

Properties of $\text{Ba}_{0.6}\text{Sr}_{0.4}\text{TiO}_3$ based Coplanar and MIM Varactors

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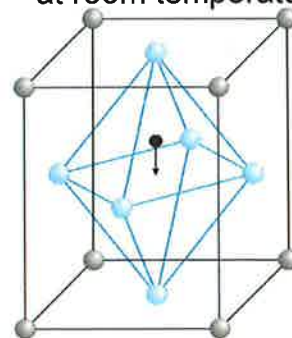
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Varactors – motivation / theory

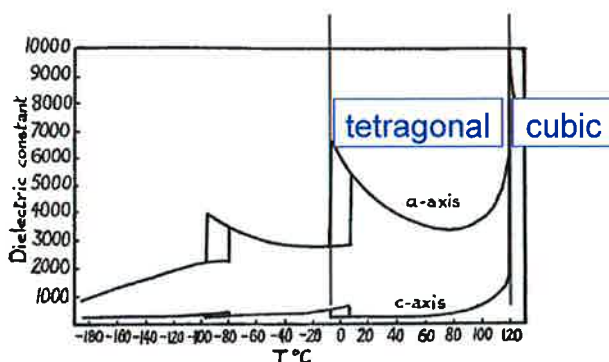
■ Barium-titanium-oxide (BT)

- Perovskite structure
- general formula ABO_3

unit cell of BaTiO_3
at room temperature



- A ion (Ba^{2+})
- B ion (Ti^{4+})
- oxygen ion (O^{2-})

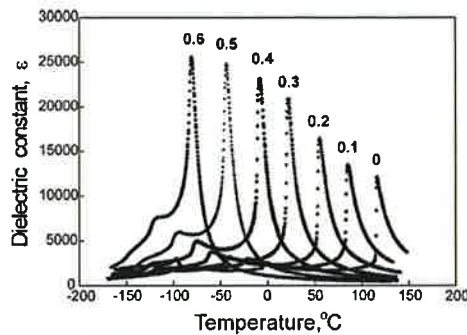
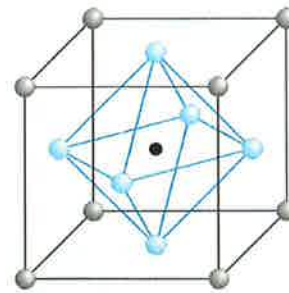


Devonshire, Philosophical Magazine Series 7, 40, (1949)

■ Barium-titanium-oxide (BT)

- Perovskite structure
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unit cell of $Ba_{0.6}Sr_{0.4}TiO_3$
at room temperature



BST ($Ba_{1-x}Sr_xTiO_3$)

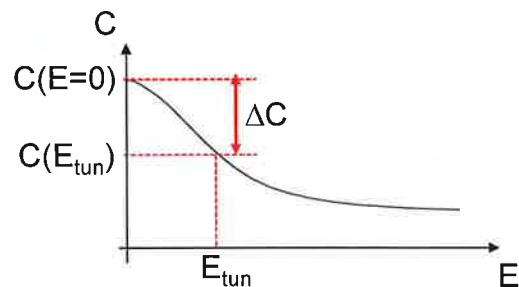
- substitution of Ba^{2+} by Sr^{2+}
- $SrTiO_3$ completely miscible in $BaTiO_3$
→ shift of the phase transition

Jeon, Journal of the European Ceramic Society, 24, 6 (2004)

■ BST as tunable dielectric

- tuning of capacitance/permittivity by an electrical field

$$\tau = \frac{\Delta C}{C(E=0)} = \frac{(C(E=0) - C(E_{tun}))}{C(E=0)}$$

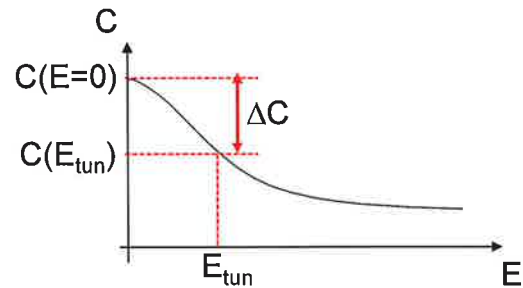


Varactors – motivation / theory

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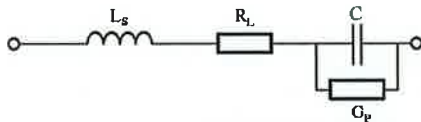
- tuning of capacitance/permittivity by an electrical field

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- loss factor of varactor

$$\frac{1}{Q} = \tan \delta$$

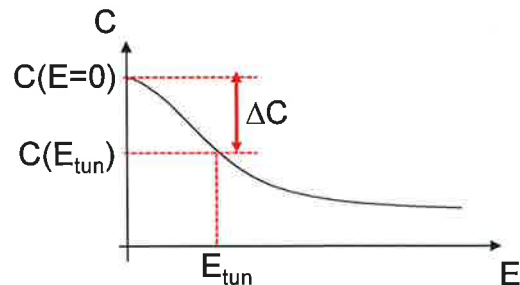


Varactors – motivation / theory

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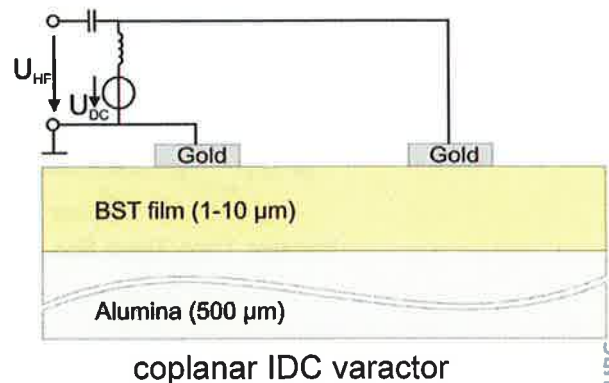
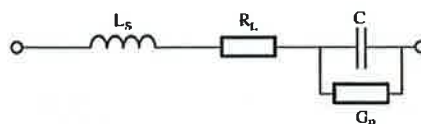
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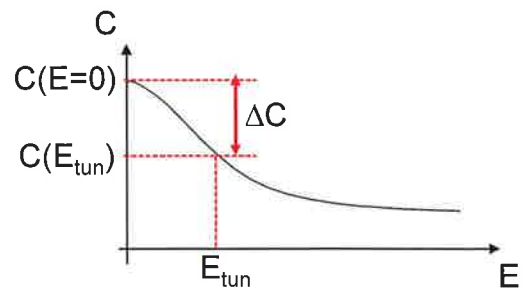
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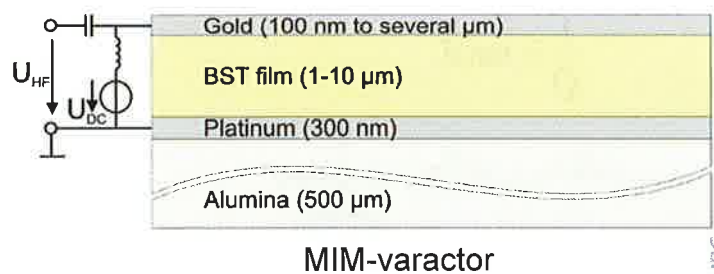
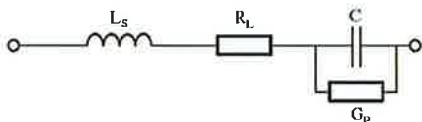
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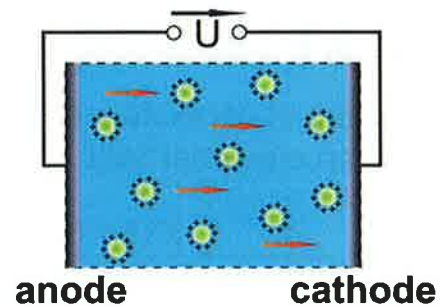
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EPD – motivation / theory

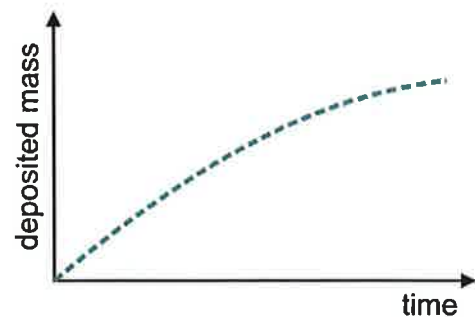
■ Characteristics

- films derived from suspensions
- deposition enforced by electrical field
- high homogeneity of green body
- predictable thickness of films



$$m = c_{solid} \mu \cdot \frac{A_{electr} U \cdot t}{d_{electr}}$$

Hamaker, Trans. Farad. Soc., (1940)



Experimental results - processing of films

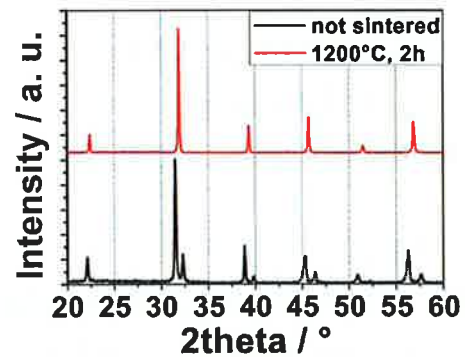
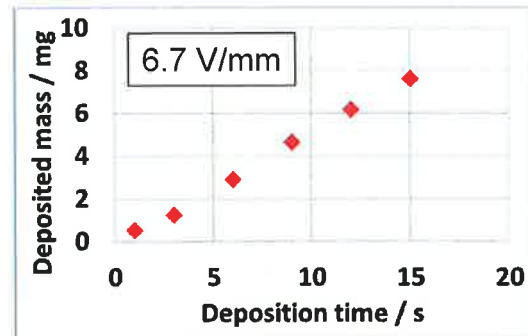


Film thickness specified by

- electrical field
- deposition time

Cofiring

- powder mixture (60 % BaTiO₃, 40 % SrTiO₃)
- 2 h @ 1200°C
- BST formed by interdiffusion of BaTiO₃ and SrTiO₃



Experimental results - MIM varactors vs. IDC varactors

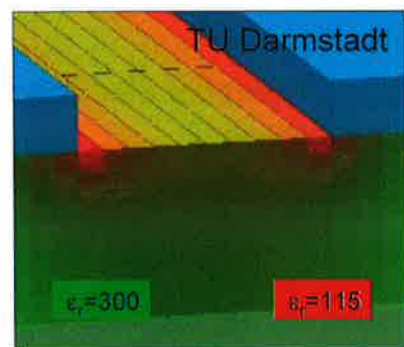
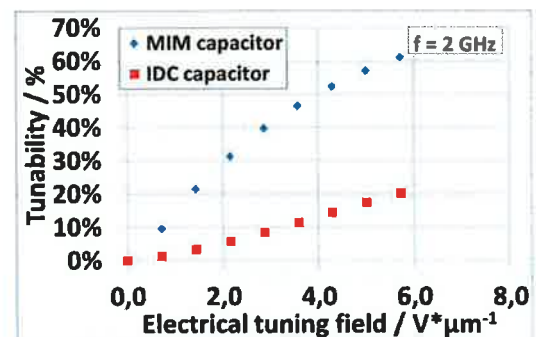


Tuning field

- IDCs: Inhomogenous field distribution
- MIMs: Homogenous field distribution

Tunability

- up to 60 % at 5 V/μm for MIMs
- good linearity
- MIMs homogeneously tuned
- MIMs superior to IDCs



Experimental results - MIM varactors vs. IDC varactors



Tuning field

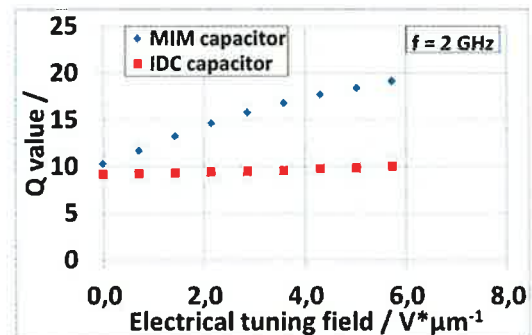
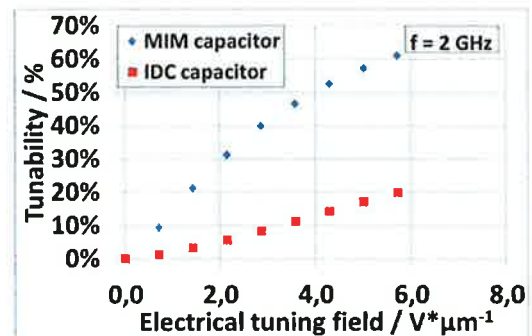
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Q value

- about 10 without tuning field
- increase with tuning field (MIMs)



Experimental results - MIMs: Electrodes

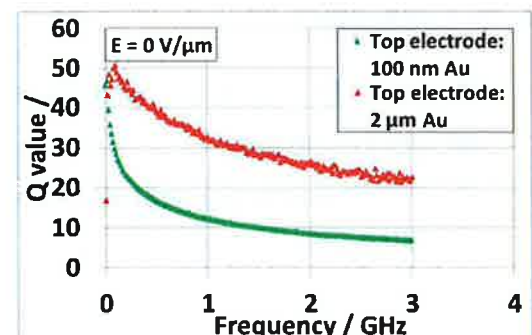
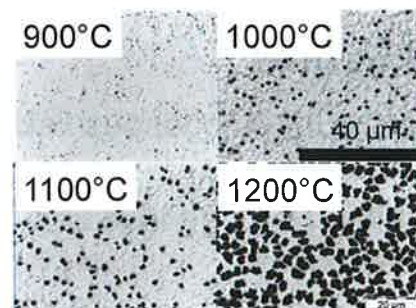


Bottom electrode

- 300 nm platinum
- degradation during sintering

Top electrode

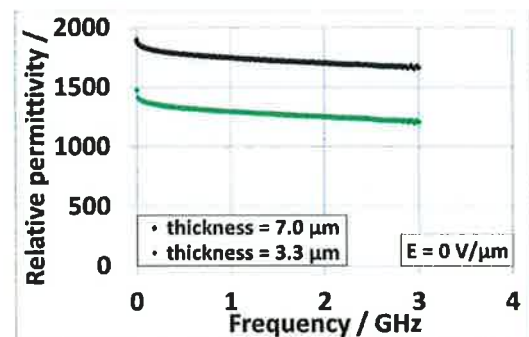
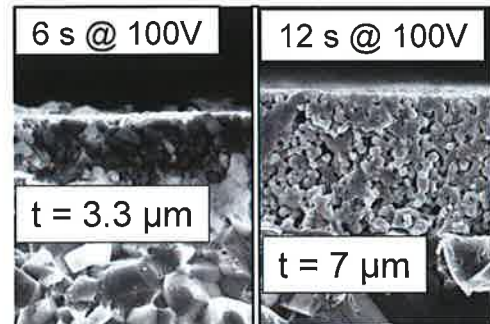
- galvanically reinforced
- increase of Q from 8 to 26 at 2 GHz
- strong impact of electrode thickness on Q



Experimental results - MIMs: Film thickness of BST

■ Permittivity

- decreases slightly with frequency
- decreases with decreased film thickness
- defects in platinum electrode: Reaction between BST and substrate



Conclusions

- **BST is a promising tunable dielectric**
- **Preparation of BST thick films (1 – 10 μm) via EPD codeposition and cofiring process of BaTiO_3 and SrTiO_3**
- **MIM structures superior to IDC structures**
- **Degradation of the bottom electrode (thermal budget)**
- **Strong influence of electrodes on dielectric properties**

Acknowledgement



- DFG for funding

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- In cooperation between

- University of Freiburg / IMTEK - WPT
- Karlsruhe Institute of Technology (KIT – IAM)
- Technical University of Darmstadt (TU Darmstadt – IMP)



Thank you for your attention