Characterization of Inkjet Printed Polymer/Ceramic Composite Thick Films

M. Mikolajek[1], A. Friederich[1], C. Kohler[1], A. Rathjen[2], K. Krüger[2], J. R. Binder[1]

[1] Institute for Applied Materials (IAM), Karlsruhe Institute of Technology

[2] Institute of Automation Technology, Helmut Schmidt University Hamburg

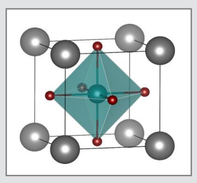
Motivation

Inkjet printing is a promising technology for the selective deposition of functional components for the fabrication of electronic devices, such as capacitors. Ferroelectric ceramics like barium strontium titanate (BST) are widely used as dielectric materials, but require high temperature sintering. Besides ferroelectric ceramics, organic polymers are often used as dielectric materials. In contrast to ceramics, they are known for high mechanical flexibility and low temperature requirement, but also for low permittivity. A promising method to overcome the drawbacks of both material classes is the combination of both types in polymer-matrix composites.

This poster displays the preparation of composite thick films via inkjet printing in one process step. The use of a composite ink allows process temperatures below 150 °C and therefore printing on flexible substrates. The ink development is shown, as well as its printability. Therefore, the topography of printed structures on different substrates are displayed. Finally, the fabrication of all-inkjet-printed MIM capacitors is shown.

Ink Preparation and Ink Properties

BST dispersion

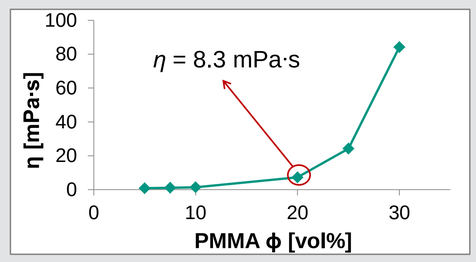


$Ba_{0,6}Sr_{0,4}TiO_3$

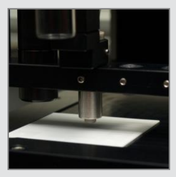
10 vol% BST
+ Butyldiglycol (BDG)
+ Dispersant[1]

2:1

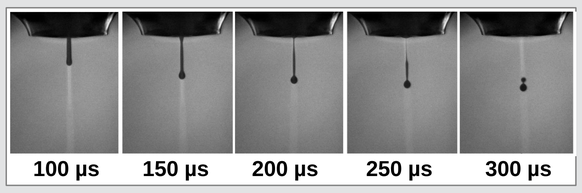
PMMA solution in butanone



	Solid content ϕ [vol%]	Density ρ [g/cm³]	Viscosity η [mPa·s]	Surface tension σ [mN/m]
BST dispersion	10	1.40	12.9	29
PMMA solution	20	0.88	8.3	24
Composite ink	13	1.24	10.8	25

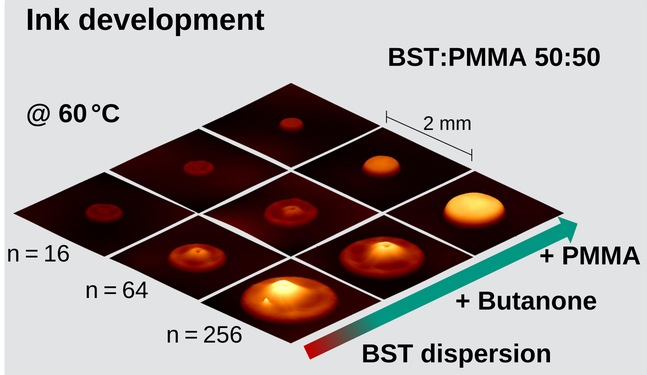


***Oh* = 0.2**
U_{head} = 90 V
t_{Head} = 30 µs
T_{head} = 25 °C



Inkjet Printed BST/PMMA Composite Structures

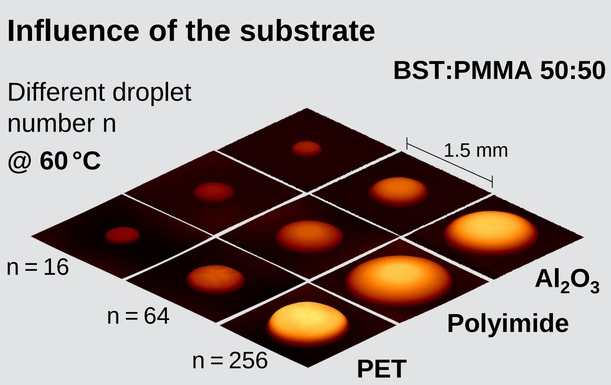
Ink development



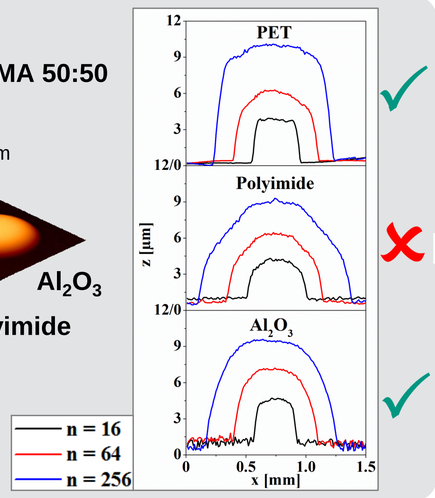
Butanone evaporates very fast

➢ Rapid increase in viscosity

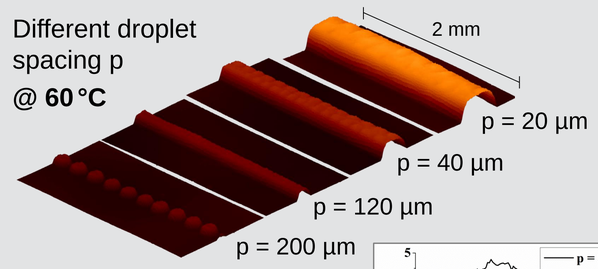
Influence of the substrate



No coffee stain effect!

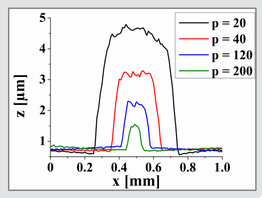


Printed line structures on PET



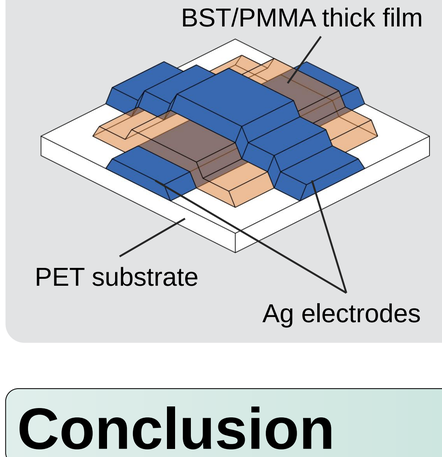
Suitable for

- Structures of different size
- Lines with varying width and height

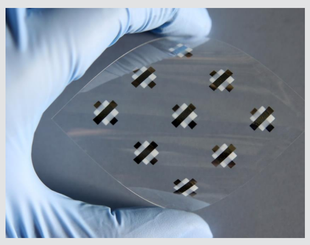


Flexible All-Inkjet-Printed Metal-Insulator-Metal Capacitors

Capacitor layout



Printed capacitors



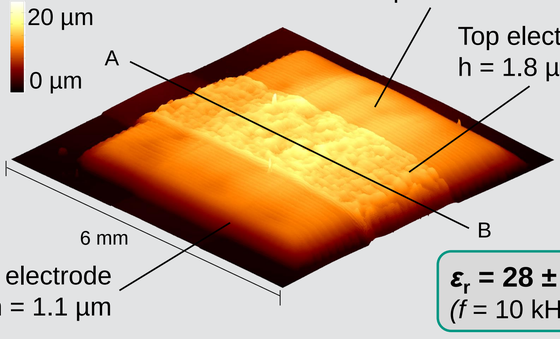
Using a commercial Ag nanoink

Layer structure

2 layer BST/PMMA 50:50
2 layer bottom electrode
3 layer top electrode

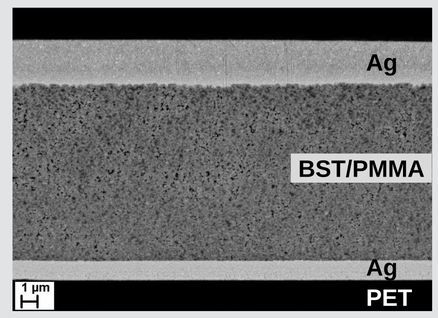
Thermal treatment:
1 h @ 140 °C

Topography



$\varepsilon_r = 28 \pm 1.7$
(f = 10 kHz)

Cross sectional image



Conclusion

This poster displays the preparation of composite thick films via inkjet printing in one process step. Therefore, a barium strontium titanate (BST) dispersion was prepared and combined with a highly loaded PMMA solution to obtain an ink with a 50:50 volume ratio of BST and PMMA. The ink characteristics and printability were investigated, in particular the drying behavior of the ink on different substrates and the topography of the composite structures. It is shown that the coffee stain effect was successfully suppressed and that homogeneous composite layers were achieved. Afterwards, all-inkjet-printed MIM capacitors were fabricated, using the developed composite ink.

Acknowledgement

This work was supported by grants from the Deutsche Forschungsgemeinschaft
(BI 1636/1-1; KR 1851/5-1)

Literature:
[1] A. Friederich et al., “Rheological control of the coffee stain effect for inkjet printing of ceramics”, *J. Am. Ceram. Soc.* 96.7 (2013)