



ETREMA PRODUCTS INC.
Subsidiary of Edge Technologies, Inc.

DATA SHEET

Terfenol-D

For many actuator and transducer applications the advanced Smart Material, ETREMA TERFENOL-D® enables increased capability in a smaller package. TERFENOL-D is a near single crystal metal alloy, which converts electrical power to mechanical power, and vice versa. TERFENOL-D is said to be a Smart Material because of its ability to adapt to outside influences. With higher energy density, long life, and electric drive advantages, TERFENOL-D is replacing older actuators and actuation technologies. Etrema is the world's leading supplier of TERFENOL-D materials, and also provides transducer or actuator design and manufacturing services for TERFENOL-D driven products.

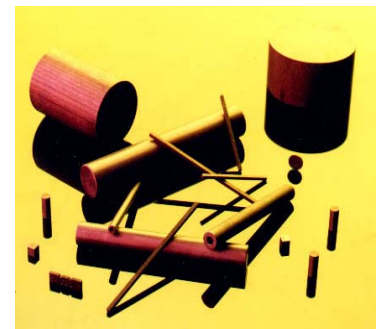
SMART MATERIAL

Smart materials have significant uses in commercial products as well as military applications. Overall, world-wide sales of smart materials exceed \$1 Billion annually, with electrostrictive technology accounting for 75% of the market, magnetostrictive and shape memory materials each capture a 10% share and rheological fluids the remaining 5%. The share held by TERFENOL-D is growing rapidly.

The name TERFENOL-D comes from the metallic elements; terbium (TER), iron (FE), Naval Ordnance Labs (NOL), and Dysprosium-D. NOL developed and named the material, and is now known as Naval Surface Warfare Center (NSWC). The Navy developed TERFENOL-D for higher power sonar that would also have greater bandwidth and greater reliability. Etrema holds patents and licenses to many TERFENOL-D applications, including several key patents on the material and the methods of manufacture of TERFENOL-D .

TERFENOL-D ATTRIBUTES

- **HIGH STRAIN**
- **HIGH FORCE**
- **WIDE BANDWIDTH**
- **HIGH RELIABILITY/UNLIMITED CYCLE LIFE**
- **WIDE TEMPERATURE RANGE**
- **MICROSECOND RESPONSE TIME**



Etrema provides TERFENOL-D ready-to-use, lowering the effective cost to manufacturers. Etrema's patented crystal growing machines produce solid metallic rods. Other shapes are produced by Etrema's machining processes. Contact Etrema for a quotation on the quantity and configuration needed. Or, work with us to optimize performance and cost for any application.

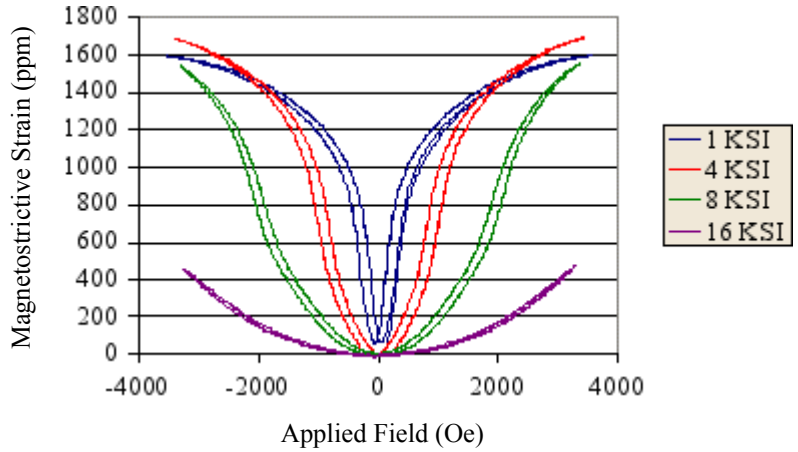
TERFENOL-D is "magnetostrictive," meaning it changes shape in a magnetic field. TERFENOL-D has a greater shape change, or strain, than other common transducer materials, such as piezoceramics or nickel alloys. This means acoustic devices driven by TERFENOL-D have greater power, and actuators have more displacement and more force. Like other magnetostrictive alloys, TERFENOL-D does not change with time or number of cycles.

What is Magnetostriction?

Magnetostriction is the property that causes certain ferromagnetic materials to change shape in a magnetic field. TERFENOL-D is said to produce "giant" magnetostriction, strain greater than any other commercially available smart material. Magnetic domains in the crystal rotate when a magnetic field is applied, providing proportional, positive and repeatable expansion in microseconds.



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TERFENOL-D versus field at various preloads

TERFENOL-D PHYSICAL PROPERTIES

Nominal Composition Tb_{0.3}Dy_{0.7}Fe_{1.92}

Mechanical Properties

Young's Modulus 25-35 GPa
 Sound Speed 1640-1940 m/s
 Tensile Strength 28 Mpa
 Compressive Strength 700 Mpa

Thermal Properties

Coefficient of Thermal Expansion 12ppm/°C
 Specific Heat 0.35kJ/kg-K
 Thermal Conductivity 13.5 W/m-k

Electrical Properties

Resistivity 58 x 10⁻⁸ Ω-m
 Curie Temperature 380 °C

Magnetostrictive Properties

Strain (estimated linear) 800-1200ppm
 Energy Density 14-25 kJ/ m³

Magnetomechanical Properties

Relative Permeability 3-10
 Coupling Factor 0.75