User Training for the
"Laboratorio di Ateneo"

PoliFAB

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Gases and high pressure installations

General description

At PoliFAB there are various installations and containers of different types of gases under pressure, used as technical utilities for cleanroom equipments. Such installations were built and certified according to legal prescriptions and best practices, and they include pipelines, valves, pressure reducers and containers under pressure higher than 0.5bar with respect to the atmosphere. The laboratory hosts wall-installed pressure reducers for technical utilities (compressed air, technical nitrogen 5.0N and vacuum) and process gases, which are all part of high pressure installations. Users must have special care in case they need to regulate pressure or open/close the lines at the wall-installed pressure reducer. Process gas bottles are stored in the gas bunker, outside the cleanroom. Inside the cleanroom there is a C_4F_8 gas bottle (backside of the RIE) due to its specific storage conditions requirements, and other small gas bottles with few liters volume. **Connections and any change to gas lines from pressure reducers to the equipment can be performed exclusively by th Staff.**

The different types of gases used in cleanroom processes are classified in three families: inert gases, comburent gases (oxidizers), toxic and explosive gases. The last family includes ammonia and silane gases and will be treated in a dedicated paragraph, due to the danger of these two gases.

Inert gases and comburent gases

In the following table you can find a list of the inert gases and comburent gases present in the laboratory, along with their GHS H-phrases.

Inert gases	H risk
N_2	280
He	280
Ar	280
CO_2	280
CF_4	280
C_4F_8	280
CHF_3	280
SF_6	280

Comburent gases	H risk
O_2	270 - 280
N_2O	270 - 280

H risk	H phrase
270	May cause or intensify fire; oxidizer
280	Contains gas under pressure; may explode if heated

All gases, including inert gases, involve the risk of suffocation, since gas-containing atmospheres may have a relative amount of oxygen too low for human breathing (< 20%). Symptoms include loss of mobility and loss of consciousness, and victims may not even realize they are suffocating. Inert gases at low concentration may have a narcotic effect with symptoms including dizziness, headache, nausea and loss of coordination. Fresh air helps contrasting these symptoms. If the use of a self-contained breathing apparatus is necessary to enter a specific ambient or to help an injured person, the Staff will take care of this operation. This event is unlikely to occur in our cleanroom, due to the air flows that can change the whole volume of air inside the cleanroom 5 times per hour. **In any case, all malfunctioning of the gas installations must be reported to the Staff.**

Oxidizer gases (O_2, and N_2O) must be treated with special care, as they involve the risk of increasing fire. An oxidizer gas participates to combustion, can activate and maintain it even in absence of air. The most common oxidizer is Oxygen (O_2), while other oxidizers are nitrous oxide (N_2O), nitrogen dioxide (NO_2) and nitrogen monoxide (NO). Oxidizer gases also include halides (fluorine and

chlorine) and substances that can produce them. Oxidizer gases are usually stored compressed and liquefied. Oxygen can be very dangerous because an increase of its concentration in the atmosphere increases the risk of fire. At concentrations higher than 30% this risk becomes very relevant. Fire risk increases at high oxygen concentration, in case a flammable gas is also present:

- The flammability range widens as the superior limit of flammability increases (e.g. for methane it increases from 15% to 61%).
- Fire propagation speed increases (for methane it increases from 0.4 m/s to 40 m/s).
- The fire activation energy decreases (for methane is 100 times lower).
- The combustion temperature increases (for methane from 2000 °C to 3000 °C).
- The self-activation temperature decreases.

Nearly all substances burn in atmosphere of pure oxygen, therefore its presence in the ambient can dramatically change the probability of fire. Users who operate systems which utilize an oxidizer gas have to carefully follow the user manual and in particular:

- Substitution of pumps or mechanical parts in contact with oxidizers or lubricant refill with oils which are not compatible with oxidizers is forbidden
- Follow the limits of pressure and flux suggested for each process, as reported by the manuals or recommended by the cleanroom Staff

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Toxic and explosive gases

At PoliFAB there are two toxic and explosive gas lines, serving only the plasma-enhanced chemical vapor deposition machine (PECVD) in the thin film area (operator side) and in the grey corridor (machine back side): Ammonia (NH_3) and Silane (SiH_4), both used as precursor gases for thin film deposition. Due to the dangers represented by the presence of these two gases (ammonia is toxic and can explode in certain conditions, while silane is explosive), the laboratory is equipped with a management and leak control system than ensures operation in complete safety. All users have to know the access procedures and emergency procedures described in this document before they get the authorization to cleanroom access, even if their activities will not regard PECVD deposition nor the thin films area. **It is mandatory for every cleanroom user to know the risks and emergency procedures related to the exposure to the two dangerous gases, described in the safety datasheets attached to this document. The following table lists the GHS H-risks related to the two gases and their hazard statements.**

Gas	H-risk	H-phrase
Ammonia	221	Flammable gas
	280	Contains gas under pressure; may explode if heated
	331	Toxic if inhaled
	314	Causes severe skin burns and serious eye damage
	400	Very toxic to aquatic life
	EUH071	Corrosive to the respiratory tract
Silane	220	Extremely flammable gas
	280	Contains gas under pressure; may explode if heated

Ammonia is an extremely toxic gas and causes, if inhaled, serious pulmonary edema. It is also flammable, though having a small flammability range. Silane gas is extremely flammable, but it is not classified as a toxic gas.

In order to ensure safety to all operators in the cleanroom, gas sensors (2 for each gas) are installed close to the PECVD machine and a gas control unit is located right before the cleanroom entrance, outside of the first air-lock. Sensors and control unit are equipped with an acoustic and visual alarm (light signal tower) which shows the status of the system. Before entering the cleanroom users have to check the status of the control unit.

OPERATIVE INSTRUCTIONS: before entering the air-lock, users have to check the status of the light signal tower located on top of the control unit. It can display 3 different colors: green, yellow and red.

GREEN LIGHT: no issue has been detected by the control unit and gas bottles are open. Access to the cleanroom is possible. **All gases, including the two dangerous ones are available.**

YELLOW LIGHT: no issue has been detected by the control unit and gas bottles are closed. **The access to the cleanroom is possible, since no leak of NH_3 nor SiH_4 has been detected.** The supply of ammonia and silane is blocked because the bottles are closed or because of a minor issue with the control system, with no danger for safety. Any other gas, including oxidizers, can be used. In this configuration, evacuation from the laboratory is not necessary and no alarm will be present. Most of the times, for safety reasons the bottles of silane and ammonia are kept closed at the bunker gas, therefore the yellow light status is the most typical to observe.

RED LIGHT: this light is on only in case of detection of dangerous gas in ambient; the acoustic alarm is also on. The system will block the supply of silane and ammonia from their cabinets and also oxidant gases (O_2, N_2O) flows will be interrupted. **Cleanroom access is forbidden and users have to immediately evacuate the cleanroom** through the emergency exit of the lab and reach the assembly point (gate towards via Pascoli). In case the emergency exit of the cleanroom is blocked or the access through it not possible, it is recommended to leave the cleanroom via the first air-lock, leaving its two doors open for the other users. Evacuation is possible also through an emergency exit located on the stairs between the basement and the office floor.

The following table shows the behavior of the gas control and management system, along with the light signal tower codes and the actions users have to perform accordingly.

Light signal tower	Status	Access	Blocked gases	Evacuation
RED	Gas leak detected	**NO**	NH_3, SiH_4, O_2, N_2O	**YES**
YELLOW	Standby or malfunctioning	**YES**	NH_3, SiH_4	**NO**
GREEN	Functioning	**YES**	-	**NO**

In case of emergency

In case of accident during operations, users have to behave maintaining the highest safety for themselves and the others. Even in case of accidents without consequences to people or instruments, users have to report to the cleanroom Staff as soon as possible and with as much detail as possible. Users also have to keep the Staff informed about situations that can be potentially dangerous for safety or that do not comply with the instructions present in this document or in the other cleanroom safety training documents.

In case of dangerous gas leakage the visual and acoustic alarms will turn on and all users have to immediately evacuate the cleanroom through the emergency exits and reach the emergency assembly point (gate towards via Pascoli). In case the emergency exit of the cleanroom is blocked or the access through it not possible, it is recommended to leave the cleanroom via the first air-

lock, leaving its two doors open for the other users. An emergency exit is also located on the stairs between the basement and the office floor.

In the event of a health emergency, defined as any situation where one or more operators show health problems, even of light intensity, it is necessary to evaluate how dangerous the event is. Only after checking that the accident scene is not dangerous for other users, you can help the involved operators. At the same time it is mandatory to inform the Staff about the events. In case Staff members are not available and the event can be dangerous for other users, you must activate the fire alarm. In case of health emergency, defined as risk to human life, any user can call the emergency number 112. After this, inform the Staff personnel. Due to the dangers of the two gases, in particular the toxicity of ammonia, the access to potentially contaminated areas is forbidden without the use of a self-contained breather, which in any case can be used by trained personnel only. All users must know the first aid procedures described in the safety datasheets of ammonia and silane.

In case of fire, activate the fire alarm using the dedicated button and inform the Staff. If you hear a fire alarm, immediately leave the workplace and evacuate through the closest emergency exit and reach the emergency assembly point at the gate towards via Pascoli. In case the emergency exit of the cleanroom is blocked or the access through it is not possible, it is recommended to leave the cleanroom via the first air-lock, leaving its two doors open for the other users. May it be more convenient, an other emergency exit is located on the stairs between the basement and the office floor.