NanOx4EStor

Nanoscaled ferroelectric (pseudo)-binary oxide thin film supercapacitors for flexible and ultrafast pulsed power electronics

At a Glance

Funded under: M-ERA.NET3

Overall budget: € 642.822,00

Duration: 4 September 2022 – 3 September 2025

Coordinated by: University of Minho, Portugal

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The Project

The main goal of the **NanOx4EStor** project is to develop innovative and cost effective high-throughput technologies for the fabrication of advanced supercapacitors based on wake-up free (pseudo-)binary oxide thin films, fabricated by physical vapour deposition (PVD) processes, with optimized ferroelectric and energy storage (ES) properties through (i) strain, (ii) interface and (iii) dead-layer engineering.

Consortium

University of Minho (UMinho), Portugal

National Institute of Materials Physics (NIMP), Romania

École Centrale de Lyon (ECL), France

Dissemination

Project website:
https://inl.cnrs.fr/projects/nanox4estor/

LinkedIn Group
https://www.linkedin.com/groups/9260371/

ResearchGate
https://www.researchgate.net/project/Nanoscaled-ferroelectric-pseudo-binary-oxide-thin-film-supercapacitors-for-flexible-and-ultrafast-pulsed-power-electronics

Publications

5. J. P. B. Silva et al., "Roadmap on ferroelectric hafnia- and zirconia-based materials and devices", APL Mater 11, 089201 (2023).

4. A. P. S. Crema, M. C. Istrate, A. Silva, V. Lenzi, L. Domingues, M. O. Hill, V. S. Teodorescu, C. Ghica, M. J. M. Gomes, M. Pereira, L. Marques, J. L. MacManus-Driscoll, J. P. B. Silva, Ferroelectric orthorhombic ZrO_2 thin films achieved through nanosecond laser annealing" Advanced Science 10, 2207390 (2023).

3. A. Silva, I. Fina, F. Sánchez, J. P. B. Silva, L. Marques, V. Lenzi, "Unraveling the ferroelectric switching mechanisms in ferroelectric pure and La doped HfO_2 epitaxial thin films", Materials Today Physics 34, 101064 (2023).

Conference presentations and proceedings

8. Benoît Manchon, Greta Segantini, Pedro Rojo Romeo, Ingrid Canero Infante, Dominique Drouin, Bertrand Vilquin, Damien Deleruyelle. Study of Imprint Dynamics in HZO Ferroelectric Capacitors. Oral presentation at International Symposium on Applications of Ferroelectrics – ISAF 2023, Cleveland, USA (July 2023).

7. Jordan Bouaziz, Greta Segantini, Benoît Manchon, Ingrid Cañero Infante, Nicolas Baboux, Matthieu Bugnet, Pedro Rojo Romeo, D Deleruyelle, Bertrand Vilquin. Elaboration and imprint consideration in HfZrO2 ferroelectric capacitors. Oral presentation at Novel High-k Application Workshop 2023 in Dresden, Germany (May 2023).

6. A. Silva, I. Fina, F. Sánchez, J. P. B. Silva, L. Marques, V. Lenzi, Promising routes for achieving low coercive field in HfO_2 thin films. Oral presentation at Novel High-k Application Workshop 2023 in Dresden, Germany (May 2023).

5. J. P. B. Silva, V. Lenzi, C. M. Istrate, C. Ghica, B. Šmíd, V. Matolín, L. S. Marques, J. L. MacManus-Driscoll, Ferroelectricity in epitaxial ZrO2 thin films, Oral presentation at COST action OPERA Workshop "Fundamental research – New Materials", Madrid, Spain (April 2023).

4. Jordan Bouaziz, Greta Segantini, Benoît Manchon, Rabei Barhoumi, Ingrid Cañero Infante, Damien Deleruyelle, Nicolas Baboux, Pedro Rojo Romeo, Bertrand Vilquin. Engineering the nano and micro structures of sputtered HfZrO2 thin films. Oral presentation at 15th International Meeting on Ferroelectricity-IMF 2023, Tel-Aviv, Israel (March 2023).

Roadmap on ferroelectric hafnia- and zirconia-based materials and devices

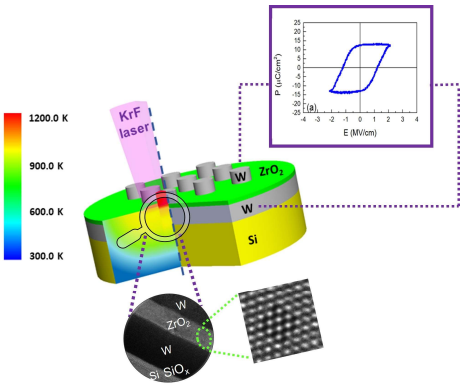
J. P. B. Silva and B. Vilquin, from UMinho and ECL partners, are co-authors of the roadmap on ferroelectric hafnia- and zirconia-based materials and devices. J. P. B. Silva and B. Vilquin wrote the energy storage and sputtering sections, respectively.

ABSTRACT

Ferroelectric hafnium and zirconium oxides have undergone rapid scientific development over the last decade, pushing them to the forefront of ultralow-power electronic systems. Maximizing the potential application in memory devices or supercapacitors of these materials requires a combined effort by the scientific community to address technical limitations, which still hinder their application. Besides their favorable intrinsic material properties, HfO_2–ZrO_2 materials face challenges regarding their endurance, retention, wake-up effect, and high switching voltages. In this Roadmap, we intend to combine the expertise of chemistry, physics, material, and device engineers from leading experts in the ferroelectrics research community to set the direction of travel for these binary ferroelectric oxides. Here, we present a comprehensive overview of the current state of the art and offer readers an informed perspective of where this field is heading, what challenges need to be addressed, and possible applications and prospects for further development.

Ferroelectric orthorhombic ZrO_2 thin films achieved through nanosecond laser annealing

A new approach for the stabilization of the ferroelectric orthorhombic ZrO_2 films is demonstrated in the recent work of NanOx4EStor partners UMinho and NIMP through nanosecond laser annealing (NLA) of as-deposited $Si/SiO_x/W(14\ nm)/ZrO_2(8\ nm)/W(22\ nm)$, grown by ion beam sputtering. The NLA process optimization is guided by COMSOL multiphysics simulations. Macroscopic polarization-electric field hysteresis loops show ferroelectric behavior, with saturation polarization of 12.8 μC cm^{-2}, remnant polarization of 12.7 μC cm^{-2} and coercive field of 1.2 MV cm^{-1}. The work benefited also from the contribution of the group lead by Judith L. MacManus-Driscoll at the University of Cambridge in the UK, who is also member in the project Advisory Board.



Ferroelectric switching mechanisms in ferroelectric pure and La doped HfO_2 epitaxial thin films

Epitaxial orthorhombic phase La doped HfO_2 films are promising for achieving robust ferroelectric polarization without wake-up effect. However, lowering the coercive field is crucial for achieving low-power memory devices. Density functional theory (DFT) calculations done by the UMinho partner, combined with experimental results, demonstrated that the polarization switching in epitaxial La:HfO_2 films can be understood based on the synergetic contribution of the presence of a non-ferroelectric monoclinic phase and the La doping itself that causes a reduction of the nucleation and DW motion energy barriers for the crossing path, which makes it more probable than the non-crossing one.