Inkjet Printed BST Thick-Films for X-Band Phase Shifter and Phased Array Applications

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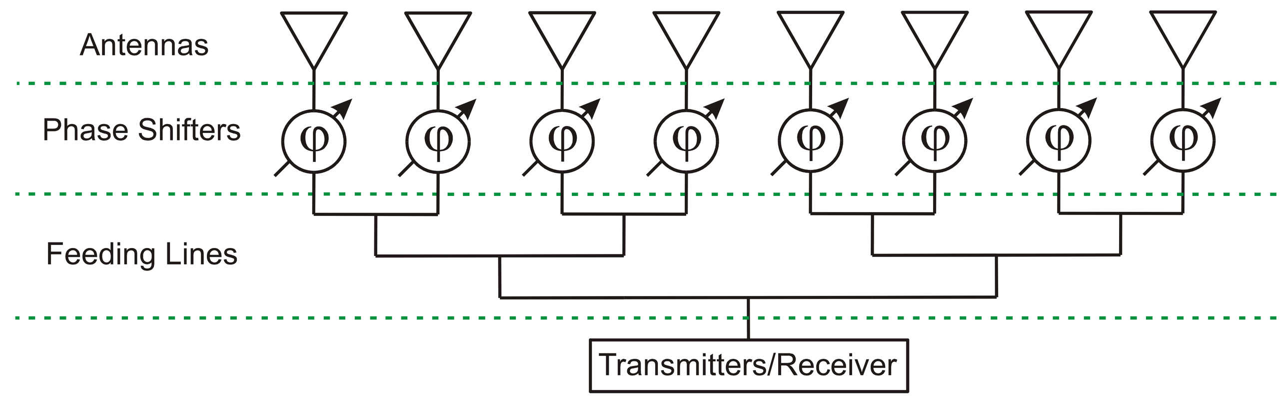
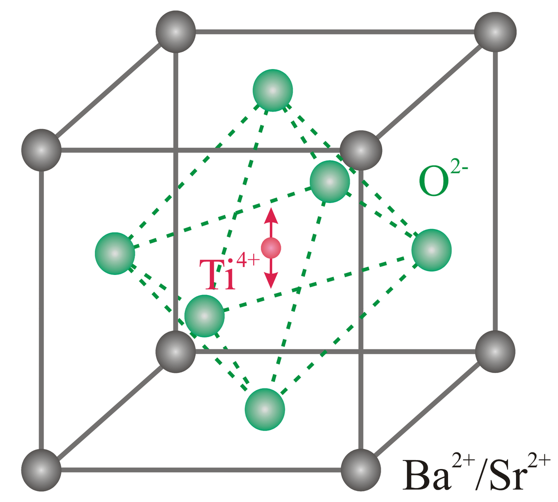
Motivation

The phased array antenna consists of:
- Feeding network
- Phase shifters
- Antennas



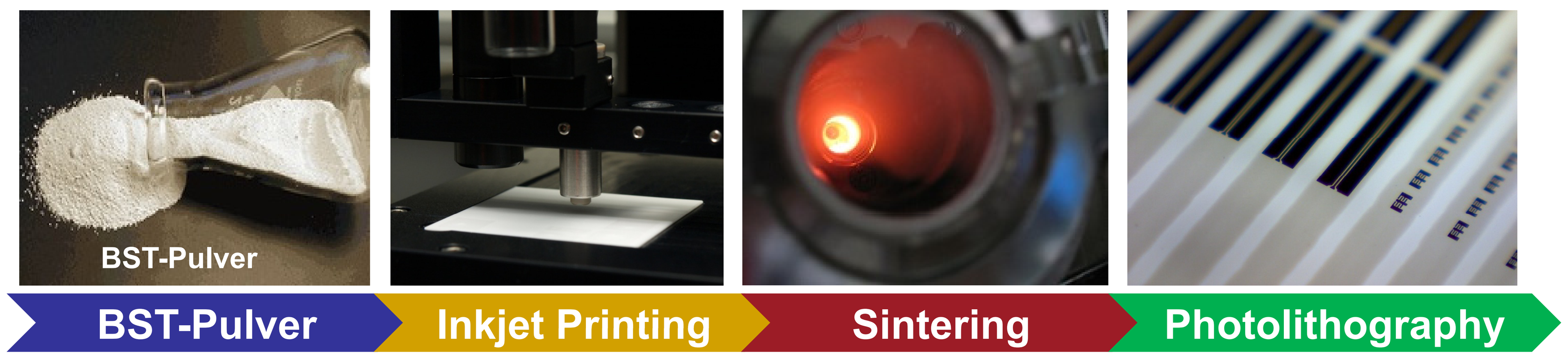
Ferroelectric material:
Barium-Strontium-Titanate (BST)
- Low power consumption
- High tuning speed
- High linearity
- Adequate dielectric loss



- System performance is depended on the insertion loss of the feeding network and the phase shifters
- A tunable compact phase shifter can reduce the total size
- The kernel elements in the phase shifters are varactors
- Different technologies to fabricate tunable varactors: semiconductor, MEMS, ferroelectric, liquid crystal and ferrite

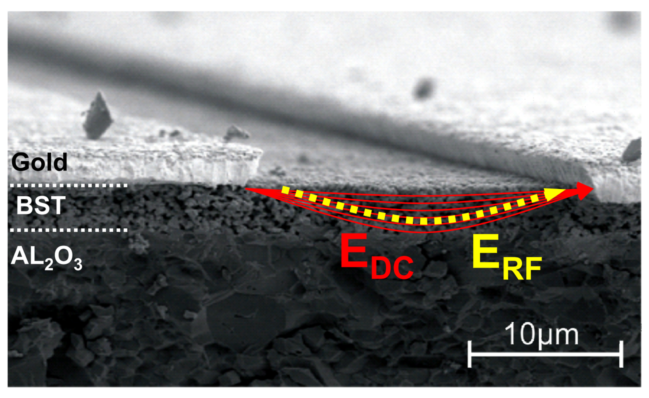
Inkjet Printing of BST

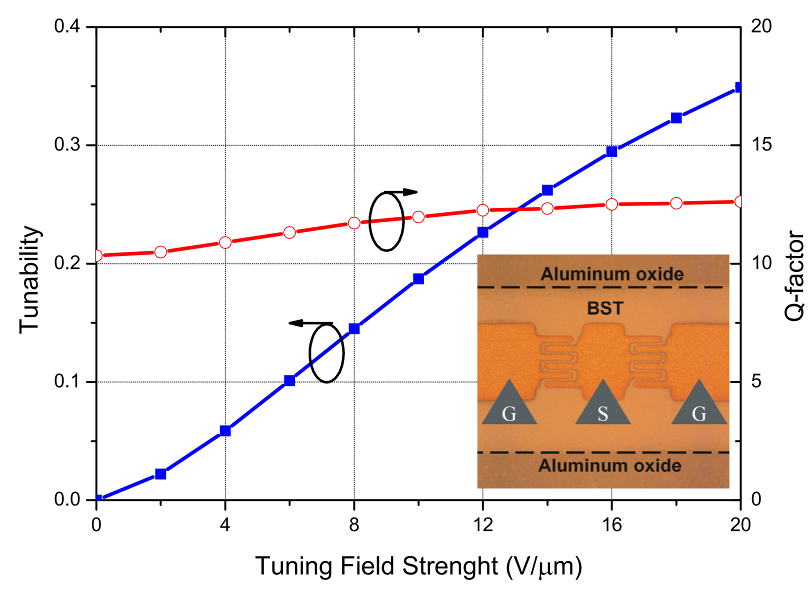
Inkjet printing technology:
- Selective printing of BST material
- Flexible fabrication process
- Simultaneous multi material printing option
- Single nozzle printhead with 100µm orifice diameter



BST material Characterization by IDC
- Interdigital capacitors (IDC) measured by on-wafer probes
- The permittivity of the material changes from 220 (0V) to 140 (200V)
- By applying 20 V/µm a maximum tunability is 35%

Tunability
T(E)=ΔC(E)/C(0)



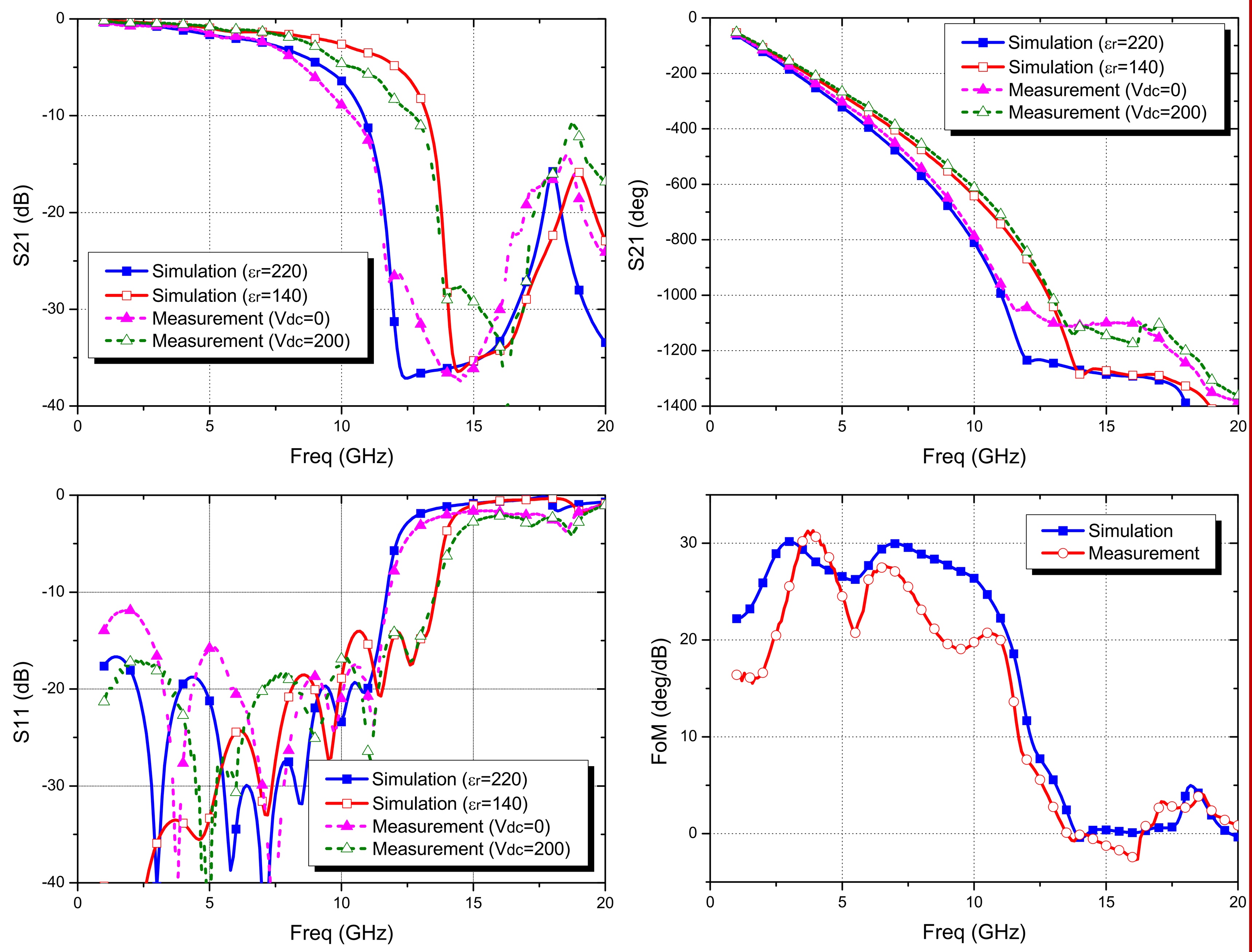


Characterization results at 10GHz

Simulation & Measurement

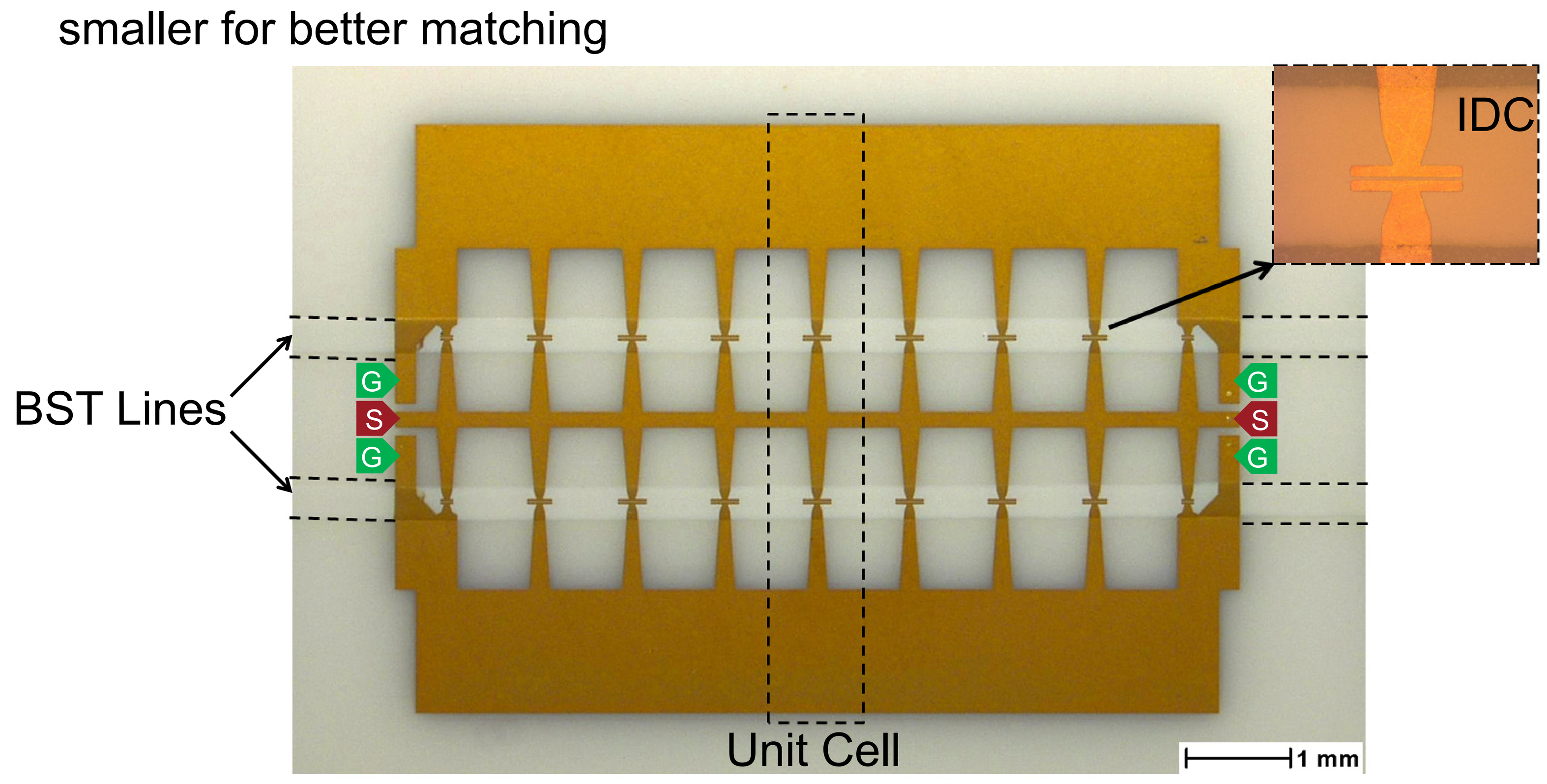
Simulation:
- The phase shifter designed for the frequency range of 8-10 GHz
- Agilent ADS simulation tool is used
- The tunable capacitors are designed on a substrate consisting of BST layer on top of an aluminum oxide substrate
- The permittivity of the BST layer changes between 220 to 140
- The gap width of the capacitors is 10µm
- Insertion loss decreases with the change in permittivity
- The transmitted phase can be tuned continuously

On-Wafer measurements results:
- Measurement in a 50 Ω system
- Tuning voltage applied by using Bias-T
- Tuning Voltage changed between 0 to 200 V
- The achieved phase shift at 10 GHz was 175° with a FoM of 20°/dB
- Higher losses than expected



Phase Shifter Realization

- Single photolithography process
- Top electrode: 2µm Gold by electroplating
- The BST strips have a thickness of 2.1µm and width of 300µm on top of an aluminum oxide with 635µm thickness
- The BST thick-film is printed at the areas beneath the interdigital capacitors
- Each phase shifter has 9 unit cells, each unit consist of two tunable capacitors
- The capacitance of the first unit cell at the input and output were chosen smaller for better matching



Conclusion

Inkjet printing BST thick-film
- A new method for tunable microwave components

Realization of a loaded line phase shifter
- The fabricated prototype exhibits a compact size (8mm × 6mm)
- Low current consumption (less than 0.1mA)

Further Work
- Increase FoM
  - Loss factor of the BST has to be reduced
- Using metal-insulator-metal capacitors
  - Reduce the biasing voltage
  - Increase the tunability

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