TUMA2

2D Scanner for Surface-Wise Measurements of Complex Permittivity of Emerging LTCC and ULTCC Materials

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QWED

(Booth #2245)

LTCC/ULTCC vs HTCC

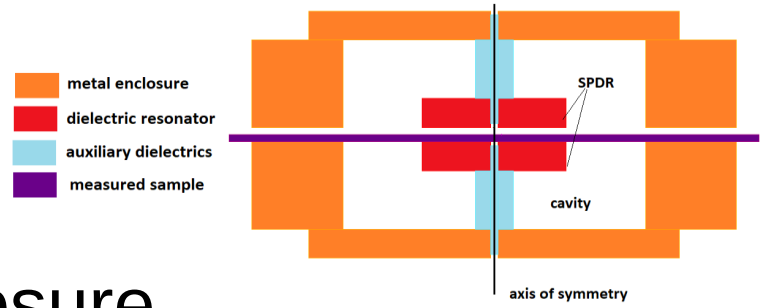
- Lowered sintering temperature (compared to HTCC) - keeping compatibility with existing fabrication methods
- Lowered energy consumption
- Lower production costs
- Environmental friendliness
- Application to demanding 5G and 6G systems
  - Telecommunication
  - Computer industry
  - Automotive industry

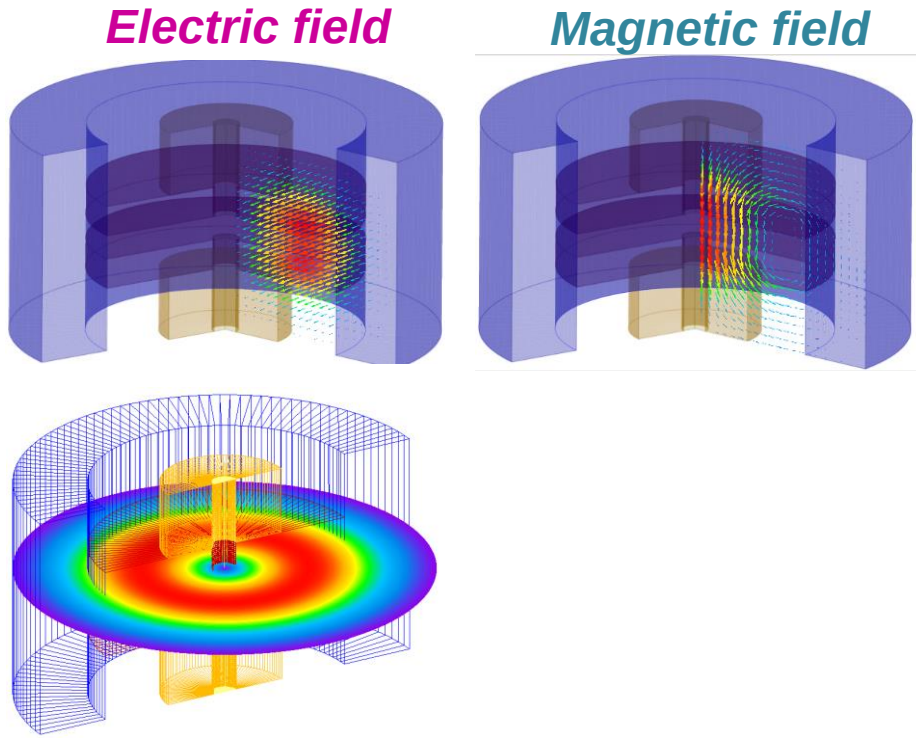
EM characterization

- Precise measurements of complex permittivity
- Point-wise measurements – typical
  - resonant methods are proven to be the most accurate
- Surface-wise testing - ?
- 2D maps of dielectric constant and loss tangent across material surface
- Important for high component packaging on single substrate

SPDR fixtures for materials testing

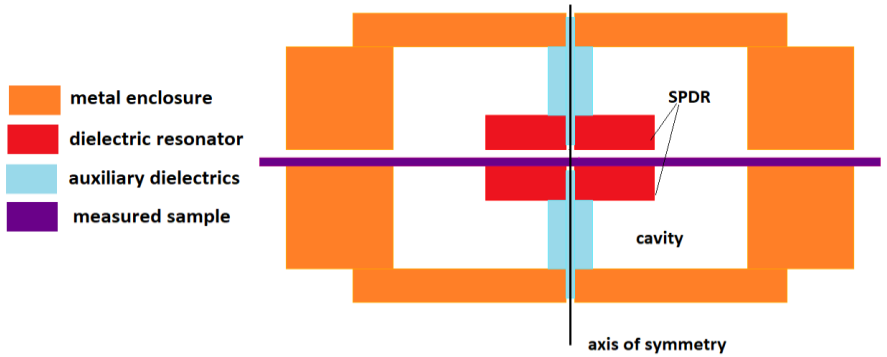
- Split-Post Dielectric Resonators (SPDRs)
- H-field is only vertical at the side wall of the enclosure
- E-field tangential to SUT
- Easy SUT insertion through slot
- Field patterns remain practically unchanged





SPDR fixtures for materials testing

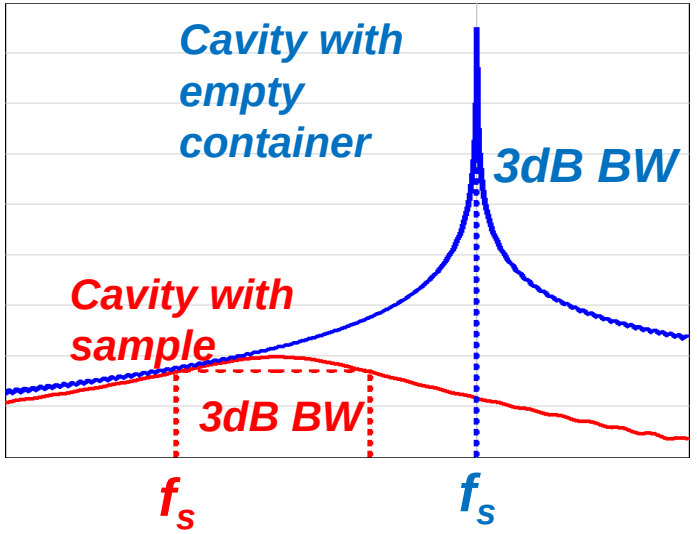
- Non-destructive measurement
- Resonant frequencies and Q-factors change, upon SUT insertion



SUT of $\varepsilon_s = \varepsilon_s' - j\,\varepsilon_s''$ *is inserted into DR:*

resonant frequency changes from f_e *to* f_s

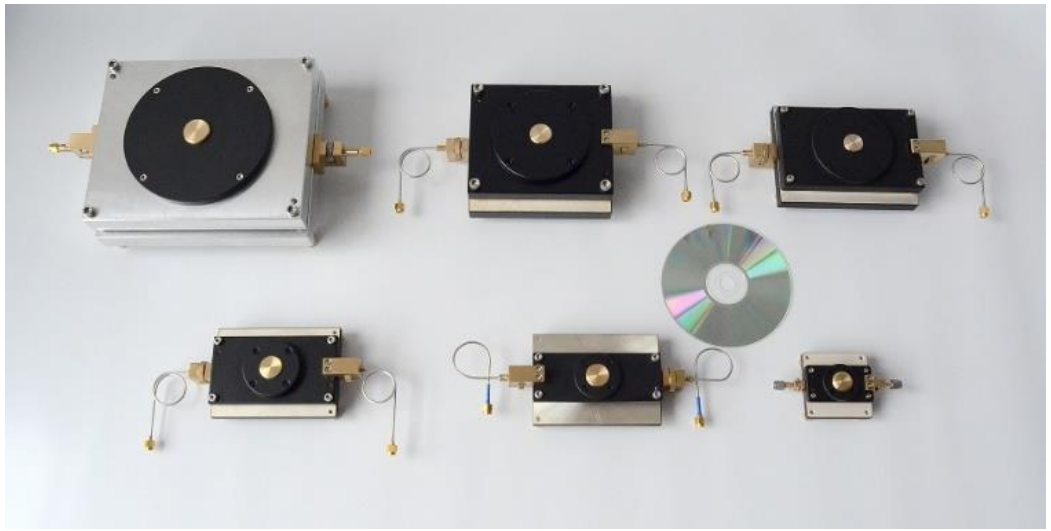
and Q-factor changes from Q_e *to* Q_s.



Transmission curve |S21|

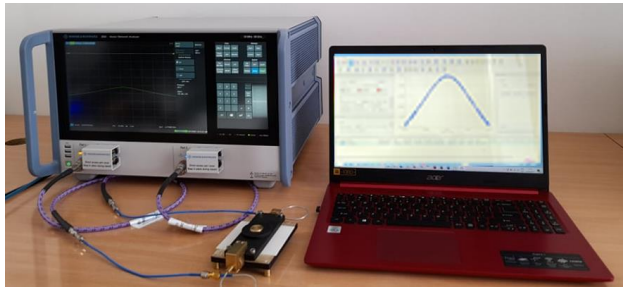
Point-wise measurement with SPDR

Family of SPDR test-fixtures

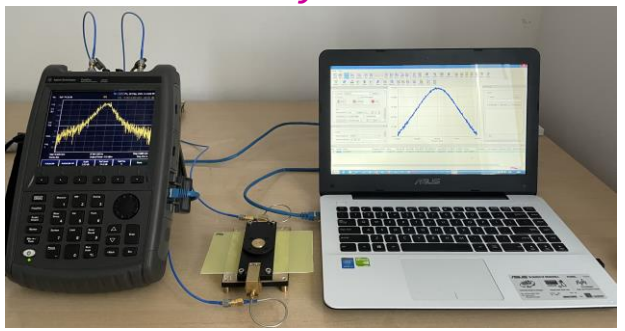


Devices covering 1 – 15 GHz

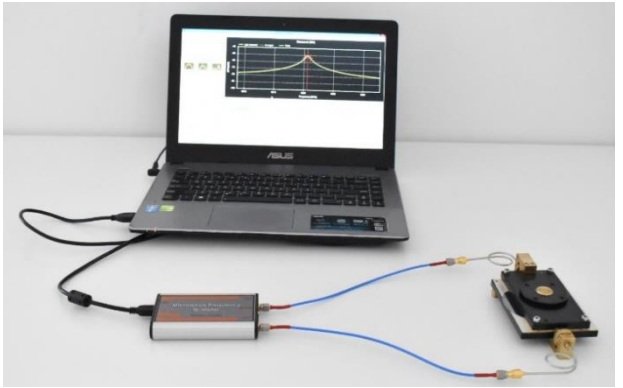
Measurement setups



Laboratory-scale VNA



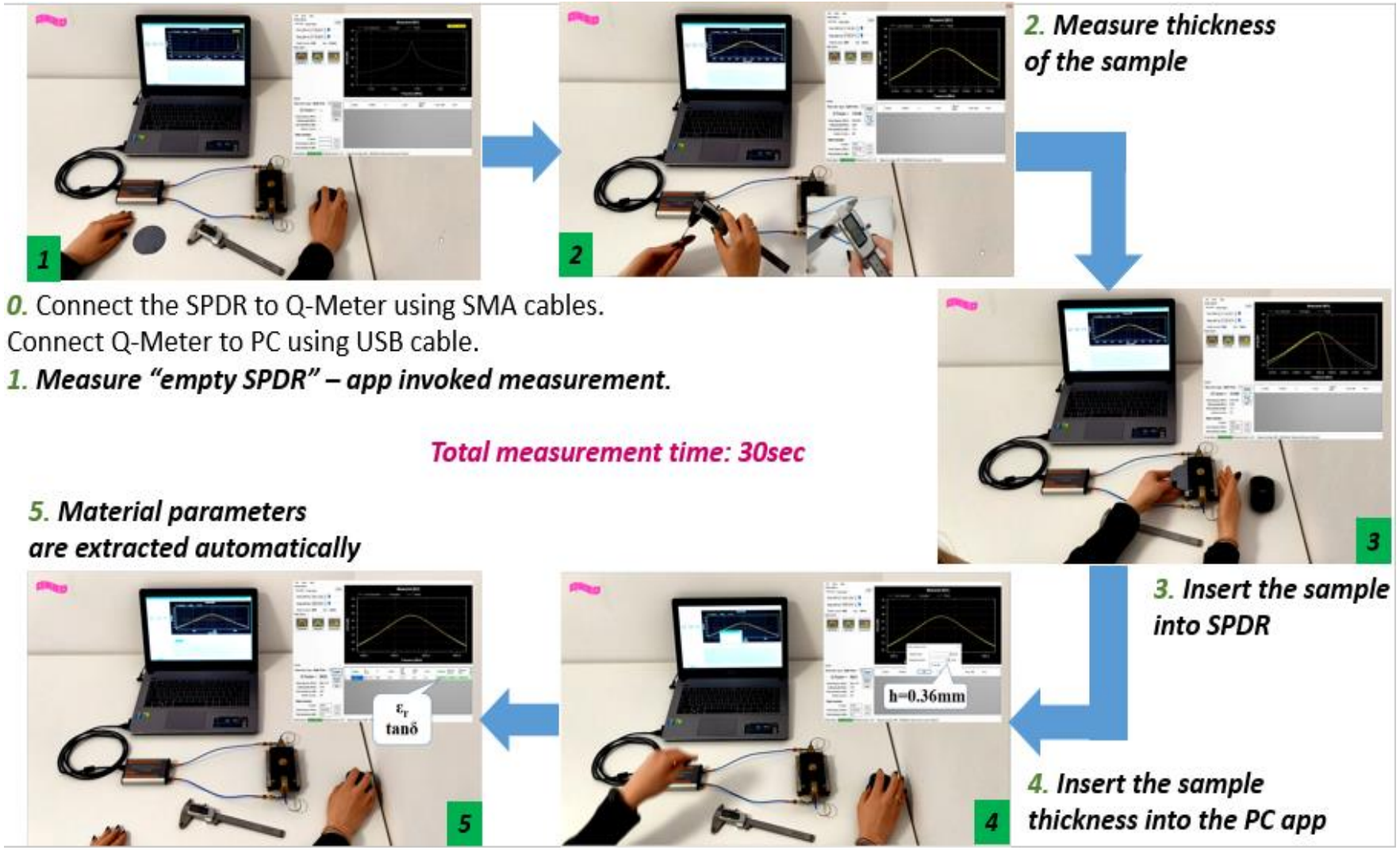
Hand-held VNA



Portable Microwave Q-Meter

Point-wise measurement with SPDR

Operation workflow – with the use of Q-Meter



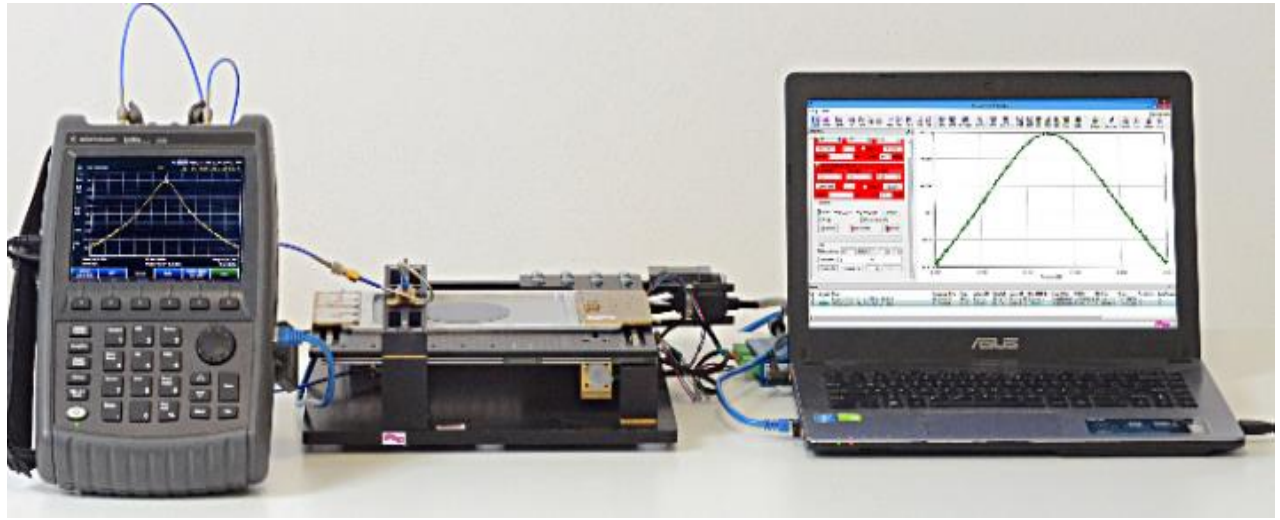
Surface-wise measurements

- Microwave measurement performed over a grid of points across SUT surface
- Extracted parameters' values aggregated into 2D maps of Dk, Df, and resistivity

- 2D SPDR scanner operating at 10GHz
- SUT placed on a Teflon foil (stable and intact)

- Positioning and measurement controlled and invoked with dedicated *Master Unit Control Application* (PC app)

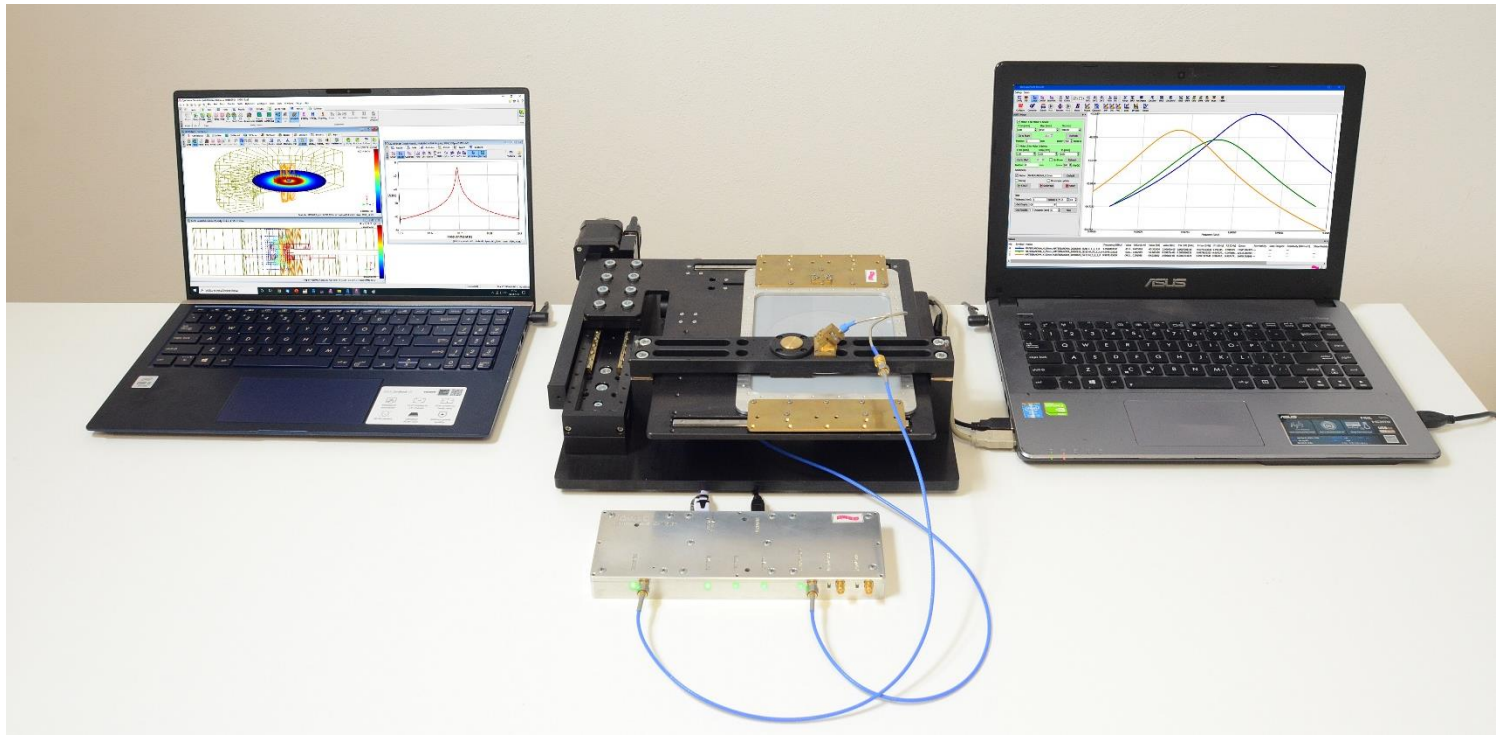
2D SPDR scanner measurement setup



Surface-wise measurements (2)

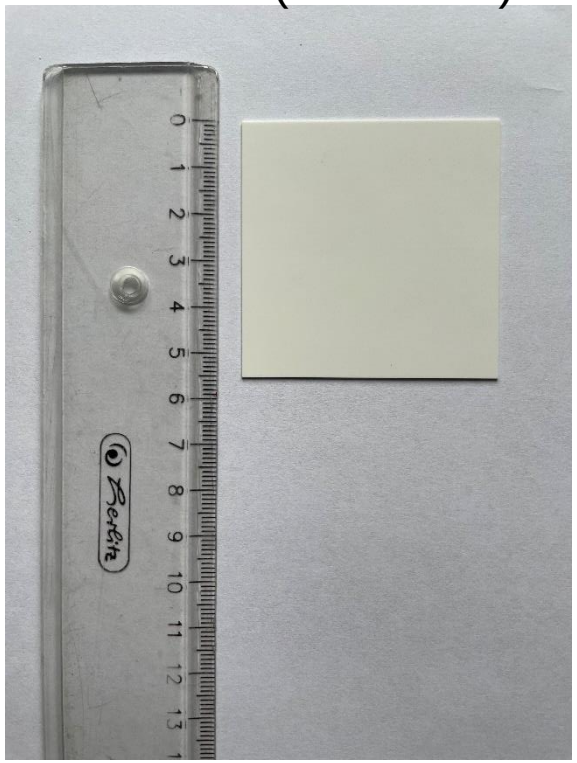
- Fast measurements required
- Microwave Q-Meter
  - Low-cost replacement for VNA
  - Portable

Portable 2D SPDR scanner measurement setup

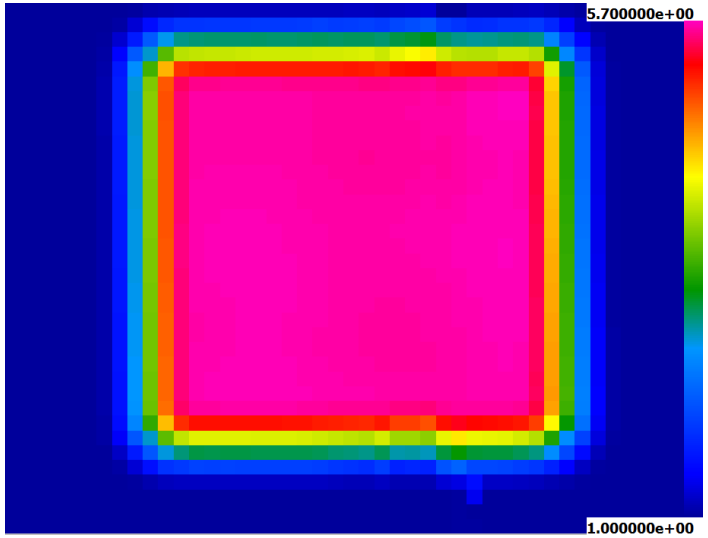


LTCC materials

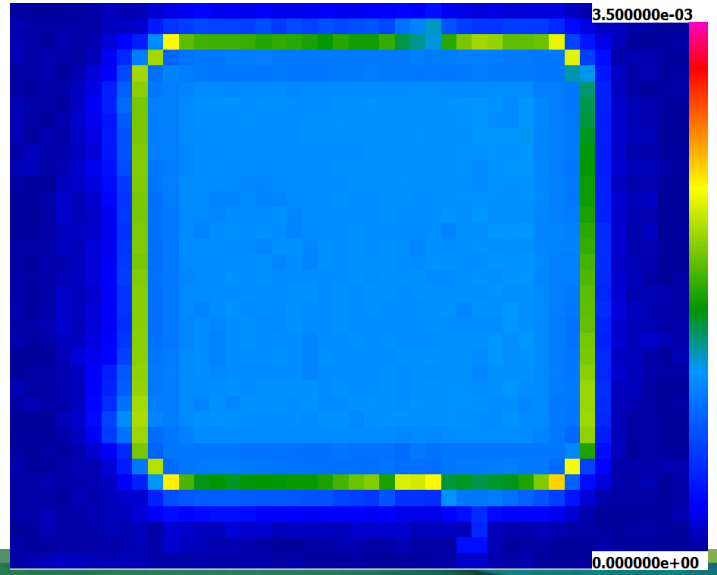
Commercial Ferro A6M substrate (50x50mm)



Dielectric constant



Loss tangent



2D surface imaging with SPDR 10GHz scanner

Scanning range:	85 x 70 mm
Scanning step:	2 mm
Number of meas. Points:	1548
Scanning time:	ca. 2 hour

Dielectric constant variation: ca. 5.56 – 5.68
Loss tangent variation: ca. 0.00101 – 0.00118

Uncertainty due to thickness variation – ±1%

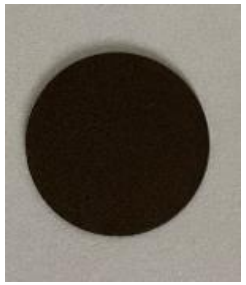
ULTCC materials

ULTCC material fabrication scheme

- Material fabrication procedure:
  - solid state synthesis of oxide components,
  - ball milling,
  - uniaxial pressing of pellets.
- Sintering at 610-650° C for 1 - 2h.

Test samples by Łukasiewicz IMiF

Li_2WO_4+4% $CuBi_2O_4$ | $LiBO_2$+4%$AlF_3CaB_4O_7$

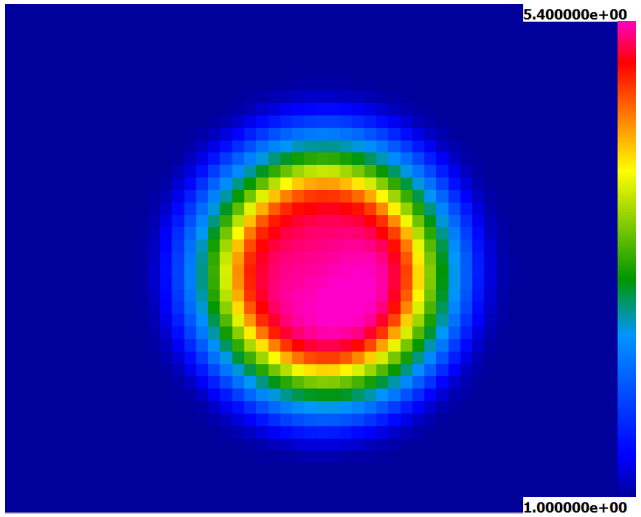


φ=20 mm

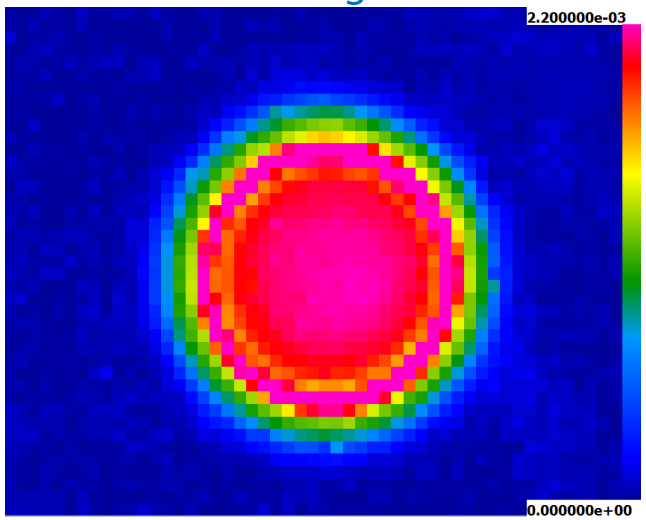
Expected by chemical composition: Dk= 4 - 6.5
Df= 0.0005-0.005

ULTCC testing (1)

Dielectric constant



Loss tangent

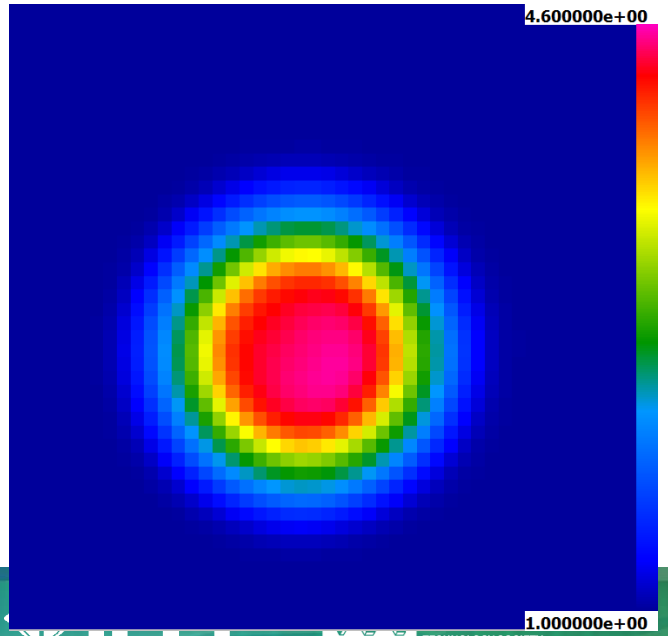


Scanning range: 50 x 40 mm
Scanning step: 1 mm
Number of meas. Points: 2091
Scanning time: ca. 2.5 hour

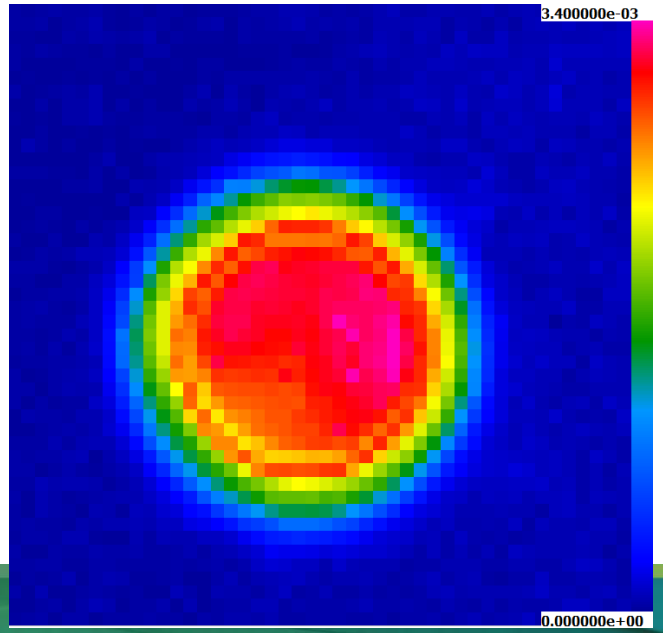
Dielectric constant variation: ca. 5 – 5.5
Loss tangent variation: ca. 0.00202 – 0.00219

Uncertainty due to thickness variation – ±2.5%

Dielectric constant



Loss tangent



Scanning range: 50 x 55 mm
Scanning step: 1 mm
Number of meas. Points: 2856
Scanning time: ca. 3.5 hour

Dielectric constant variation: ca. 4.25 – 4.53
Loss tangent variation: ca. 0.003 – 0.00339

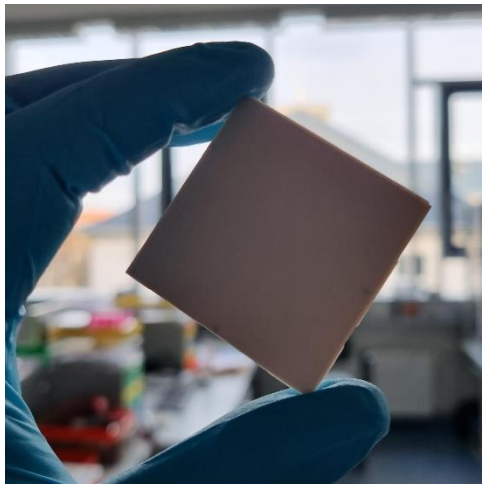
Uncertainty due to thickness variation – ±3%

ULTCC materials (2)

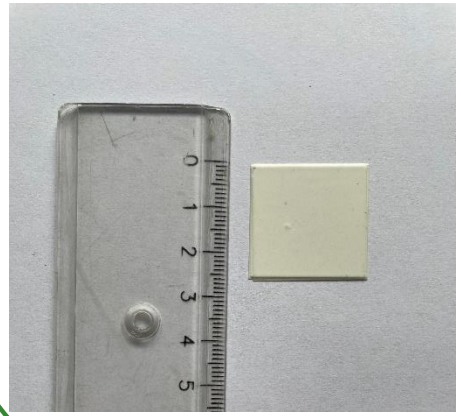
ULTCC tapes to substrates (ULTCC40)

- Fabrication procedures:
  - Solid state mixing of raw materials (Al_2O_3, SiO_2 Bi based glass powders)
  - Tape casting
  - Multilayer lamination
  - Binderburnout and sintering
- Sintering at 650°C/30min

Test samples by Fraunhofer IKTS



50 x 50 x 0.5 mm



Expected by chemical composition:

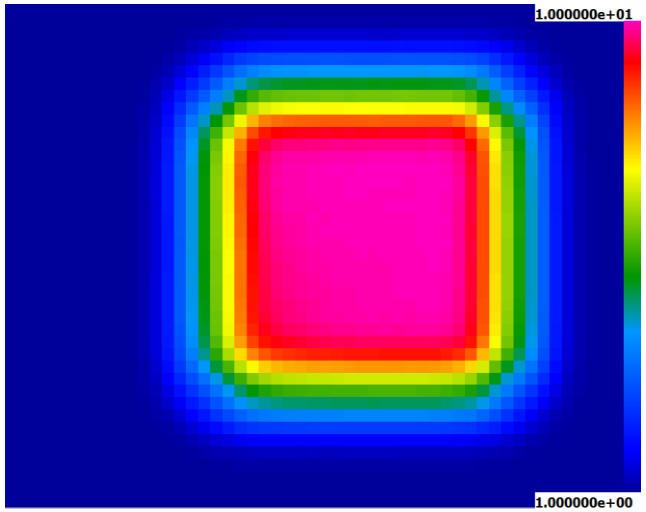
Dk= 10

Df= 0.002 at 10 GHz

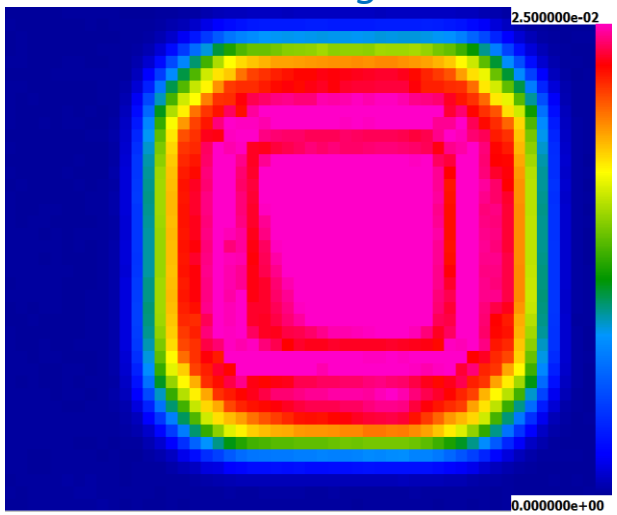
TCDk ~ 600-750 ppm/K

ULTCC testing (2)

Dielectric constant



Loss tangent

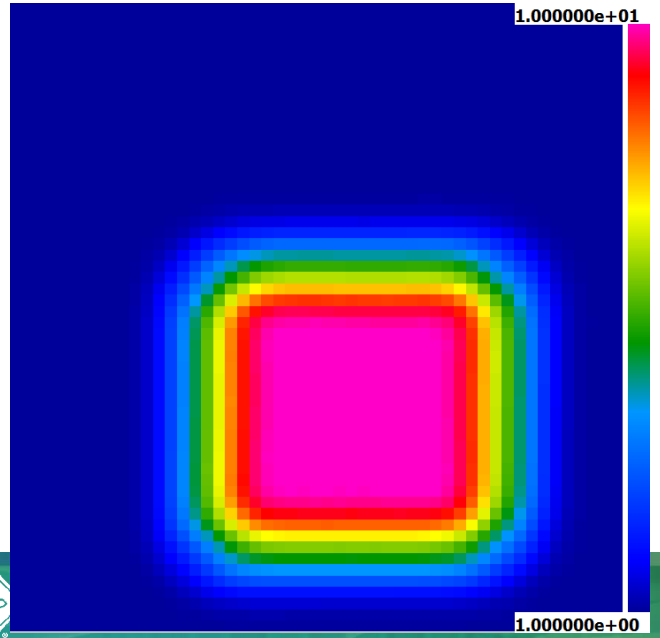


Scanning range: 50 x 40 mm
Scanning step: 1 mm
Number of meas. Points: 2091
Scanning time: ca. 2.5 hour

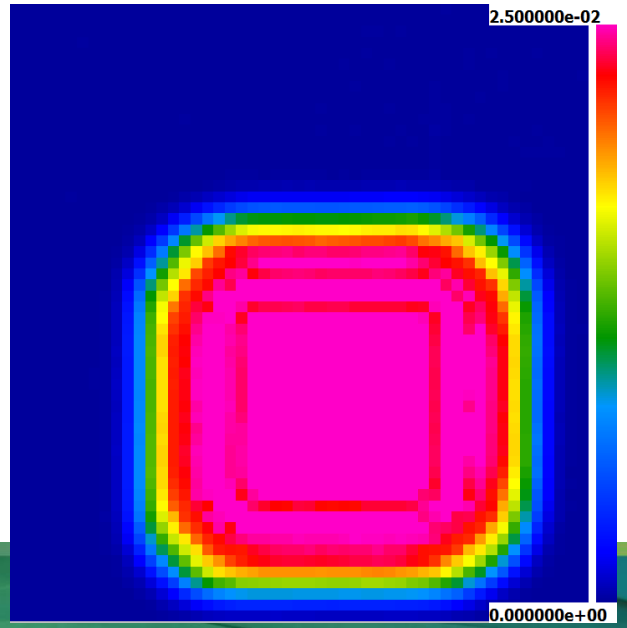
Dielectric constant variation: ca. 9.6 – 9.99
Loss tangent variation: ca. 0.022 – 0.0275

Uncertainty due to thickness variation – ±2%

Dielectric constant



Loss tangent

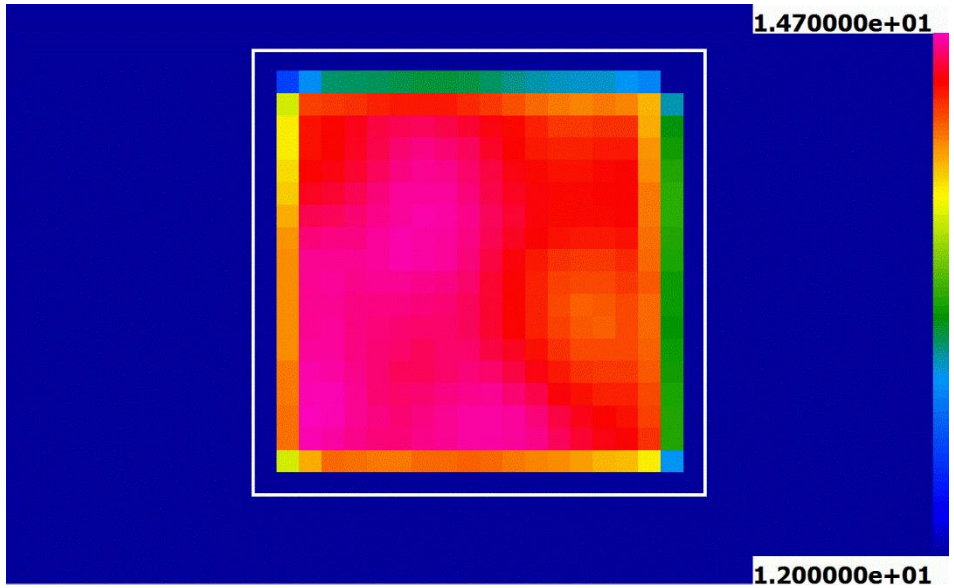


Scanning range: 50 x 55 mm
Scanning step: 1 mm
Number of meas. Points: 2856
Scanning time: ca. 3.5 hour

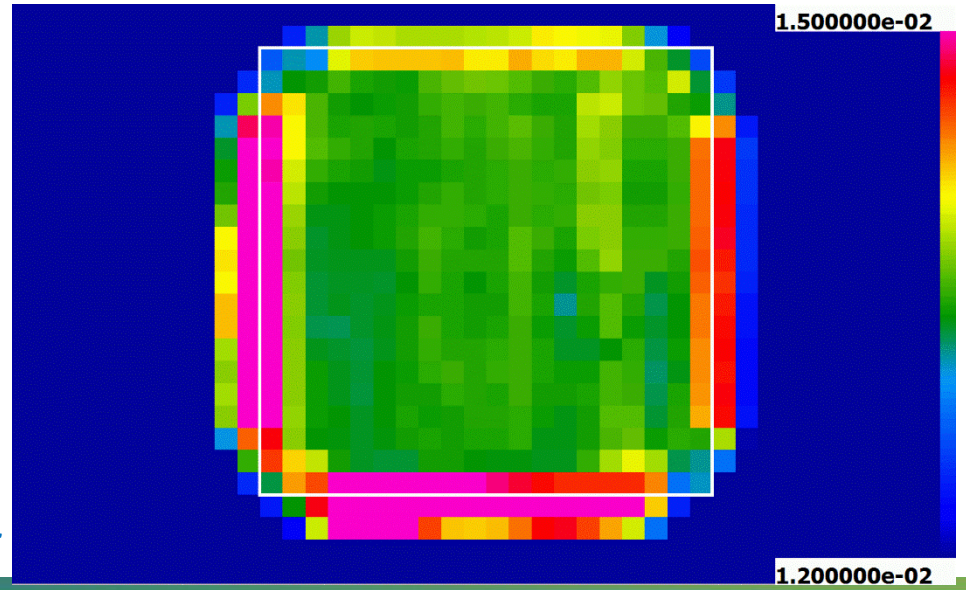
Dielectric constant variation: ca. 10.02 – 10.13
Loss tangent variation: ca. 0.028 – 0.038

Uncertainty due to thickness variation – ±0.5%

ULTCC testing (3)



Dielectric constant



Loss tangent

ULTCC Sample 3

Scanning range:	80 x 50 mm
Scanning step:	2 mm
Number of meas. Points:	1001
Scanning time:	ca. 1 hour

Dielectric constant variation: ca. 14.7 – 14
Loss tangent variation: ca. 0.0135 ±0.002

Uncertainty due to thickness variation – ±2%

** M. Olszewska-Placha et al. "Bulk glass-ceramic composites and ULTCC substrates for microwave and millimetre-wave applications", Materials Research Bulletin, April 2024*

Summary

- Quantitative and qualitative measures of uniformity of dielectric properties
- Material quality testing
- Detection of defects
- Repeatability of technological fabrication process
- Important for increasing density of electronic components over single substrate

Acknowledgement

This work presents results of ULTCC6G_EPac project under M-ERA.NET2 program receiving funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 685451.

*Part of this work was co-funded by the Polish National Centre for Research and Development under **M-ERA.NET2/2020/1/2021** contract*

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