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Preparation of integrated passive microwave devices through inkjet printing

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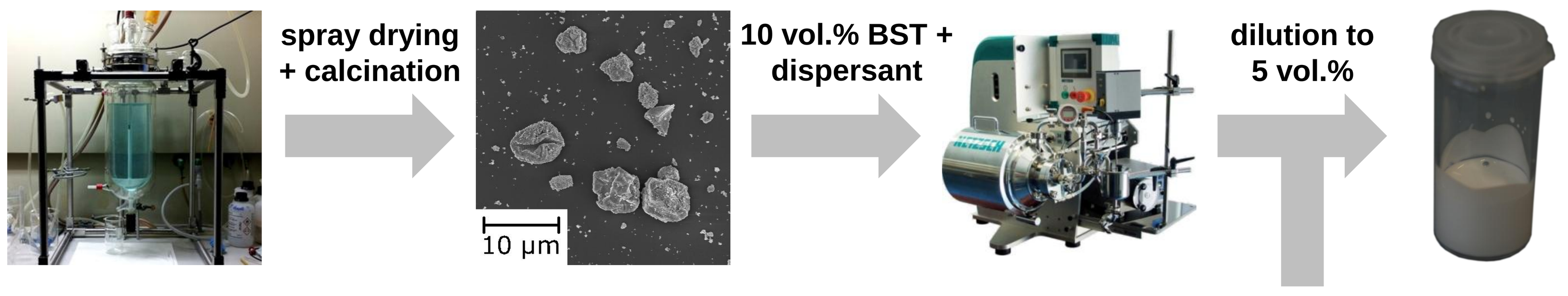
Introduction

Inkjet printing is the most frequently used digital technique for graphic printing. Currently, there is also a large interest in using inkjet printing for the manufacturing of functional components such as electronic devices or sensor systems. This is due to the fact that inkjet printing is a contactless process and does not require a printing mask. Hence, it allows a cheap and flexible production of two- and three-dimensional structures on a wide variety of substrates.

Ferroelectric ceramics are promising materials for passive tunable devices such as phase shifters, tunable matching networks, tunable filters and tunable antennas [1,2]. Currently, most attention is given to the solid solution $Ba_xSr_{1-x}TiO_3$ (BST).

This publication covers the development of BST inks for the inkjet printing of passive tunable microwave components.

Ink preparation and ink properties



Material: $Ba_{0.6}Sr_{0.4}TiO_3$ (*composite:* +0.75 wt.% ZnO, +0.65 wt.% B_2O_3)
Solvent: butyl diglycol

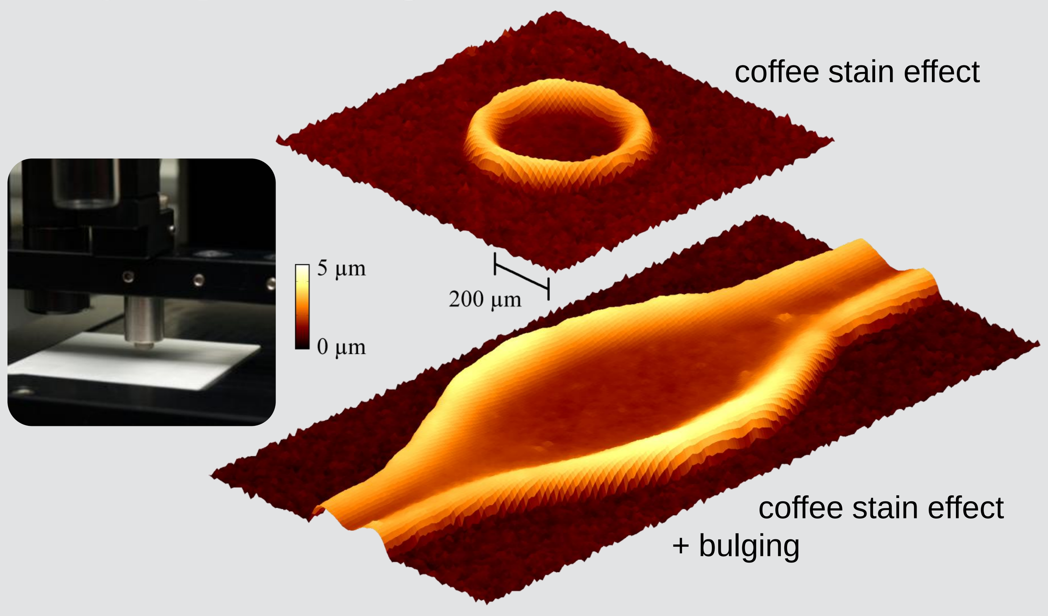
+ 1 vol.% ethyl cellulose
+ 49 vol.% isopropyl alcohol
(optimized ink composition [3])

Ink properties:

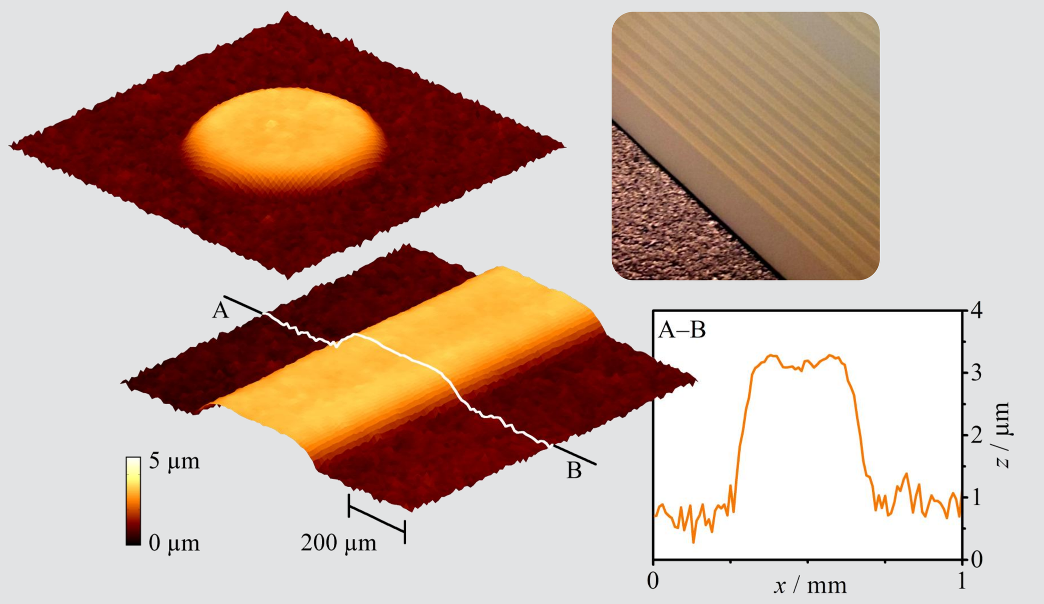
	d_{50} (nm)	η (mPa·s)	ρ (g/cm³)	γ (mN/m)	*Oh*
BST ink	270	22.7	1.11	24.4	0.44
BST–ZnO–B_2O_3 ink	200	34.0	1.08	23.9	0.67

Material and process development

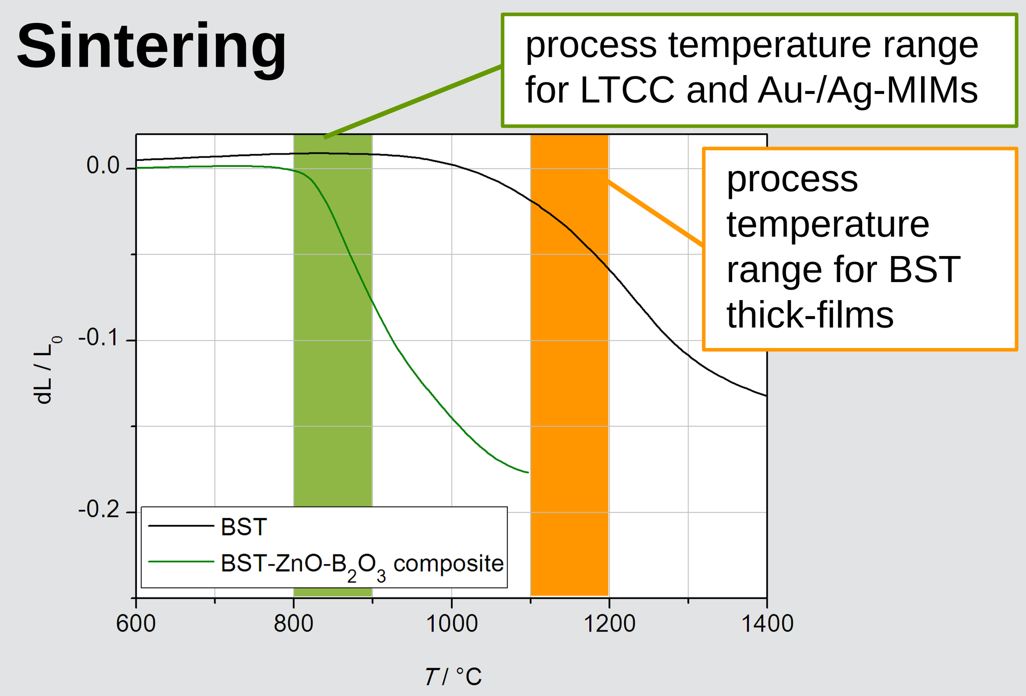
Inkjet printing of initial ink



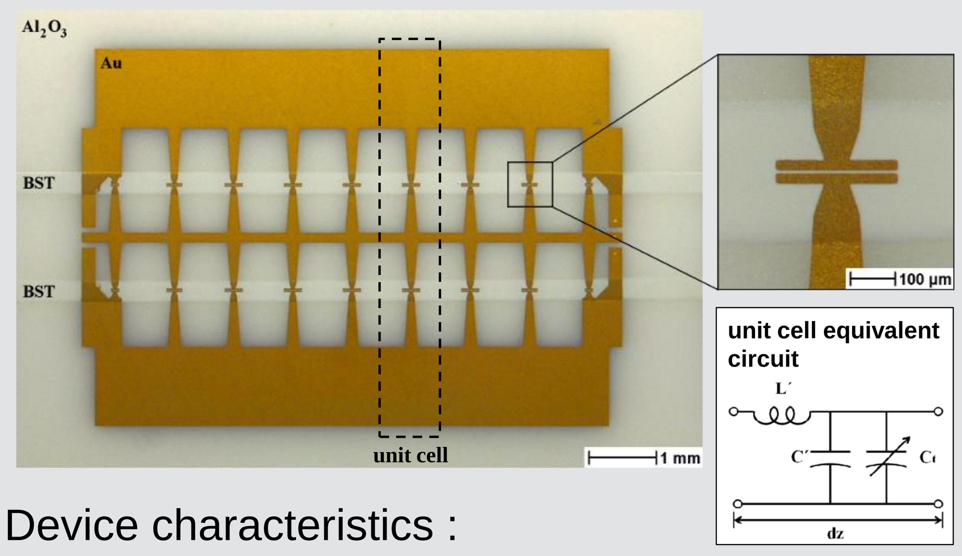
Optimized ink composition



Sintering

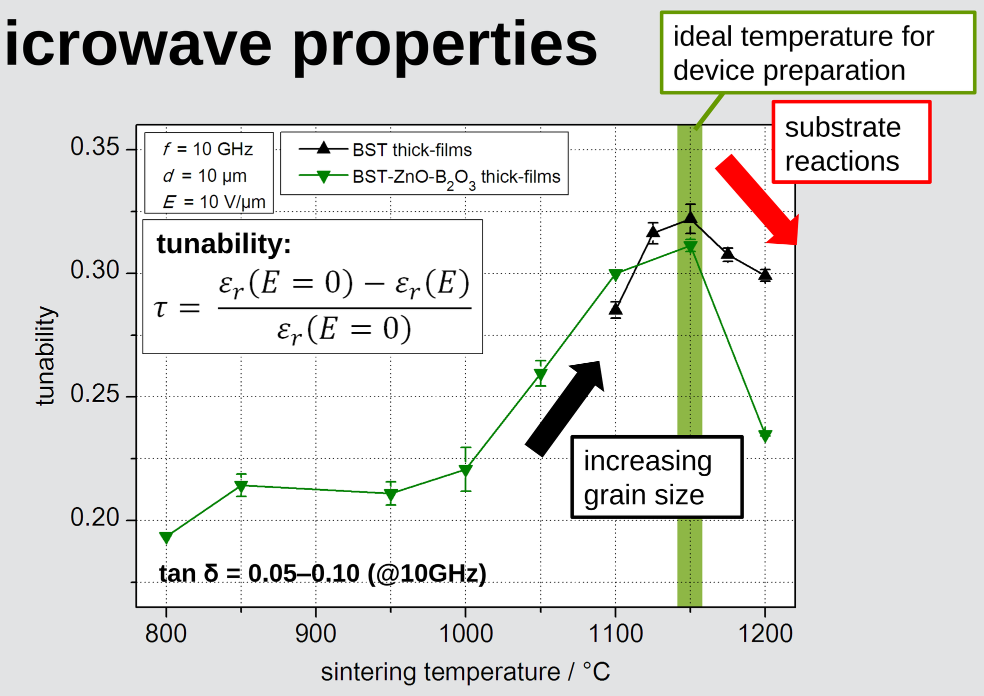


Loaded line phase shifter



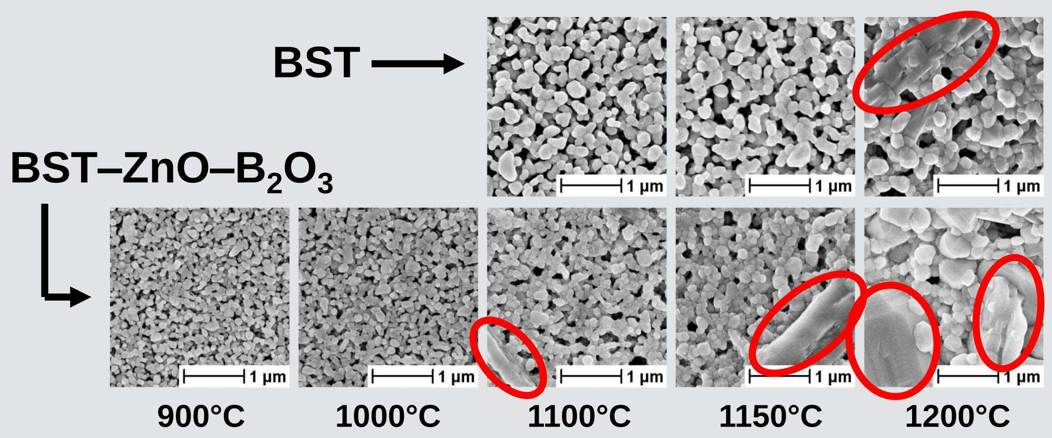
Device characteristics :
$\Delta\varphi$ = 170°, FoM = 20°/dB (@10 GHz)

Microwave properties



$$\tau = \frac{\varepsilon_r(E=0) - \varepsilon_r(E)}{\varepsilon_r(E=0)}$$

Microstructure

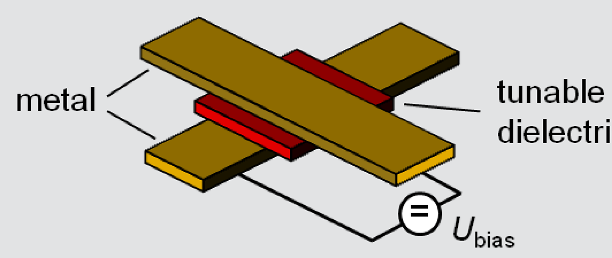


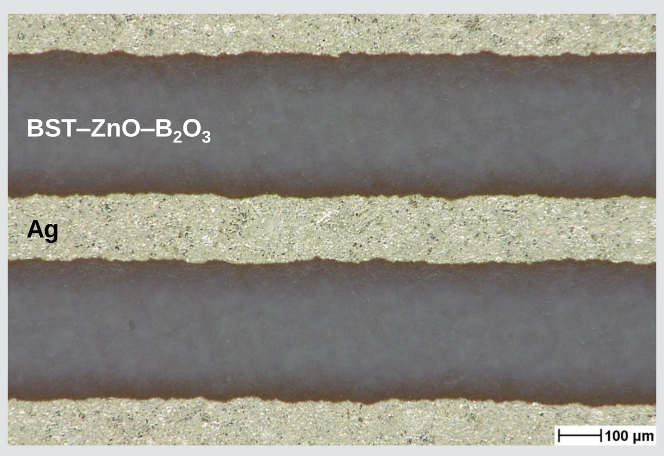
○ substrate reactions
(also observed in the XRD-patterns)

Outlook

MIM preparation

Aim: low-cost passive tunable microwave devices through multilayer printing and co-firing





Inkjet printed BST–ZnO–B_2O_3 thick-films on a screen printed Ag thick-film, sintered at 850°C

Multilayer capacitor with evaporated Au top-electrode:
→ Tunability: τ = 30% (@ 40 V, 3 GHz) ✓

References:
[1] A.K. Tagantsev et al., “Ferroelectric materials for microwave tunable applications”, *J. Electroceram.*, Vol. 11, No. 1–2, pp. 5–66, 2003
[2] S. Gevorgian, “Ferroelectrics in Microwave Devices, Circuits and Systems”, first edition, Springer, London, 2009
[3] A. Friederich et al., “Rheological control of the coffee stain effect for inkjet printing of ceramics”, *J. Am. Ceram. Soc.* (accepted)

Conclusions

Two barium strontium titanate (BST) inks were prepared, printed on alumina substrates and sintered at different temperatures. The microstructure of the thick-films reveals the evolution of grain growth with increasing temperature. A reaction with the substrate was observed for both inks at high sintering temperatures. The optimal microwave properties were achieved at a sintering temperature of 1150°C.

A coplanar tunable loaded line phase shifter was prepared on the inkjet printed BST thick-films to demonstrate the suitability for conventional microwave device preparation.

The investigated BST–ZnO–B_2O_3 composition allows sintering below 900°C. First experiments with co-fired inkjet printed BST–ZnO–B_2O_3 on screen printed Ag thick-films confirm the suitability of the composition for the preparation of metal–insulator–metal (MIM) devices.