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Iron Doped $Ba_{0,6}Sr_{0,4}Ti_{1-x}Fe_xO_3$ Thin Films Deposited by RF Magnetron Co-sputtering

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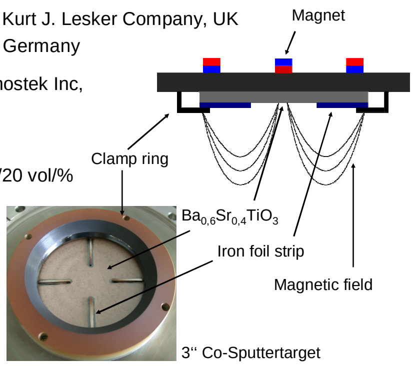
Introduction

Barium strontium titanate (BST) is a very promising material for tunable microwave applications like phase-shifters and filters. Therefore much effort has been spent on BST thin film deposition and subsequent annealing processes to tune the film properties. Well characterized are e.g. the properties of iron doped thin films [1] and powders [2] with different Ba/Sr concentration ratios prepared by sol-gel techniques. In this work we focus on the deposition and characterization of iron doped BST thin films with tailored stoichiometries using RF magnetron co-sputtering. The main sputter parameters were studied to tune the elemental composition and a subsequent annealing step leads to the necessary crystallinity of the thin films.

Film Preparation

- 3"-RF magnetron sputter set-up with a double cross recipient
- $Ba_{0.6}Sr_{0.4}TiO_3$ 3"-sputter target, Kurt J. Lesker Company, UK and iron foil Goodfellow GmbH, Germany
- Platinized Si(100) substrates, Inostek Inc, South Korea.
- Sputter parameter:
  - sputter gas: Ar/O_2 80/20 vol/%
  - operating pressure: 1.0 Pa
  - RF power: 85 W
- Subsequent heat treatment in oxygen atmosphere in a tube furnace



Film Characterization

Chemical Binding States

XPS X-ray Photoelectron Spectroscopy, **K-Alpha**, mono AlKα, ThermoFisher Scientific, UK; **sputter depth profiles:** 1keV Ar-Ion beam, raster size 1mm

Crystal Structure

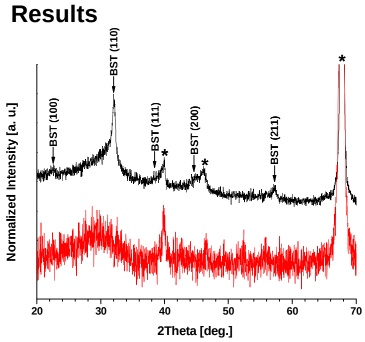
XRD X-ray Diffractometry, **D8**, Bruker AXS GmbH, Germany

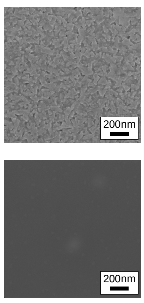
Morphology

AFM Atomic Force Microscopy, **MFP-3D-Bio**, Asylum Research, USA

SEM Scanning Electron Microscopy, **Supra 55VP**, Carl Zeiss NTS GmbH, Germany

Results





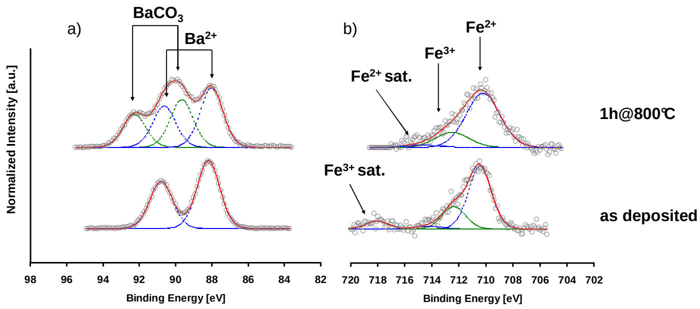
Grazing incident X-ray diffraction pattern and **SEM** images of the as deposited and heat treated BST thin film. Substrate related peaks are marked by asterisks.

➔ **single phase BST, with a microcrystalline morphology after annealing at 800℃**

References

[1] Y. Ye, T. Guo, *Ceramics International*, ***2009***, *35, 2761-2765.*
[2] F. Paul, J.-R. Binder, H. Gesswein, H.-J. Ritzhaupt- Kleissl, J. Hausselt, *Ceramics International*, ***2009***, *35, 479- 486.*

Results

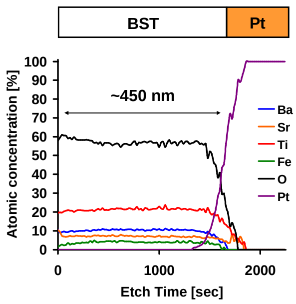


Ba 4d (a) and Fe $2p_{3/2}$ (b) **XPS spectra** of iron doped BST thin films on Pt-Si substrates in the as deposited state and after subsequent annealing.

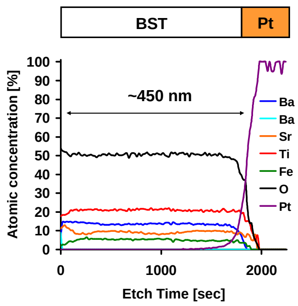
XPS binding energies of the chemical components in the iron doped BST thin films

	Ba4d		Sr3d	Ti2p		Fe2p				O1s			C1s	
	Ba^{2+}	$BaCO_3$	Sr^{2+}	Ti^{3+}	Ti^{4+}	Fe^{2+}	Fe^{2+} sat.	Fe^{3+}	Fe^{3+} sat.	O^{2-}	CO_3^{2-}	C-O/C=O	reference	CO_3^{2-}
as deposited BE [eV]	88,9		132,7	456,1	457,7	710,4	714,3	712,4	718,0	529,4	531,0	532,1	285,0	289,0
1h 800℃ BE [eV]	88,0	89,7	132,6	456,2	457,9	710,2	714,7	712,5		529,3	531,3	532,3	285,0	288,4

Experimental uncertainty: ± 0,2eV



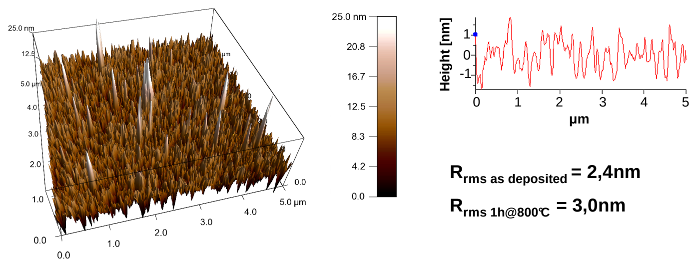
XPS sputter depth profile of an iron doped BST thin film on a Pt-Si substrate in the as deposited state



XPS sputter depth profile of an iron doped BST thin film on a Pt-Si substrate after annealing 1h@800℃

➔ **high energy Ba4d doublet is attributed to Ba atoms in a "surface state" related to $BaCO_3$**

➔ **homogeneous element distribution in the film, loss of chemical information due to sputter-induced reduction ($Ti^{4+}\rightarrow Ti^0$; $Fe^{3+}\rightarrow Fe^0$)**



AFM image and **section graph** of the *1h@800℃* annealed sample

➔ **enhanced surface roughness of the subsequent annealed sample due to crystallization of the BST thin film**

Conclusion

- **RF magnetron co-sputtering and subsequent annealing process allows production of iron doped, crystalline BST thin films with a homogeneous dopant distribution**