## Description

### Image

### Caption

1. A sample of shock absorbing foam with a slowly disappearing hand imprint. © Chris Lefteri 2. Flexible foams are used for cushions, mattresses and packaging. © Sumed International UK

### The material

Polymer foams are made by the controlled expansion and solidification of a liquid or melt through a blowing agent; physical, chemical or mechanical blowing agents are possible. The resulting cellular material has a lower density, stiffness and strength than the parent material, by an amount that depends on its relative density - the volume-fraction of solid in the foam. Flexible foams can be soft and compliant, the material of cushions, mattresses, and padded clothing. Most are made from polyurethane, although latex (natural rubber) and most other elastomers

### Composition (summary)

Hydrocarbon

## General properties

| | | | | | |
|---|---|---|---|---|---|
| Density | | 0.999 | - | 2.18 | lb/ft^3 |
| Price | * | 1.18 | - | 1.31 | USD/lb |
| Date first used | | 1947 | | | |

## Mechanical properties

| | | | | | |
|---|---|---|---|---|---|
| Young's modulus | | 3.63e-5 | - | 1.45e-4 | 10^6 psi |
| Shear modulus | | 1.45e-5 | - | 7.25e-5 | 10^6 psi |
| Bulk modulus | | 3.63e-5 | - | 1.45e-4 | 10^6 psi |
| Poisson's ratio | | 0.23 | - | 0.3 | |
| Yield strength (elastic limit) | | 0.00145 | - | 0.0174 | ksi |
| Tensile strength | | 0.0348 | - | 0.123 | ksi |
| Compressive strength | | 0.00145 | - | 0.0174 | ksi |
| Elongation | | 10 | - | 135 | % strain |
| Hardness - Vickers | | 0.001 | - | 0.012 | HV |
| Fatigue strength at 10^7 cycles | * | 0.0218 | - | 0.102 | ksi |

| | | | | |
|---|---|---|---|---|
| Fracture toughness | * 0.00455 | - | 0.0182 | ksi.in^0.5 |
| Mechanical loss coefficient (tan delta) | * 0.1 | - | 0.5 | |

## Thermal properties

| | | | | |
|---|---|---|---|---|
| Melting point | 233 | - | 350 | °F |
| Glass temperature | -172 | - | 8.33 | °F |
| Maximum service temperature | 188 | - | 233 | °F |
| Minimum service temperature | -99.7 | - | -9.67 | °F |
| Thermal conductor or insulator? | Good insulator | | | |
| Thermal conductivity | 0.0208 | - | 0.0277 | BTU.ft/h.ft^2.F |
| Specific heat capacity | 0.418 | - | 0.54 | BTU/lb.°F |
| Thermal expansion coefficient | 66.7 | - | 122 | µstrain/°F |

## Electrical properties

| | | | | |
|---|---|---|---|---|
| Electrical conductor or insulator? | Good insulator | | | |
| Electrical resistivity | 1e20 | - | 1e23 | µohm.cm |
| Dielectric constant (relative permittivity) | 1.1 | - | 1.15 | |
| Dissipation factor (dielectric loss tangent) | 5e-4 | - | 0.003 | |
| Dielectric strength (dielectric breakdown) | 102 | - | 152 | V/mil |

## Optical properties

| | |
|---|---|
| Transparency | Opaque |

## Critical Materials Risk

| | |
|---|---|
| High critical material risk? | No |

## Processability

| | | | | |
|---|---|---|---|---|
| Castability | 3 | - | 5 | |
| Moldability | 1 | - | 4 | |
| Machinability | 3 | - | 4 | |
| Weldability | 1 | | | |

## Durability: water and aqueous solutions

| | |
|---|---|
| Water (fresh) | Excellent |
| Water (salt) | Acceptable |
| Soils, acidic (peat) | Limited use |
| Soils, alkaline (clay) | Acceptable |
| Wine | Excellent |

## Durability: acids

| | |
|---|---|
| Acetic acid (10%) | Acceptable |
| Acetic acid (glacial) | Limited use |

| | |
|---|---|
| Citric acid (10%) | Acceptable |
| Hydrochloric acid (10%) | Limited use |
| Hydrochloric acid (36%) | Limited use |
| Hydrofluoric acid (40%) | Limited use |
| Nitric acid (10%) | Limited use |
| Nitric acid (70%) | Unacceptable |
| Phosphoric acid (10%) | Limited use |
| Phosphoric acid (85%) | Unacceptable |
| Sulfuric acid (10%) | Acceptable |
| Sulfuric acid (70%) | Unacceptable |

## Durability: alkalis

| | |
|---|---|
| Sodium hydroxide (10%) | Limited use |
| Sodium hydroxide (60%) | Limited use |

## Durability: fuels, oils and solvents

| | |
|---|---|
| Amyl acetate | Unacceptable |
| Benzene | Unacceptable |
| Carbon tetrachloride | Unacceptable |
| Chloroform | Unacceptable |
| Crude oil | Limited use |
| Diesel oil | Limited use |
| Lubricating oil | Acceptable |
| Paraffin oil (kerosene) | Excellent |
| Petrol (gasoline) | Acceptable |
| Silicone fluids | Limited use |
| Toluene | Unacceptable |
| Turpentine | Unacceptable |
| Vegetable oils (general) | Excellent |
| White spirit | Unacceptable |

## Durability: alcohols, aldehydes, ketones

| | |
|---|---|
| Acetaldehyde | Unacceptable |
| Acetone | Unacceptable |
| Ethyl alcohol (ethanol) | Unacceptable |
| Ethylene glycol | Limited use |
| Formaldehyde (40%) | Unacceptable |
| Glycerol | Excellent |
| Methyl alcohol (methanol) | Unacceptable |

## Durability: halogens and gases

| | |
|---|---|
| Chlorine gas (dry) | Unacceptable |
| Fluorine (gas) | Unacceptable |
| O2 (oxygen gas) | Unacceptable |
| Sulfur dioxide (gas) | Limited use |

## Durability: built environments

| | |
|---|---|
| Industrial atmosphere | Acceptable |
| Rural atmosphere | Excellent |
| Marine atmosphere | Excellent |
| UV radiation (sunlight) | Poor |

## Durability: flammability

| | |
|---|---|
| Flammability | Highly flammable |

## Durability: thermal environments

| | |
|---|---|
| Tolerance to cryogenic temperatures | Unacceptable |
| Tolerance up to 150 C (302 F) | Acceptable |
| Tolerance up to 250 C (482 F) | Unacceptable |
| Tolerance up to 450 C (842 F) | Unacceptable |
| Tolerance up to 850 C (1562 F) | Unacceptable |
| Tolerance above 850 C (1562 F) | Unacceptable |

## Primary material production: energy, CO2 and water

| | | | | |
|---|---|---|---|---|
| Embodied energy, primary production | * 1.12e4 | - | 1.24e4 | kcal/lb |
| CO2 footprint, primary production | * 4.28 | - | 4.73 | lb/lb |
| Water usage | * 25.9 | - | 28.6 | gal(US)/lb |
| Eco-indicator 95 | 480 | | | millipoints/kg |
| Eco-indicator 99 | 386 | | | millipoints/kg |

## Material processing: energy

| | | | | |
|---|---|---|---|---|
| Polymer extrusion energy | * 584 | - | 644 | kcal/lb |
| Polymer molding energy | * 1.48e3 | - | 1.64e3 | kcal/lb |
| Coarse machining energy (per unit wt removed) | * 52 | - | 57.5 | kcal/lb |
| Fine machining energy (per unit wt removed) | * 57.3 | - | 63.4 | kcal/lb |
| Grinding energy (per unit wt removed) | * 63.2 | - | 69.8 | kcal/lb |

## Material processing: CO2 footprint

| | | | | |
|---|---|---|---|---|
| Polymer extrusion CO2 | * 0.431 | - | 0.476 | lb/lb |
| Polymer molding CO2 | * 1.09 | - | 1.21 | lb/lb |
| Coarse machining CO2 (per unit wt removed) | * 0.036 | - | 0.0398 | lb/lb |
| Fine machining CO2 (per unit wt removed) | * 0.0397 | - | 0.0438 | lb/lb |
| Grinding CO2 (per unit wt removed) | | | | |

| | | | | | |
|---|---|---|---|---|---|
| | * | 0.0437 | - | 0.0483 | lb/lb |

## Material recycling: energy, CO2 and recycle fraction

| | | | | | |
|---|---|---|---|---|---|
| Recycle | ✗ | | | | |
| Embodied energy, recycling | * | 5.1e3 | - | 5.63e3 | kcal/lb |
| CO2 footprint, recycling | * | 3.7 | - | 4.09 | lb/lb |
| Recycle fraction in current supply | | 8.02 | - | 8.86 | % |
| Downcycle | ✓ | | | | |
| Combust for energy recovery | ✓ | | | | |
| Heat of combustion (net) | * | 4.76e3 | - | 5e3 | kcal/lb |
| Combustion CO2 | * | 3.06 | - | 3.22 | lb/lb |
| Landfill | ✓ | | | | |
| Biodegrade | ✗ | | | | |
| Toxicity rating | | Non-toxic | | | |
| A renewable resource? | ✗ | | | | |

**Environmental notes**

Foaming of insulation with CFCs has a damaging effect on the ozone layer - it is now abandoned. Monomers and foaming agents pose hazards; good practice overcomes these. For cushioning, the requirements are comfort and long life; polyurethane foams have been commonly used, but concerns about flammability and durability limit their use in furniture.

## Supporting information

**Design guidelines**

Flexible foams have characteristics that suit them for cushioning and packaging of delicate objects. They are shaped by injecting or pouring a mix of polymer, catalyst and foaming agent into a mold where the agent evolves gas, expanding the foam. Expanding in a cold mold gives a solid surface skin. Closed cell foams float in water; open cell foams absorb liquids and act as sponges.

**Technical notes**

The properties of foams depend, most directly, on the material of which they are made and on the relative density (the fraction of the foam that is solid). Most commercial foams have a relative density between 1% and 30%. To a lesser extent, the properties depend on the size and the shape of the cells. Low density, closed cell, foams have exceptional low thermal conductivity. Skinned rigid foams have good bending stiffness and strength of low weight.

**Typical uses**

Packaging, buoyancy, cushioning, sleeping mats, soft furnishings, artificial skin, sponges, carriers for inks and dyes.

## Links

Reference

ProcessUniverse

Producers