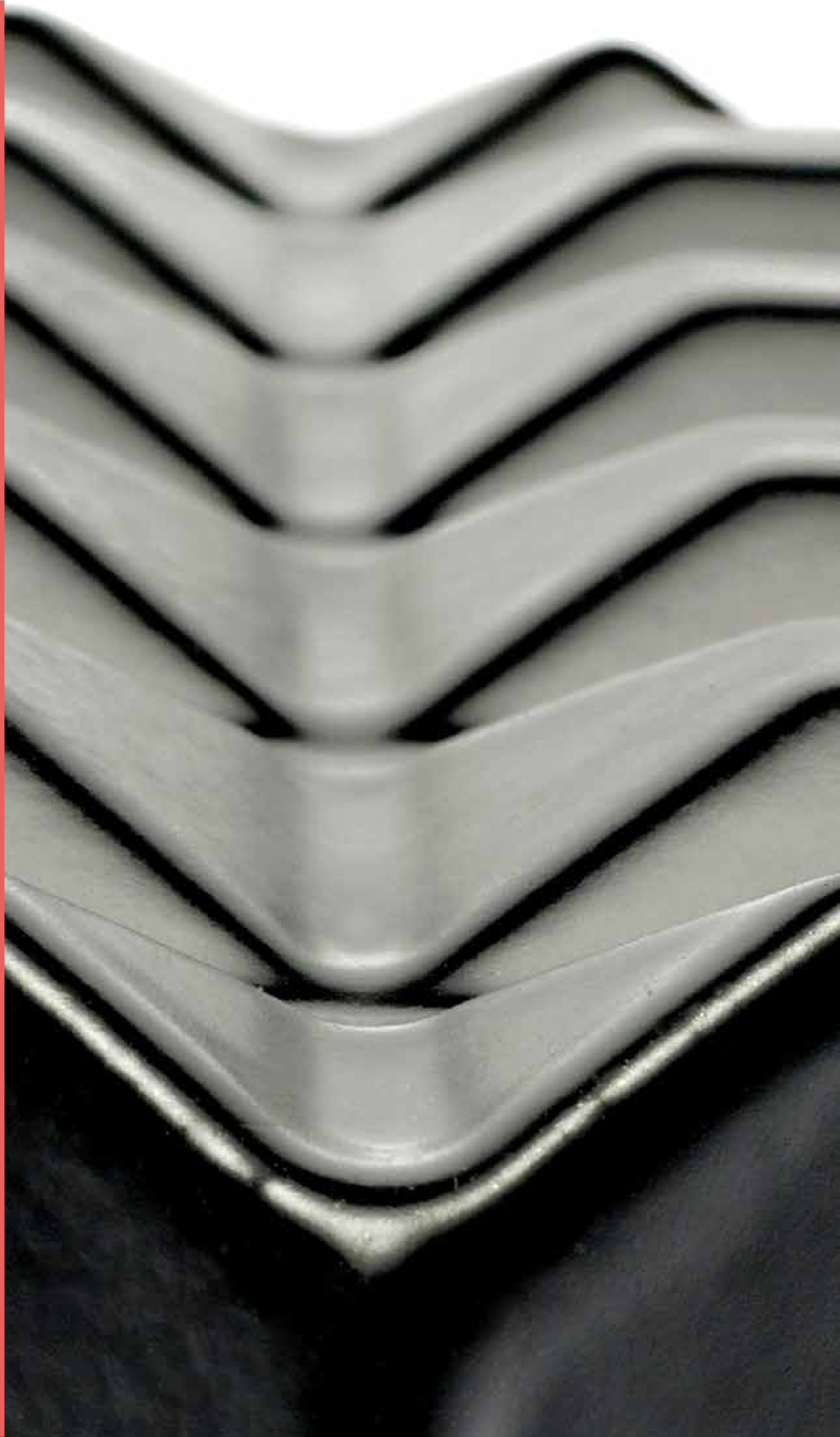
Material ConneXion®

A SANDOW Company

101 Material Report

Foams



What you need to know

Packaging, cushioning, insulation, light-weighting; each of these application areas would be that much less without the presence of foams. There is rarely an industry that does not rely on foams in some form or other. Reducing material usage, providing barriers to impact and temperature changes, even as an abrasive surface, all find unique use in the tiny cellular structure, random on a micro-scale, but uniform on a macro-scale, giving repeatable and reliable performance.

01 What Are Foams?

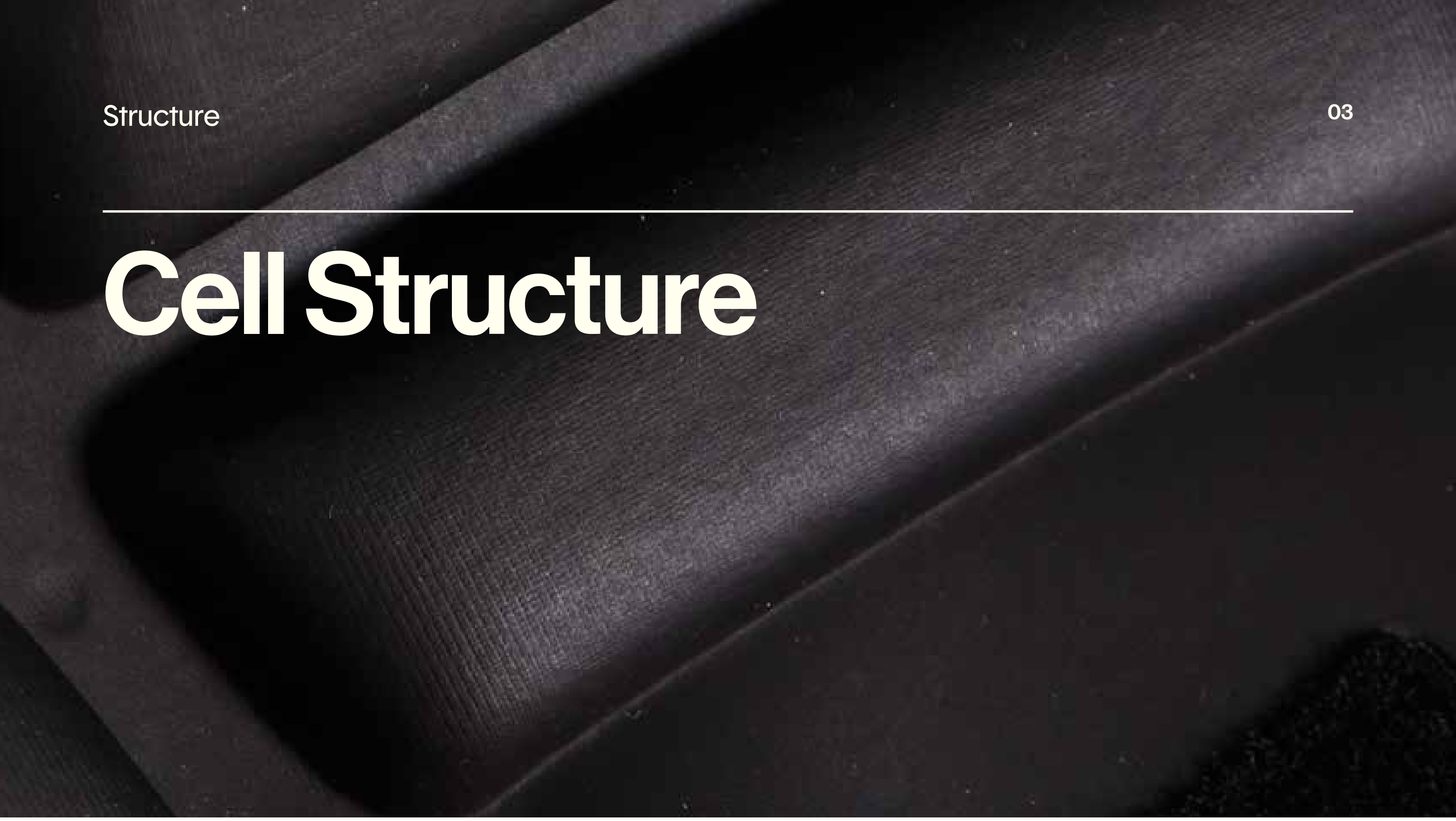
A foam is a material formed by trapped pockets of gas in a liquid or solid. Foams are present in a large variety of places including: wall insulation, couches, mattresses, biomedical implants, and more.

02 Foam Structures

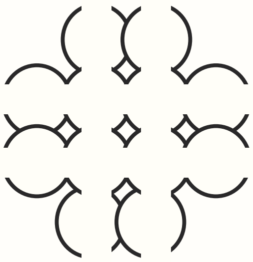
Foams can come in three different structures: open celled, closed celled, and reticulated. Most materials can be produced in either open or closed formats, depending on application need. In general, reticulated foams are considerable more expensive, as they require a secondary process (there are two currently used) to create reticulation.

03 Flexible vs. Rigid

Depending on the material of the foam, flexibility will vary. Foams derived from polymers have a direct relationship with density: the more dense a material, the more rigid it will be. This is not always the case for metallic, ceramic, and carbon foams. In these types of foams, the density is high, but they are still considered rigid. A material does not necessarily have to fall into one of the two categories. There can be materials that fall between the two.

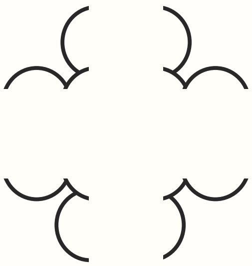


Cell Structure



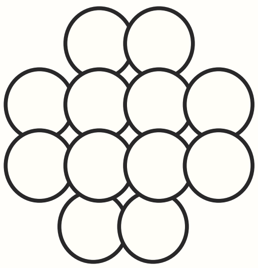
Open Cell Structure

In an open cell foam, at least 50% of its walls are open, allowing gas or liquid to flow from cell to cell. Properties include: permeability, absorption of vibration, and compressibility. They have lower insulation performance than closed cell foams. A clear example of this is a bath sponge, in which water flows through the entire material. An open cell foam can be further processed into reticulated foam.



Reticulated Foams

A reticulated foam has only about 3%–5% wall structure. It has so little material that it becomes transparent in thinner sections. This gives properties of extreme light weight, and easy flow of gas and liquid through the material. Flexible PU versions of this foam are used for outdoor cushions that dry fast after rain and can be hosed down for cleaning.

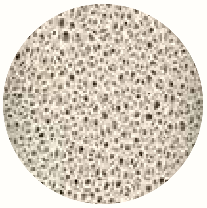


Closed Cell

Closed Cell foams have almost completely closed-in cells, are better insulators, and do not allow gasses or liquids to infiltrate the foam. The cushioning sole of a sneaker is a good example of a closed cell structure.

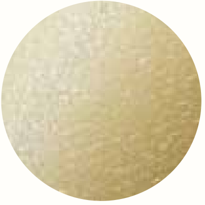
Foam Composition

Polymer The most common material type used for foams, polymers are available in both rigid and flexible constructions (constituting almost all cushioning applications), in many compositions. EVA, PU, polyolefins, PVC, fluoropolymers, elastomers and polyesters are all foamed and used extensively.



Ceramic Typically used as temperature resistant electrical and thermal insulators. They are rigid, brittle, and mostly white or gray in color. Most versions are produced by applying slurry around a polymer foam, then firing it to solidify the ceramic and burn off the polymer, leaving a reticulated structure.

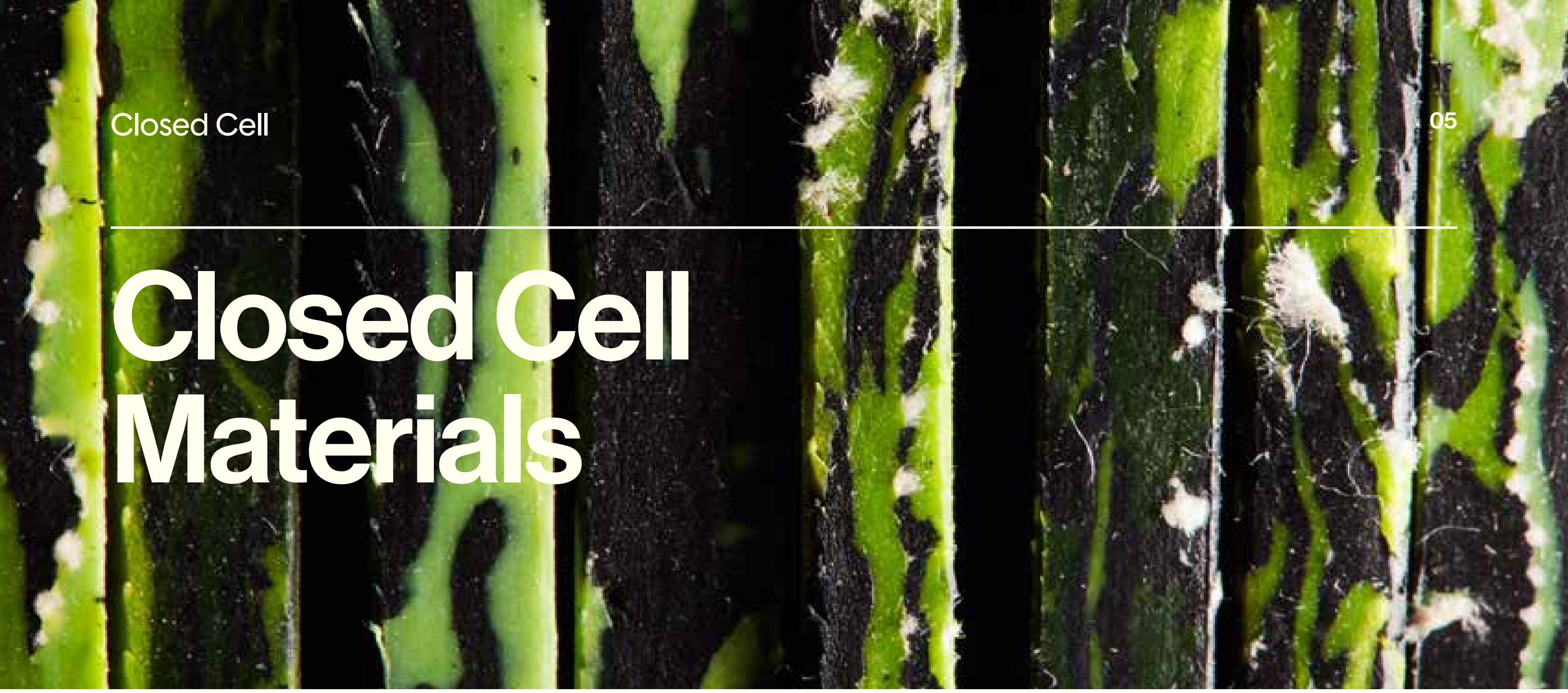
Carbon A class of highly porous materials that are 100% rigid carbon in a reticulated structure. They have high thermal conductivity, dielectric loss, and thermal mass, as well as good resistance to thermal shock and environmental degradation. Examples include fluid filters, gas diffusers, and catalyst supporters.



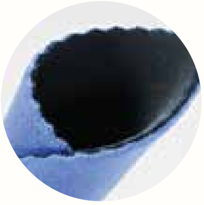
Cellulose Cellulose sponges can be either organic – retrieved directly from the ocean – or synthetic. This paper focuses only on synthetic sponges. These sponges are durable, absorbent, sustainable, and 100% biodegradable. They are mainly used for household and commercial applications, including dishwashing, and cleaning bathroom and kitchen surfaces.

Metallic Reticulated, rigid, lightweight structures that can range from closed cell to reticulated. They are produced by gas injection into the metal to 'bubble' it, or through powder metallurgy methods or similar processes in ceramics, using a polymer scaffold. Typical applications include sound and energy absorption, as catalysts, and for design and construction parts.

Glass Though not included in the material types section, aerogels, also known as 'solid smoke,' are an extreme form of foam made of pure glass that has been created using a sol-gel process. Ultra-light and incredibly heat insulating, they are also, unfortunately, quite fragile, so though they are great in fine powder form for cosmetics or as filling in apparel and industrial insulation, they are rarely used as large blocks since they fracture easily.



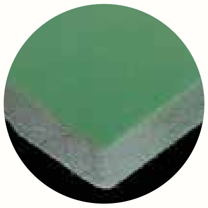
Closed Cell Materials



Neoprene A durable and flexible sponge rubber that resists UV radiation, sunlight, ozone, petroleum derivatives, chemicals, and breakdown by water.

EVA (Ethylene Vinyl Acetate) A semi-rigid product with a softer, rubber-like feel suitable for applications that need vibration absorption, weather and chemical resistance, acoustic and thermal insulation, and buoyancy with low water absorption.

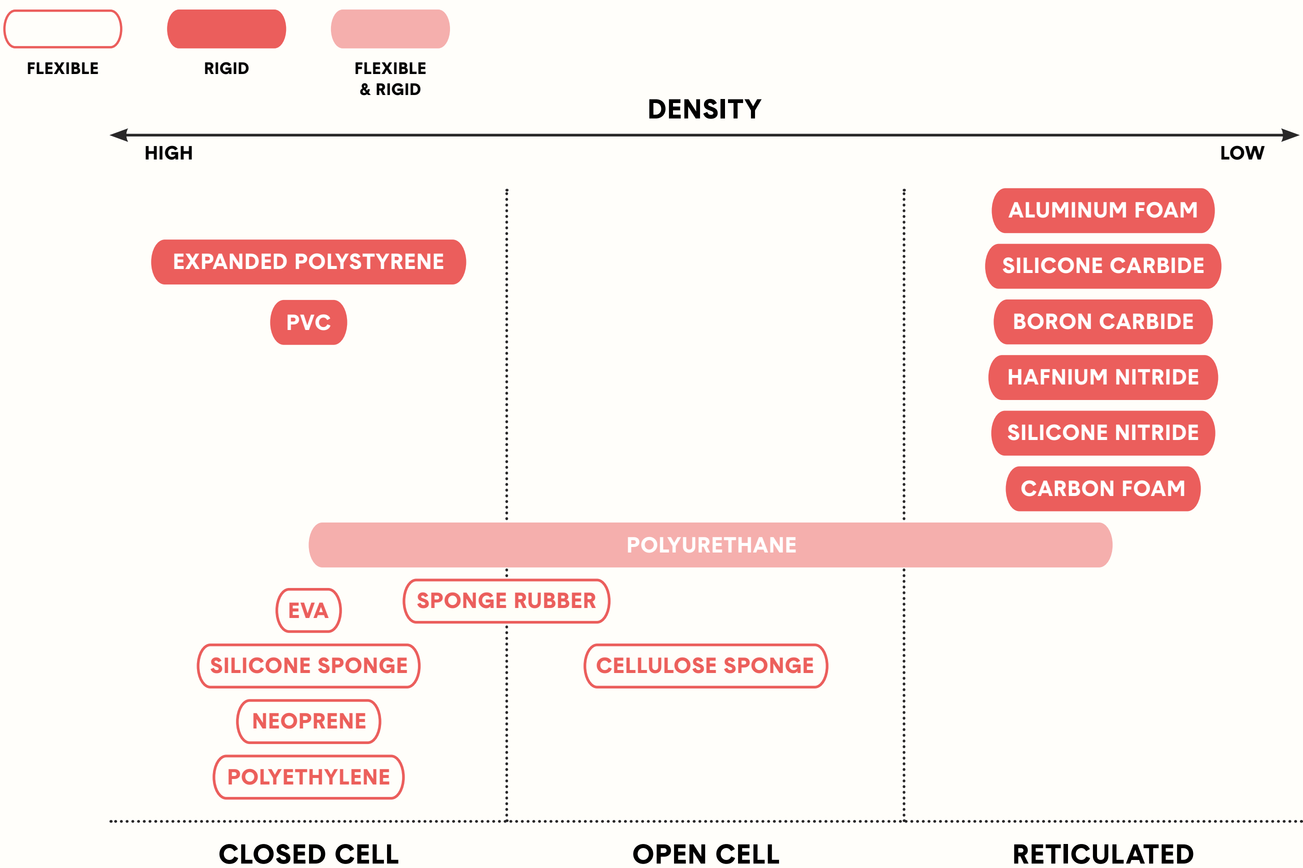
Silicone Sponge A foam rubber sponge with a low compression set, silicone sponge can handle a wide range of temperatures in addition to being UV, ozone, and weather resistant. It is also flame retardant, and a non-conductive insulating material.



Polyethylene Strong and resilient, polyethylene is usually utilized in materials that must be shock resistant, shatterproof, vibration-absorbing, insulating, and/or buoyant. It is available in different densities

Flexibility vs. Rigidity

Rigid foams provide high efficiency for thermal insulation, which contributes to the structural part of the unit. The material is easy to process and can be formed into very complex shapes. Furthermore, the material will not deflate upon puncture, and it retains buoyancy. Flexible foams tend to have a lower density and are primarily used in cushioning and packaging applications.



Safety & Sustainability

The way that foams are created includes a blowing agent that must be chosen depending on the application for which the foam will be used. There are a wide range of agents, both physical and chemical. Some chemical agents—such as HCFC's and isocyanates— raise health and environmental concerns. HCFC's are being phased out, and research and development efforts are ongoing to create blowing agents for all types of foams that do not affect human health.

A major challenge for polymer foams is the trade-off between fire retardants that are necessary to ensure a safe product (without them, PU foams are solid fuel for a fire), and the concerns over the harmful effects of these chemicals on human health.

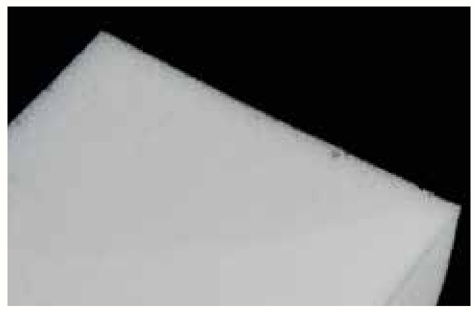
Halogenated fire retardants are ofconcern, with some being outright banned in the US and EU. Safer alternatives are available, but tend to be more costly and require greater amounts to be as effective, sometimes compromising the performance of the foam.

Process

Foams are submitted to different processes to comply with the application for which they were chosen.

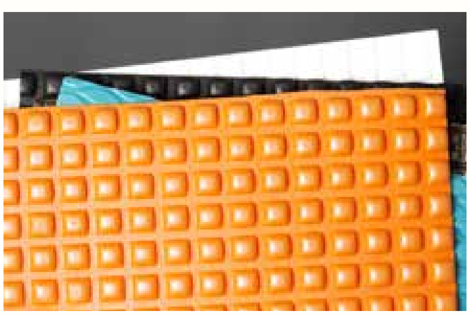
Cellulose Sponge

The process uses chemicals to create a jelly-like consistency from the constituents. This is poured into a mold and heated, foaming and solidifying the mixture. The resulting foams are soft, water absorbent, and can be composted at end of life.



Slabstock Foam

The simplest way to make foam in a continuous process on a conveyor belt, allowing the material to foam freely in air from a thin layer of semi-liquid to a thick solid foamed 'bun,' often 8 ft x 4 ft and 6 in thick. These foams are then cut to size.



Integral Skin

Integral skin can be produced in a single material by allowing the heat of the mold surface to melt the foam and cause it to ‘skin’ over. If the skin is to be of a different material, this consists of a two-part polyurethane system that combines a lightweight, flexible foam core encased in a thick outer 'skin' that is created in one single molding process. One process in one mold can translate into faster production times, lower labor costs, and improved productivity.

Molded

The foam is heated in an oven and then placed in a matched tool, which is mounted in a molding press. The mold is then closed using hydraulic pressure. This pressure forces the heated, and now pliable, material into contact with all of the mold surfaces while the pressure is maintained. Once the material has cooled, the mold is opened and the finished part is removed from the tool.

Foams

In general, if it exists in solid form, you can probably foam it. Foams can be made from almost every material, and have a widely diverse range of properties and applications. Foaming reduces weight, often creates flexibility, and can enhance sound absorption, impact absorption, and provide cushioning and thermal insulation.

Rigid and flexible, open and closed cell, as well as skinned foams are possible, and create a myriad of potential uses, with cell size, chemistry, material properties, and material type all representing additional ways in which foams can be engineered to suit the required use.

Future Thoughts

One aspect of foaming that has yet to be tackled effectively has been control of density throughout the part. Because of the way that foams are created, there is a degree of randomness to the molding such that foaming tends to occur in all places in a similar way. Increased material density has been achieved closer to mold walls using temperature control, or through gas assisted injection molding in rigid parts. However, variable density molding that targets specific areas, could achieve greater performance at more specified areas and create lighter weight sections where less strength is needed. We may see some innovations in the processing of foams in this way in the next 5 years, taking foaming to the next level.

Recyclability

Foams can be recycled in the same way that their solid counterparts can. The main challenge has been that their extreme light weight reduces their value; a truck full of expanded polystyrene packaging materials melts down to only about 2 cubic meters of material—hardly enough even to pay for the gas and labor for the truck. So, recyclability is possible for foams, but limited in profitability and, thus, is often a disadvantage for end of life scenarios for this format of material.

Innovative Applications

With the use of foaming to reduce weight and material in thin packaging plastics (MuCell® from Trexel) and the development of algae, nanocellulose, and cotton-based foams, there seems to be no limit to what foams can achieve and which materials can be used. Expect this trend in breakthroughs to continue as foams offer advantages over the solid material in performance, cost, and sustainability.

References

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and Michael F. Ashby

Polymeric Foams
and Foam Technology
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by Daniel Klempner
and Vahid Sendijarevic

Learning Guide

Discussion Questions

What aspect of the report surprised you the most?

What are some characteristics of foams?

What are some of the types of foams that you interact with in your daily life?

What are some materials that can be foamed? Are there materials that can't be foamed?

What types of foams provide the best insulation?

What are some current or potential applications for foams?

How can foams be produced?

Short Answer Questions

What is the difference between and a closed cell and an open cell foam?

Name some rigid and some flexible foams.

What is reticulation?

How can foams be produced?

What types of fire retardants are problematic for foams? Why?

Learning Guide

Long Form Essay

Polyurethane is used widely for various different types of foams. Provide an overview of the different types of applications that PU is used for, and give reasons why the material is particularly suited for these uses.

Team Activity

Design a product that needs impact resistance and absorption.

What type of foam would you want to use?

Compare 3 different types of foams for this application.

How will you produce and shape the foam to your design needs?

Materials Relevant to this Report

Alusion Aluminum Foam
MC 3581-01

The first and best metal foam, the one that started it all. By using additives to the molten aluminum during foaming, the expected collapse of the foam cells is delayed enough to allow the material to solidify in that shape.

Elastomeric Bead Foam
MC 7461-02

Bead foams are the newest solution in cushioning, as illustrated by the Boost soles of select Adidas shoes. Rather than forming from a liquid, the rubbery foam beads are molded together, creating cushioning, but also energy rebound, that is not possible with regular foams.

ECO FOAM
MC 7822-03

Another recycled foam product, this one comes from discarded furniture, car seats, and mattresses, and exhibits good enough performance to be used in shoes for insole comfort.

PORON® Vive® Energy Activated Cushioning
MC 7408-01

A PU open cell foam that has better shock absorption than regular PU and EVA. Designed as a shoe midsole or insert, it exemplifies how well foams adapt to the multifaceted cushioning needs of the human body.

Recycled Yoga Mats
MC 7722-01

Foams can be, and are, recyclable, as evidenced by this product. Recycling is limited in polymer foams, since many are not thermoplastic (PU, neoprene, many rubber foams), so this material illustrates a great development in reducing foam waste.