

Fluorine Technology

The tiger of chemistry



“Fluorine has the power to create unique materials – harnessing that power opens the door to a whole new world of innovation.”

Siegfried Rödel
Fluorine specialist



Fluorine – ‘Chemistry’s Tiger’

Fluorine is the most reactive element known to man. Its reputation has earned it the title of being ‘the tiger of chemistry’. At Air Products we can harness the power of fluorine to develop materials and surfaces with new and unique properties – and in turn help you create new and exciting products.

At Air Products, we have been working with fluorine technology for over 20 years.

Throughout that time we have built plants for the fluorination of materials and surfaces, optimised processes and developed new ways to safely supply industrial fluorination plants with process gas. Today we have systems – and satisfied customers - all over the world.

Why not ask our experts how fluorination technology can help you? Our team will work with you to develop a tailor-made solution to meet your needs.

Air Products Integrated Fluorination Business Process (IFP) – technology from the source

Through our extensive experience of working with customers to provide process control and engineering for fluorination technology, we have developed an innovative service that takes our skills and resources and combines them with your own.

We call it the Integrated Fluorination Business Process (IFP). Put simply, you tell us what you want to achieve and we develop the perfect process for the job.

What we offer:

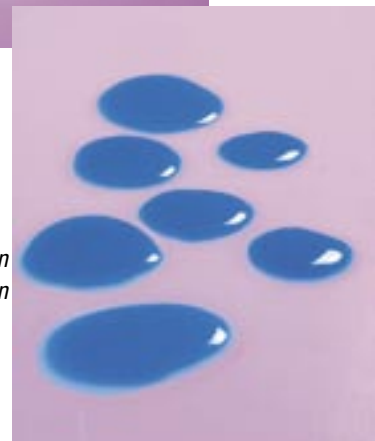
- Feasibility studies and experimental preliminary studies
- Safety and environmental analysis and advice
- Detailed and basic engineering including safety and environmental engineering
- Plant construction
- Operator training
- Process optimisation
- Process gas supply
- Test and pre-production fluorination
- Mobile fluorination plant for hire

What you get

- You benefit from decades of experience in the field of material fluorination
- You can tap into a broad base of knowledge from a business with operations and expertise all over the world
- You can be safe in the knowledge you are making the right investment decision
- You can access a worldwide presence in process gas supply and plant and safety engineering



Surface tension with fluorination



Surface tension without fluorination



Main components of the “off-line” fluorination system

Fluorine Technology

The skills to tame the ‘tiger’

What is fluorination?

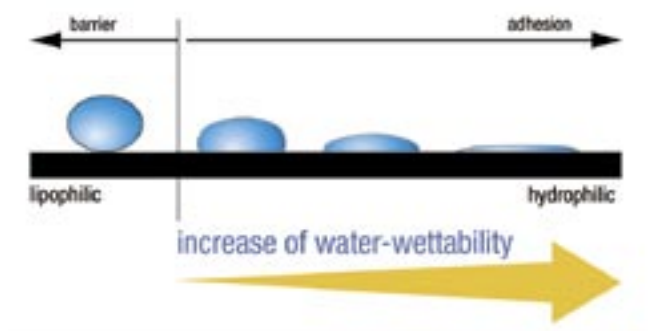
The surface treatment of plastics and other materials with gaseous fluorine is called fluorination. Using fluorination, preliminary, intermediate and final products can be developed to provide specific properties that make them suitable for subsequent processes or end uses. Fluorine nitrogen or fluorine air mixtures are applied to the base material, transforming the surface structure into a thin functional layer. This layer determines how the material interacts with the outside world.

Barrier fluorination

In barrier fluorination, mixtures are created using fluorine levels of between 1 and 20 per cent. The treatment modifies the base material to protect the surface from all types of solvents such as chemicals, organic solvents, oil and fuels. Fluorination can also be used to protect plastic surfaces against the penetration of moisture, vapours, odours and aromas. Fluorinated surfaces even provide protection against attack by bacteria and micro-organisms.

Surface activation

Fluorine air mixtures containing lower levels of fluorine can be used to improve the adhesive properties of plastics and other base materials. Unlike barrier fluorination, this treatment increases the surface energy and gives the surface hydrophilic properties. Typical applications for this technology on plastics includes: pretreatment for painting, surface structuring and gluing (to itself and to other materials); the production of natural and artificial fibres; membranes and filter materials and, in the building sector, the production of fibre-reinforced building materials.



In-line and off-line systems

There are two types of fluorination system depending on the application: a continuous or semi-continuous 'in-line' system or a discontinuous 'off-line' system.

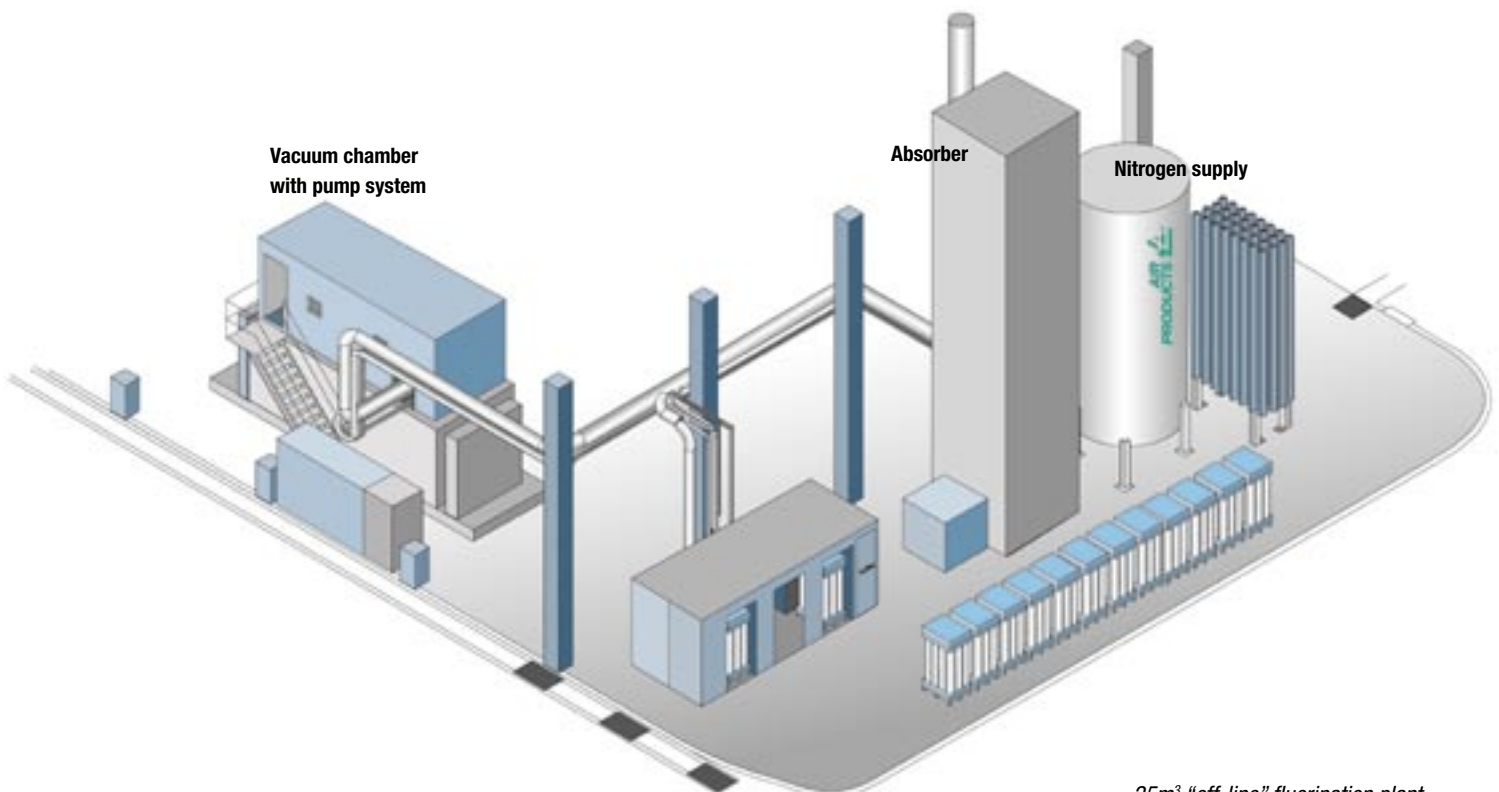
In the in-line system, fluorination takes place during the manufacturing process - for example during the blow moulding of packaging containers.

If off-line processes are used, manufacturing and fluorination take place separately. Vacuum chambers are used to treat the object and the fluorination is independent of manufacturing.

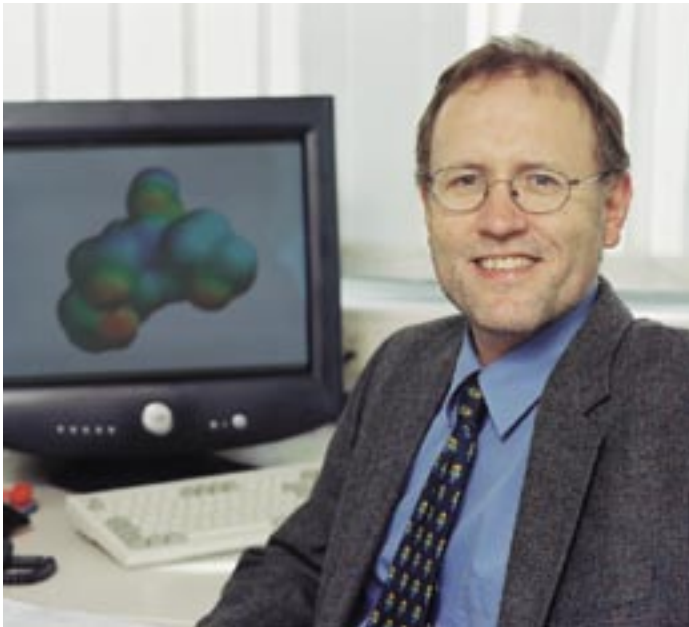
Both processes can be used on a commercial scale and at Air Products we have been successfully bringing them to our customers for many years.



1.5m³ "off-line" fluorination plant



25m³ "off-line" fluorination plant



Applications and possibilities

Materials that can be treated

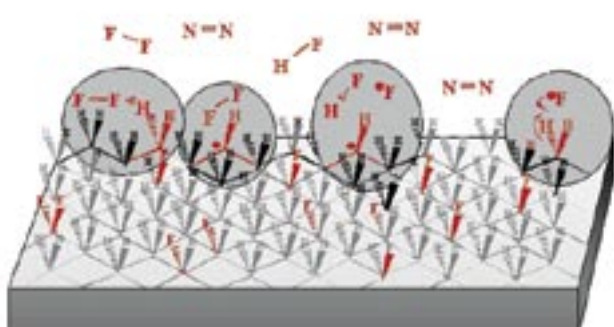
Fluorination of plastic surfaces is a chemical reaction between a solid and a gaseous reactant. The reaction is determined by the concentration, the temperature and the individual chemical properties of the reactants.

The result of fluorination is highly dependent on the structure and the chemical composition of the material. The processes that the base material has already undergone, the presence of additives and the type and concentration of pigments and dyes can have an important effect on the outcome.

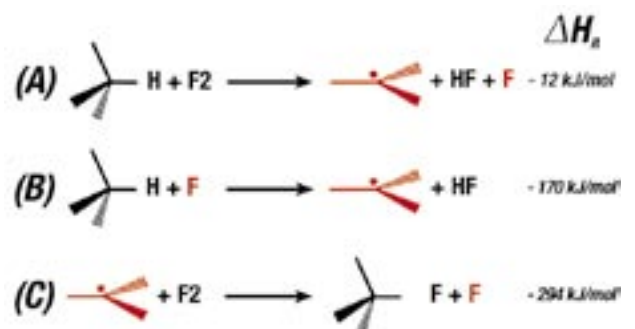
Surface energies of selected elastomers, untreated and fluorinated

Material	Abbreviation	Surface energy untreated (mN/m)	Surface energy fluorinated (mN/m)
Low-density polyethylene	LDPE	32	54
Polyethylene	PE-UHMW	37	54
Polypropylene	PP	29	66
Polyoximethylene	POM	40	72
Polyethylene terephthalate	PET	32	72
Ethylene propylene dien copolymer	EPDM	40	58
Polybutylene terephthalate	PBT	30	72
Poly carbonate	PC	32	56
Polyphenylene sulphide	PPS	32	60
Polysiloxane elastomer	SI	32	54

The list above is indicative of substances that can be fluorinated. Please contact us if want to know about other possible applications.



Fluorination of polycarbon surfaces



Initial step of the fluorination reaction

Fluorination – a gentle process for excellent results

Compared with conventional processes, fluorination is relatively gentle and remains stable for a long time. The surface treatment of plastics is one of the best demonstrations of the advantages of the technology.



Disadvantages of conventional processes

Flame and corona treatment of plastics

Both processes damage the surface of the plastic to some extent. The reason is the presence of a very large concentration of reactive agents. Very intensive and aggressive oxidation of the plastic surface leads to the polymer chains becoming unstable, enabling easy stripping. This means that the activation effect is lost after a very short period of time and an intervention in the process is rarely possible.

Low pressure plasmas

Treatment in low-pressure plasma can also be used to modify plastic surfaces. The major disadvantage is the investment required for equipment to enable the low pressure process. What's more the low process pressure only activates the outermost surface layer of the plastic. As the polymer chains in plastics always tend to move, the activation effect is lost after a very short period of time.

AIR PRODUCTS



Advantages of fluorination technology

- **Treatment of almost all plastic surfaces**

Virtually all plastic surfaces can be pre-treated with fluorine.

- **Easy process control that can be reproduced**

Because the activation is caused by the reaction of fluorine with the plastic – the intensity of which is determined by the amount of oxygen present - the process can be easily controlled and reproduced by adjusting the concentration of fluorine.

- **Lasting preliminary treatment**

Both films and complex shaped surfaces can be treated. As the treatment takes place at almost normal pressure (> 500 mbar), the fluorination reaches lower material layers as well. The preliminary treatment effect is therefore very strong.

- **Excellent results without damaging the surface**

The concentration of active agents can be easily balanced. This concentration is high enough to achieve a very good activation, yet is low enough so that it does not damage the surface.



Treated by "off-line" system



Treated by "in-line" system

Applications

Automotive and components industry

Fluorine-sealed fuel tanks

Air Products was one of the leaders in the development of fluorination for plastic containers. Working with our customers and using innovative technology for barrier fluorination of plastic fuel tanks, we managed to dramatically reduce the emission of volatile hydrocarbons.

With this unique fluorination process, we have developed a tried and tested method for fluorination during blow-moulding. This significantly reduces the diffusion of fuels and solvents from fuel tanks and plastic containers.



Building industry

Flexible fluorinated concrete

Concrete mixtures - reinforced by loose iron parts - are traditionally used for floor foundations, road surfaces and facades that are not required to carry heavy loads.

By adding fluorinated polypropylene fibres to the concrete, the stability and the shaping possibilities of concrete are dramatically expanded – a major innovation in the industry. What's more the concrete is lighter and lasts longer.



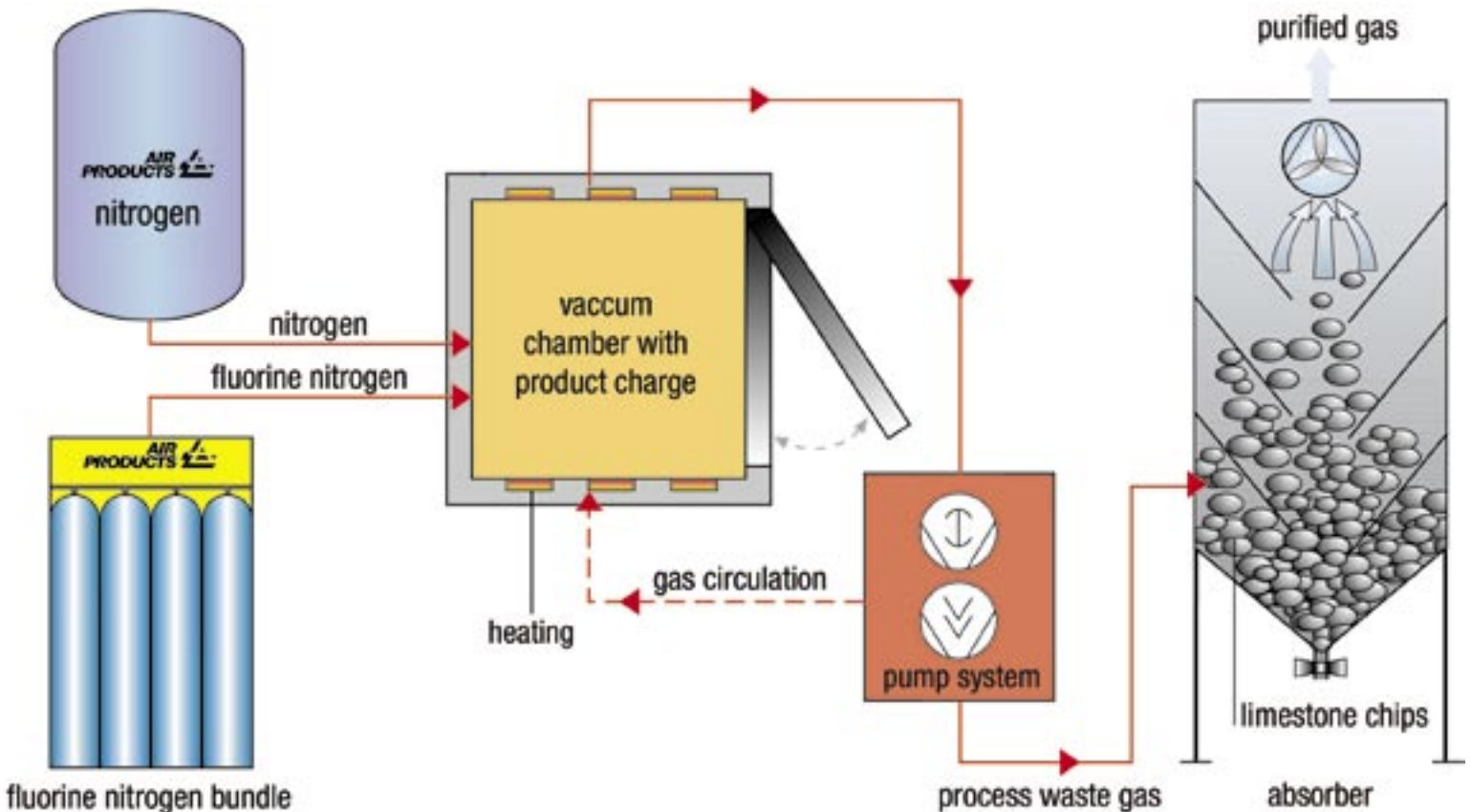
Paints, varnishes, inks and the printing industry

Coatings that stick and last

Activating surfaces with fluorine can considerably improve the adhesion of paints on critical surfaces and make the effect last. The benefits, for example when coating complex 3D objects, are significant.

What's more, formulators can design their paint systems to achieve perfect adhesion without the need for priming.

Modules required for "off-line" fluorination

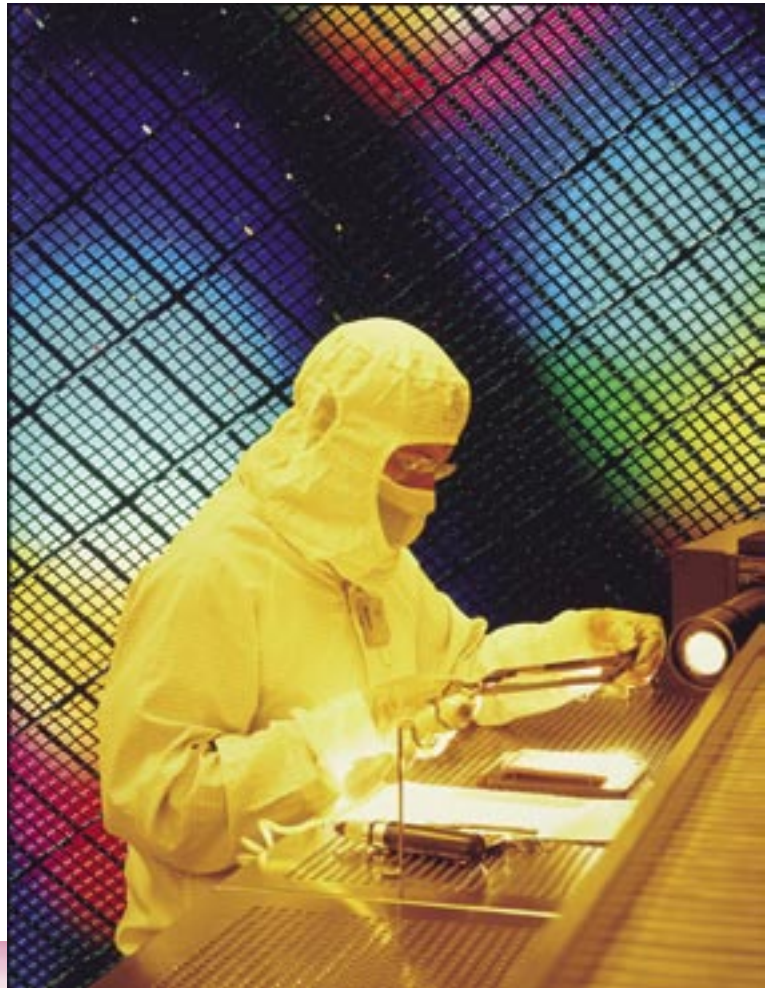


Electronics industry

Fluorine technology – when contacts are critical

In numerous applications across the semiconductor industry it is vital to achieve perfect contact and strong connections.

Once again fluorine can play a key role, and can produce significantly better results when chemically polishing high-current semiconductors.



Plastics processing

Fluorine activates surfaces

There are numerous applications for fluorine in the plastics industry – from hollow bodies and shaped parts to fibres, composites, films and foams.

An excellent example is sealing rubbers, which are used as guides in car windows.

To make the windows slide along the guides, manufacturers have to flock coat or varnish the surfaces of the guides. Fluorine activates these surfaces and ensures adhesives stick to rubber better. This process helps manufacture durable, lasting and easy sliding guide rails.



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