Master's research or engineering internship

Synthesis and characterization of high-entropy relaxor ceramics for electrical energy storage

Keywords

Ceramics, relaxor ferroelectrics, high-entropy, energy storage.

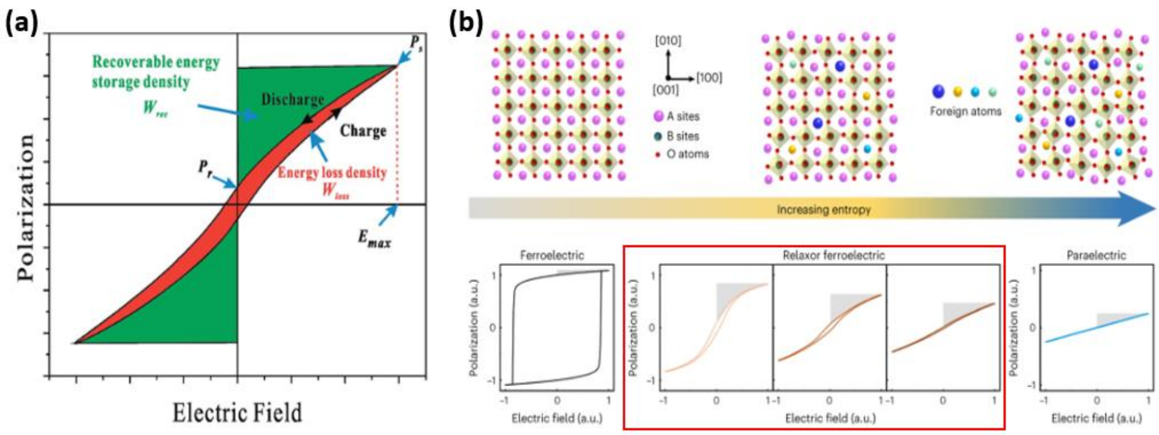
Abstract

Dielectric capacitors with high energy density and efficiency are critical for the development of pulsed power electronic devices and advanced energy storage systems. The electrostatic energy storage density of a dielectric capacitor is directly related to its electric polarization under an electric field and its dielectric breakdown strength (E_b). It can be calculated using the following formula (Fig. 1a) :

$$W_{rec} = \int_{P_r}^{P_{max}} E\, dP$$

A high maximum polarization (P_{max}), a low remanent polarization (P_r), and a high applied electric field (E_{max}) are crucial for achieving high recoverable energy storage density (W_{rec}) and high energy efficiency[1-3]. Due to the large remanent polarization (P_r) in ferroelectrics, the low maximum polarization (P_{max}) in linear dielectrics, and the significant hysteresis in antiferroelectrics, achieving optimal energy storage density and efficiency remains challenging. To optimize energy storage performance, polar nanoregions (PNRs) with a rapid polarization response to an applied electric field are typically engineered in relaxor ferroelectric materials. This results in slim P-E hysteresis loops with a high P_{max} and low P_r[4].

The project aims to stabilize a single-phase structure in lead-free relaxor ceramics based on $Ba_{0.5}Na_{0.5}TiO_3$ with a perovskite ABO_3 structure. This will be achieved through the high-entropy approach[5], which induces high local disorder and significant lattice distortion. This approach is a promising and flexible strategy for developing high-performance relaxor ferroelectrics over a wide temperature range, suitable for capacitors with high energy density and efficiency (Fig. 1b).



Nat. Energy. 8 (2023) 956-964

Fig.1 : Schematic diagram : (a) recoverable energy density W_{rec} (green zone) ; (b) concept of high-entropy relaxors for energy storage.

GREMAN UMR 7347, Bât. E, Parc de Grandmont, 37200 Tours, France
Tel +33 (0)2 47 36 70 88 / www.greman.univ-tours.fr

During this internship, the main planned steps are as follows :

- The solid-state reaction method and the sol-gel process are proposed for the synthesis of high-entropy relaxor phases.
- Shaping and densification of the ceramics by conventional sintering and spark plasma sintering (SPS).
- In situ study of the structure (temperature and electric field) by X-ray diffraction (XRD) and Raman spectroscopy, as well as microstructure analysis by scanning electron microscopy (SEM-EDS) and transmission electron microscopy (TEM), to examine the effect of compositional heterogeneity on structural disorder in high-entropy relaxor ceramics.
- Study of dielectric properties (dielectric constant and dielectric loss) and ferroelectric properties (polarization-electric field) as a function of temperature and frequency, to evaluate energy density and efficiency.

References

[1] Wang *et al*. Electroceramics for high-energy density capacitors : Current status and future perspectives. *Chem. Rev*. 121 (2021) 6124-6172.
[2] Ait Laasri *et al*. Ferroelectric BT-PVDF composite thick films for energy storage. *J. Electron. Mater*. 50 (2021) 1132-1139.
[3] Autret-Lambert *et al*. A core-shell synthesis of CCTO ceramics showing colossal permittivity and low electric for application in capacitors. *Solid State Sci*. 109 (2020) 106431.
[4] Shi *et al*. Tailoring ferroelectric polarization and relaxation of BNT-based lead-free relaxors for superior energy storage properties. *J. Chem . Eng*. 428 (2022) 132612.
[5] Rost *et al*. Entropy-stabilized oxides. *Nat. Commun*. 6 (2015) 8485.

Candidate Profile

This internship is aimed at a Master's 2 research student or an engineering student, who is motivated and curious, with a strong background in chemistry, materials science, and characterization techniques.

Location

The internship will take place at the GREMAN laboratory (UMR CNRS 7347), between the Blois campus (IUT de Blois) and the Grandmont campus in Tours.
http://greman.univ-tours.fr/

Remuneration

As per regulations, approximately 610 € net per month.

Duration

The internship will last for 6 months, starting in February 2025. The project may lead to a 3-year PhD, beginning in the 2025 academic year, subject to funding.

Supervision and Contacts

Please send your CV and cover letter to :
Hicham Ait Laasri, Associate Professor, GREMAN Laboratory, IUT of Blois - University of Tours.
hicham.aitlaasri@univ-tours.fr
Cécile Autret-Lambert, Full Professeur, GREMAN Laboratory, University of Tours.
cecile.autret@univ-tours.fr