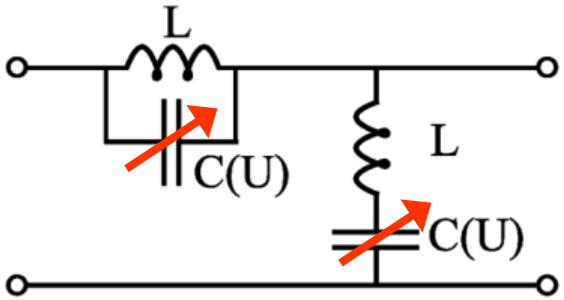
The effect of $ZnO\text{-}B_2O_3$ addition on the dielectric properties and microstructure of screen-printed low-sintered BST thick films

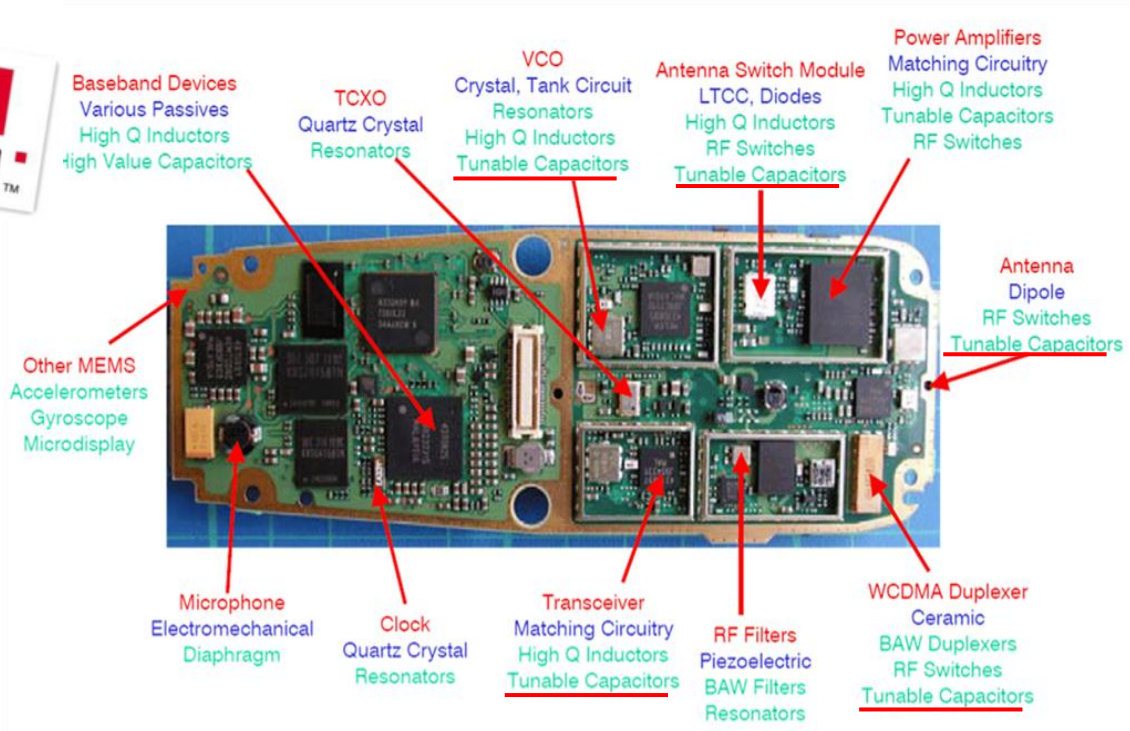
Institute for Applied Materials – Materials Process Technology (IAM-WPT)

C. Kohler, X. Zhou, M. Sazegar,
R. Jakoby, F. Stemme, J. Hausselt, J.R. Binder

Electronic Materials and Applications 2012, Orlando, Florida

Motivation

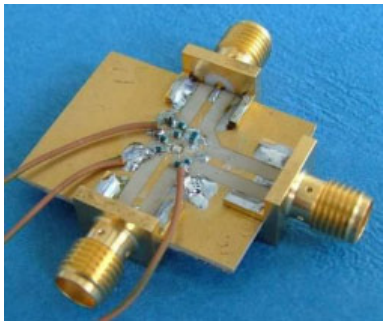




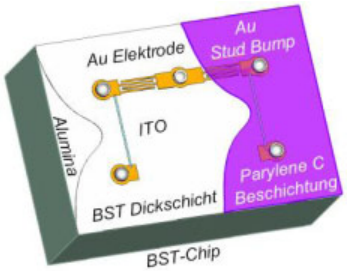
Tunable capacitors (varactors) are essential elements of tunable microwave components

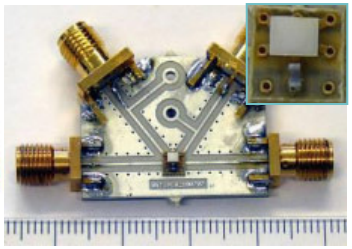
RF components based on BST thick-films

Tunable filter



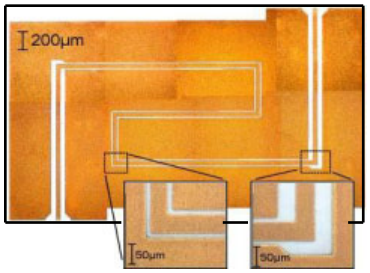
Tunable matching network



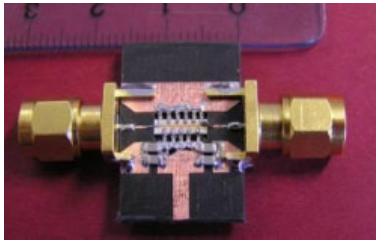


Phase shifter

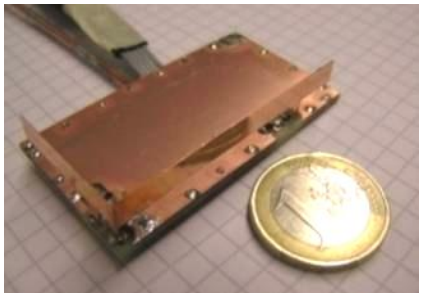
CPW based phase shifter



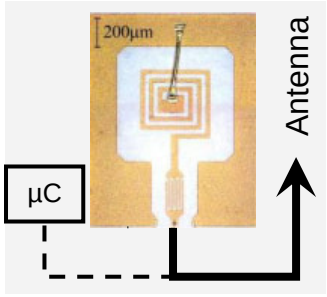
Left-handed phase shifter



Multiband antenna



RF-ID modulator



Microwave Engineering, Technical University Darmstadt

http://www.mwe.tu-darmstadt.de/de/fachgebiete/mikrowellentechnik/forschung/ferroelectrics/ferroelectrics.html

Restrictions of BST thick films

- **Sintering temperature (~1200°C)**

  → not compatible with LTCC technology (T_m of silver = 962°C)

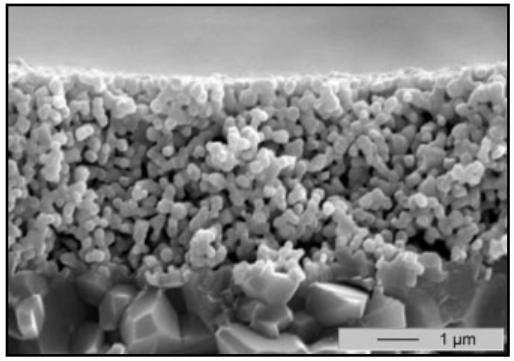
  → Processing of low-fired electrodes (e.g. Ag, Au) **after** firing of BST thick film

  → Co-fired MIM devices only possible with high fireable electrodes (e.g. Pt)

- **Porosity of BST thick films**

  → lowered mechanical stability

  → adsorbed water causes extrinsic dielectric loss



Additives for: 1.) Lowering sintering temperature

2.) Reduction of porosity

3.) Adjusting of dielectrical performance (low loss)

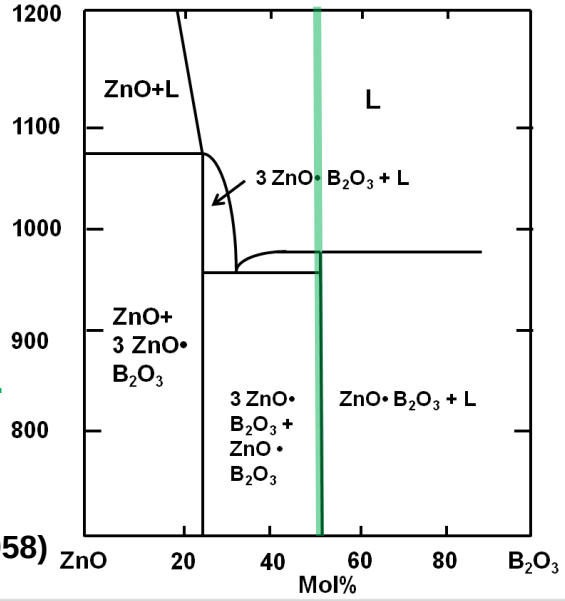
Requirements Additives

	SiO_2	B_2O_3	Li_2O
• Lowering sintering temperature of BST	-	+	+
• No or limited formation of secondary phases	-	±	±
• Low permittivity and **dielectric loss**	+	±	-
• Low softening point and wetability	-	+	+

Focus on binary borate system

System:

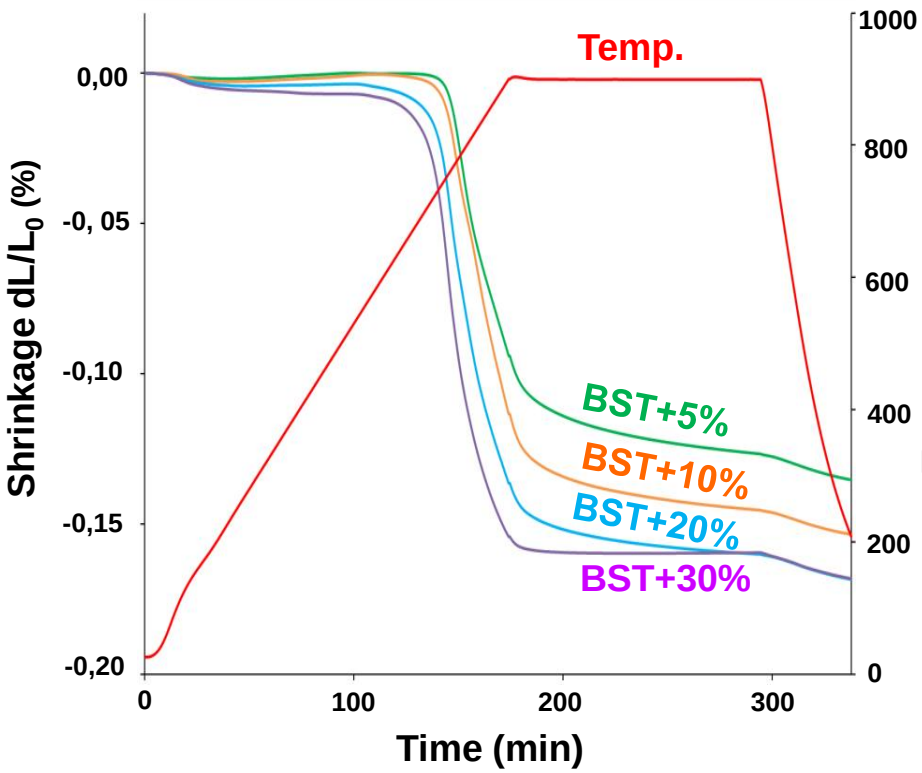
$ZnO - B_2O_3$ 1:1



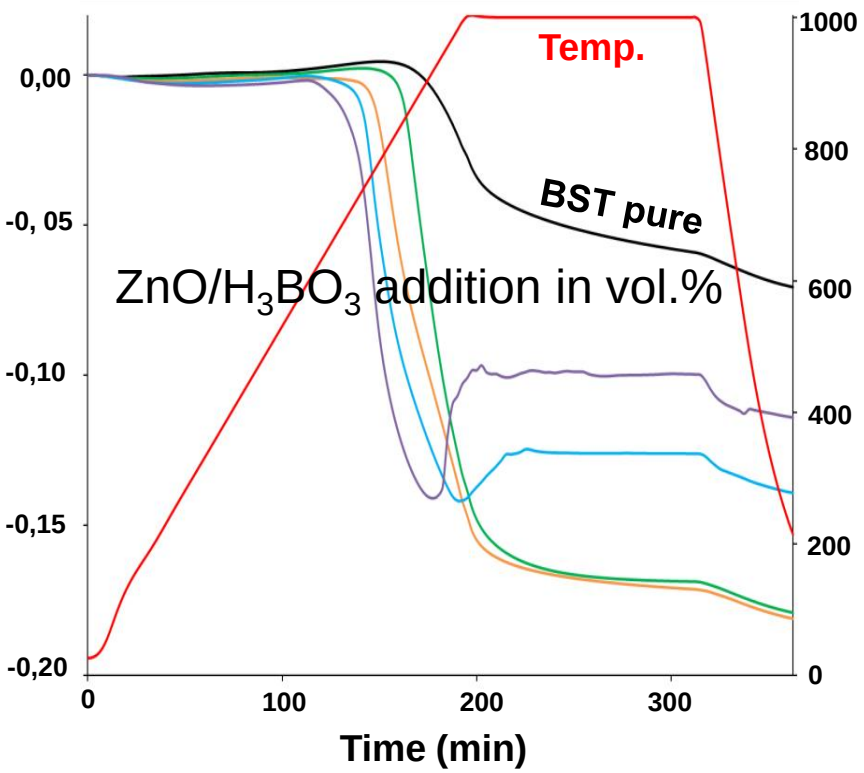
(based on Leonov,1958)

Dilatometry (pellets)

900°C/2h



1000°C/2h



→ **Densification at lower sintering temperatures**

Processing

Reactants:
(Ba / Sr / Co)-Acetates
Ti(IV)- Isopropoxide
in **Acetic acid + water**

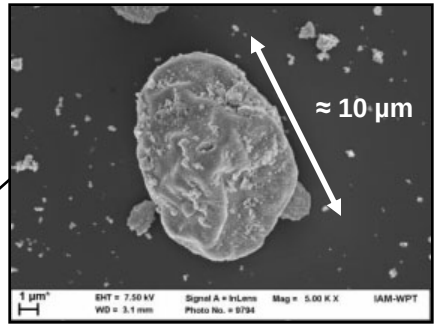
Sol

Spray-drying

Precursor

Calcination (900°C)

Calcinded powder



Addition of ZnO-H_3BO_3, Milling

Powder mixtures

Addition of ZnO-H_3BO_3:
5, 10, 20 vol%
(1.85, 3.84, 8.24 wt%)

Dispersing

Paste

Screen-Printing, Drying

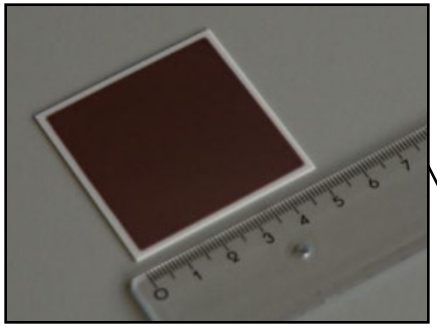
Thick film (green)

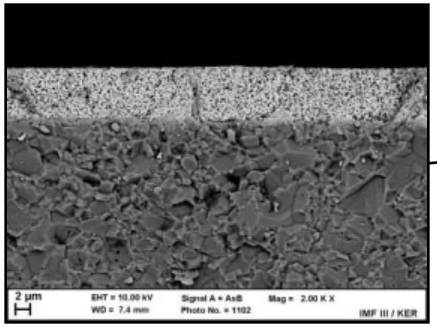
Sintering(800 – 1000°C)

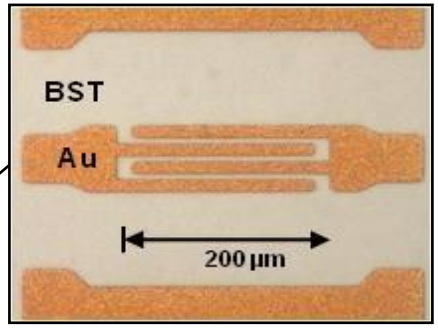
Thick film

Metallization

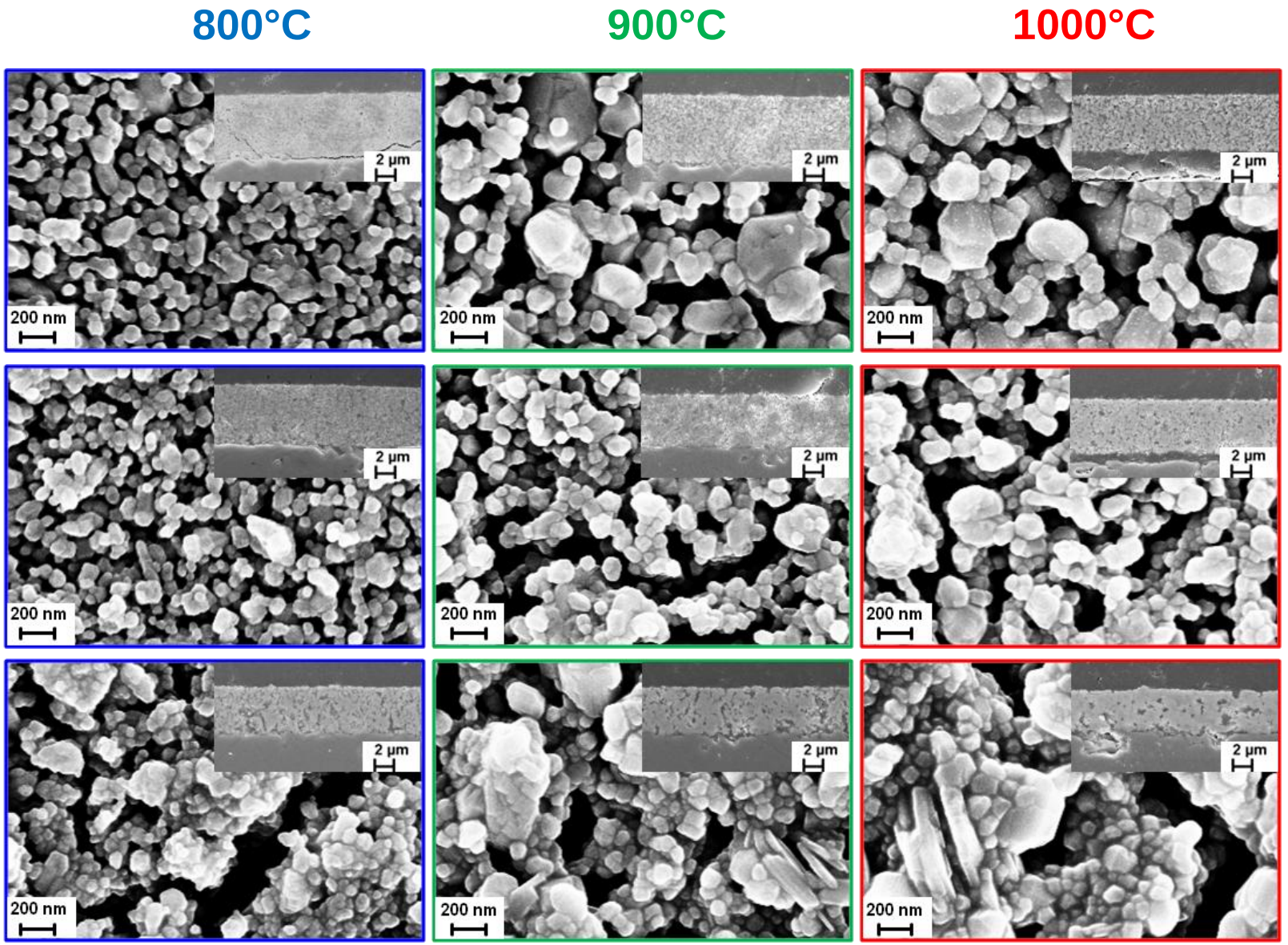
Testing structures/devices







Microstructure of thick films



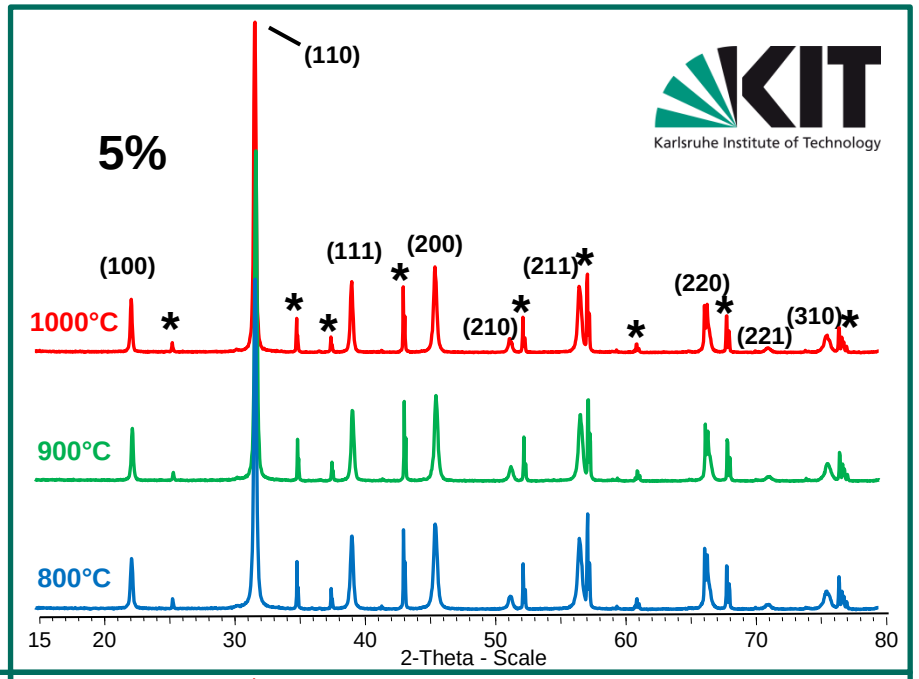
Thick films – phase content

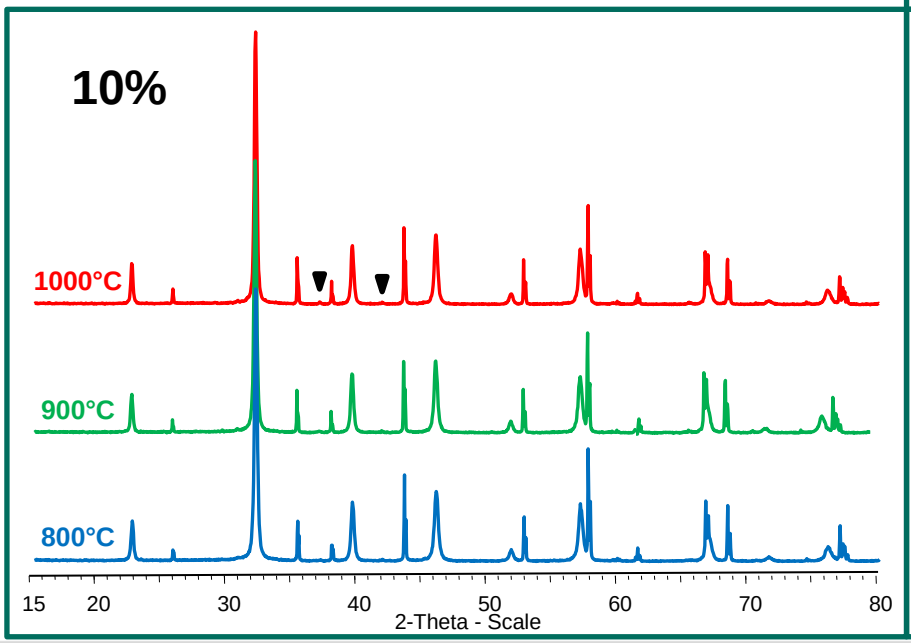
(hkl) : BST

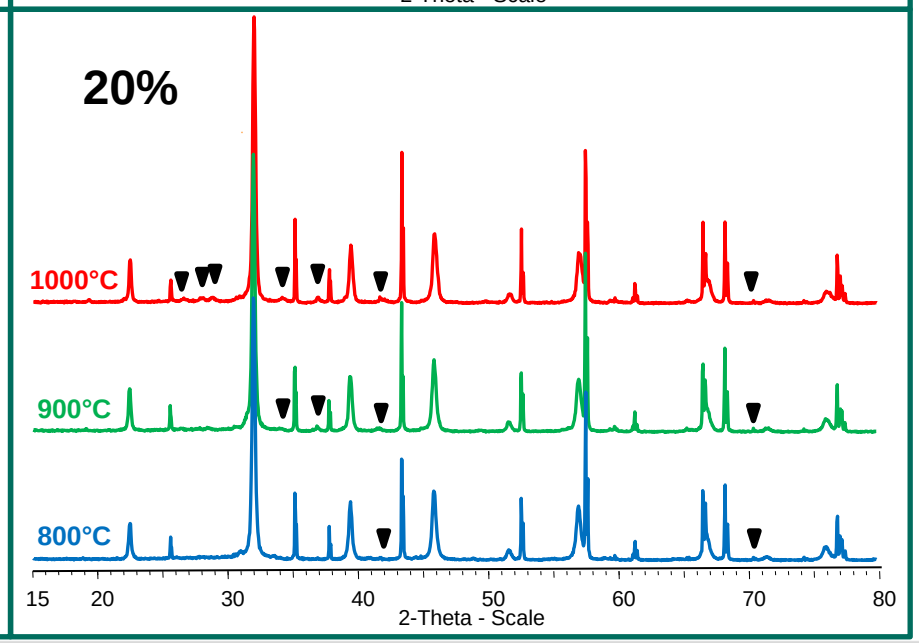
* : Al_2O_3

→ Low formation of secondary phases

→ no obvious shift of BST reflexes;
Ba/Sr ratio constant

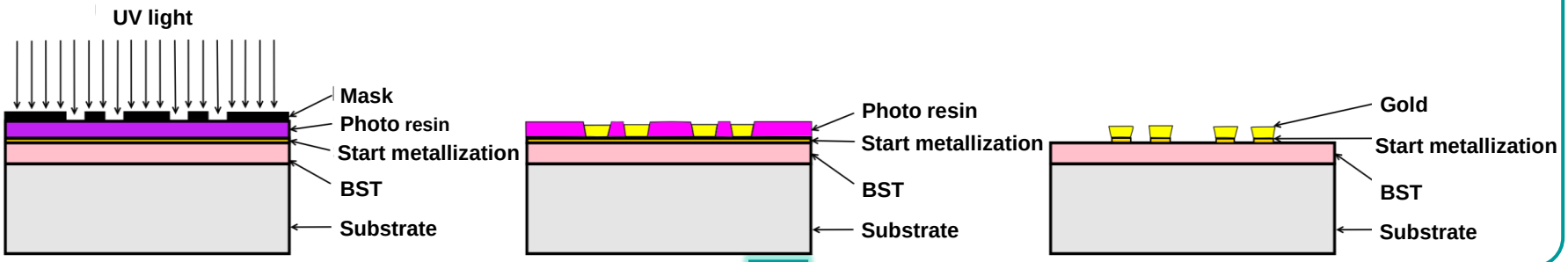






Dielectric characterisation of thick films

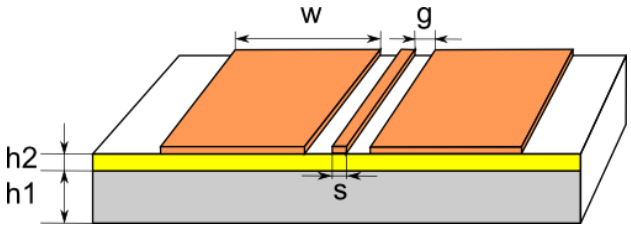
Processing of Coplanar Wave Guides (CPW)



Scattering paramters S_{ij}

$$b_1 = s_{11} \cdot a_1 + s_{12} \cdot a_2$$

$$b_2 = s_{21} \cdot a_1 + s_{22} \cdot a_2$$



w = 300 µm

g = 10 - 20 µm

s = 10 µm

h2 = 4 - 8 µm

Analytical model

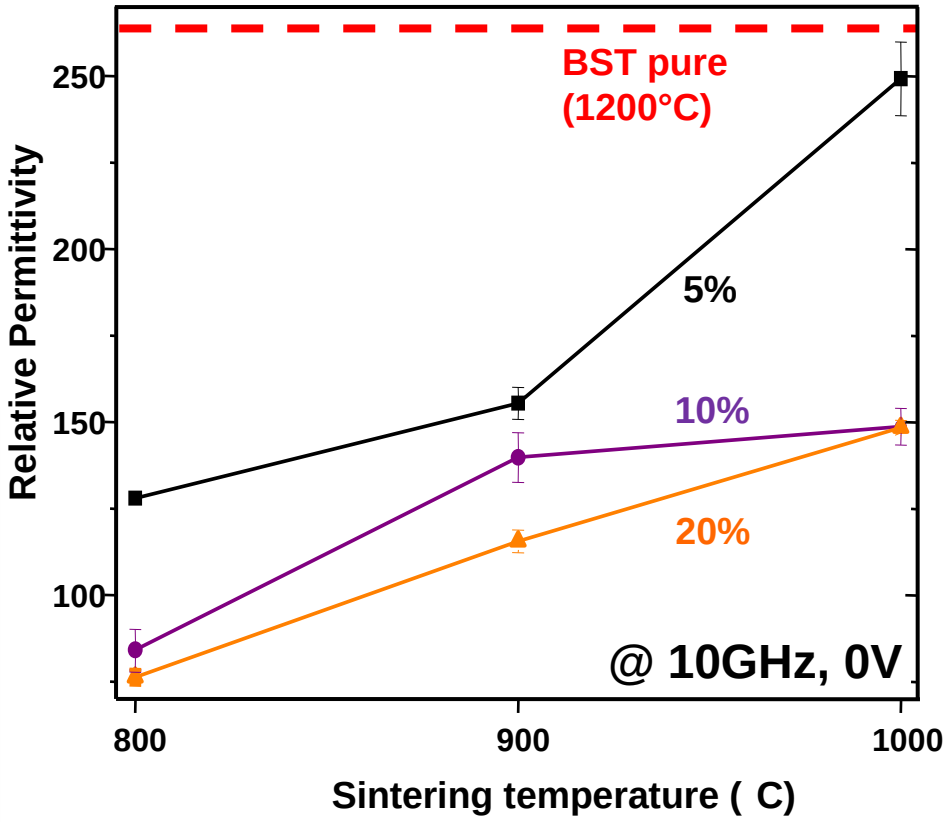
Permittivity ε_r
(f = 2 - 20 GHz)

Dielectric loss $\tan\delta$
(f = 2 - 20 GHz)

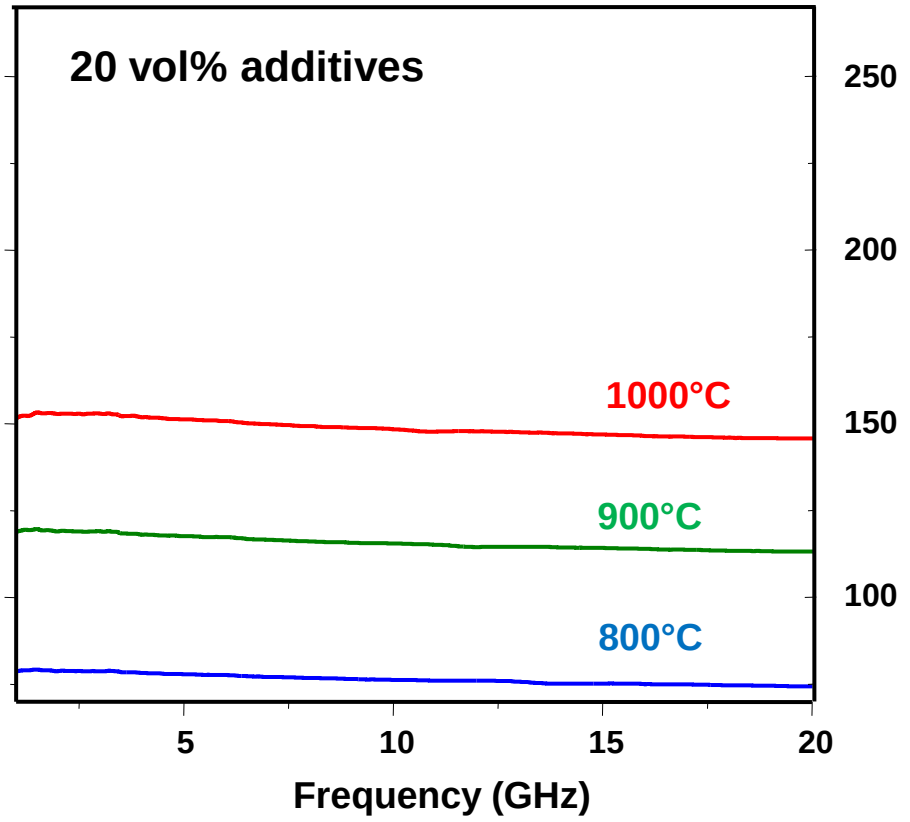
Tunability $\tau(E)$
(E = 0 - 10 V/µm)

Permittivity

Permittivity vs. Sintering temperature

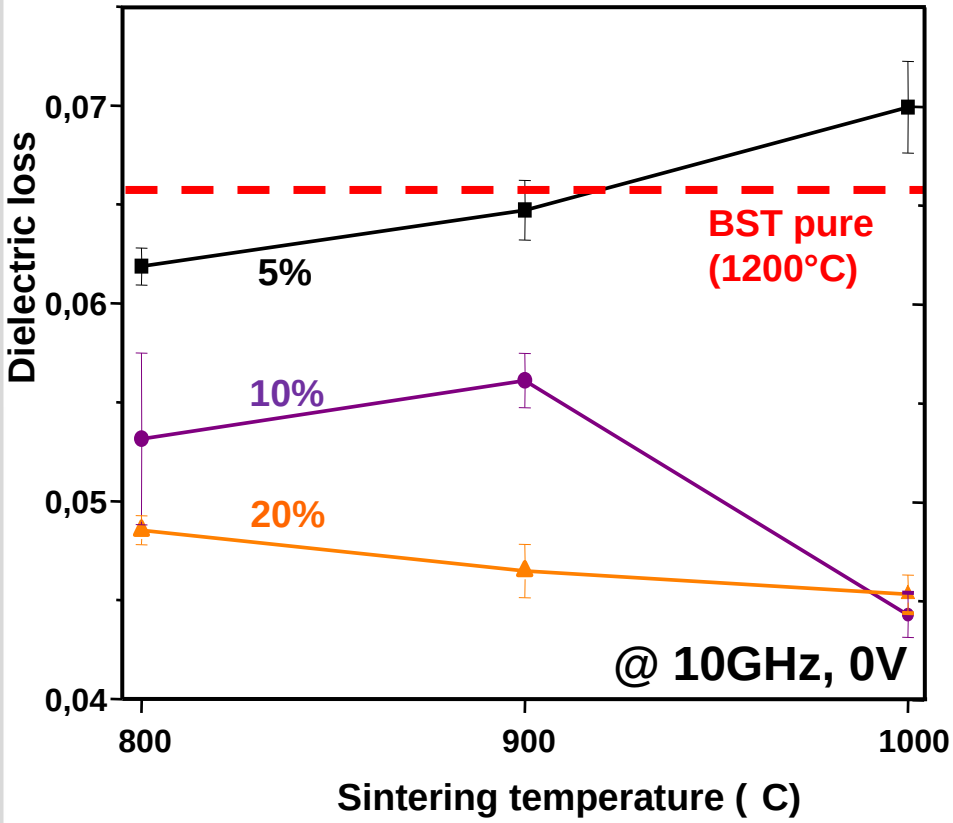


Permittivity vs. Frequency

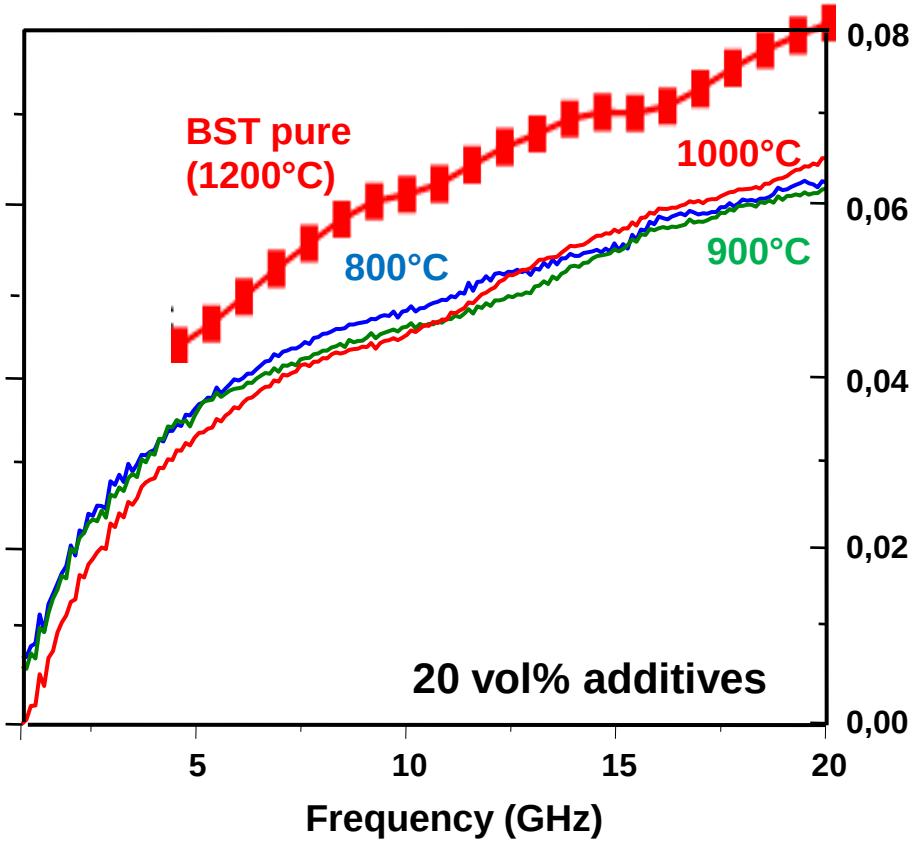


Dielectric loss

Dielectric loss vs. Sintering temperature

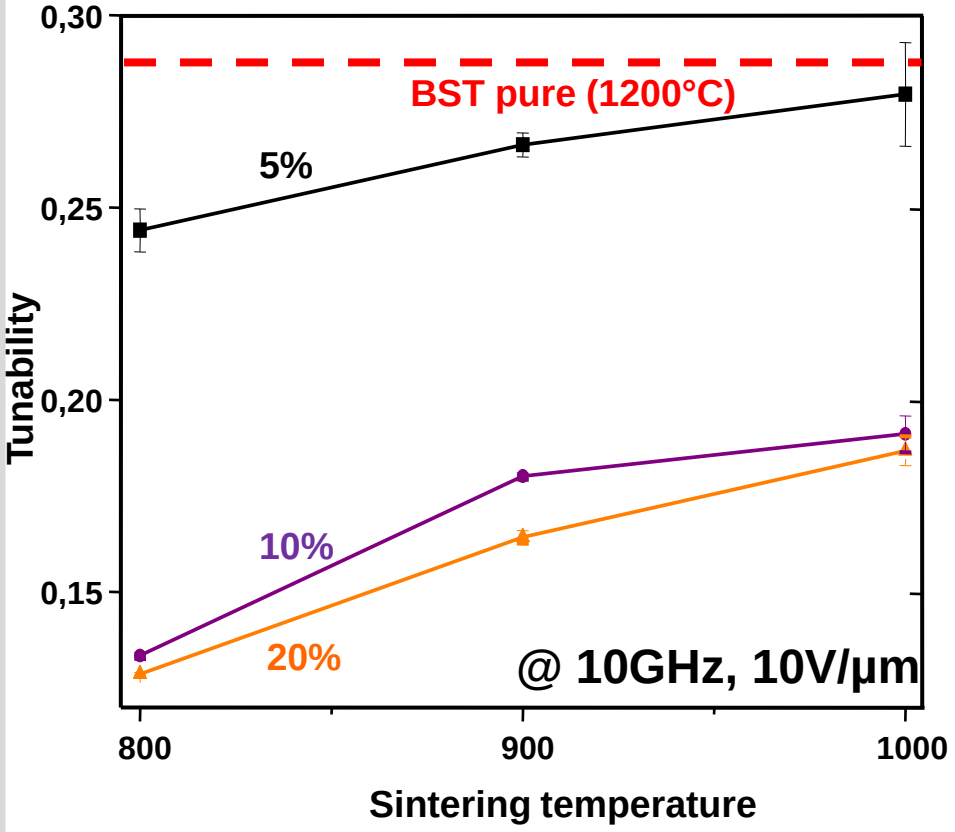


Dielectric loss vs. Frequency

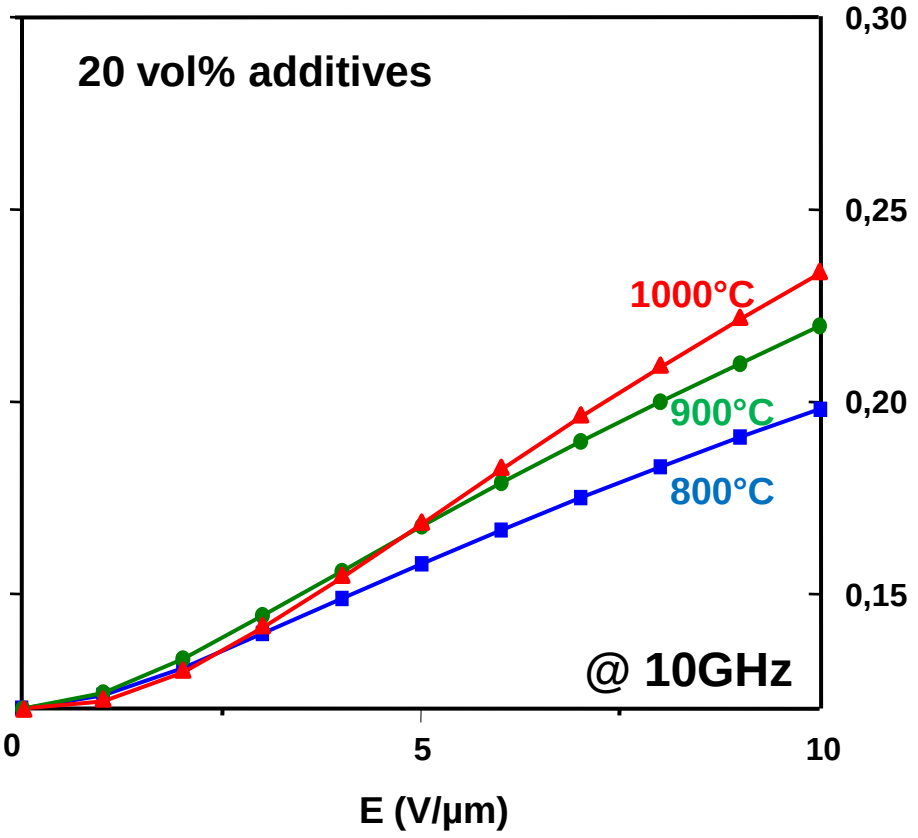


Tunability

Tunability vs. Sintering temperature



Tunability vs. E-Field



Summary

- Lowering sintering temperature achieved
- Low formation of secondary phases
- Trends in microstructure and dielectric properties
- Comparable dielectric data to undoped BST thick film without addition (sintered at 1200°C)

Outlook

- (Co-)Doped BST thick films with ZnO/H_3BO_3-additions
- Compatibility with LTCC substrates?
- Co-sintered MIM-Devices