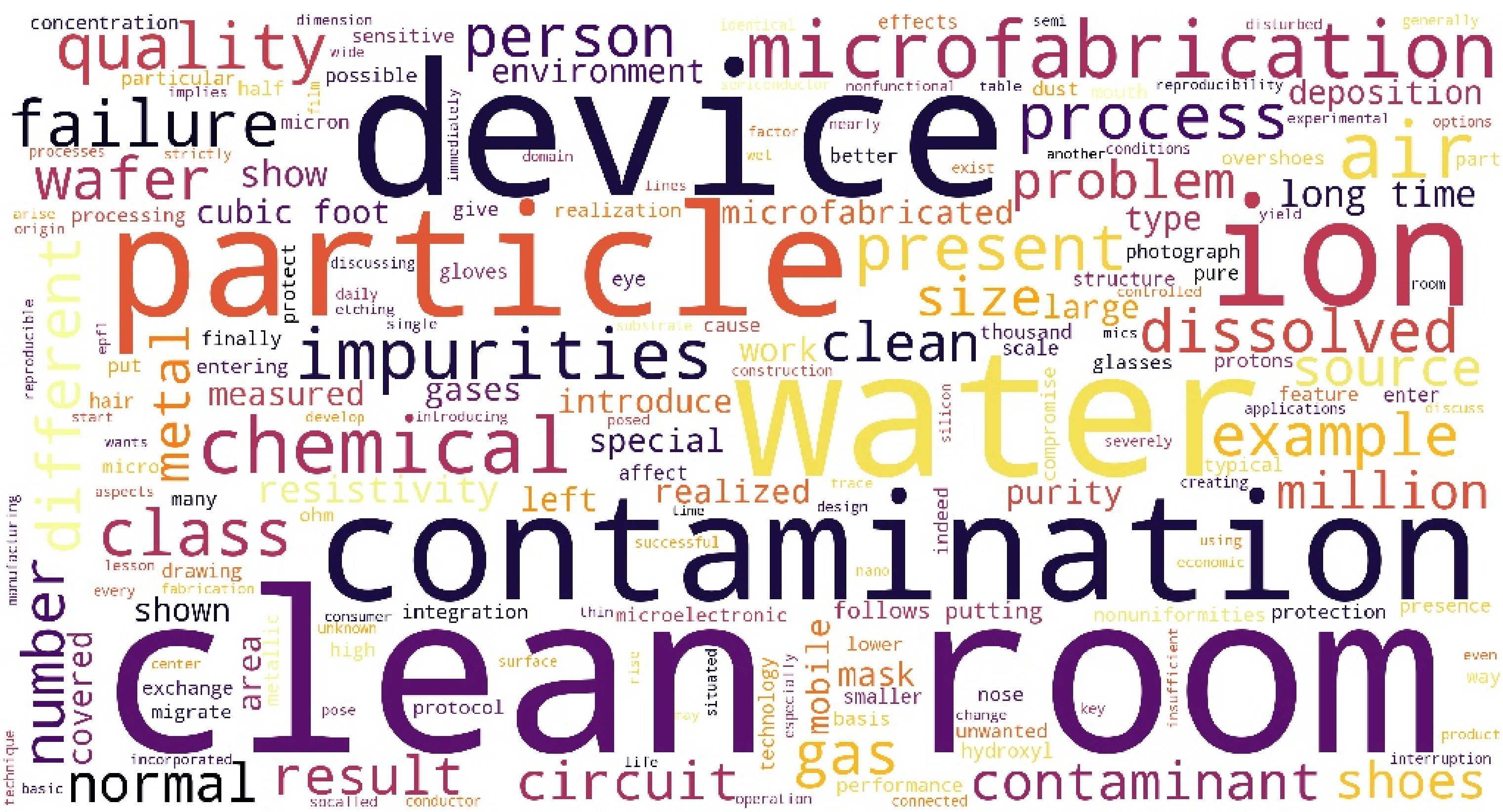

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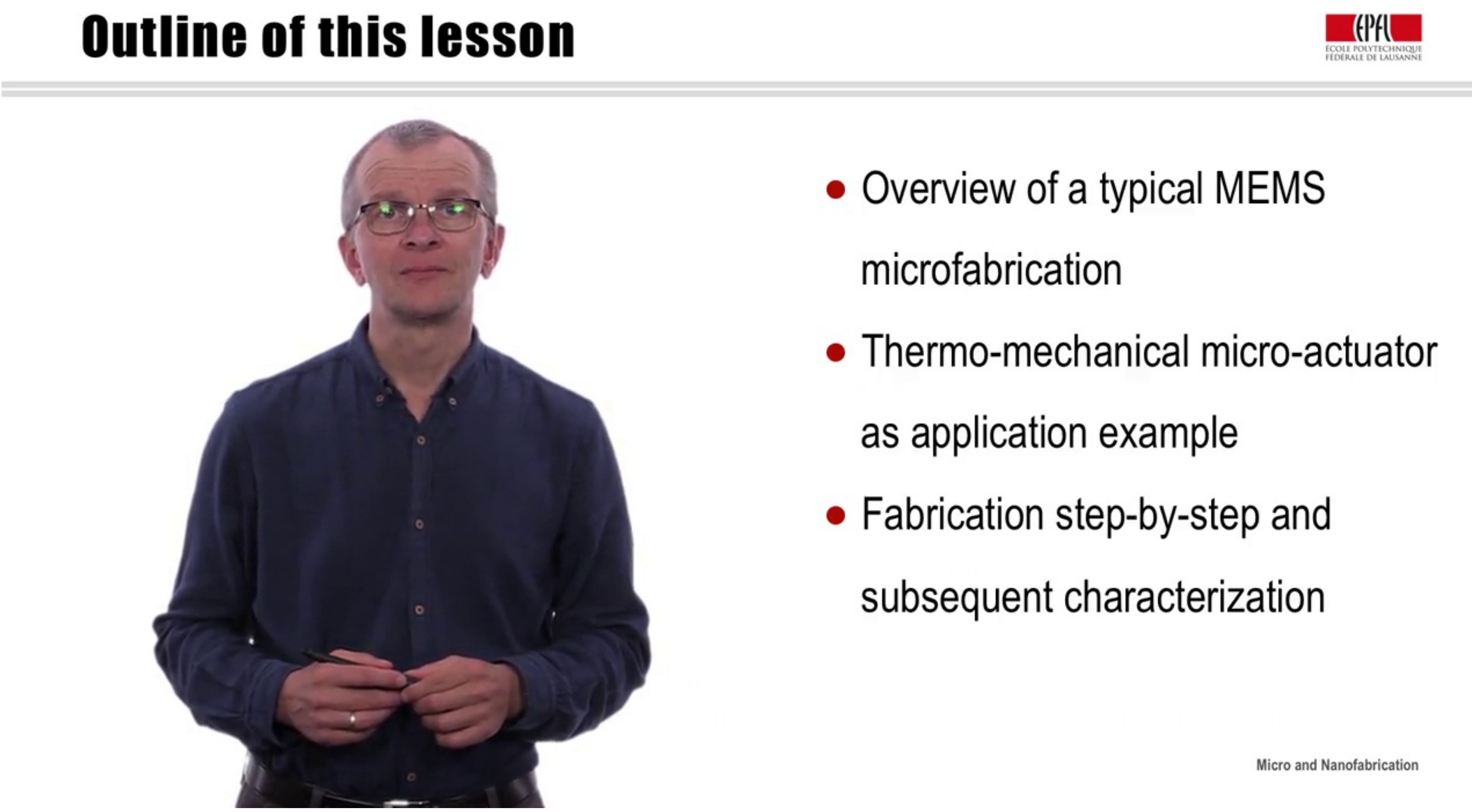
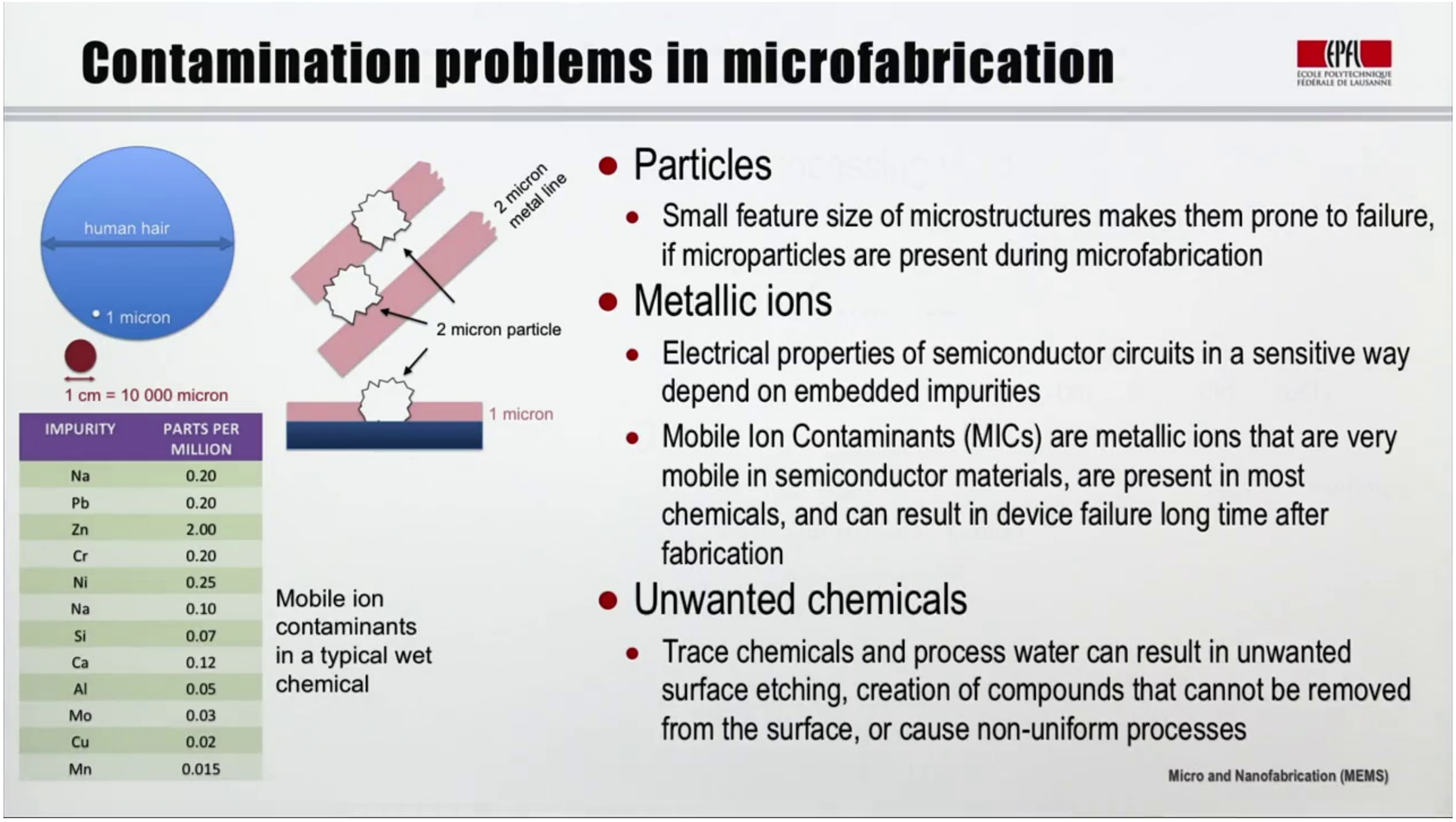
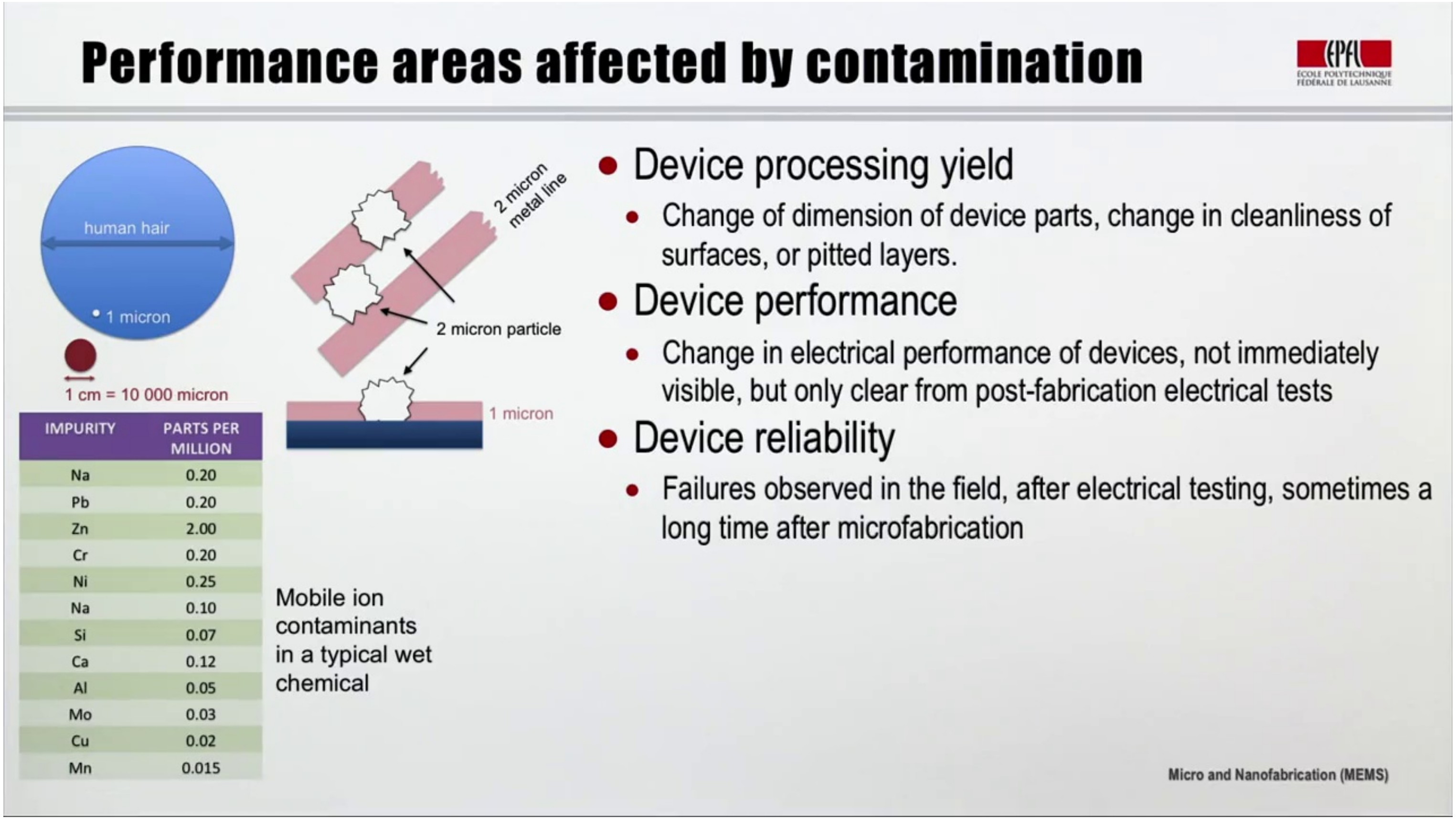


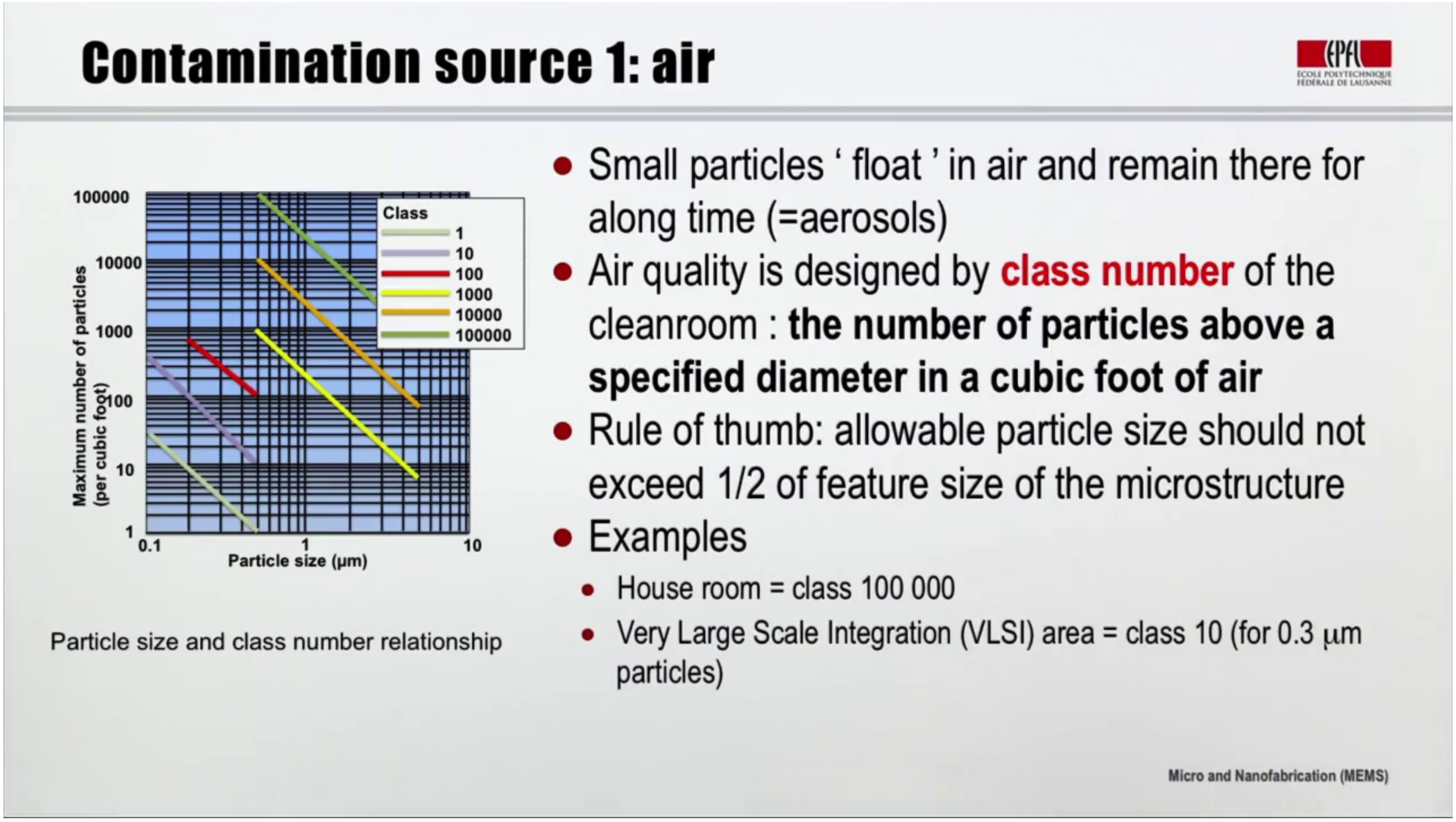
We have seen that many identical microelectronic devices can be realized on a single wafer which is a technology that is at the basis of many high performance applications in nearly every domain of our daily life. The reproducibility of microfabrication indeed is a key factor for economic realization of any consumer product. Therefore, these devices are most of the time realized in a clean room environment where experimental and manufacturing conditions are reproducible and very strictly controlled. In this lesson, we will introduce a few of the basic aspects of the design of and work in a clean room. We will start by discussing different contamination problems that may arise when one wants to develop a microfabrication process. We will discuss the different sources that are at the basis of contamination and that can result in failure of devices. We will introduce different options for creating an environment with clean air and for clean room construction. Finally, we will give an example of a clean room by introducing the center of micro and nano technology at EPFL.



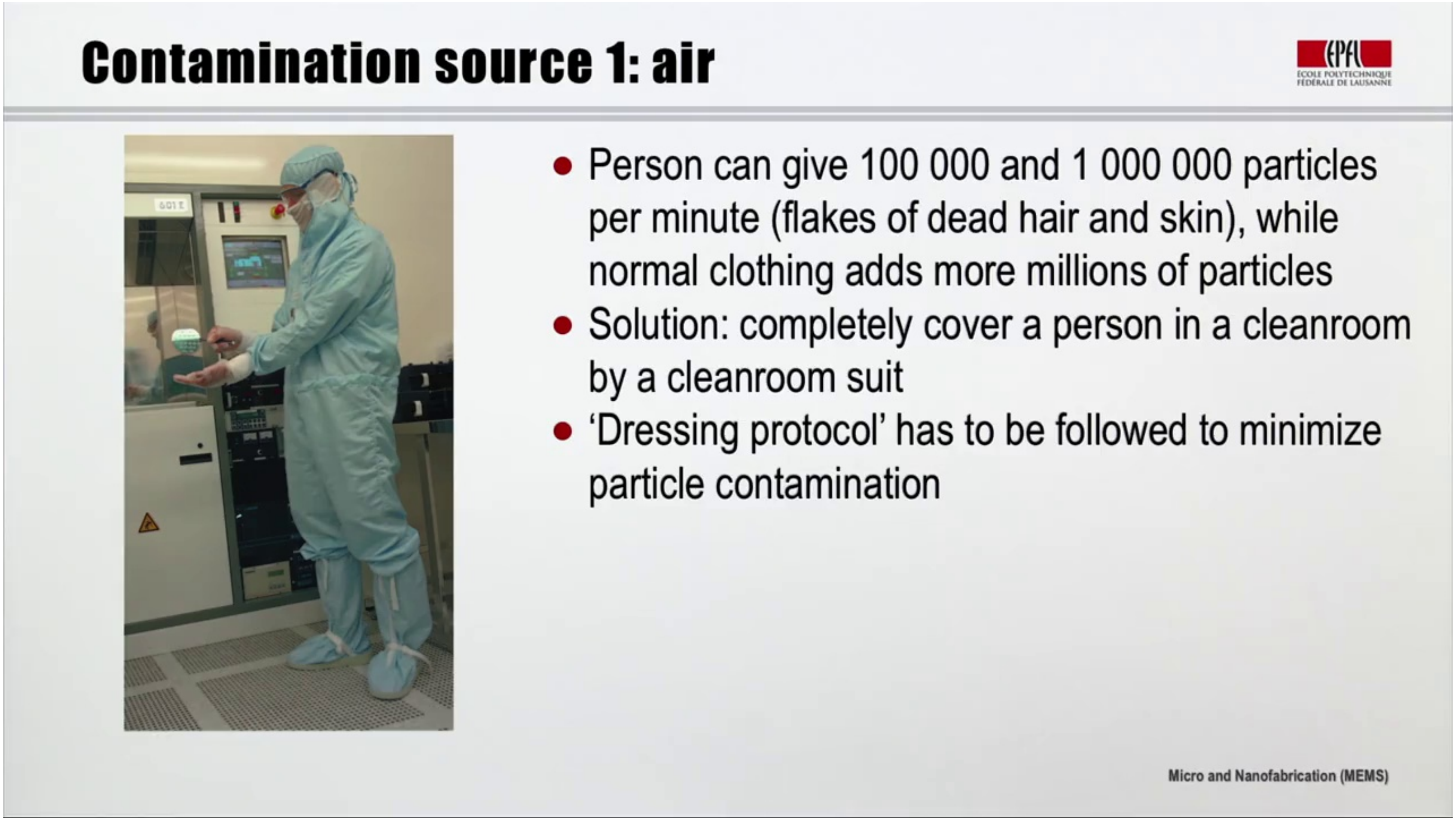
Different types of contamination exist which all can compromise successful realization of a microfabricated device. The first problem is posed by the presence of particles in the air which, when they have the size of the features of the microfabricated structure, can result in failure of the device. This drawing shows as an example two micron wide metal lines which can be realized using a thin film deposition technique. When during deposition, micro particles are situated on the substrate and when they have this size, they can give rise to these connected metal structures, like shown here. Another contamination problem is that of ion impurities. If one works with semiconductor circuits, the operation of a device can be severely disturbed when unknown metal impurities are present in the semi conductor. Especially so-called ”mobile ion contaminants” or MICs, pose problems. These contaminants can be present in most of the chemicals that are used for the microfabrication of a device. And when incorporated in the silicon, they can migrate to a sensitive area where they can cause device failure even a long time after fabrication. This implies that chemicals should be as pure as possible. The table here shows metal impurities that are present in a typical wet chemical that is used in the clean room. More generally, the presence of trace chemicals, unwanted chemicals and process water of insufficient purity, can result in unwanted surface etching effects or deposition effects which are at origin of non-uniformities in microfabrication processes.



If these contamination sources are present, they affect the devices in different ways. First of all, there is the device processing yield. Like shown in the drawing on the left, a change in dimension or an interruption of device parts results in a non-functional device. Such failure can be measured immediately after the microfabrication step by optical or microscopic inspection. Some defects are not directly visible but can be measured by evaluation of the device performance after completion of the full microfabrication process. Usually, electrical testing allows to eliminate devices from the wafer or chips from the wafer that are not functional. Contamination also affects device reliability and can cause the failure of the device a long time after its microfabrication. An example of such failure can be the diffusion of a mobile ion contaminant in an electronic circuit. The impurity can migrate to a sensitive region on the wafer, a long time after microfabrication leading to the disfunctioning of a microelectronic circuit.



An important source of possible contamination in a clean room is the air. Small particles can float in the air and remain there for a long time. They are called also aerosols. The fewer and the smaller the particles are in the air, the better is the quality of the clean room. The quality of a clean room is therefore characterized by the clean room class number, which is the number of particles above a specified diameter in a cubic foot of air. For example, in this graph, we see that the class thousand clean room has not more than a thousand particles of half a micron in size per cubic foot. A class 10 clean room has not more than 10 of these particles in a cubic foot of air. The lower the class number, the better the quality of the clean room. As a rule of thumb, particles that are present in the air should not exceed half of the feature size of the microstructure to be fabricated. As examples of air quality, a normal house room has a class of 100,000, while a very large scale integration area in a clean room should have class 10 for particles of 0.3 micrometer.



A person can produce in between 100,000 and 1 million particles per minute which are flakes of dead hair and skin, while normal clothing adds more millions of particles. It is clear that the person has to be completely covered when he is in the clean room. And he needs to be covered with a special clean and dust free tissue. The photograph on the left shows the person wearing special overshoes which are on top of the normal shoes. The person has gloves, and he wears an integral clean room suit, a mask of the mouth and the nose and glasses to protect the eyes. A particular dressing protocol has to be followed when someone enters the clean room to minimize particle contamination. Such protocol is shown in the following video.

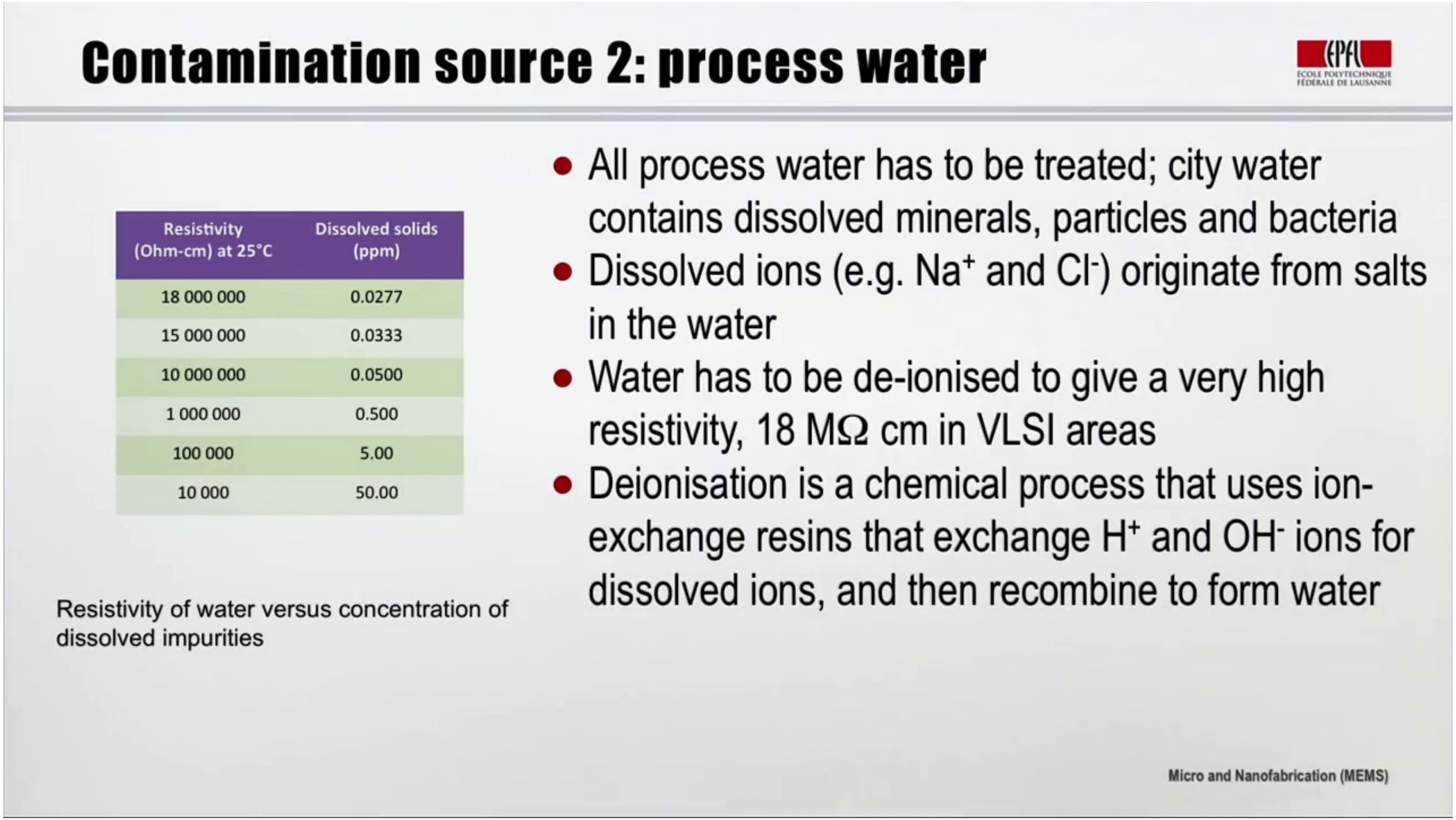
A person who works in a clean room, first takes care of not entering dust or contamination via shoes. There is a particular way of entering. Before the barrier, the environment is not clean and going in by this type of motion during which the shoes are covered

with a clean protective coating, ensures that no contamination is released from the shoes into the clean room. Next follows putting on a coat, whereby one assures that the sleeves do not touch the ground.

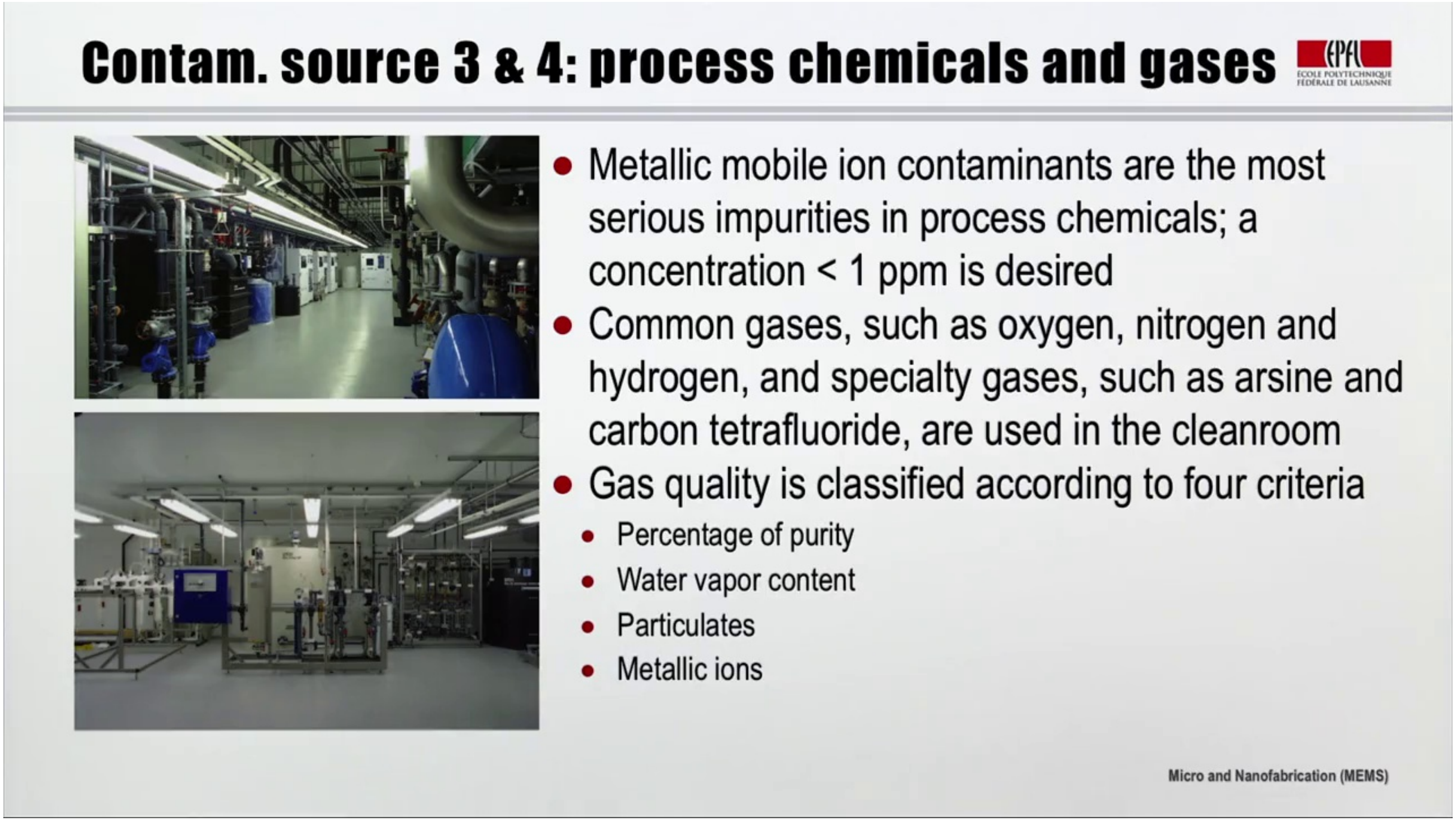
Then follows putting on this type of overshoes to further protect the clean room from contamination

originating from the feet. Then follows putting on a mask for covering the heads and the hair and a mask that covers nose and mouth. Glasses are put on for eye protection and security.

The last stage is that the operator puts on gloves for protection of the hands.



And finally, he is ready to enter into the clean room. A second source of contamination in a clean room is the water used for processing the wafers. All water that is used has to be treated, as normal city water contains dissolved minerals, particles and bacteria, which can introduce impurities or non-uniformities during microfabrication. Dissolved ions like sodium and chlorine ions can compromise quality of microfabricated circuits and can originate from salts dissolved in the water. Therefore, the water has to be deionized and the degree of ion concentration in the water can be measured by measuring the resistivity of the water. Indeed, if there are very few dissolved impurities, the resistivity of the water is very large. 18 million Ohm centimeters. If there are more impurities, resistivity is much lower. For water used in a very large scale integration area in a clean room, the resistivity of minimum 18 M Ohm cm is required. Deionisation is a chemical process that uses ion exchange resins that exchange protons and hydroxyl ions for dissolved ions in the water. After which protons and hydroxyl ions recombine to form a water molecule.



Besides process water, all process chemicals and gases that are used in a clean room should be of high purity. The most serious impurities are the metallic mobile ion contaminants in chemicals. And in a chemical, concentrations smaller than one part per million are desired. Also common gases that are used in a clean room such as oxygen, nitrogen and hydrogen, and special gases like arsine and carbon tetrafluoride, should be very pure. The gas quality can be classified according to four criteria: the percentage of purity of the gas; its water vapor content; the number of particulates in the gas; and the number of metallic ions in the gas. The photographs on the left show the typical infrastructure for water and gas handling which is present in proximity of the clean room.