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Challenges in the synthesis & optical characterization of 2D ferroelectric $\text{Ba}_{0.85}\text{Ca}_{0.15}\text{Ti}_{0.9}\text{Zr}_{0.1}\text{O}_3$ by RF sputtering



Yusuf K. Bostan¹, Florian Jean², Denis Remiens¹, Jing Hua TENG³, El Hadj Dogheche¹

¹Institut d'Electronique, Microelectronique & Nanotechnologie IEMN CNRS UMR 8520, Université Polytechnique Hauts de France, 59313 Valenciennes,

²Univ. Polytechnique Hauts-de-France, EA 2443 - LMCPA - Laboratoire des Matériaux Céramiques et Procédés Associés, F-59313, Valenciennes, France

³Institute of Materials Research and Engineering, Agency for Science, Technology and Research (A*STAR), 2 Fusionopolis Way, Innovis, Singapore, 138634, Singapore



ABSTRACT

Ferroelectric materials, such as BaTiO_3 and $(\text{Ba,Ca})(\text{Ti,Zr})\text{O}_3$ (BCTZ), are essential in modern technology, thanks to their permanent electrical dipoles and unique properties like piezoelectricity. These lead-free perovskites are especially valuable, offering tunability for advanced applications such as transducers and tunable lenses. Despite their potential, achieving high-quality BCTZ thin films via magnetron RF sputtering remains a significant challenge. Our current study aims to find the optimum deposition parameters for BCTZ thin films by RF sputtering. [1-6]

EXPERIMENT

ADDAX magnetron RF sputtering system was utilized for all depositions. Hand-made quartz tubular furnace was used for post-annealing treatments. Siemens D5000 X-ray diffractometer (XRD) was conducted to examine crystallinity of the films. Thickness of the films was measured via Veeco Dektak 150 profilometer. The prism coupling measurements have been conducted in Metricon 2010/M. New XRD holders were fabricated via Elegoo Saturn-3 12K SLA 3D printer.

BEHIND THE LOGIC & RESULTS

What are the challenges in fabricating highly crystallized sub-micron BCTZ films by sputtering? What is the sputtering process, and what are the two distinct approaches?

1. Depositions with in-situ temperature.
2. Depositions at room temperature followed by post-annealing treatments.

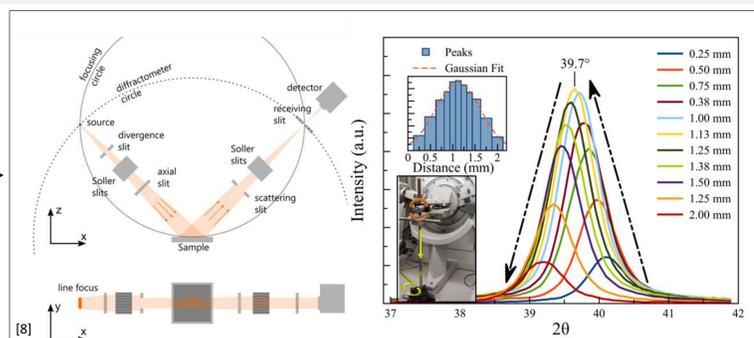
We started with post-annealing method. The main parameters are:

- Deposition position : determined after mapping the distribution,
- Substrates : Si, Sapphire, Si(Pt/Ti), Sapphire(Pt/Ti),
- RF power : 100W and 50W,
- Post-annealing temperature : ranging from 500°C to 800°C.

All samples exhibited weak XRD signals. What was the problem?

Was furnace calibrated well? We re-calibrated it, yet it did not solve our problem. So, was it about XRD? This was the first challenge.

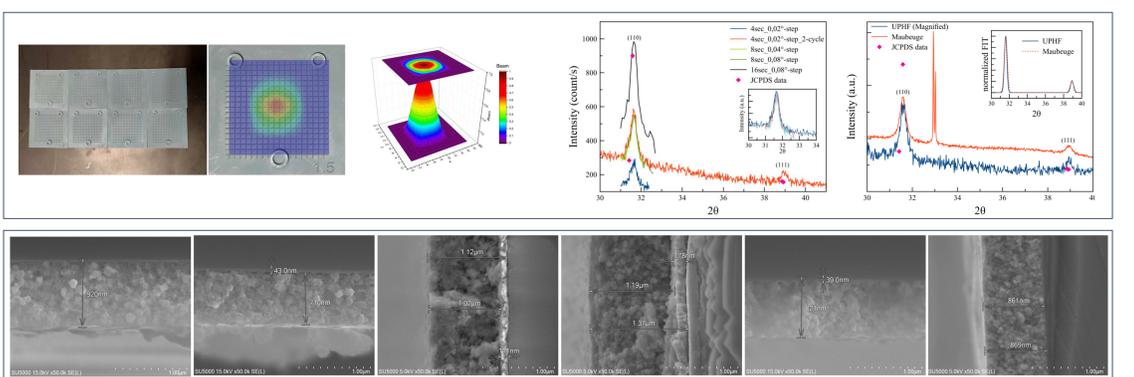
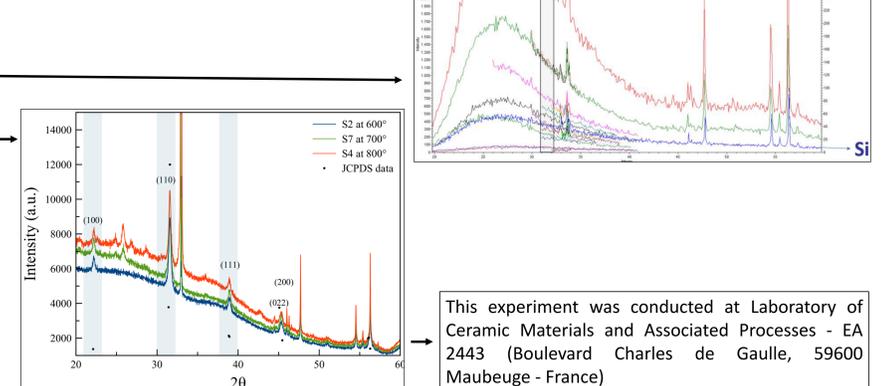
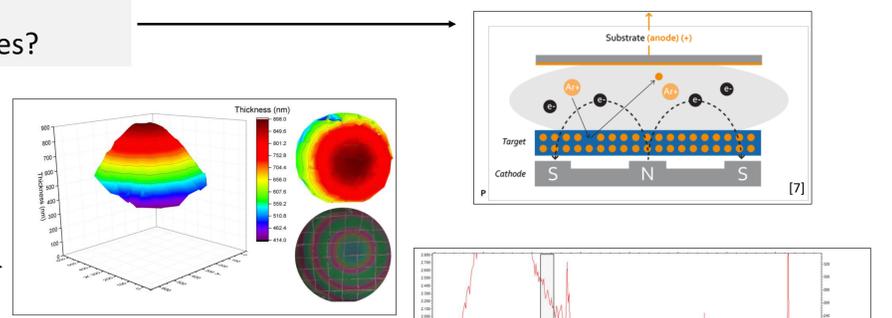
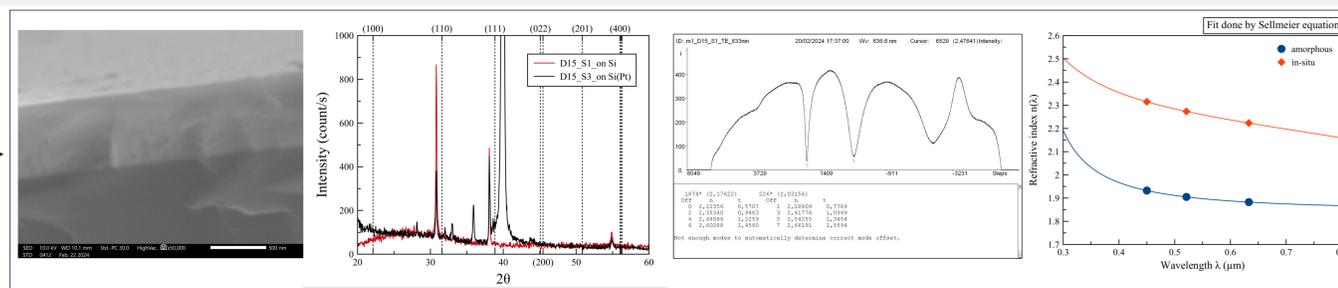
The solution lay in a fundamental understanding of XRD principles.



XRD signals were enhanced with a new holder design and understanding the fundamentals of XRD. Yet, peaks were still weak for all samples. What was the next problem?

Cross-section measurements were conducted to uncover the main reason. It showed that there was porosity in all samples regardless of the power, substrates, post-annealing temperatures or their deposition locations.

Finally, we changed our approach from the room temperature deposition process to in-situ temperature which solved the density problem, increased the XRD signals, enhanced the refractive index and improved the crystal quality. However, the peak is shifted to lower 2θ angle, so this is the new problem that awaits a solution.



This experiment was conducted at Laboratory of Ceramic Materials and Associated Processes - EA 2443 (Boulevard Charles de Gaulle, 59600 Maubeuge - France)

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Contact info:
 Yusuf K. Bostan < yusuf.bostan@uphf.fr >
 El Hadj Dogheche < elhadj.dogheche@uphf.fr >

<https://www.iemn.fr>