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PackAlliance:
European alliance for innovation training
& collaboration towards future packaging

Linking Academy to Industry.

Training program: modules

- **Eco-design & novel manufacturing processing**
- New materials and biomaterials
- Citizen and Consumer Engagement
- Residue management and valorisation

Co-funded by the Erasmus+ Programme of the European Union

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Blowing

Process for the production of hollow bodies and bottles through the injection of air, inside a **preform** (from **injection molding**) or a **parison** (from **extrusion**).
Blow molding is limited to thermoplastics polymers .
The most used polymers are:
PET, PC, HDPE, LDPE, PP, ABS, PVC).

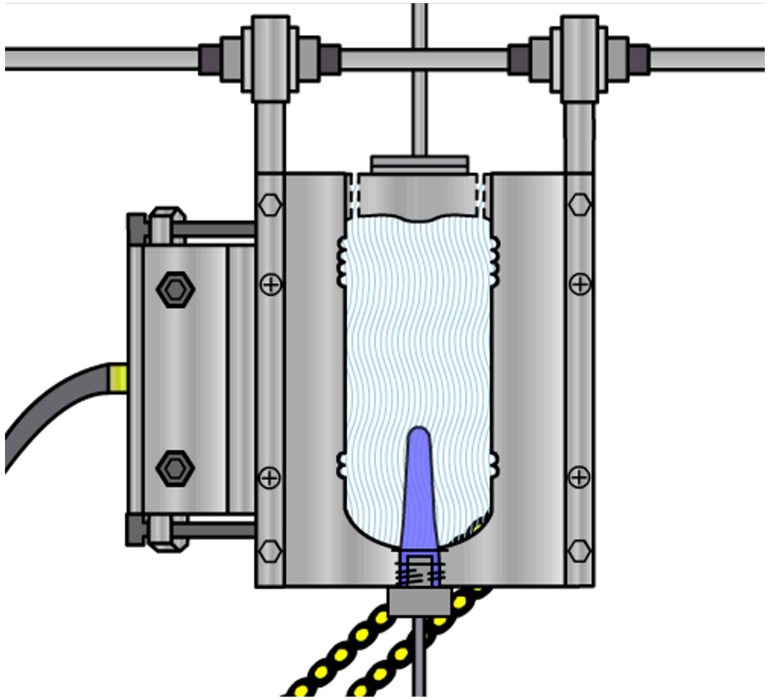
Two variants:

- Molding for **injection blow molding (IBM)**
- Molding for **extrusion blow molding (EBM)**

Injection blow molding (IBM)

Injection blow molding it is used for the production of thin-walled bottles and hollow bodies.

1. Injection moulding of the "preform"
2. Blow molding of the preform, with compressed air
3. Cooling down of the bottle
4. Opening mold and part exit



http://www.bpf.co.uk/data/iframe/injectionstretchblowmoulding.html

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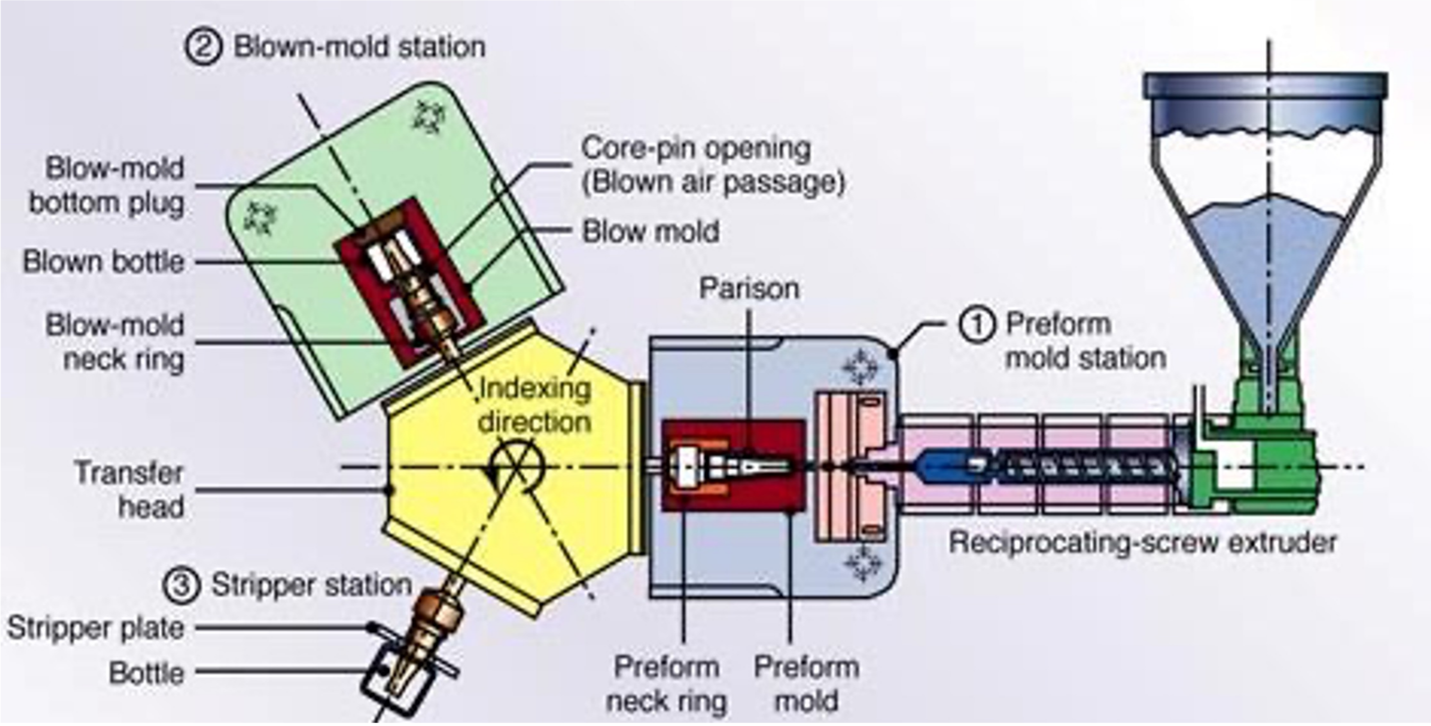
Single-stage blowing

A single-stage process gains its name from the fact that it creates preforms, stretches, and blows them on the same machine before cooling.



https://www.youtube.com/watch?v=eDoVB4u_syo

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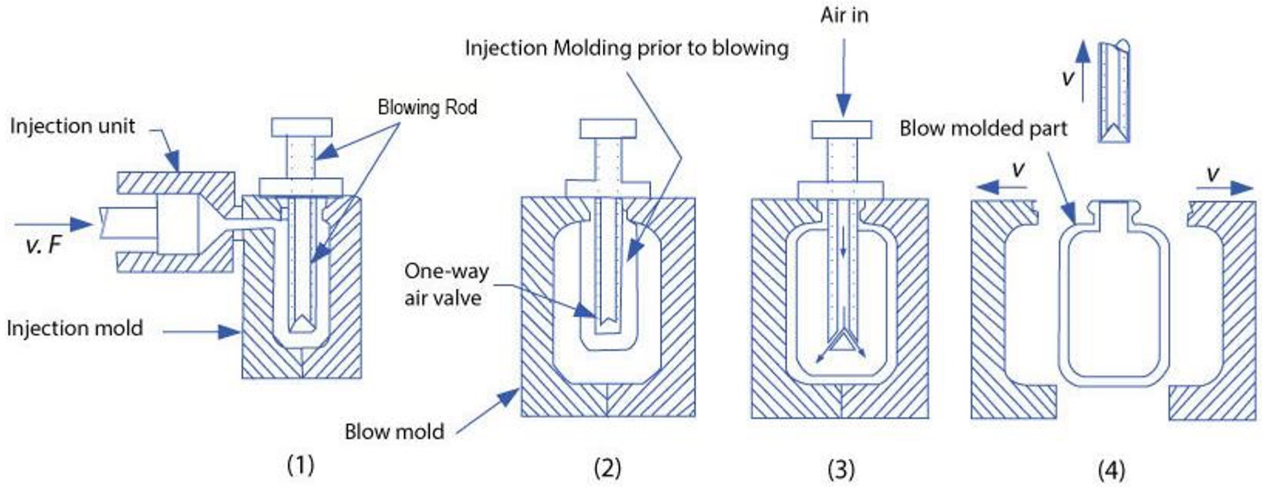
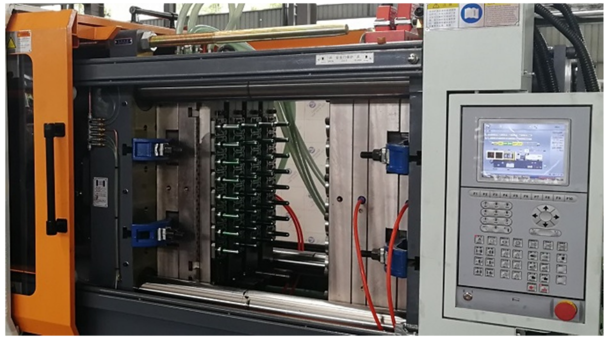
Two-stage blowing

The technique used in two-stage injection stretch blow molding machines involves two machines. These are the injection molding system and stretch blow molding machine.

Here, the plastic is molded into a fully-cooled preform in the first machine before being shipped to the second machine.





https://www.youtube.com/watch?v=so9OyGGlCv4

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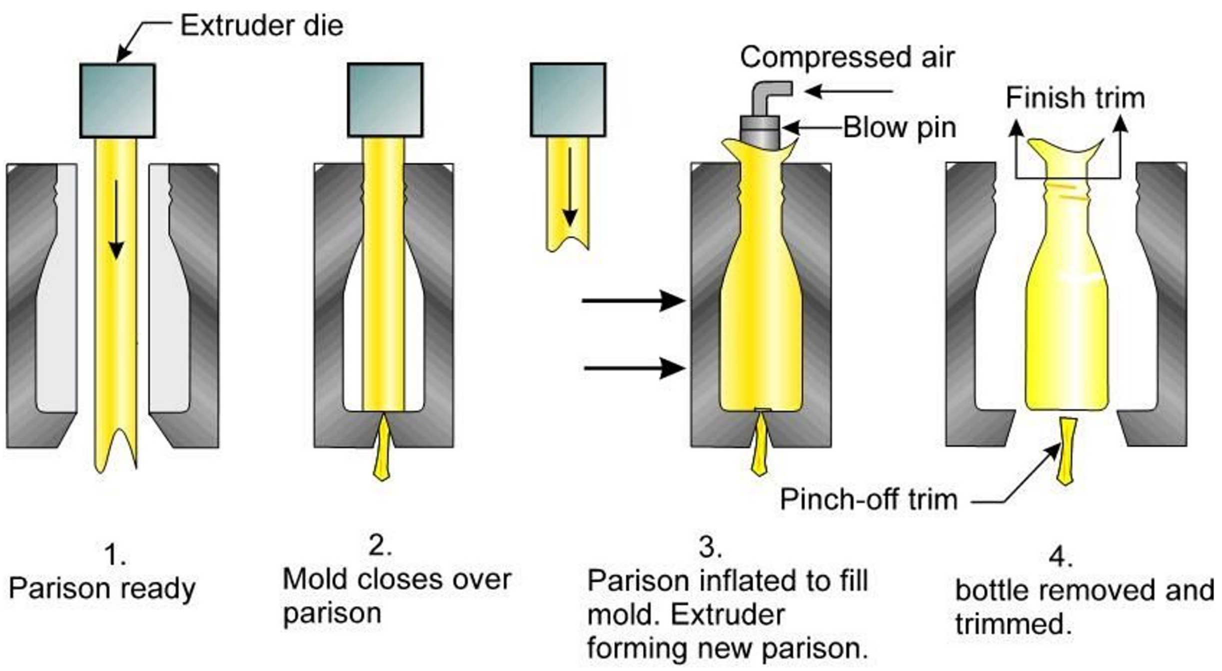
Extrusion blow molding (EBM)

In Extrusion Blow Moulding (EBM), plastic is melted and extruded into a hollow tube (a parison). This parison is then captured by closing it into a cooled metal mold. Air is then blown into the parison, inflating it into the shape of the hollow bottle, container, or part. After the plastic has cooled sufficiently, the mold is opened and the part is ejected.



http://www.bpf.co.uk/data/iframe/extrusion-Blow-Moulding.html

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The **Blow molding** process

Combining continuous extrusion and molding

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Blowing

- In **injection molding and blow molding**, a piece of tubular shape (preform), is first obtained by injection molding.

- Compared to **blow-extrusion, blow-injection** allows better control over the weight of the part and its wall thickness. It also allows greater precision in areas not subject to blowing (injection-molded neck areas, with the possibility of screwing caps and any closures).

- In the process in which it is expected **stretching during blowing**, the working temperature is suitably chosen to allow the orientation of the macromolecules and therefore the improvement of the properties.

- It allows to obtain a great variety of hollow shapes with thin thicknesses, equipped with suitable channels for the entry of gas or liquids. The costs are very high and limit the process to mass production. Among the products typically made, plastic bottles and hollow containers, especially those with threaded closures

- The **multilayer blow molding-injection** it is typically used for components that need to be both gas tight and resistant. Barrier layers will therefore be provided on the inside, while the outer layer will have characteristics of toughness, impact resistance and compatibility with subsequent text or image printing processes.

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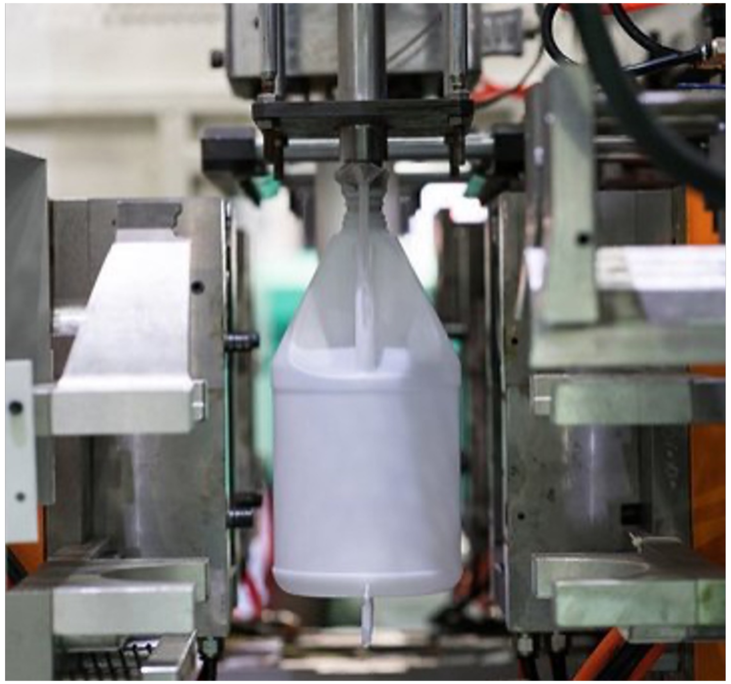
Extrusion blow molding



https://www.youtube.com/watch?v=8Ql4H40TX_c

Injection blow molding

https://www.youtube.com/watch?v=NE4c1gwzPb4

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Thermoforming

Thermoforming is one of the most widespread, and oldest, methods of transforming plastic materials, and is widespread in food packaging.

The polymers most used for this process are **only thermoplastics** and in particular: PP, PE and PS.

http://www.bpf.co.uk/data/iframe/Thermoforming_RPC_BPF.html

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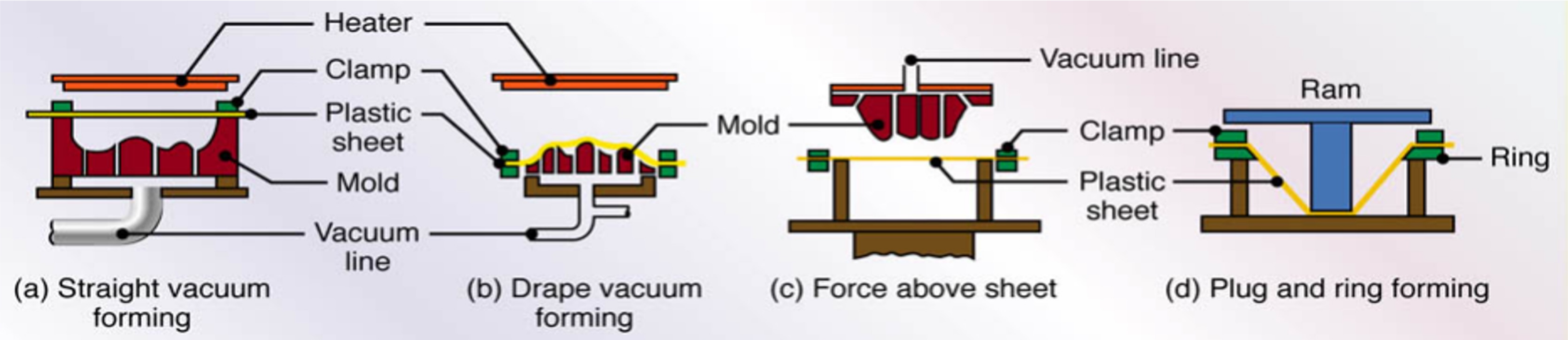
Thermoforming

It's a **hot deformation process** for films or sheets, previously transformed by extrusion. They undergo a "modeling".

In particular, these materials are placed in an oven where the polymer reaches its softening temperature and are thus formed with a mold that shapes them giving them the desired shape.



http://www.bpf.co.uk/data/iframe/vacuumform1.html

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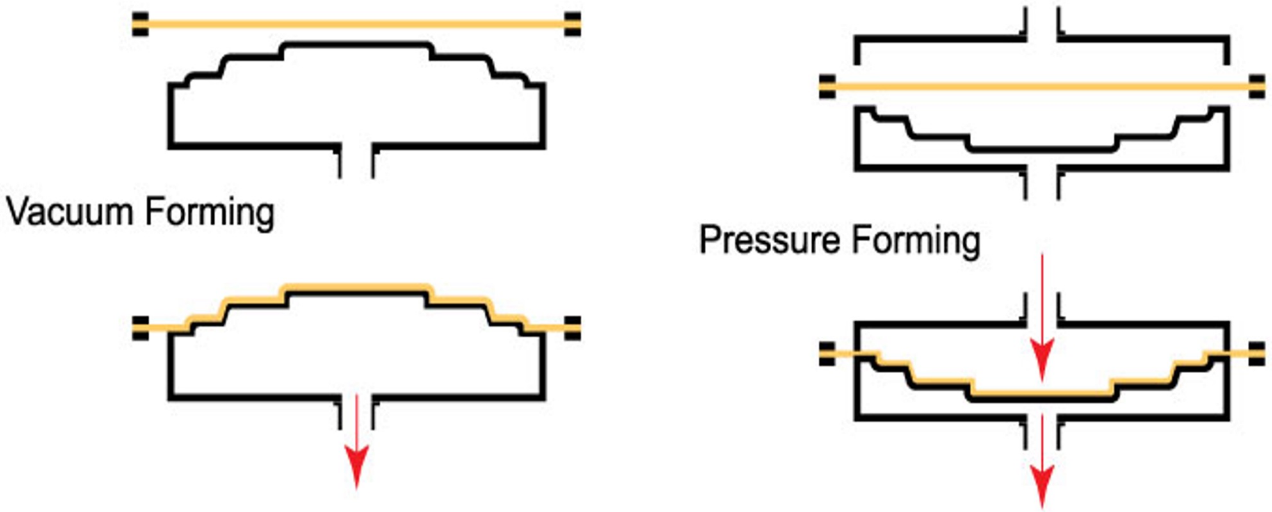
Thermoforming

You can use:

1. **THE VOID** through the suction of the air that remains between the film and the surface of the mold up to low vacuum levels (~ 0.5 mbar of final pressure) to obtain faithful shapes;

1. **THE PRESSURE** which allows to add compressed air (up to 10 bar). It allows to obtain a greater fidelity of the details.



https://www.youtube.com/watch?v=VyIBsmoiqqs

Polymer Foam

Materials containing gaseous voids surrounded by a denser matrix.

Foams have been widely used in a variety of applications: Insulation, cushion,absorbents, etc .

Various polymers have been used for foam applications: Polyurethane (PU), polystyrene (PS), polyethylene (PE), polypropylene (PP), poly(vinyl chloride) (PVC), polycarbonate (PC), etc.

Polyurethane occupies the largest market share (53%) in terms of amount consumed, while polystyrene is the second (26%).

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Polymer Foam - Advantageous / Disadvantageous

They have low density so they are light weight materials.
Some polymer foams have low heat or sound transfer, making them optimal insulators.
Many are flexible and soft, meaning they provide more comfort as cushion.

Inferior mechanical strength.
Low thermal and dimensional stability.

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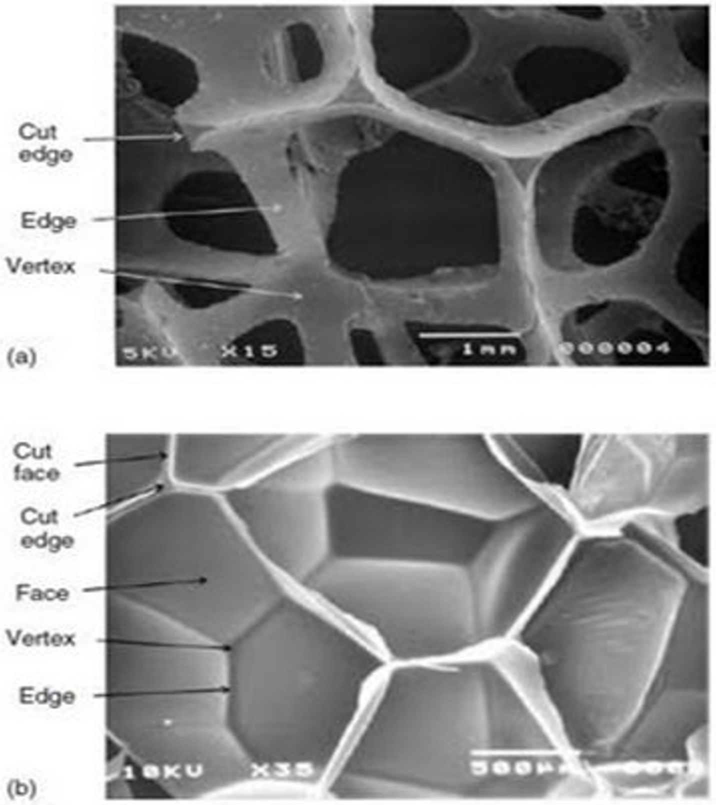
Polymer Foam - Classification of Polymer Foams

Polymer foams can also be defined as either **closed cell** or **open cell** foams.

In **closed cell** foams, the foam cells are isolated from each other and cavities are surrounded by complete cell walls.
Generally, closed cell foams have lower permeability, leading to better insulation properties, Absorb sound, especially bass tones.
Closed cell foams are usually characterized by their rigidity and strength
In open cell foams, cells are connected with each other. They have softer and spongier appearance.

Open cell foams are incredibly effective as a sound barrier in normal noise frequency ranges and provide better absorptive capability.
The advantages of closed-cell foam compared to open-cell foam include its strength and its greater resistance to the leakage of air or water vapor.
The disadvantage of the closed-cell foam is that it is denser, requires more material, and therefore, is more expensive.



SEM photograph of (a) PU open-cell foam of density 28 kg m^{-3}; and (b) closed-cell low density polyethylene (LDPE) foam of density 24 kg m^{-3}.

Fonte: Fundamentals of cell opening in polymer foaming - Tesi Tammaro_Daniele

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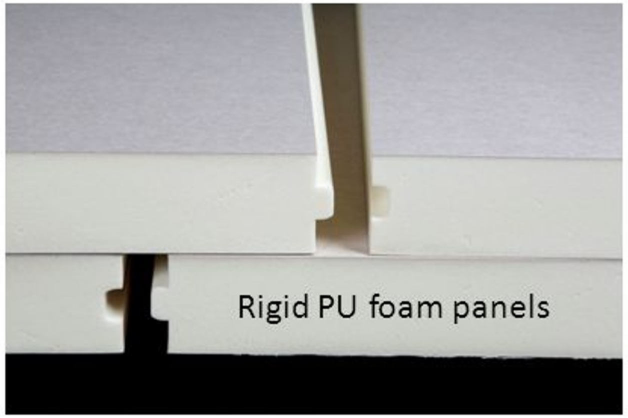
Polymer Foam - Classification of Polymer Foams

Polymer foams can be classified as **rigid** or **flexibl**e foams.

Rigid foams are widely used in applications such as building insulation, appliances, transportation, packaging, furniture, food and drink containers.



Flexible foams are used as furniture, transportation, bedding, carpet underlay, textile, sports applications, shock and sound attenuation.

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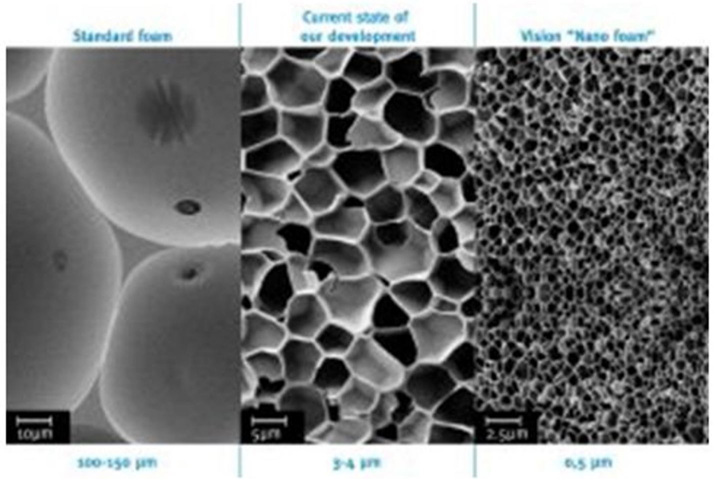
Polymer Foam - Classification of Polymer Foams

According to the size of the foam cells, polymer foams can be classified as:

Macrocellular (>100 µm),
Microcellular (1–100 µm),
Ultramicrocellular (0.1–1 µm)
Nanocellular (0.1–100 nm).

The thermal insulation performance of a polyurethane rigid foam depends chiefly on the size of the foam pores. The smaller the diameter, the lower the thermal conductivity and the better the insulating effect.

Today's polyurethane rigid foams typically have pore sizes of roughly 150 micrometers, which exceeds the pore size of nanofoams planned for the future by a factor of approximately 1,000.



Fonte: https://www.timetoast.com/timelines/linea-del-tiempo-sobre-diferentes-materiales

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Foaming process

The principle of foaming processes includes the steps of polymer saturation or impregnation with a foaming agent, providing super saturated polymer-gas mixture by either sudden increment of temperature or decrease in pressure, cell growth, and stabilization.

In thermoplastic foaming processes, it is important to obtain foams with closed cell structure with thin polymer cell walls covering each cell.

In order to provide this structure, cell growth must be controlled through the process. Temperature limit is critical in obtaining microcellular structure. If temperature is higher excessively, then melt strength of the polymer can be low-inducing cell rupture. On the other hand, if temperature is too low, this will result in longer foaming times and increment in viscosity of the polymer. As a consequence, cell growth will be restrained, and insufficiently foamed products will be obtained. Therefore, the process conditions have serious importance on cell morphology of the polymer foams. The most known thermoplastic foaming processes are **extrusion foaming**, and **foam-injection molding**.

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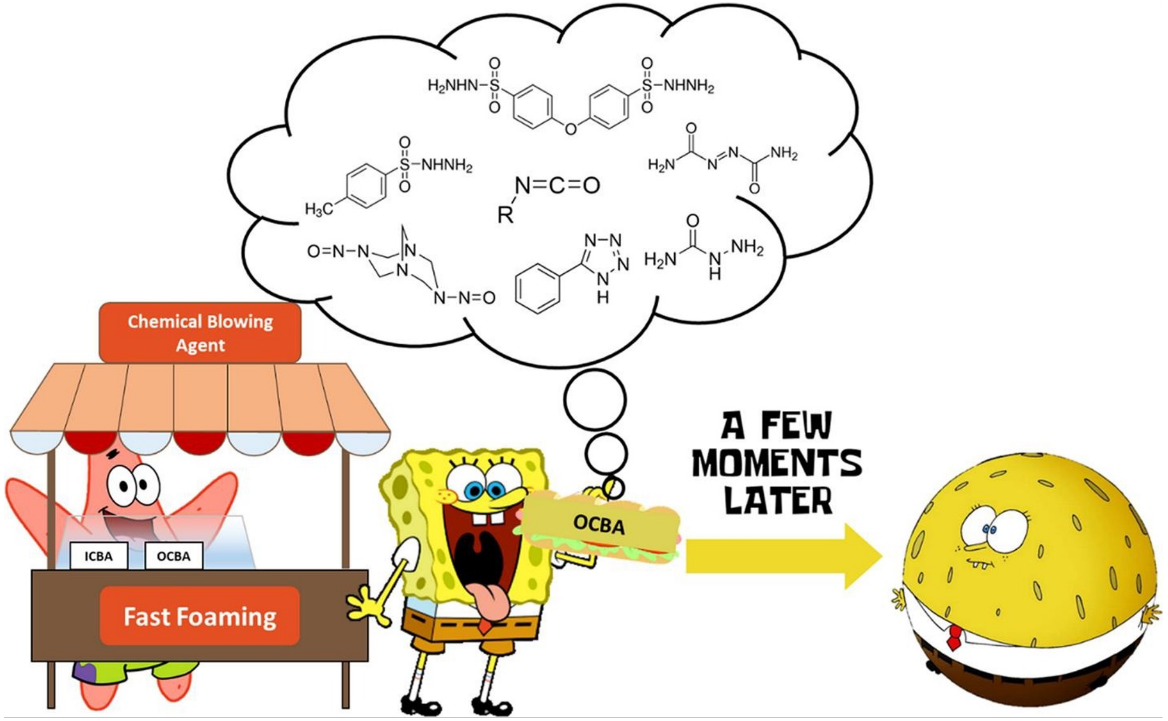
Blowing agent

A blowing agent is a substance which is capable of producing a cellular structure via a foaming process in a variety of materials that undergo hardening or phase transition, such as polymers, plastics, and metals.
They are typically applied when the blown material is in a liquid stage. The cellular structure in a matrix reduces density, increasing thermal and acoustic insulation, while increasing relative stiffness of the original polymer.



Blowing agent
https://www.youtube.com/watch?v=ldlu4uRhuBY

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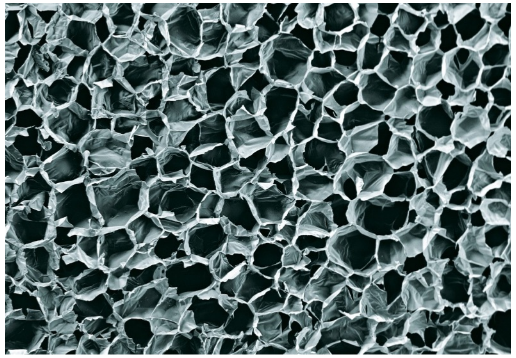
Foaming

Chemical Blowing Agent
(Chemical Foaming Agent, CFA)

Cellular structure created by a chemical reaction and heat during the plasticating process.
Gas generated is usually CO_2, N_2, or a combination for high-to-medium density foams.

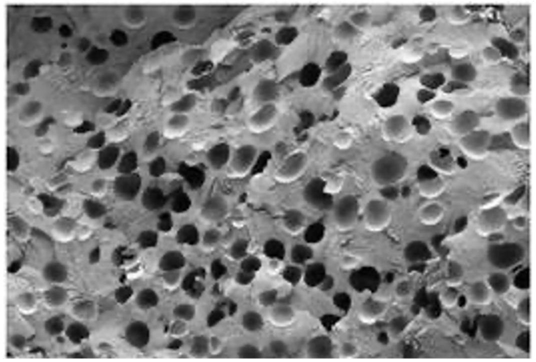
N_2 and/or CO_2



Physical Blowing Agent
(Gas Injection)

Cellular structure created by injecting gas in a super critical state directly into the barrel through equipment modifications.
For high and medium density foams, gases utilized are usually N_2 or CO_2.

N_2 or CO_2



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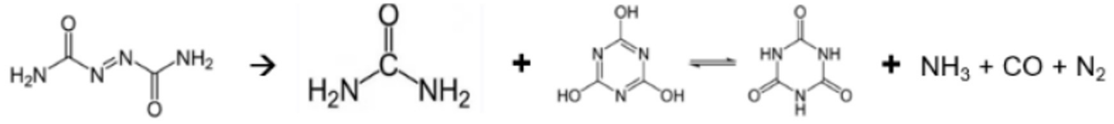
Foaming - Chemical reaction

Exothermics

Azodicarbonamide (ADC) : Creates Nitrogen and Ammonia, generates heat upon decomposition.
Typically best for PVC or ABS compounds. Heat up the System.
Make Larger cells in Olefins, Styrenics, etc. Best suited for extruded plastic lumber.



50 years of use in rubber and plastics
Slow gas diffusion rate
Positive for some applications and negative for others
Rapid and Robust gas expansion
N_2 is not as soluble in olefins and styrenes as CO_2

Endothermics

Carbonate / Acid Blends (SAFOAM® Endothermic) : Creates CO_2 and water, absorbs heat.
Most are FDA, Cool the system, usually make the best structure (small plentiful cells, white).

$3NaHCO_3 + C_6H_8O_7 \rightarrow C_6H_5Na_3O_7 + 3CO_2 + 3H_2O$

(sodium bicarbonate) + (citric acid) → (sodium citrate) + (carbon dioxide) + (water)

30 Years of use in Thermoplastics
Self Nucleating
Rapid gas diffusion rate
Faster crystallization times due to CO_2 being a plasticizer
Slow, controlled gas release (less pressure)
CO_2 is more soluble in the polymer melt than N2

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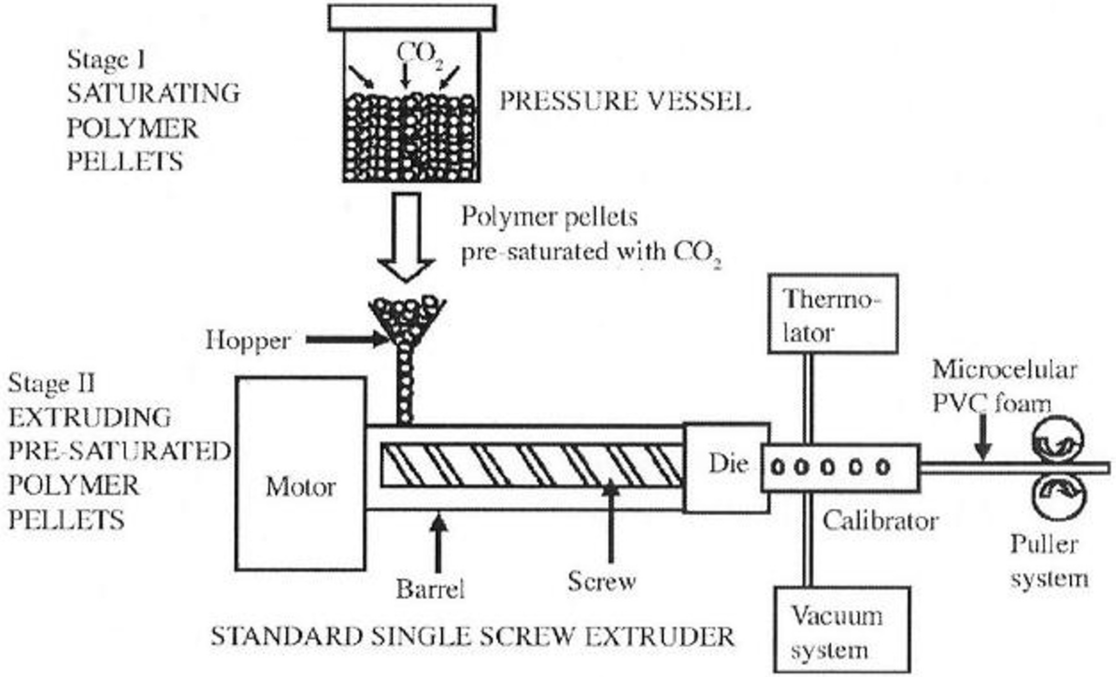
Continuous Extrusion Foaming

Is the most commonly used technology in the foam industry. Both single- and twin-screw extruders can be used for plastic foaming.
In a typical extrusion foaming process, the foaming gas is first injected into the barrel and mixed with the polymer to form a homogenous solution.
When the homogenous polymer/gas mixture passes through a die, a rapid pressure drop induces phase separation and cell nucleation.
Pressure drop, and especially the pressure drop rate, is the primary driving force for cell nucleation.
An extra shaping die is used to control the product shape and foam expansion.
The foamed materials continue to expand until the extrudate temperature is lower than Tg and the foam product is vitrified.



Fonte: http://faculty.washington.edu/vkumar/microcel/extrusion.html

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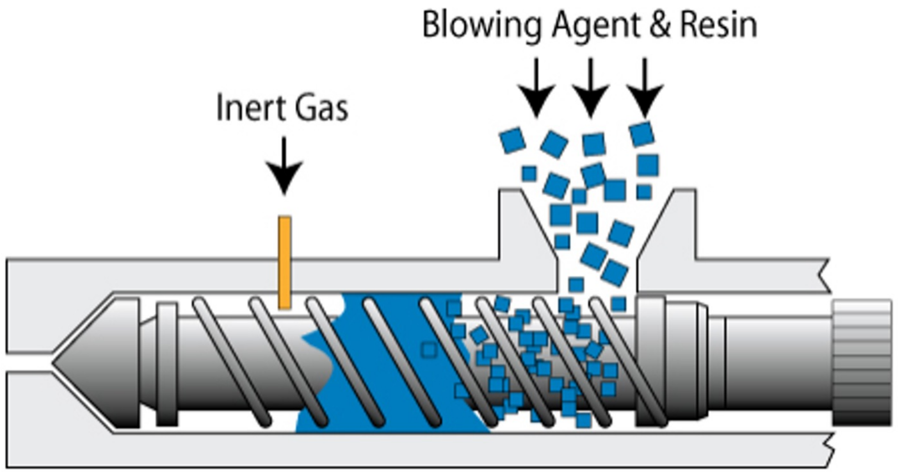
Foaming - Mold technology

Two types of mold technologies can be used:

1. In the low-pressure process the mold is filled with 80 to 95 % polymer gas melt. By the non volumetric filling of the cavity (80 – 95 %) and the pressure drop in the mold the melt can expand and fill up the remaining mold volume. It is called the low pressure process, since the cavity pressure remains relatively low. The degree of foaming is in the range 5 to 20 %.

1. In the high-pressure process (also known as "precision mold opening" or "breathing mold technology”) structural foams with lower density can be produced by molds with variable cavity (vertical flash face). The mold cavity is completely filled with polymer melt and then immediately opened by a few millimeters. Through this opening of the cavity a pressure drop occurs and the melt is able to foam. The opening takes place by the pull-back of the clamping unit (‘’Core Back’’).



Core Back
https://www.youtube.com/watch?v=rnQHbBIe6AE

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Foaming - Why Use Chemical Foam

- Reduces Cost
  - Less Material Consumption
- Reduces Weight
- Eliminates Sink
  - Improved Printing on Flat Surfaces
- Higher Production Efficiency
  - Lower Processing Temperatures
  - Faster Cycle Time
  - Reduces Machine Energy
- Improves Thermal Insulation
- Improves Sound Insulation
- Easily Scalable
  - Stable and Repeatable
  - Simple Process, Easy to Feed
- Easy Startup Cost
  - Easy to use Additive
  - No Modifications to Equipment Needed
  - Shutoff nozzles are a benefit in Injection Molding

Disadvantages

Are the non-volatile by-products of the carrier polymer (masterbatch), which remain in the device.
Therefore the mechanical resistance can be lowered and a premature failure of the component can occur.

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Linking Academy to Industry.

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ecoembes
El poder de la colaboración

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