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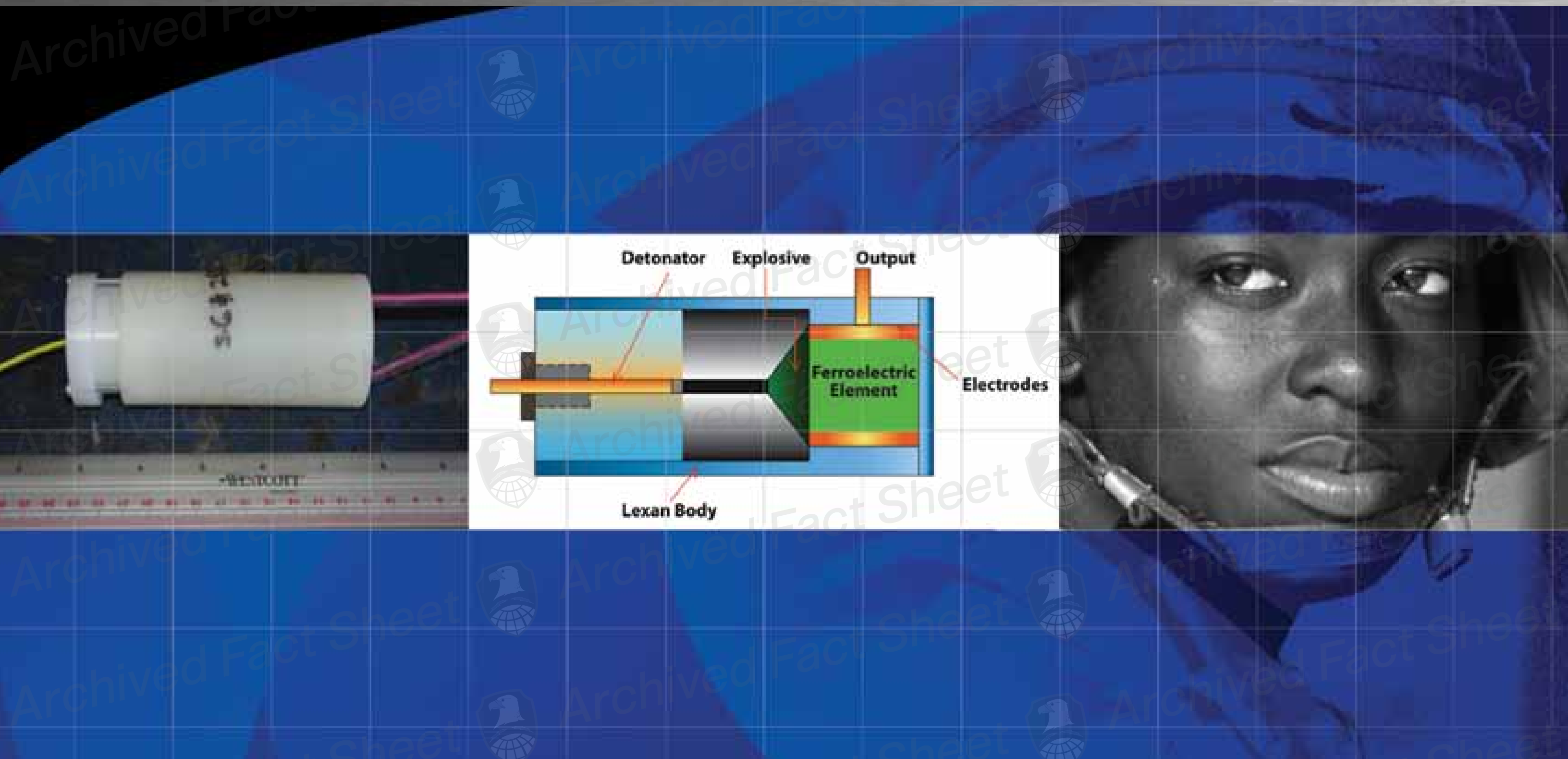
High Energy Density Ferroelectric Ceramics for Explosive Pulsed Power Applications



Summary

- High energy density
- Two to three times higher voltage than conventional piezoelectric material
- Enabling technology for compact explosive pulsed power (EPP) devices
- Wide range of shapes and sizes are available
- System specific component design

New Ferroelectric Generator Ceramics are an enabling technology for explosive pulsed power devices.

Ferroelectric generators are single-shot, high-voltage power supplies that are an integral part of current and future pulsed-power devices. Commercially available piezoelectrics have been used to demonstrate their potential; however, new higher energy-density materials were required to enable compact systems. New materials have been developed to meet this need. The production process has been successfully increased from lab-scale to pilot-scale levels. Open-circuit energy densities of more than 2 J/cc and voltage levels of more than 100 kV have been demonstrated, as well as two to three times the power output compared to typical piezoelectric materials.

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Overview

New energy storage ceramics are being developed for explosively-driven power supplies. These power supplies use explosively-driven shock waves to release the electrical energy stored within the ceramics. One such ceramic is PZT 95/5. It is being incorporated into a new class of electromagnetic pulse (EMP) weapons designed to disrupt or destroy electronic circuits and components. This new material provides two to three times more power output than state-of-the-art materials by using advanced processing methods to fabricate high density ferroelectric ceramics with significantly increased energy storage capabilities. This results in devices that are small enough to be man-portable yet powerful enough to disrupt electronics across significant ranges. Our materials are enabling EMP weapons to move from laboratory to battlefield. The weapons enabled by this technology will save Soldiers' lives by allowing them to remotely defeat electronics in a less-than-lethal-manner with limited collateral damage.

Benefits for Tomorrow's Defense

Ferroelectric generators will provide the Army with a new class of munitions with either enhanced lethality or less-than-lethal capability. This technology is adaptable for use in a variety of munitions. By modifying the source of power and/or power conditioning circuits, the ferroelectric generator can be used to drive a variety of loads such as high-power microwave and ultra wideband sources for defeating electronics, lasers for blinding sensors, and transmitters for doing bomb damage assessment and for burst communications.

Technical Concept

In the 1960s, a new PZT formulation was developed as a pulsed power generator material for nuclear weapons. This formulation became known as PZT 95/5 (i.e. $Pb(Zr_{0.95}Ti_{0.05})O_3$). This formulation was designed to lie very close to a phase boundary between an electrically polarizable ferroelectric phase and non-polarizable antiferroelectric phase. When a shock wave travels through a polarized PZT 95/5 ceramic, the compressive pressure causes the material to convert to the antiferroelectric phase resulting in almost instantaneous, complete depolarization.

Conventional weapon designers have generally tended toward commercially available Navy Type-I piezoelectric ceramics for use in FEGs. These materials are usually designed to lie on another phase boundary (known as the morphotropic phase boundary) between rhombohedral and tetragonal ferroelectric phases. This boundary enhances piezoelectric properties; however, unlike PZT 95/5, commercial piezoelectrics do not undergo a shock-induced phase transition that causes complete depolarization (at least not at pressures achievable with a small amount of explosive). In addition, the energy density of such materials will generally be lower than PZT 95/5. Consequently, these materials cannot be used to demonstrate pulsed-power and RF weapons concepts; they do not deliver enough energy to field compact devices.

Typical Properties

This table includes some selected physical and electrical data for PZT 95/5.

Property:	Unit:	Value:
Density	g/cm3	7.75
Polarization	µC/cm2	33-38
Dielectric constant	-	300
Dielectric loss	-	0.02
Max. electric field (open circuit)	kV/cm	55 - 65
Energy density (open circuit)	J/cm3	1.5 - 2.5
Piezo. coefficient, d33	pC/N	68
Piezo. coefficient, g33	Vm/N	26.3x10-3
Elastic constant, s11E	m2/N	7.68x10-12
Elastic constant, c11E	N/m2	130x109
Velocity of sound	m/s	4200

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