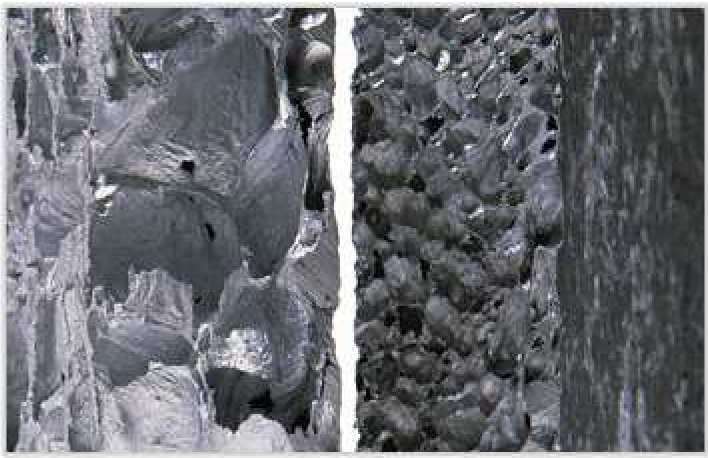
Description

Image



Caption

1. Close-up of the material. © Chris Lefteri 2. Samples of foamed aluminum with various facing materials. © Chris Lefteri

The material

Metal foams are a new class of material, as yet imperfectly characterized but with alluring properties. They are light and stiff; they have good energy-absorbing characteristics (making them good for crash protection and packaging) and attractive heat-transfer properties (used to cool electronic equipment and as heat-exchangers in engines. Some have open cells, very much like polymer foams but with metallic characteristics (ductility, electrical conductivity, weldability and so forth). Others have closed cells, like "metallic cork". They are visually appealing, suggesting their use in architecture and interior design. At this point in time there are some 12 suppliers marketing a range of metal foams, mostly based aluminum, but other metals - copper, nickel, stainless steel and titanium - can be foamed. The data listed here are for a typical aluminum-based foam.

Composition (summary)

Most are based on Al with additions of Ca, SiC or

General properties

Density		15	-	30	lb/ft^3
Price	*	5.2	-	5.72	USD/lb
Date first used		1956			

Mechanical properties

Young's modulus		0.0653	-	0.174	10^6 psi
Shear modulus	*	0.029	-	0.087	10^6 psi
Bulk modulus	*	0.0653	-	0.174	10^6 psi
Poisson's ratio	*	0.28	-	0.3	
Yield strength (elastic limit)		0.102	-	0.29	ksi
Tensile strength		0.102	-	0.363	ksi
Compressive strength		0.123	-	0.725	ksi
Elongation		1	-	4	% strain

Hardness - Vickers		0.045	-	0.12	HV
Fatigue strength at 10^7 cycles	*	0.029	-	0.087	ksi
Fracture toughness		0.546	-	1.09	ksi.in^0.5
Mechanical loss coefficient (tan delta)	*	0.005	-	0.04	

Thermal properties

Melting point		1.02e3	-	1.14e3	°F
Maximum service temperature	*	284	-	374	°F
Minimum service temperature		-459			°F
Thermal conductor or insulator?		Poor conductor			
Thermal conductivity		2.2	-	4.04	BTU.ft/h.ft^2.F
Specific heat capacity		0.217	-	0.229	BTU/lb.°F
Thermal expansion coefficient		10.6	-	11.7	µstrain/°F

Electrical properties

Electrical conductor or insulator?		Good conductor			
Electrical resistivity	*	34	-	89	µohm.cm

Optical properties

Transparency	Opaque

Critical Materials Risk

High critical material risk?	No

Processability

Castability	2	-	3
Machinability	3	-	4
Weldability	2	-	3
Solder/brazability	1	-	2

Durability: water and aqueous solutions

Water (fresh)	Excellent
Water (salt)	Acceptable
Soils, acidic (peat)	Unacceptable
Soils, alkaline (clay)	Excellent
Wine	Excellent

Durability: acids

Acetic acid (10%)	Limited use
Acetic acid (glacial)	Unacceptable
Citric acid (10%)	Acceptable
Hydrochloric acid (10%)	Acceptable

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

Durability: alkalis

Sodium hydroxide (10%)	Unacceptable
Sodium hydroxide (60%)	Unacceptable

Durability: fuels, oils and solvents

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

Durability: alcohols, aldehydes, ketones

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

Durability: halogens and gases

Chlorine gas (dry)	Limited use
Fluorine (gas)	Acceptable

O2 (oxygen gas)	Acceptable
Sulfur dioxide (gas)	Acceptable

Durability: built environments

Industrial atmosphere	Acceptable
Rural atmosphere	Excellent
Marine atmosphere	Excellent
UV radiation (sunlight)	Excellent

Durability: flammability

Flammability	Non-flammable

Durability: thermal environments

Tolerance to cryogenic temperatures	Excellent
Tolerance up to 150 C (302 F)	Excellent
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

Geo-economic data for principal component

Annual world production, principal component	3.63e7	ton/yr
Reserves, principal component	4.91e7	l. ton

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 3.78e4	-	4.17e4	kcal/lb
CO2 footprint, primary production	* 20.8	-	23	lb/lb
Water usage	* 15	-	44.9	gal(US)/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 2.77e3	-	3.07e3	kcal/lb
CO2 footprint, recycling	* 1.71	-	1.89	lb/lb
Recycle fraction in current supply	0.1			%
Downcycle	✓			
Combust for energy recovery	✗			
Landfill	✓			
Biodegrade	✗			
Toxicity rating	Non-toxic			
A renewable resource?	✗			

Environmental notes

Metal foams are non-flammable (unlike those made of polymers) and can, in principle, be recycled.

Supporting information

Design guidelines

Metal foams can be machined, and some can be cast to shape but at present this is a specialized process. They are best joined with adhesives, which give a strong bond. Some foams have a natural surface skin with an attractive texture, but this is lost if the foam is cut. Their most striking characteristics are their low densities, good stiffness and ability to absorb energy when crushed.

Technical notes

Metal foams are made by casting methods that entrap gas in the semi-liquid metal, or by replication techniques using a polymer foam as a precursor. Once cast they are as chemically stable as the metal from which they were made, have the same melting point and specific heat, but much lower density.

Typical uses

Metal foams have promise as stiffeners to inhibit buckling in light shell structures, as energy absorbing units, both internal and external, in motor vehicles and trains, and as cores for light, stiff sandwich panels. Open cell foams have a large exposed surface area that enables their use as heat exchangers for power electronics. Industrial designers have seen potential in exploiting the reflectivity and light-filtering properties of open cell foams, and the interesting surface textures of those with closed cells.

Tradenames

Duocell, Alporas

Links

Reference

ProcessUniverse

Producers