LOCAL PIEZOELECTRIC PROPERTIES OF ORIENTED PZT BASED FERROELECTRIC THIN FILMS

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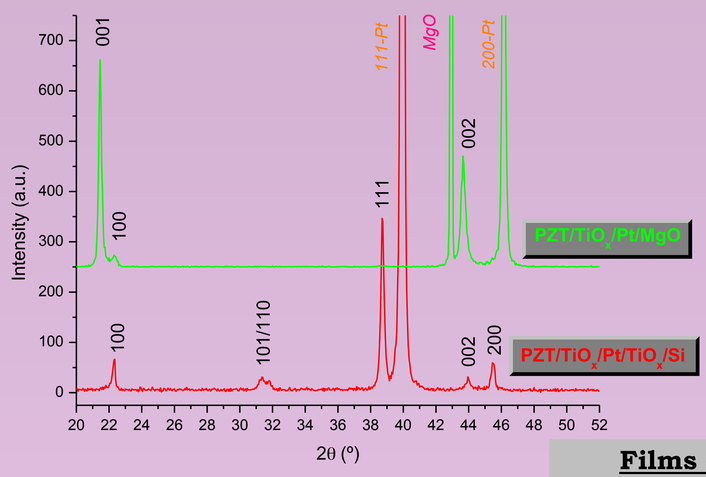
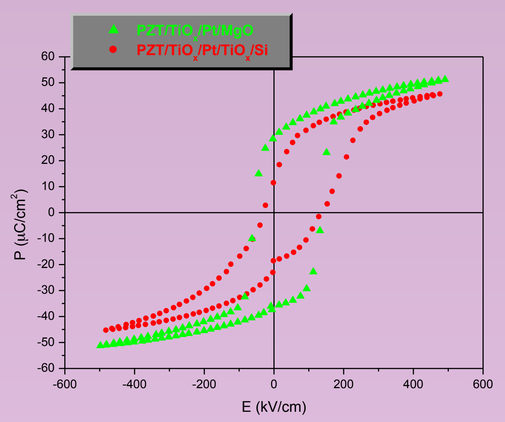
Summary

The preparation of highly oriented ferroelectric thin films is the subject of intense work due to the large improvement of the properties that is achieved. However, the reduction of the device dimensions driven by the miniaturisation trends followed by the microelectronics industry has shifted the attention to the study of the local properties of these films at the nanometer scale, more relevant for their potential application in the new nanodevices. Therefore, the study of the influence of the global texture on the local properties of these highly oriented films becomes an important issue that must be addressed. In the present work, we study by piezoresponse force microscopy (PFM) a series of PZT based ferroelectric thin films obtained by multitarget sputtering with different preferential orientations. The modification of the substrate by the deposition of an extra TiO_x layer, and the use of MgO based substrates instead of the usual Si based ones, produce changes in the main texture components of the film. The local distribution of the polar axis of these crystallites can be analysed through the phase and amplitude piezoresponse images obtained on the films. The results allow us to discuss the origin of some special features observed, like the appearance of protruding grains in films with specific orientations, and the homogeneity of the piezoelectric performance at the nanoscale.

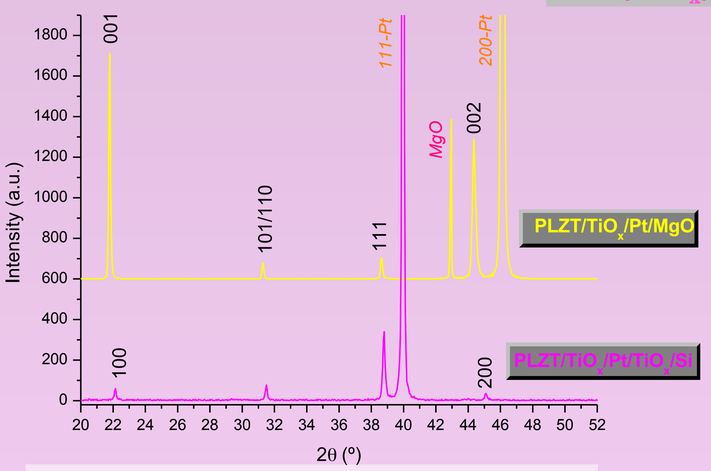
PZT THIN FILMS ($PbZr_{0.28}Ti_{0.72}O_3$)

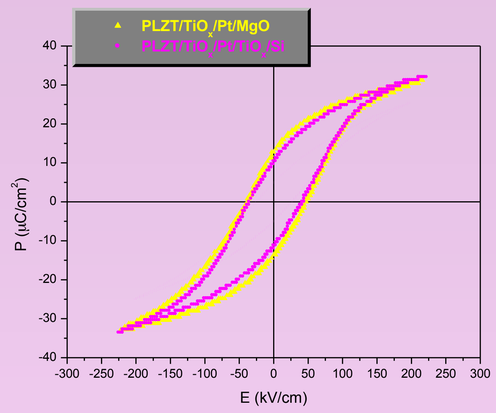
Preferential orientation control by TiO_x seeding
- Si-based substrates: *R. Bouregba et al. Mat. Res. Bull. 35 (2000) 1381*
- MgO-based substrates: *R. Bouregba et al. Ferroelectrics 256 (2001) 47*





PLZT THIN FILMS ($Pb_{0.85}La_{0.10}Zr_{0.40}Ti_{0.60}O_3$)





Films deposited on different substrates

	Orientation	Lotgering factor
$PZT/TiO_x/Pt_{(100)}/MgO_{(100)}$	<001>	0.93
$PZT/TiO_x/Pt_{poly}/TiO_x/Si$	<111>	0.70
$PLZT/TiO_x/Pt_{(100)}/MgO_{(100)}$	<001>	0.85
$PLZT/TiO_x/Pt_{poly}/TiO_x/Si$	<111>	0.68

Sputtering conditions

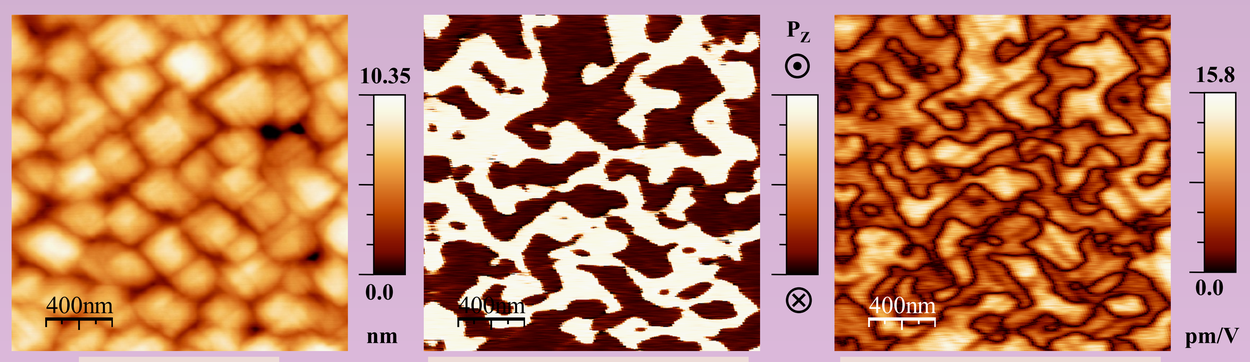
Targets	Pb, Ti, Zr and ceramic $LaTiO_3$
Temperature	550°C
Gas pressure	0.8 Pa
Ratio $O_2/(Ar+O_2)$	0.25
Distance target/substrate	40 mm
Estimated growth rate	1-2 nm/min

Piezoresponse Force Microscopy

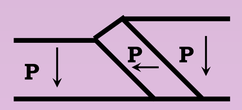
Nanotec® Electrónica with WSxM® software
Pt/Ir coated tips on cantilevers with a nominal force constant of 42 N/m (Nanosensors)
(*doped Si tip 4-6 Ω/cm - Olympus)
Out-of-plane piezoresponse (V_{AC}=1 V at 50 kHz)

Out-of-plane Piezoresponse Force Microscopy

$PZT/TiO_x/Pt/MgO$ Orientation <001>

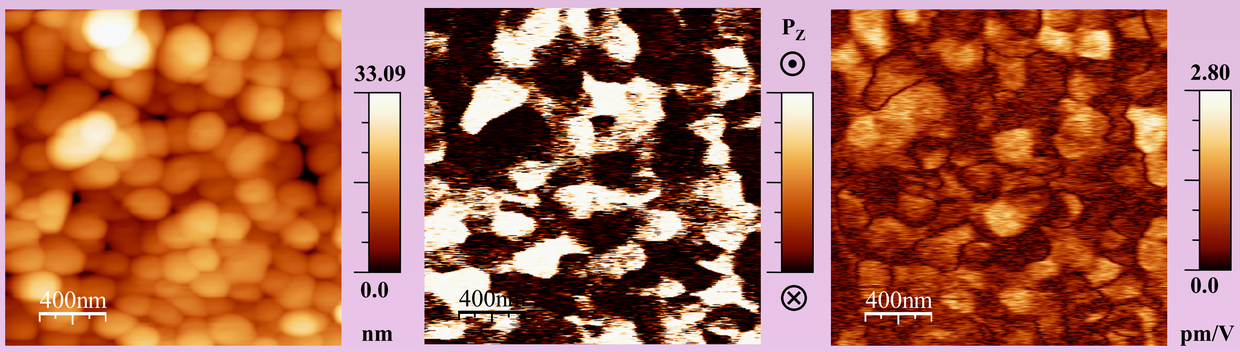


Topography | Piezoresponse Phase | Piezoresponse Amplitude



The SFM analysis of the topography reveals a c/a/c/a polydomain configuration for this epitaxial film. This is confirmed with the piezoresponse amplitude results. Superimposed we observe a network of "wavy" domains that corresponds to 180° domain walls that are not confined within the limits of the c/a domains.

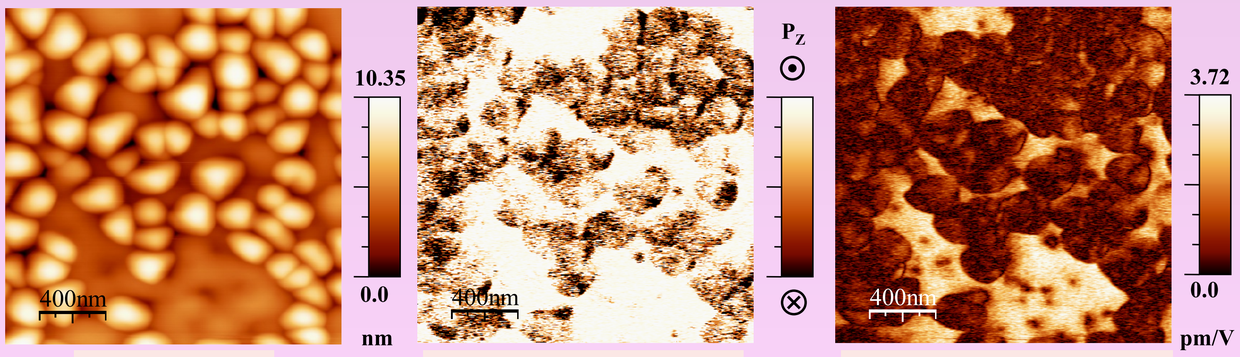
$PZT/TiO_x/Pt/TiO_x/Si$ Orientation <111>



Topography | Piezoresponse Phase | Piezoresponse Amplitude

The analysis show a polycrystalline material with an almost equal distribution of crystals with the polarization vector pointing towards the film surface and pointing towards the substrate.
The electric field applied to probe the material may excite, overall in the case of the smaller grains, not only the grain below the tip, but all the neighboring grains, resulting in a collective response.

$PLZT/TiO_x/Pt/TiO_x/MgO$ Orientation <001>



Topography | Piezoresponse Phase* | Piezoresponse Amplitude*

We observe protruding grains distributed on a flat surface. The flat regions present the highest values of piezoresponse and they can be ascribed to (001) epitaxially grown regions. The protruding grains corresponds with the volume of the film with random orientation. The differences in the local piezoelectric response between regions are larger than in the previous films.

Discussion

The analysis of the piezoelectric behavior at the nanoscale of several polycrystalline PZT based thin films with different orientations reveals inhomogeneities that, except for the (100) epitaxial film, may not to be tolerable for their application in nanodevices. We have studied here the two main preferential orientations that can be induced in these tetragonal perovskite films by modifications of the substrate: <001> and <111>. The orientation along the polar axis should be preferred, but any reduction of the degree of orientation will produce larger property variations among the oriented and non-oriented regions than the ones observed in <111> oriented films. These aspects must be taken into account when thinking of taking advantage of the nanoscale properties of these films. It is also important to note that the nanocharacterization by PFM can shed light onto some local features of the films, like the observed protruding grains, whose origin and nature cannot be studied by other means. This makes PFM an essential tool in the analysis of oriented ferroelectric films.

Acknowledgements

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