Microwave sintering of $Ba_{0,6}Sr_{0,4}TiO_3$ Thick-Films

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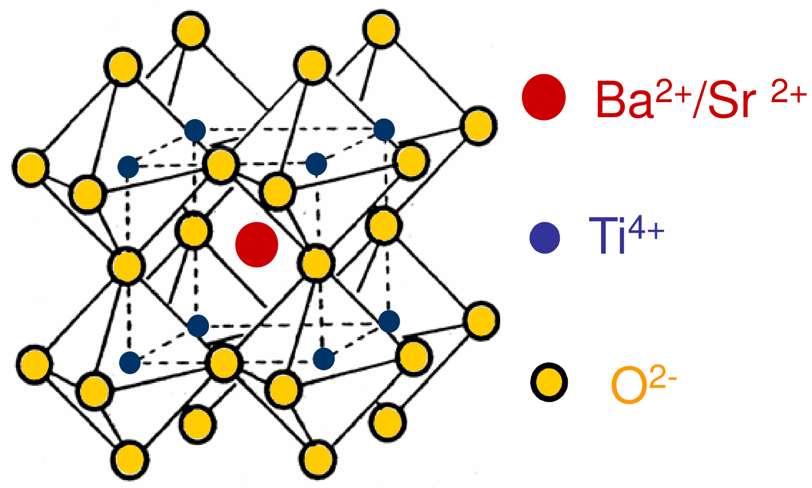
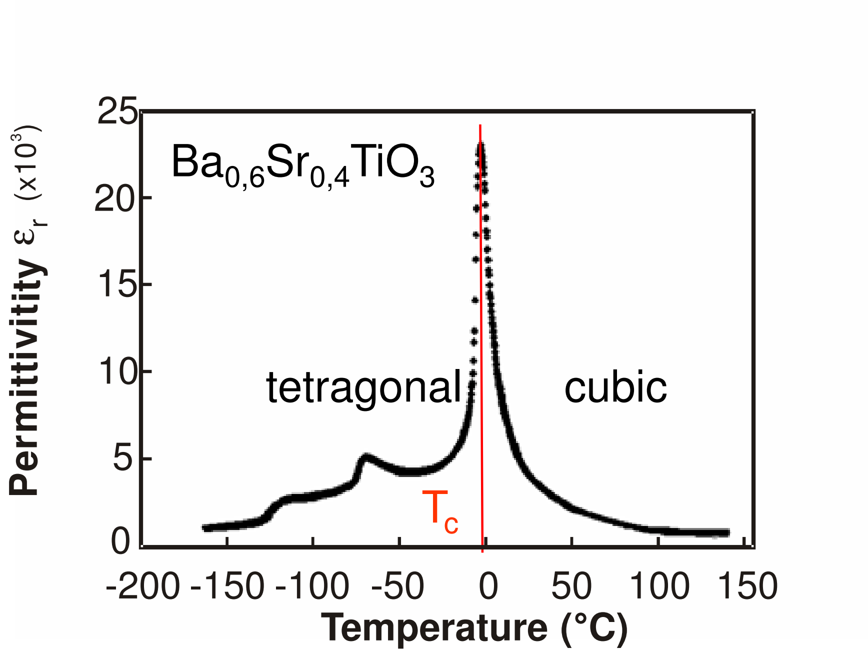
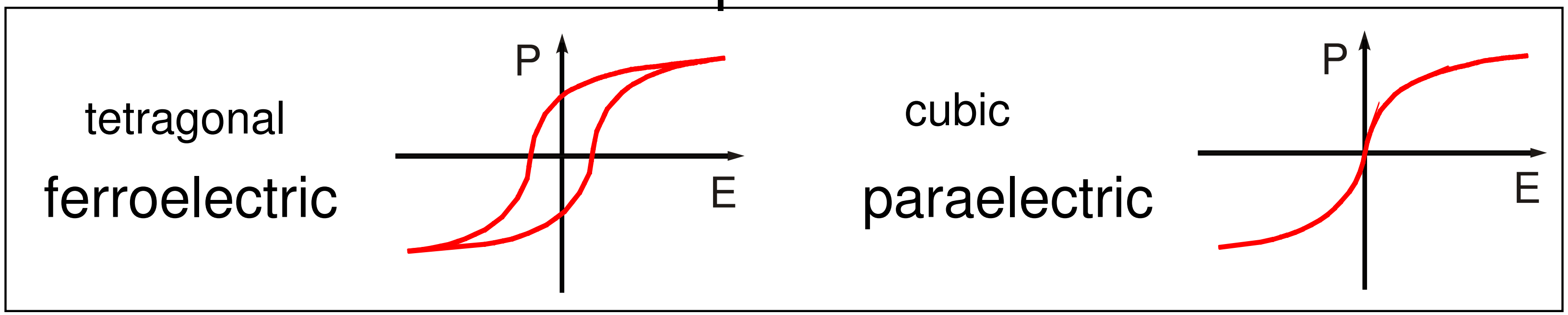
Introduction





P-E-Loops

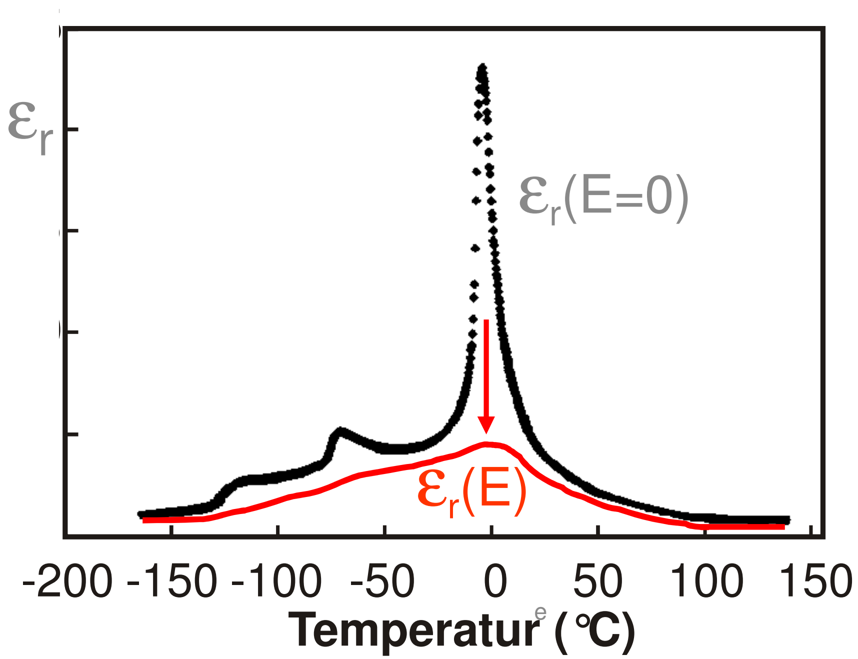


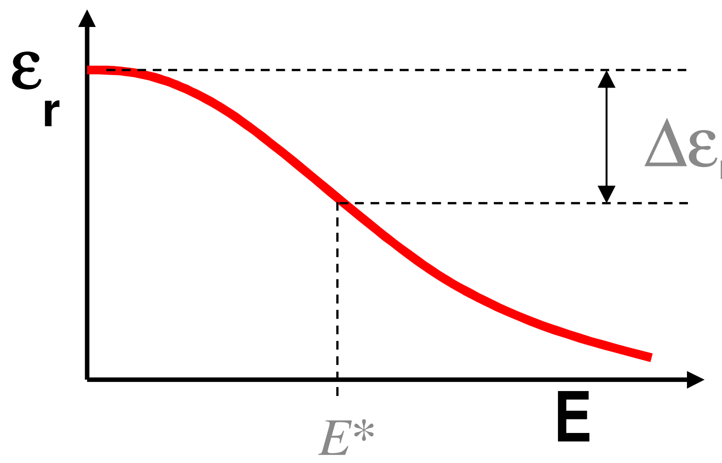
Introduction

Decrease of permittivity

tunability : decrease of permittivity through external el. field

tunability $\tau(E^*) = \frac{\Delta\varepsilon_r(E^*)}{\varepsilon_r(E=0)}$

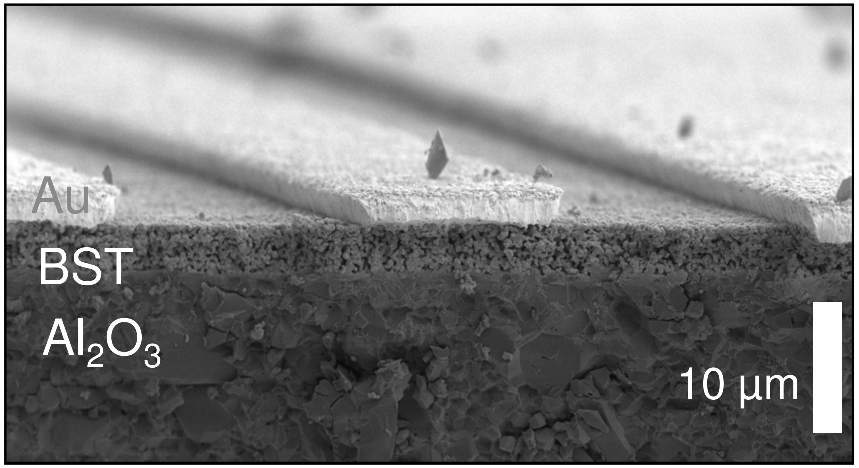




Motivation

functionality

• permittivity of $Ba_{0.6}Sr_{0.4}TiO_3$ shows nonlinear tunability under static E-field

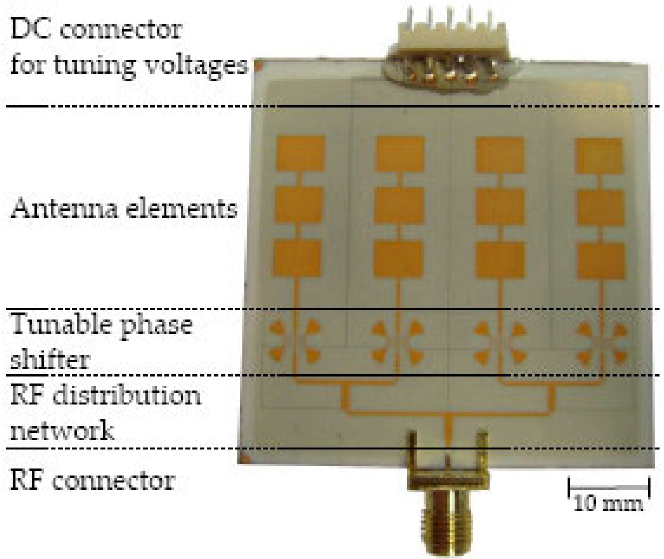


cross-section of coplanar waveguide

application

tunable RF-components

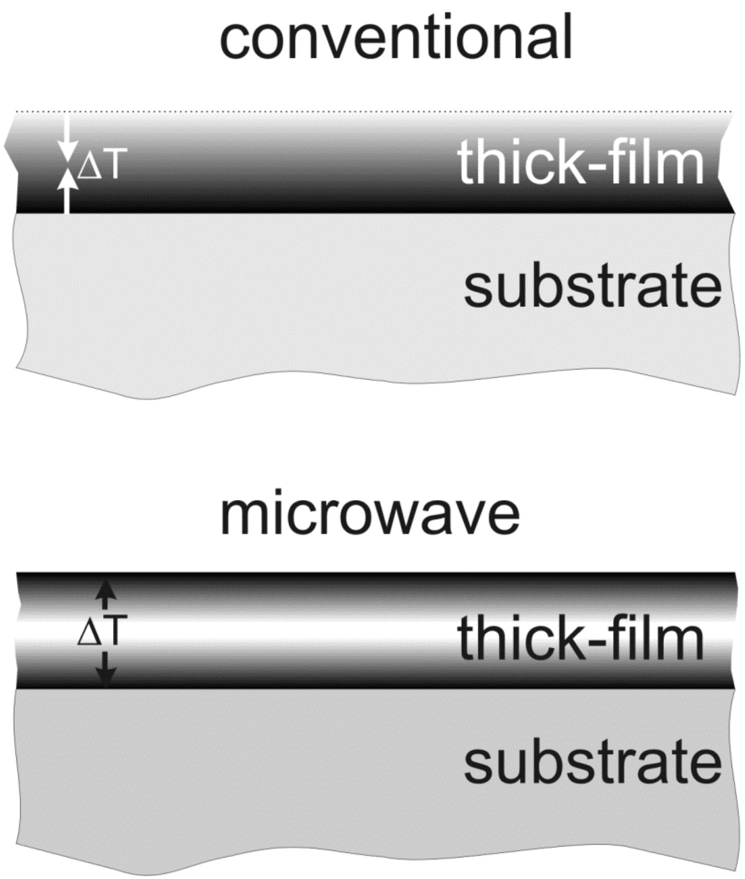
- reconfigurable circuits
- phaseshifters (delay lines)
- electronically steerable oszillators & filters



passive phase array antenna

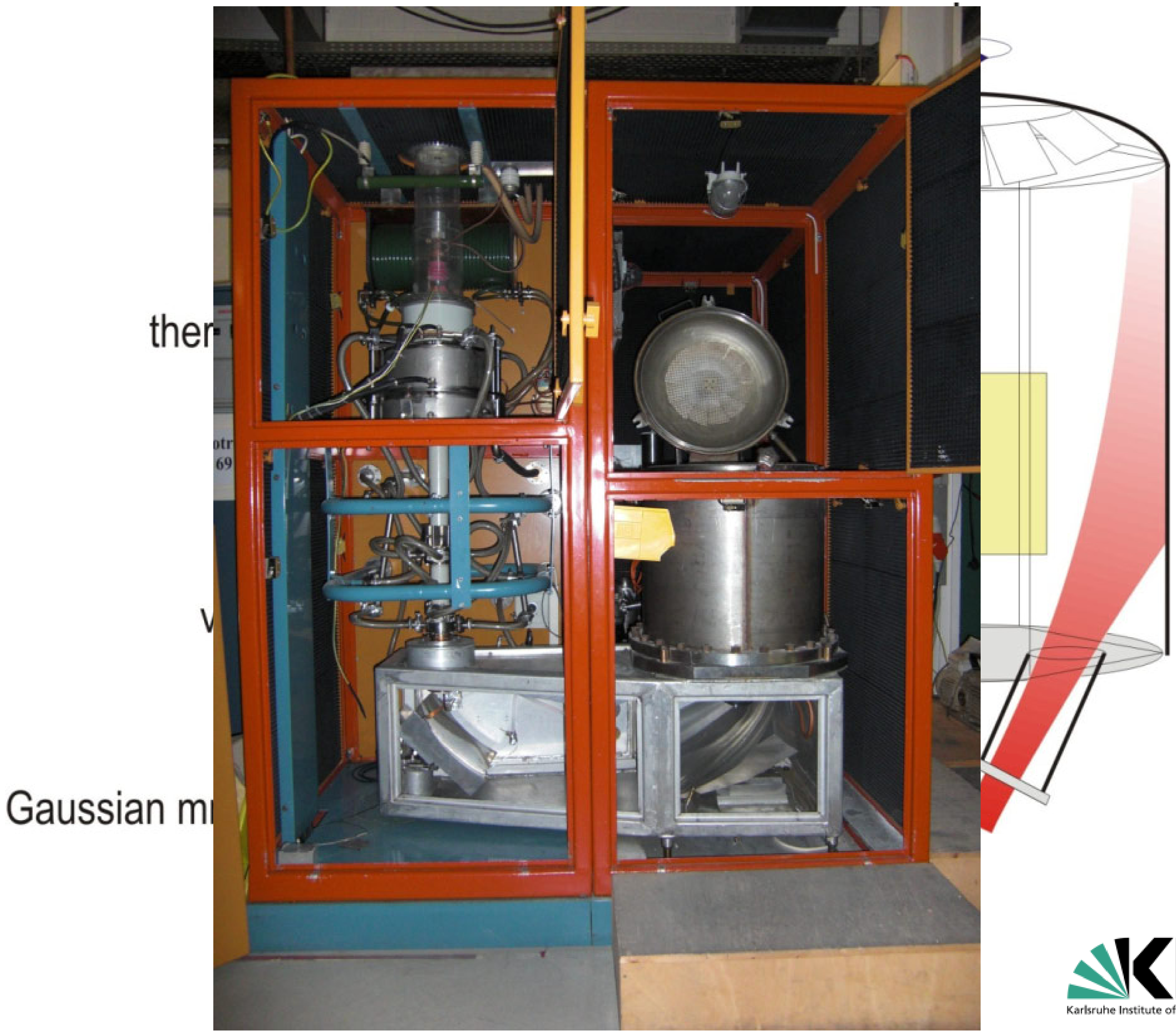
H. Maune et al. , Microsystem Technology 17 (2011) 213-224

Microwave sintering (MWS)



- heating from „outside“ in conventional sintering
- inverse heating profile in MWS
- regions with high dielectric loss heat up stronger
- short processing time and high heating rates

Microwave sintering (MWS)



G. Link, IHM at Karlsruhe Institute of Technology

Specimen fabrication

Precursor*

↓

Calcination
- 700°C
- 1100°C

↓

Ceramic Powder

↓

Screen-printing

↓

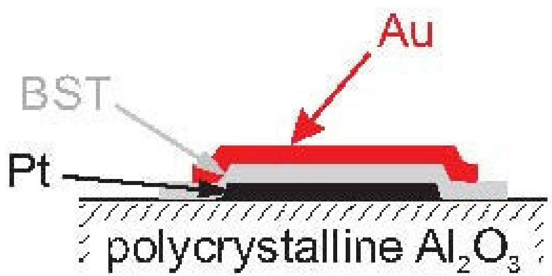
Sintering
- MWS
- CS

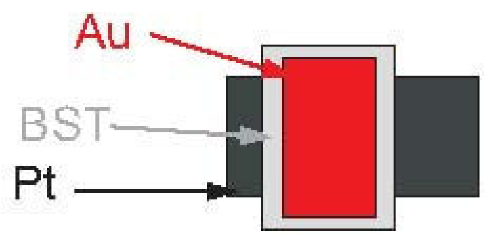
↓

Top electrode

thermal treatments in air

Name of specimen	Calcination temperature (CT)	conventional sintering (CS)	microwave sintering (MWS)
heating	5 K/min	5 K/min	20 K/min
cooling	max. 10 K/min	5 K/min	5 K/min
BST-CT700-CS	700°C, 1h	1200°C, 1h	-
BST-CT1100-CS	1100°C, 1h	1200°C, 1h	-
BST-CT700-MWS	700°C, 1h	-	1200°C, 20 min





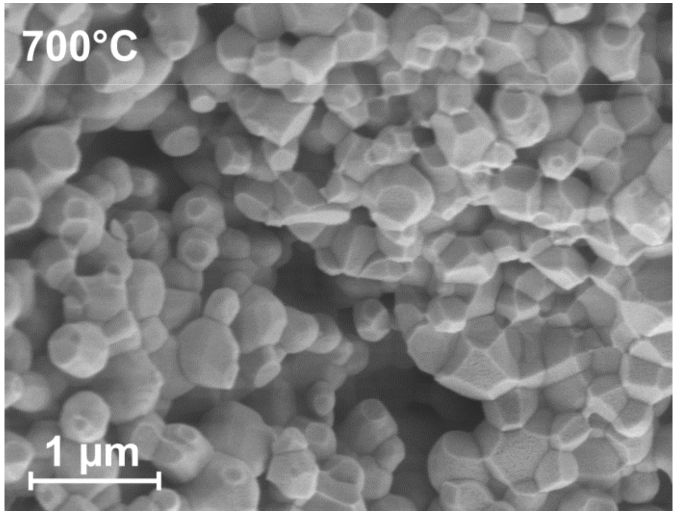
MWS: Microwave sintering
CS: conventional sintering

*F. Paul et al. , Ceramics International 35 (2009) 479-486

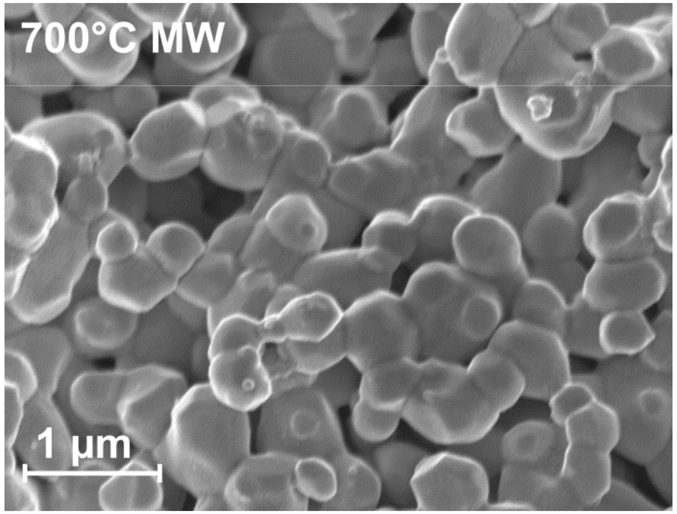
Microstructure

SEM cross-sections

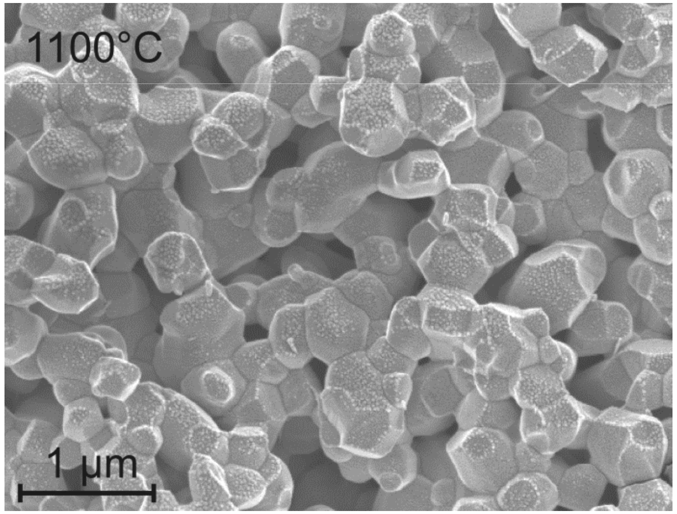
BST-CT700-CS



BST-CT700-MWS



BST-CT1100-CS



- calcined 700°C, 1h
- sintered conventionally 1200°C, 1h

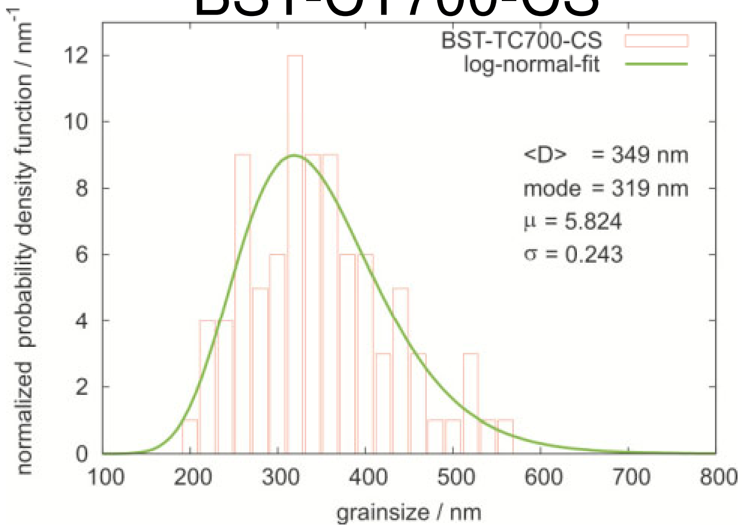
- Calcined 700°C
- sintered by microwave (30 GHz) 1200°C, 20Min.

- calcined 1100°C, 1h
- sintered conventionally 1200°C, 1h

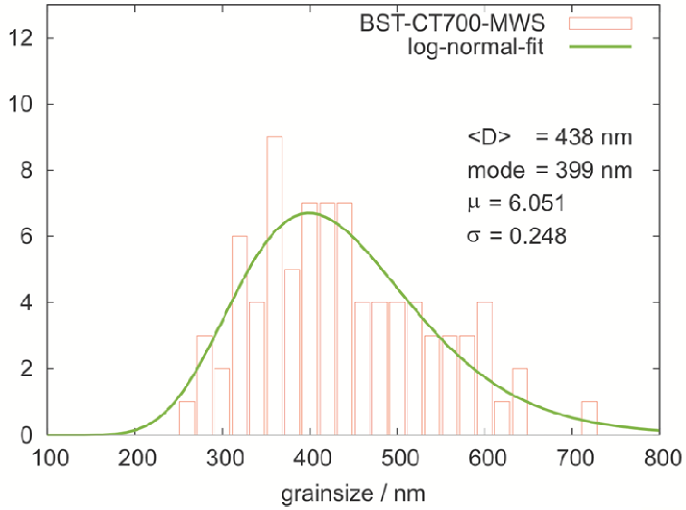
Microstructure

grain sizes and porosities

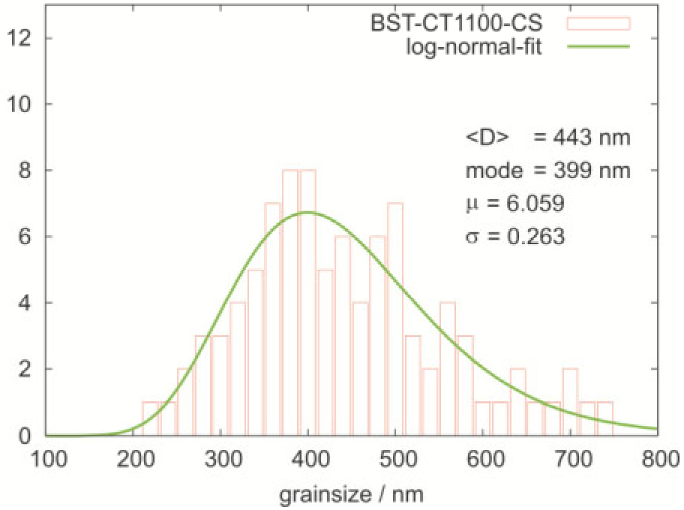
BST-CT700-CS



BST-CT700-MWS



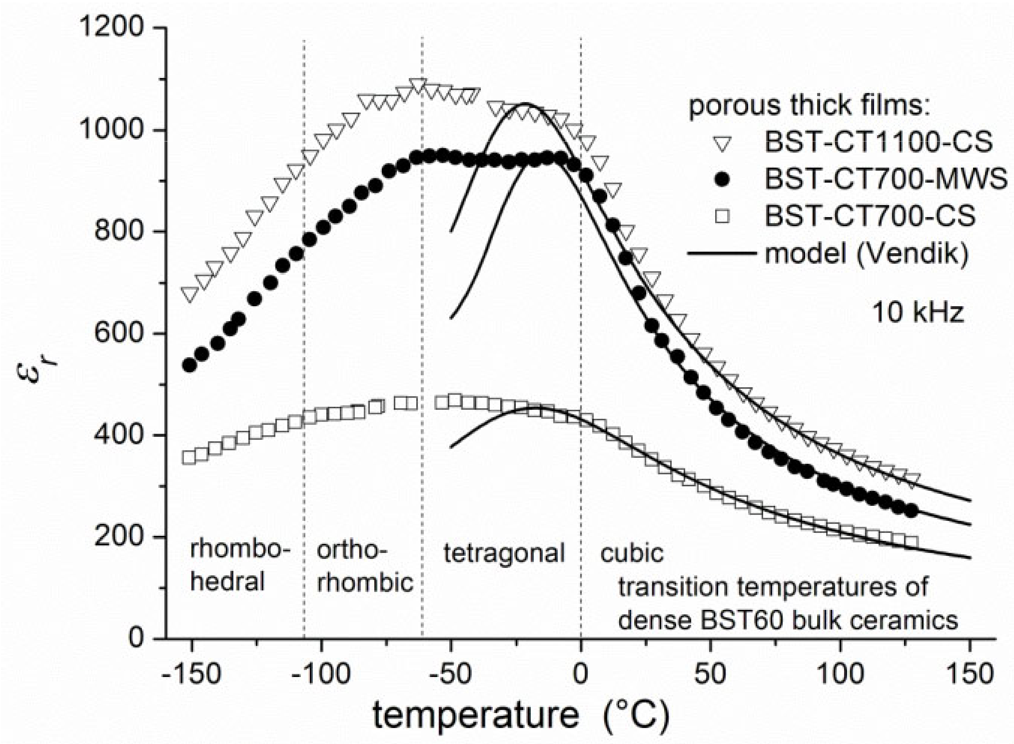
BST-CT1100-CS



name of film / sample	mean grain size $\langle D \rangle$ (nm)	σ_D (nm)	mode (nm)	porosity (%)	thickness (µm)
BST-CT700-CS	349	85	319	41	10,5
BST-CT700-MWS	438	109	399	34	15,5
BST-CT1100-CS	443	116	399	33	19

Dielectric properties

Permittivity



- Low ε_r compared to bulk ceramics
- Decreased temperature dependence
- Broad phase transition peaks
- High calcination Temp.: increases ε_r
- MWS.: increases ε_r
- T_c is shifted to lower temperatures

modelling of the dielectric data after O. G. Vendik, S. P. Zubko, Journal of Applied Physics, 88(2000) 5343-5350

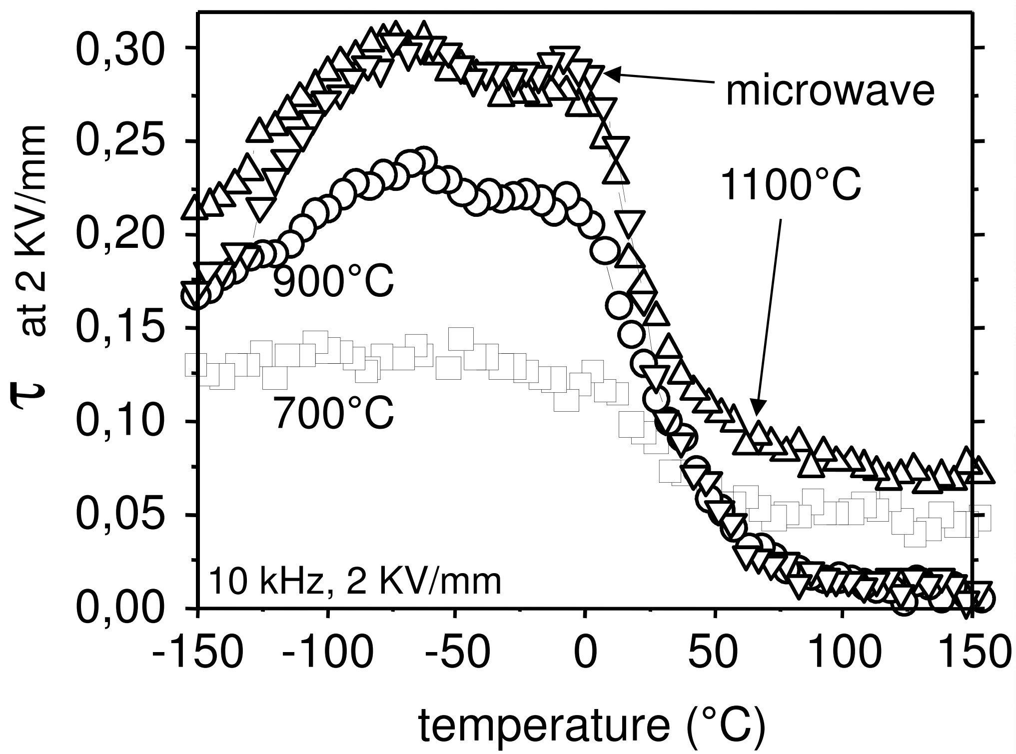
Dielectric properties

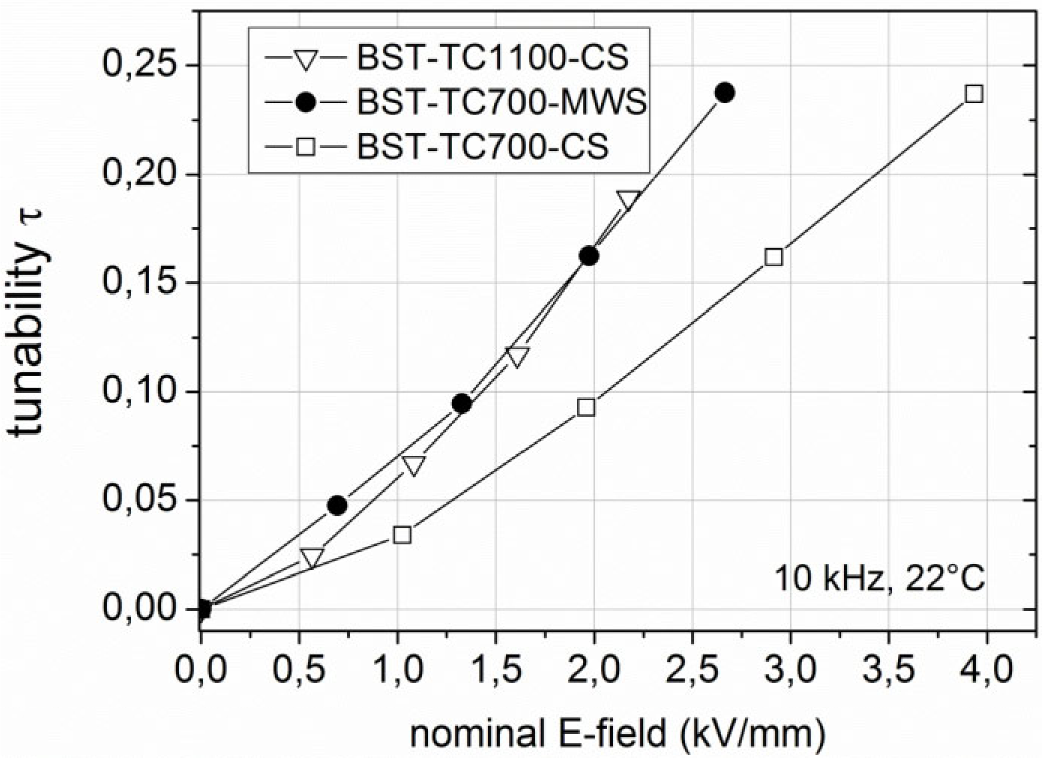
fitted parameters (Vendik model)

	T_C / K (±3)	ξ_S (±0.005)	mean grain size / nm	porosity / %
BST-CT700-CS	223	0.13	349	41
BST-CT700-MWS	240	0.055	438	34
BST-CT110-CS	230	0.073	443	33
BST60 ceramic	270	0.01*	-	-

- higher crystal quality after CT= 1100°C and MWS
- more bulky behavior after CT= 1100°C and MWS (T_c, ξ_S)
- *BST60 bulk-ceramics exhibit much lower values of ξ_S as suggested by Vendik (ξ_S >0.1)

Dielectric properties
tunability





- high tunability due to high calcination temperature and microwave sintering
- increased tunability, compared to bulk ceramics with similar grain size

Conclusion

- thermal treatment plays a crucial role in processing of BST ceramics and thick films
- Dielectric properties are heavily dependent on microstructure and crystal quality
- porous BST thick films show decreased
  - permittivity
  - Tc
  - temperature dependence
  - cristal quality as bulk ceramics
- MWS is a high impact sintering method, comparable to long lasting conventional heating and sintering

Thank you for your attention

Thank you for collaboration and help:

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- Prof. R. Jakoby, Dr. H. Maune, Dr. Giere, Microwave Engineering, University of Darmstadt

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