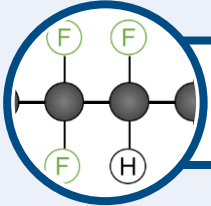


## Agenda



1. Chemical basics of fluorination technology



2. Construction of offline fluorination plant



3. Benefits of fluorination technology



4. Application examples

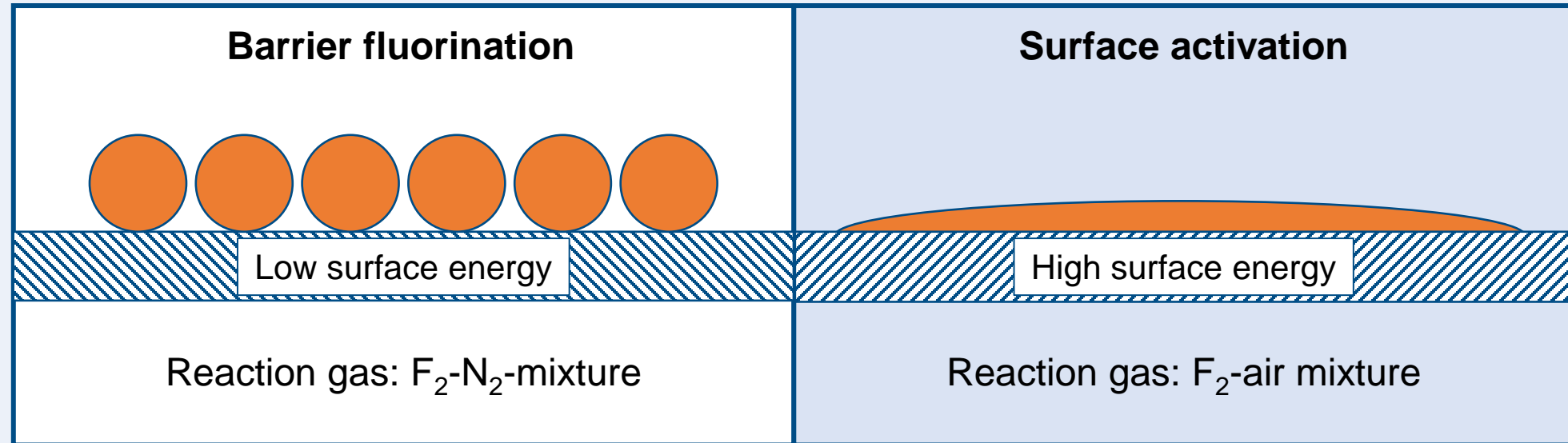
### Property of the chemical element fluorine

- Fluorine is part of the seventh main group of the periodic table, the elementary group of halogens, and has the structural formula  $F_2$ .
- Fluorine is gaseous at room temperatures and has a green-yellow colour.
- Fluorine is a highly toxic and corrosive gas. Handling it requires the highest safety standards.
- Fluorine is the most reactive element and therefore does not occur in nature in its elemental pure form. Fluorine was first discovered in fluorspar.
- Fluorine is obtained through the electrochemical reaction of the electrolysis of fluorides.



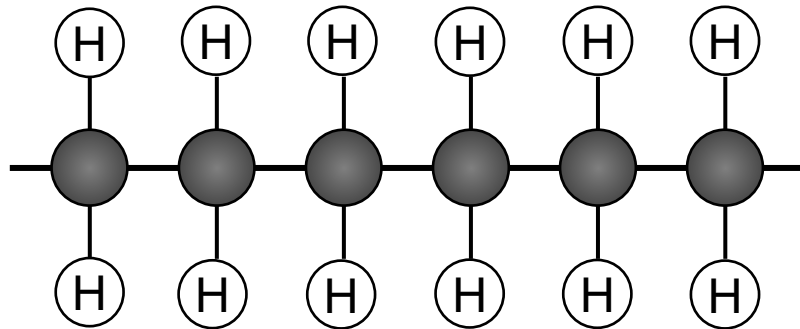
Fluorspar

### Fluorination - one technology two technical application areas

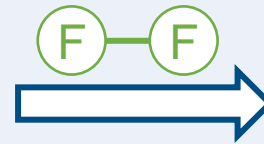


- Depending on the composition of the reaction gas, the properties of the plastic surface can be optimised in different ways by fluorination.
- Dehoust primarily uses barrier fluorination with a reaction gas consisting of an F<sub>2</sub>-N<sub>2</sub> mixture.

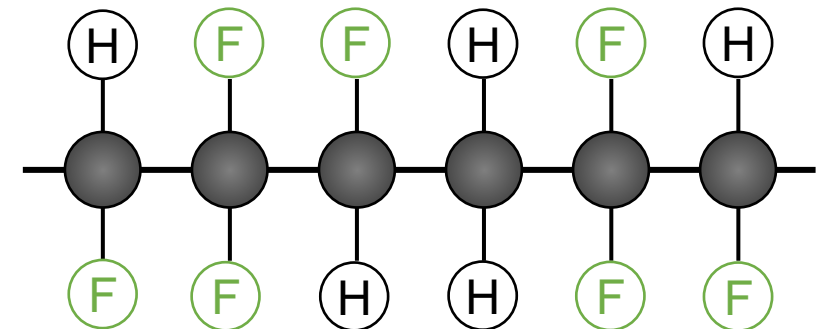
### View of the polymer structures



- Untreated polymer chains of carbon and hydrogen atoms
- Polymer molecules consist of multiple monomer structures



Supply  
of  $F_2-N_2$



- Stepwise substitution of individual hydrogen atoms by fluorine atoms in the surface boundary layer

- Fluorination is a chemical reaction and not a surface coating technology.
- The reaction only takes place in the molecular surface edge layers (approx.  $1\mu\text{m}$ ) and thus fluorine atoms have a low penetration depth.

### View of the reaction conditions

- The fluorination process is a form of halogenation.
- The reaction gas consists of a gas mixture of 10% fluorine gas (F<sub>2</sub>) in a nitrogen medium (N<sub>2</sub>).
- In a previously vacuumed chamber, the parts to be fluorinated are exposed to a fluorine atmosphere. The exposure time of the fluorine gas is only a few minutes.
- The residual product of fluorination is the toxic gas hydrogen fluoride (HF), which is neutralised by absorber systems.
- The fluorination process is defined by the following process parameters:
  - Fluorine partial pressure (fluorine gas concentration in the reaction gas).
  - Process temperature
  - Duration of fluorine gas exposure
- By varying the process parameters, different fluorination grades can be achieved.

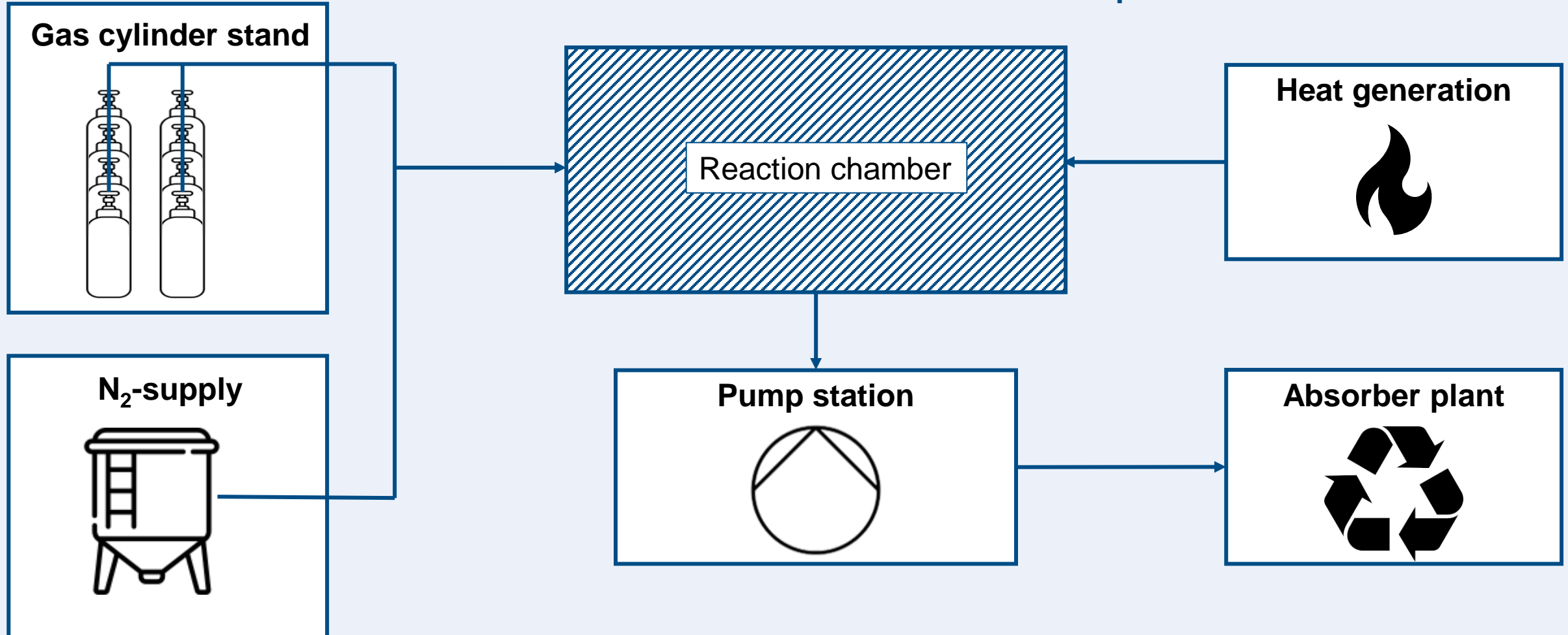
### Offline vs. Inline fluorination

| Process parameters       | Offline fluorination            | Inline fluorination        |
|--------------------------|---------------------------------|----------------------------|
| Fluorination temperature | 50°C – 75°C                     | 100°C – 120°C              |
| Fluorination pressure    | 200mbar – 650mbar               | 6bar – 8bar                |
| Fluorination duration    | 60min – 120min                  | During blow moulding cycle |
| Fluorine concentration   | 10% - 20%                       | 1% - 2%                    |
| Process profile          | Discontinuous                   | Dynamic                    |
| Part geometry            | Three-dimensional moulded parts | Sheet material             |
| Process execution        | External vacuum chamber         | Inside blow moulding cycle |

#### Advantages of offline fluorination:

- High flexibility regarding the shape of the plastic parts to be fluorinated
- High degree of optimisation of product properties
- Good reproducibility and controllability of the fluorination process

### Schematic structure of an offline fluorination plant



### Technical plant components

#### Gas cylinder stand

- The fluorine bundle station supplies the reaction chamber with the reaction gas. (10% F<sub>2</sub>).
- The gas supply is controlled automatically via remote-controlled valves.
- The fluorine bundle station is used as the gas transfer station and thus represents the system interface.
- The fluorine bundle station is protected against gas leakage by redundant safety systems and is continuously monitored by several measuring devices.
- The fluorine bundle station may only be entered and equipped by instructed and specially trained personnel.





### Technical plant components

#### Reaction chamber

- The reaction chamber is often also called a vacuum or fluorination chamber.
- The reaction chambers of the Dehoust plants have a volume of 20m<sup>3</sup> and are closed hydraulically.
- The fluorination reaction takes place inside the reaction chamber. For this purpose, the chamber is first vacuumed and then filled with the reaction gas.
- The reaction gas circulates continuously inside the chamber to obtain a uniform fluorination result.
- The reaction chamber is loaded and unloaded unmanned by an automated scale system.



### Technical plant components

#### Pump station

- The pump station is the interface between the reaction chamber, the fluorine bundle station and the absorber systems.
- The pump system consists of a double-stage combination of a vacuum pump and a circulation pump.
- The pumping system is able to vacuum the chamber in less than 10 minutes.
- To reduce the pump system's susceptibility to failure, pumps with few rotating mechanical parts are used.



### Technical plant components

#### Absorber plant

- The absorber plants bind and neutralise the toxic hydrogen fluoride and the excess reaction gas from the reaction chamber via a double-stage system.
- Used absorber technologies:
  - Calcium carbonate absorber ( $\text{CaCO}_3$ )
  - Aluminium oxide absorber ( $\text{Al}_2\text{O}_3$ )
- Residual products of the absorption process are non-toxic and can be recycled in cement production.
- The exhaust air from the absorber system is continuously checked for pollutants.



Absorber plant

#### Residual product absorber



### Fluorination plants at Dehoust GmbH



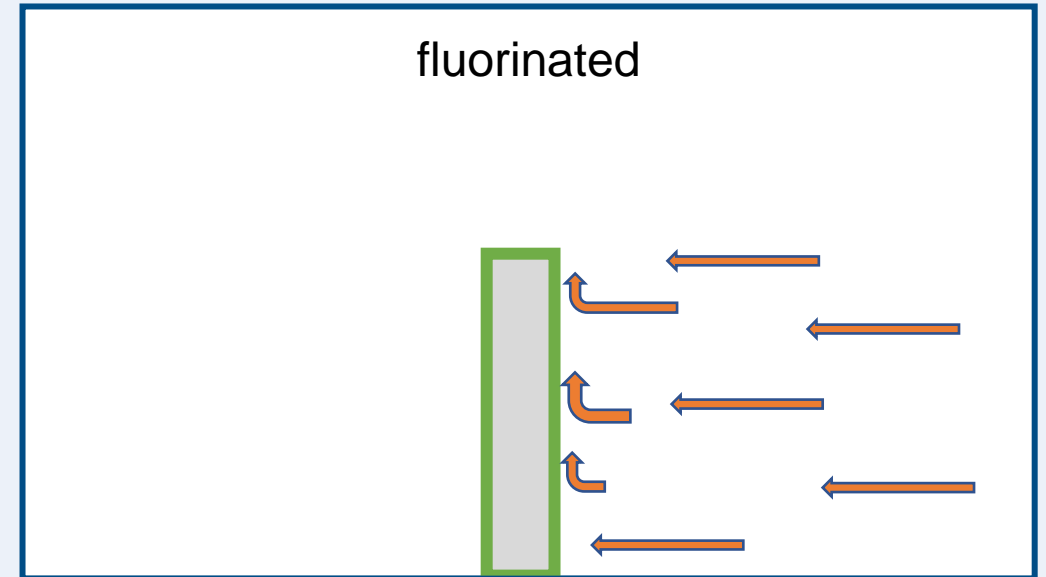
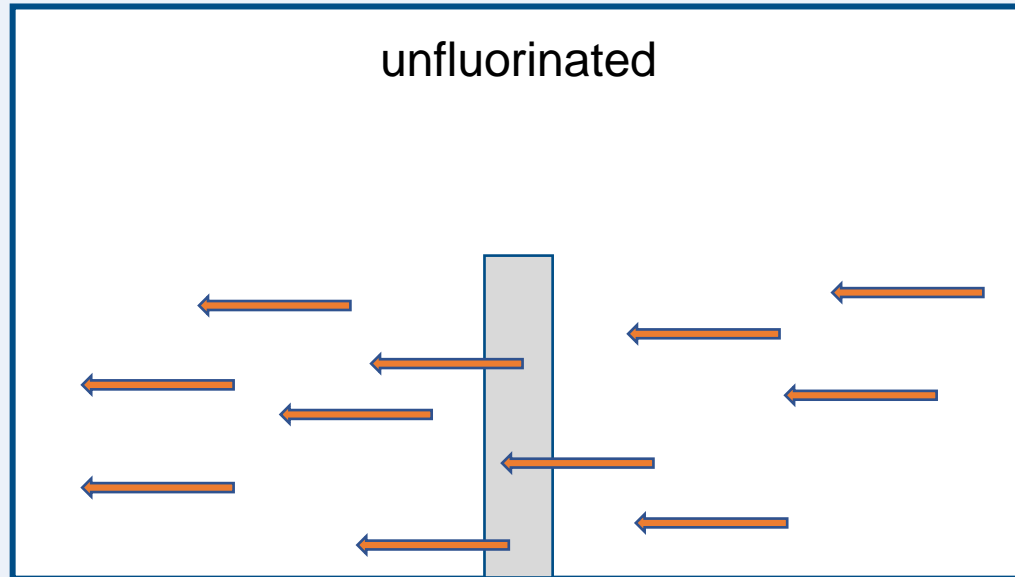
Fluorination plant 1



Fluorination plant 2

### Surface activation through offline fluorination

#### Permeation



- Non-polar media (e.g. fuel oil, aromatics, AdBlue©) permeate over time through untreated plastic containers.
- The fluoroplastic layer provides a low-energy surface which prevents or significantly slows down the penetration and thus permeation.

### Surface activation through offline fluorination

Long-term stable optimisation of the surface properties

Reproducible reaction process through standardisation of the reaction parameters

No damage (mechanical and thermal) to the plastic surfaces and structures

Applicable for almost all types of plastics as well as part sizes and part geometries

Consistent treatment qualities throughout the product

### Double-walled Triosafe plastic tanks



Triosafe 750l



Triosafe 1000l



Triosafe 1100l



Triosafe 1500l

### Combi tank inner shells 720l and 1000l

