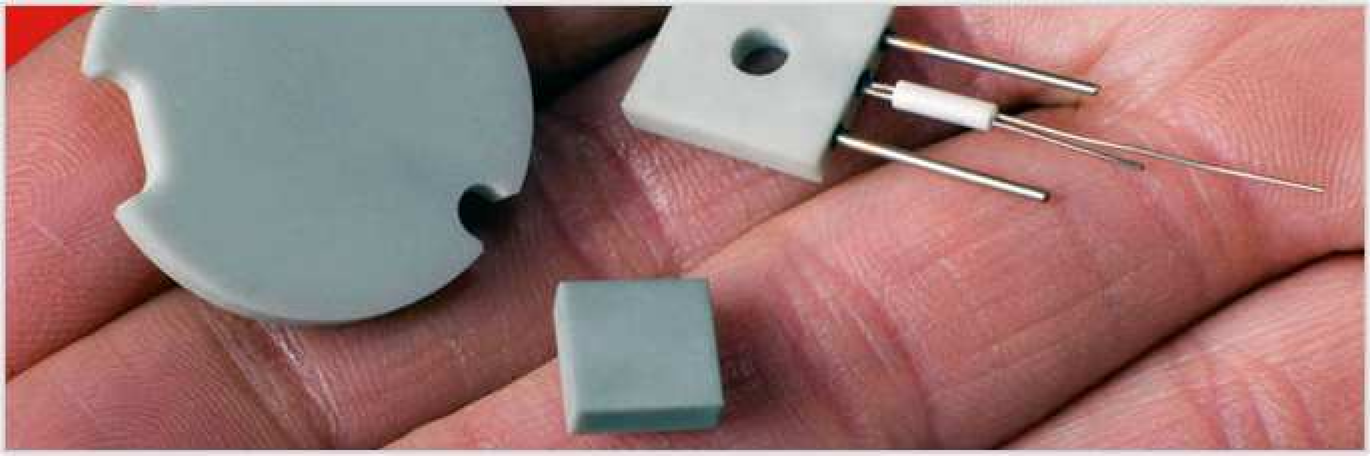
Description

Image



Caption

Aluminum nitride components. © Used with permission from Watlow Electric Manufacturing Company, 2013

The material

Aluminum nitride, (AlN) has an unusual combination of properties: it is an electrical insulator, but an excellent conductor of heat. This is just what is wanted for substrates for high-powered electronics; the substrate must insulate yet conduct the heat out of the microchips. This, and its high strength, chemical stability and low expansion give it a special role as a heat sinks for power electronics. It is transparent to microwaves and RF frequencies, and thus makes good microwave windows.

Composition (summary)

AlN

General properties

Density		3.26e3	-	3.33e3	kg/m^3
Price	*	104	-	166	USD/kg
Date first used		1984			

Mechanical properties

Young's modulus		302	-	348	GPa
Shear modulus		126	-	139	GPa
Bulk modulus	*	200	-	232	GPa
Poisson's ratio		0.23	-	0.26	
Yield strength (elastic limit)	*	300	-	350	MPa
Tensile strength	*	300	-	350	MPa
Compressive strength		1.97e3	-	2.5e3	MPa
Elongation		0			% strain
Hardness - Vickers		990	-	1.26e3	HV
Fatigue strength at 10^7 cycles	*	168	-	248	MPa
Fracture toughness		2.5	-	3.4	MPa.m^0.5

Mechanical loss coefficient (tan delta)	* 1e-5	-	3e-5	

Thermal properties

Melting point	2.4e3	-	2.51e3	°C
Maximum service temperature	* 1.03e3	-	1.73e3	°C
Minimum service temperature	-273			°C
Thermal conductor or insulator?	Good conductor			
Thermal conductivity	140	-	200	W/m.°C
Specific heat capacity	780	-	820	J/kg.°C
Thermal expansion coefficient	4.9	-	5.5	µstrain/°C

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	1e19	-	1e21	µohm.cm
Dielectric constant (relative permittivity)	8.3	-	9.3	
Dissipation factor (dielectric loss tangent)	5e-4	-	9.2e-4	
Dielectric strength (dielectric breakdown)	17	-	20	1000000 V/m

Optical properties

Transparency	Opaque

Critical Materials Risk

High critical material risk?	No

Processability

Moldability	2	-	3
Machinability	1	-	2

Durability: water and aqueous solutions

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

Durability: acids

Acetic acid (10%)	Excellent
Acetic acid (glacial)	Excellent
Citric acid (10%)	Excellent
Hydrochloric acid (10%)	Excellent
Hydrochloric acid (36%)	Excellent
Hydrofluoric acid (40%)	Limited use

Nitric acid (10%)	Excellent
Nitric acid (70%)	Excellent
Phosphoric acid (10%)	Excellent
Phosphoric acid (85%)	Excellent
Sulfuric acid (10%)	Excellent
Sulfuric acid (70%)	Excellent

Durability: alkalis

Sodium hydroxide (10%)	Excellent
Sodium hydroxide (60%)	Excellent

Durability: fuels, oils and solvents

Amyl acetate	Excellent
Benzene	Excellent
Carbon tetrachloride	Excellent
Chloroform	Excellent
Crude oil	Excellent
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)	Excellent
Ethylene glycol	Excellent
Formaldehyde (40%)	Excellent
Glycerol	Excellent
Methyl alcohol (methanol)	Excellent

Durability: halogens and gases

Chlorine gas (dry)	Excellent
Fluorine (gas)	Acceptable
O2 (oxygen gas)	Excellent
Sulfur dioxide (gas)	Excellent

Durability: built environments

Industrial atmosphere	Excellent
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)	Excellent
Tolerance up to 450 C (842 F)	Excellent
Tolerance up to 850 C (1562 F)	Excellent
Tolerance above 850 C (1562 F)	Excellent

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 221	-	244	MJ/kg
CO2 footprint, primary production	* 11.9	-	13.2	kg/kg
Water usage	* 232	-	256	l/kg

Material processing: energy

Grinding energy (per unit wt removed)	* 133	-	147	MJ/kg

Material processing: CO2 footprint

Grinding CO2 (per unit wt removed)	* 9.95	-	11	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle	✖			
Recycle fraction in current supply	0.5	-	1	%
Downcycle	✔			
Combust for energy recovery	✖			
Landfill	✔			
Biodegrade	✖			
Toxicity rating	Non-toxic			
A renewable resource?	✖			

Environmental notes

Technical ceramics that are used in the pure state, as AlN usually is, are very energy

Supporting information

Design guidelines

Aluminum nitride is particularly unusual for its high thermal conductivity (among ceramics only beryllia, BeO, and diamond have higher values) combined with a high electrical resistance, low dielectric constant, good corrosion and thermal shock resistance. It is resistant to attack by molten metals, but is hydrolyzed slowly by water. Technical ceramics are formed by the following steps.(a) Pressing, isostatic pressing, powder extrusion (for bars and tubes) or powder injection molding (for intricate, high-volume parts).(b) Green-machining in the unfired state, using standard tools.(c) Firing or "sintering" typically at 1550 - 1700 C for 12 to 20 hours; the part shrinks by about 20%.(d) Diamond grinding to achieve tighter tolerance and surface finish: +/- 10 microns is achievable. The cost of a ceramic part is greatly increased if it has to be diamond-ground. Thus design for net-shape sintering, eliminating step (d) is highly desirable. The standard tolerance for as-fired dimensions is +/- 1% or 125 microns, whichever is greater.

Technical notes

Aluminum nitride is difficult to sinter when pure. To allow sintering between 1600 and 1900 C, additions of CaO or Y2O3 are made.

Typical uses

Microwave windows, insulators for specialty spark plugs and igniters, substrates and packaging for microcircuits, chip carriers, heat sinks, electronic and semiconductor components, windows, heaters, clamp rings, gas distribution plates.

Links

Reference

ProcessUniverse

Producers