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

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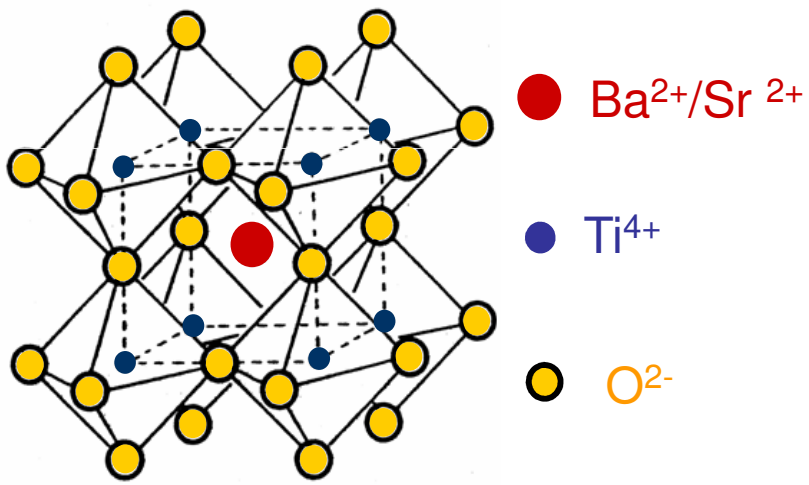
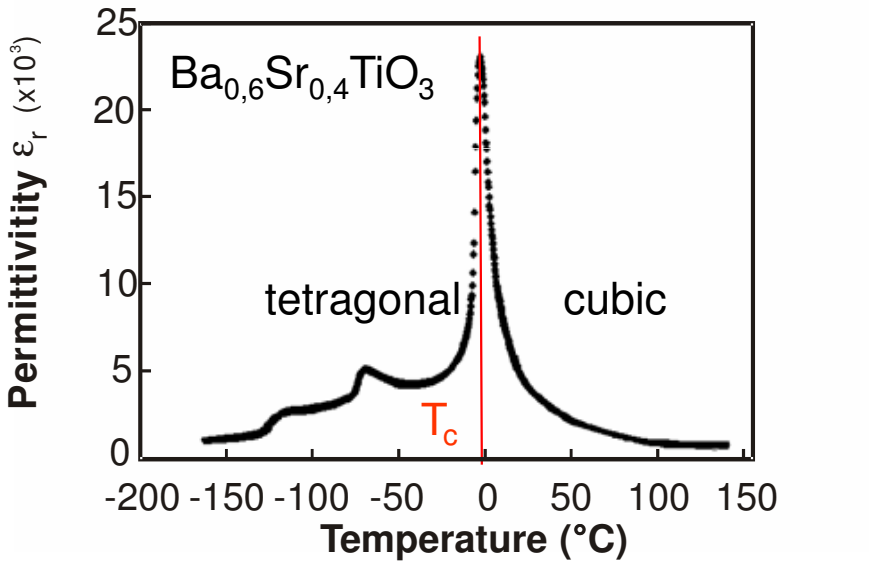
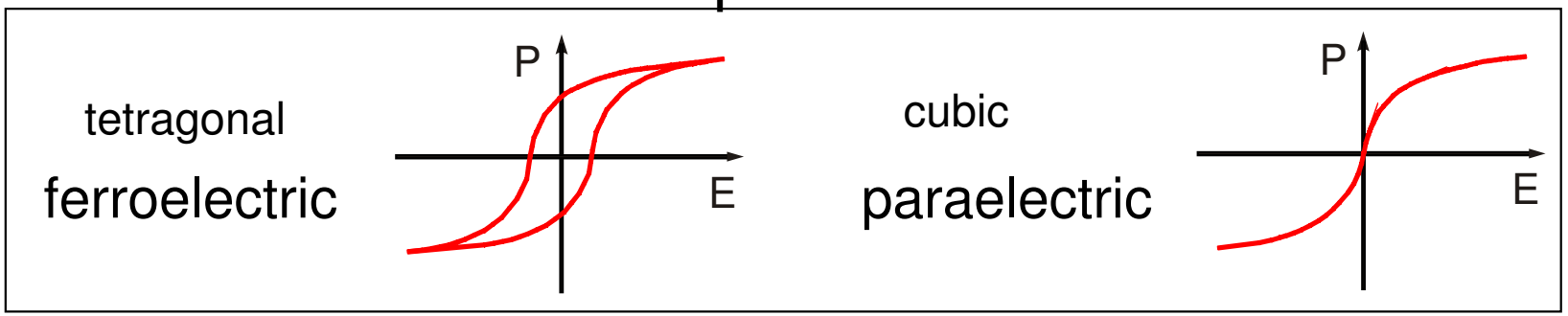
Introduction





P-E-Loops

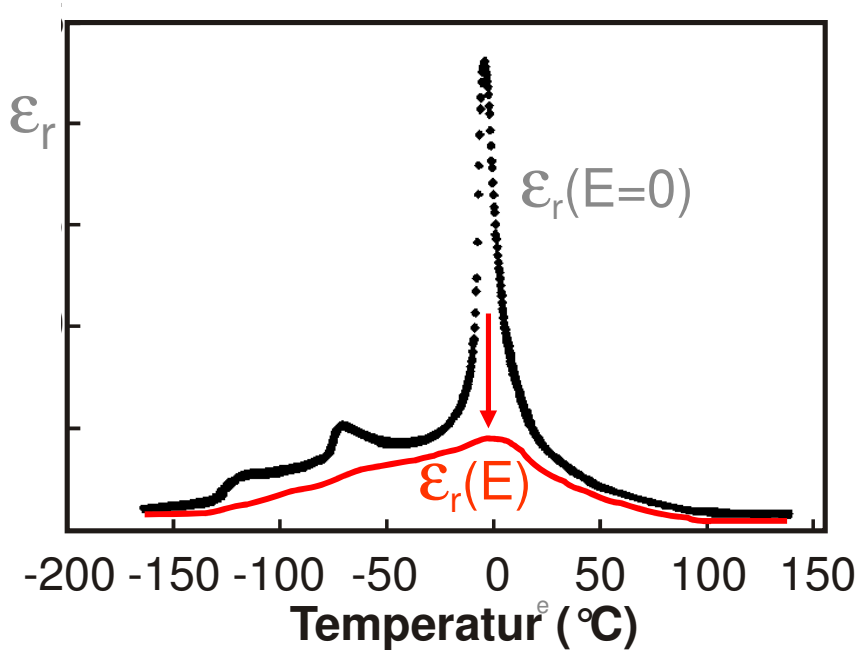


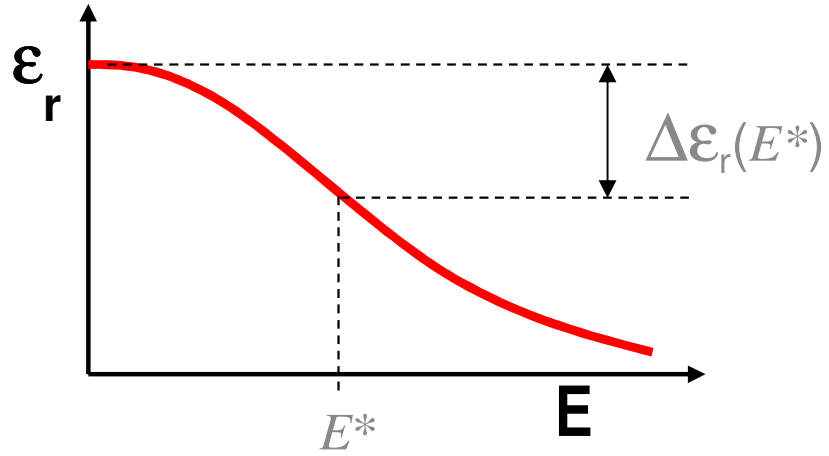
Introduction

Decrease of permittivity

tunability : decrease of permittivity through external el. field

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

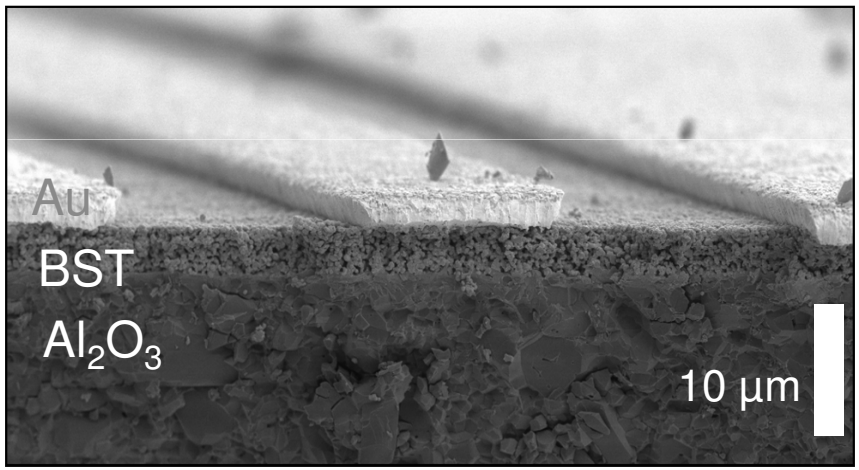




Motivation

functionality

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

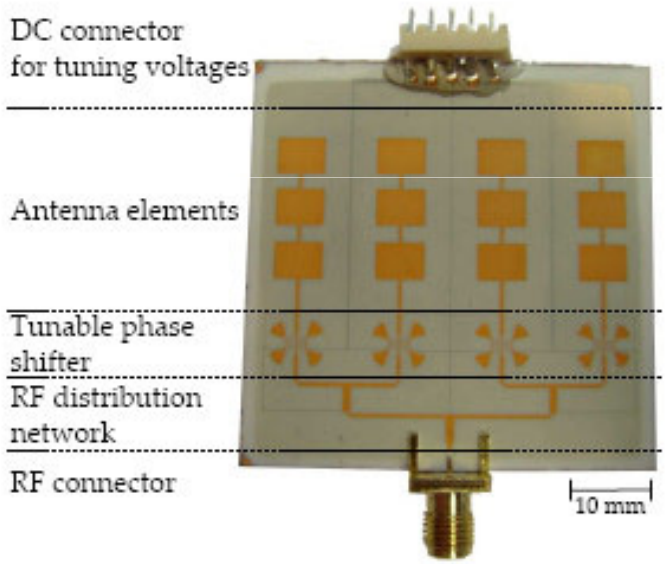


cross-section of coplanar waveguide

application

tunable RF-components

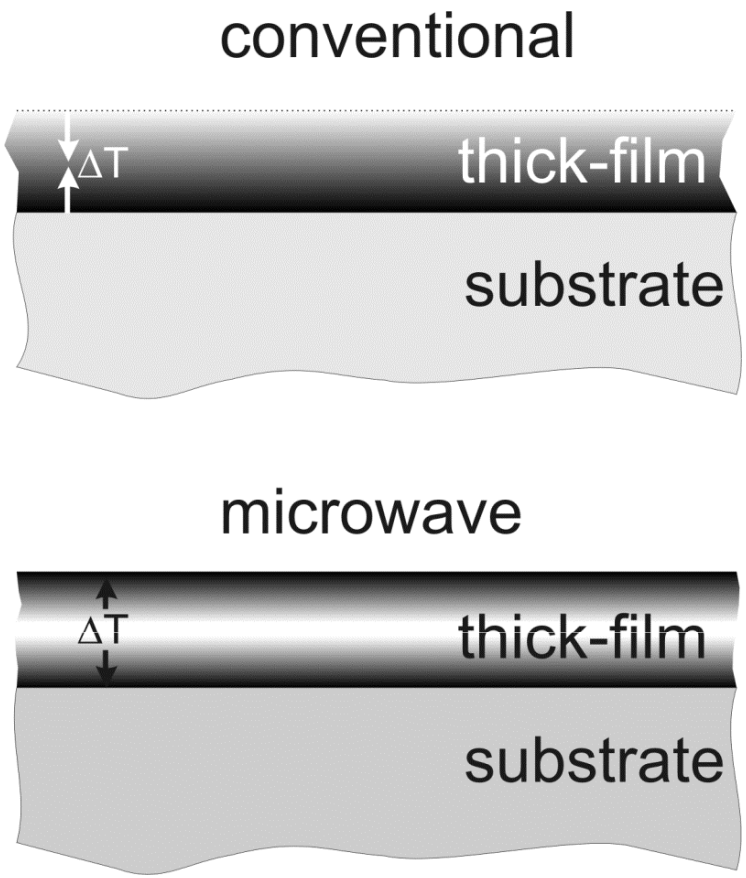
- reconfigurable circuits
- phaseshifters (delay lines)
- electronically steerable oszillators & filters



passive phase array antenna

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

Microwave sintering (MWS)

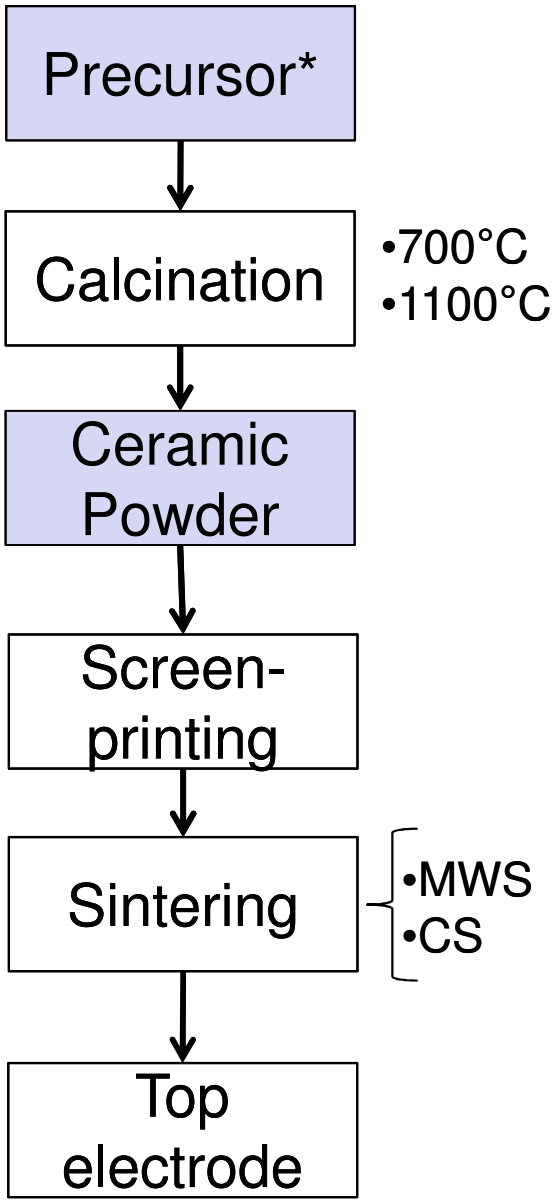


- heating from „outside“ in conventional sintering
- inverse heating profile in MWS
- regions with high dielectric loss heat up stronger
- short processing time and high heating rates

Microwave sintering (MWS)

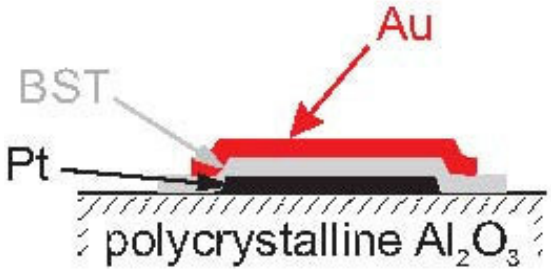
Karlsruhe Institute of Technology

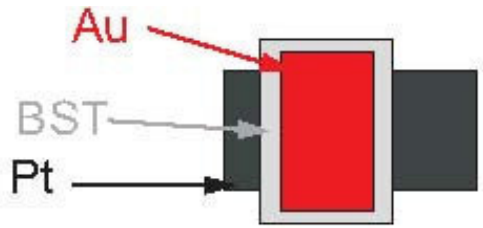
Specimen fabrication



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





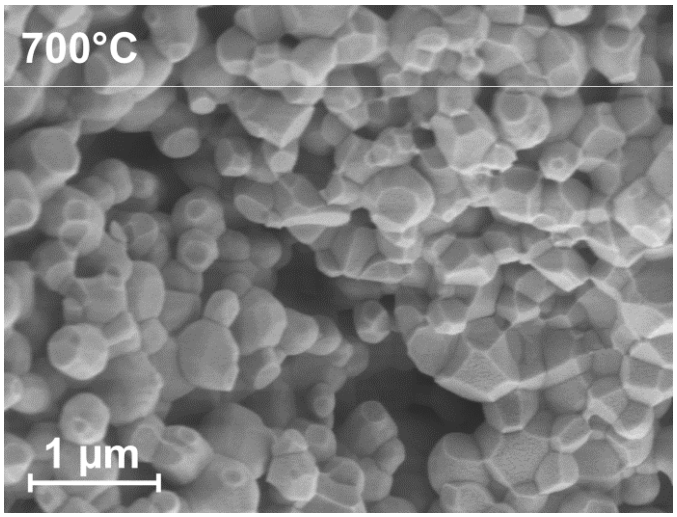
MWS: Microwave sintering
CS: conventional sintering

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

Microstructure

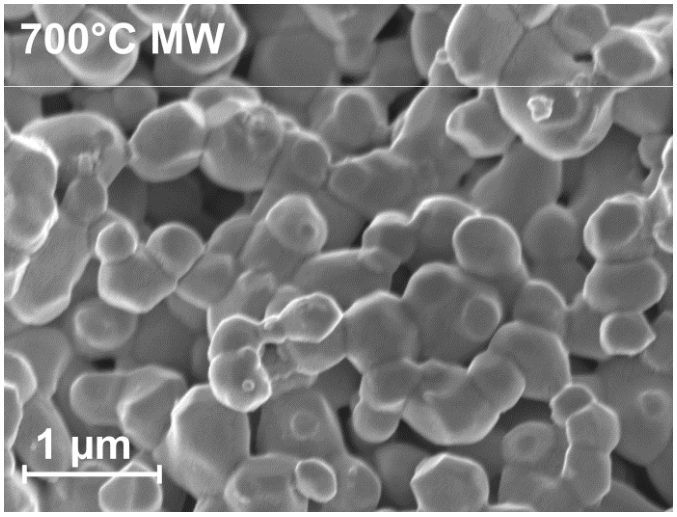
SEM cross-sections

BST-CT700-CS



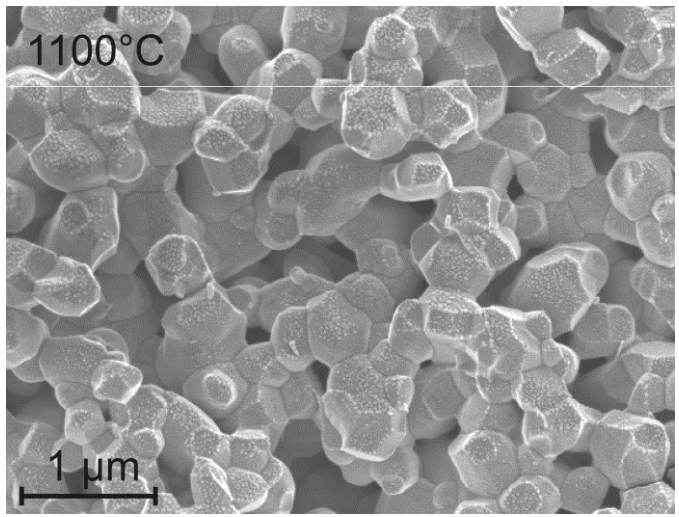
- calcined 700°C, 1h
- sintered conventionally 1200°C, 1h

BST-CT700-MWS



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

BST-CT1100-CS

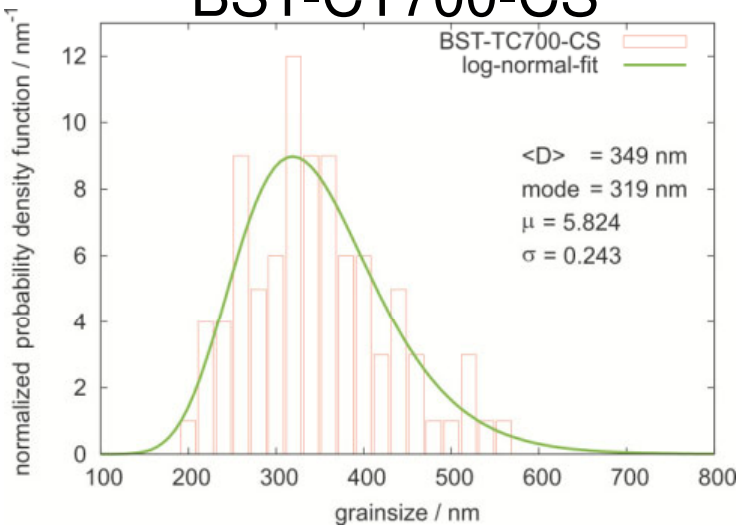


- calcined 1100°C, 1h
- sintered conventionally 1200°C, 1h

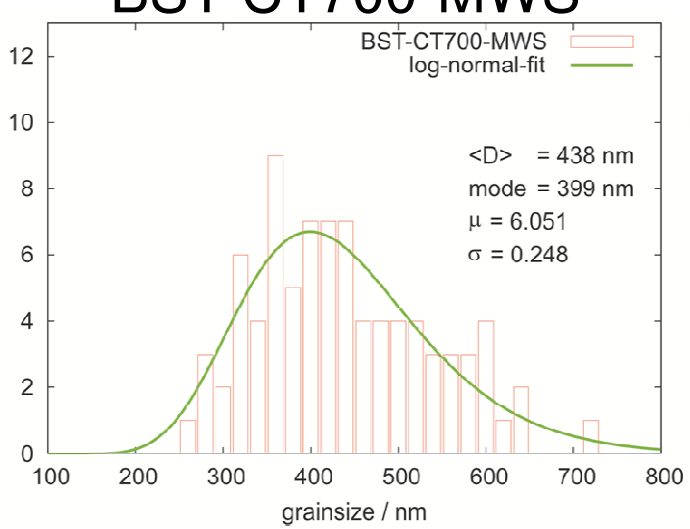
Microstructure

grain sizes and porosities

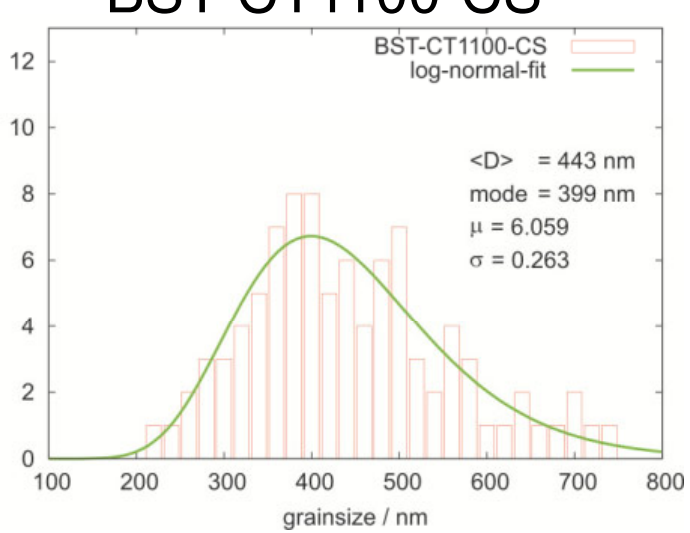
BST-CT700-CS



BST-CT700-MWS



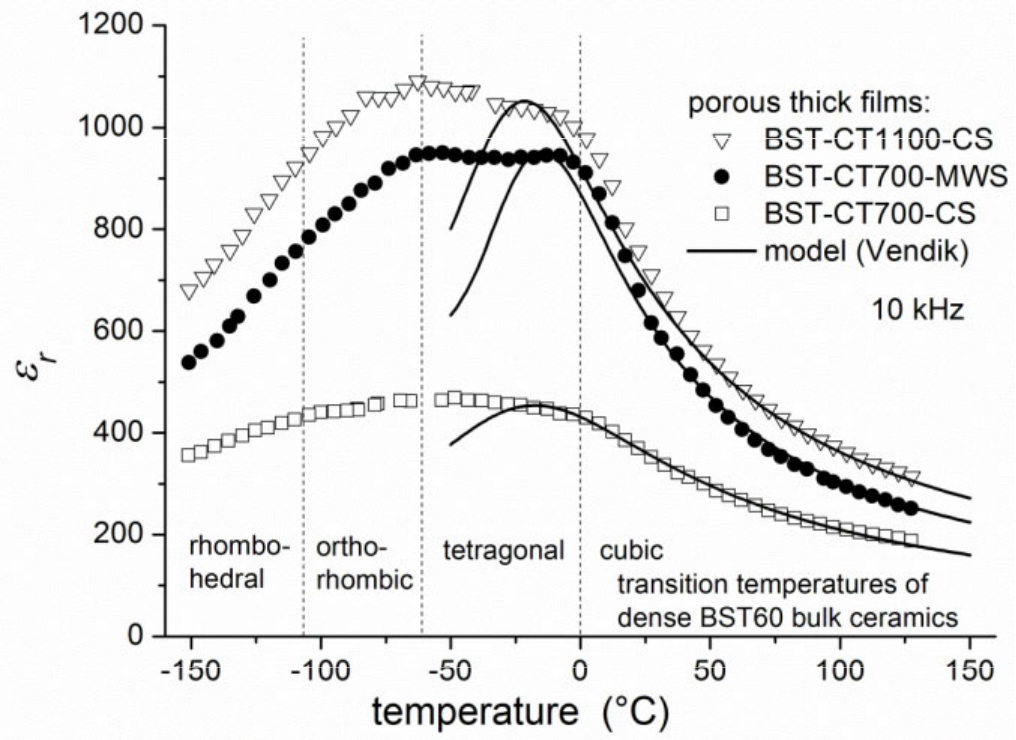
BST-CT1100-CS



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

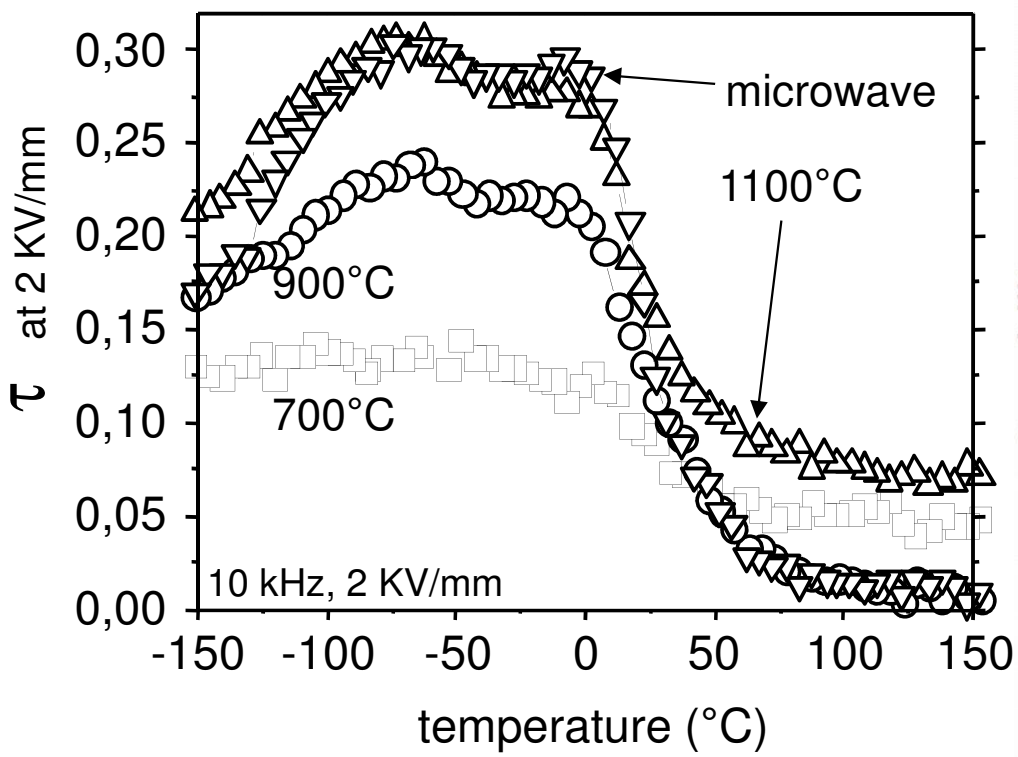
fitted parameters (Vendik model)

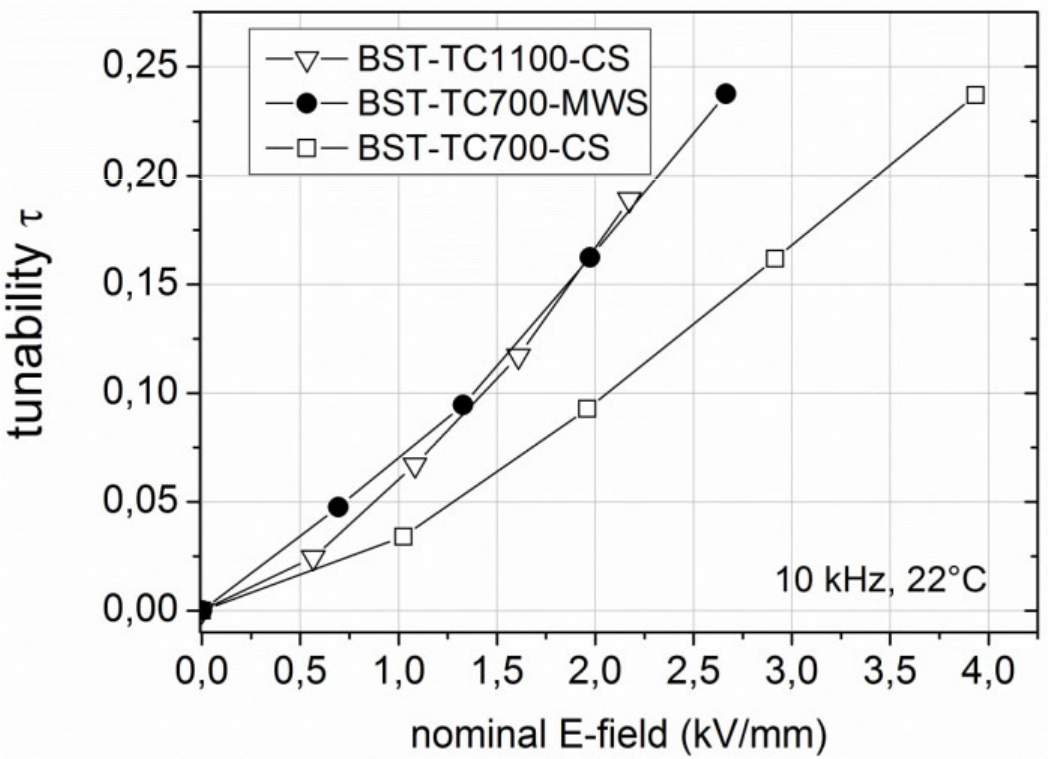
	T_C / K (±3)	ξ_S (±0.005)	mean grain size / nm	porosity / %
BST-CT700-CS	223	0.13	349	41
BST-CT700-MWS	240	0.055	438	34
BST-CT110-CS	230	0.073	443	33
BST60 ceramic	270	0.01*	-	-

- 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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