

Zirconium Doped Ceria Electroceramic with a High Electrostriction Coefficient

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Overview

Electrostrictive materials can generate large movement under voltage, making them attractive for numerous applications. However, only one electrostrictive material with a large electrostriction coefficient is currently available for commercial use: PMN-PT ($\text{Pb}(\text{Mg}_{1/3}\text{Nb}_{2/3})\text{O}_3 \cdot \text{PbTiO}_3$). Although the composition required to achieve a high electrostriction coefficient in PMN-PT is known, it is difficult to manufacture, resulting in very limited distribution. PMN-PT has several disadvantages including: (1) it is lead-based and is not biocompatible, and (2) it is not compatible with Si microfabrication processes (CMOS) despite its potential use in microelectromechanical systems (MEMS). Researchers from the Weizmann institute have identified the composition of dopants in ceria (CeO_2) that increase the electrostriction coefficient to values that rival those of PMN-PT. Doped ceria is much easier to produce, contains no lead, and is compatible with Si microfabrication, making it an attractive alternative to PMN-PT

The Need

Electrostrictors are applicable in every device where voltage-controlled movement is required. Currently, the only commercially available electrostrictive material is PMN-PT. Unfortunately, despite the high demand for such materials, its production is a closely guarded US-Military secret. Hence its distribution is highly limited.

The Solution

Doping ceria with Zr can increase the electrostriction coefficient to $10^{-16} \text{ m}^2/\text{V}^2$, the same as PMN-PT. Doped ceria is much easier to produce compared to PMN-PT.

Technology Essence

Doped ceria is very easy to produce and achieves a very high electrostriction coefficient. It has superior mechanical and electrical properties to PMN-PT. Importantly, doped ceria can be used in Si microfabrication processes, making it significantly advantageous.

Applications and Advantages

Suggested Applications

- Radar\Sonar. Electrostrictors are very advantageous for these applications as there is no converse effect as in piezoelectrics
- MEMS: acoustic wave generators, switches, RF filters, actuators
- Lab-on-a-chip: pumps, density separators

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Advantages

- Compatible with semiconductor fabrication technologies
- Lead (Pb) free: making it environmentally friendly and biocompatible. Zr-Ce oxides are approved by the FDA for dental implants
- High operational temperature ($> 200^{\circ}\text{C}$, up to 800°C). PMT-PT degrades at high operating temperatures
- Chemical robustness. Inert (does not decompose) in aqueous mediums in a wide pH range, stable in atmospheric conditions, high pressures, and vacuum
- Mechanical robustness. Higher Young's modulus (200-300 GPa) compared to PZT and PMN-PT (~ 100 GPa), meaning they can produce more work for the same strain and be farther from the yield (breaking) point
- Electrical robustness. Zr doped ceria have higher breakdown voltages (~ 100 kV/mm) as compared to PMN (17 kV/mm)
- Unlike piezoelectricity, electrostriction deforms under voltage, but not vice-versa, making it a highly sought-after material in radars/sonars

Development Status

This project has proof of concept as a bulk material: pellets (~ 10 mm diameter, 1 mm thickness) that can produce very high strains under an electric field. A reliable electrode needs to be developed for commercial bulk use. A thin film adaptation is under development.

Patent Status

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