Evaluation of the strength of Low Temperature Co-fired Ceramics under biaxial stress

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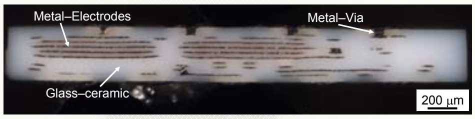
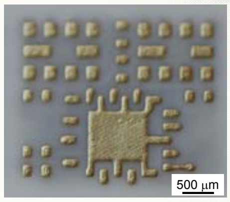
Introduction

Low Temperature Co-fired Ceramics (LTCCs) are 3D micronetwork of metal structures embedded within a glass-ceramic substrate (*i.e.* printed circuit), which are used as **high precision electronic devices** (*e.g.* mobile and automotive technologies).

The aim of this work is to determine the **mechanical biaxial strength** of LTCCs. The effect of surface metallisation and internal structure is analysed.



Cross-section of a typical LTCC component

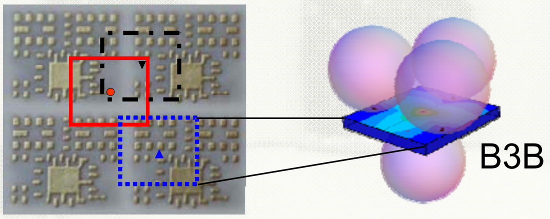


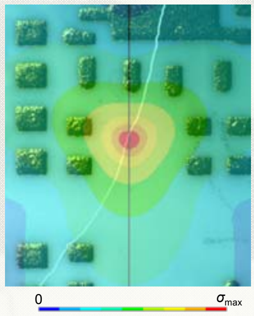
Top surface of a LTCC

Experimental testing

Specimens (≈10x10x0.4mm^3) are cut from the panels. **Different locations** have been tested.

1: near vias; 2: far from electrodes; 3: btw. electrodes





Maximal stress distribution around location 2.

The mechanical strength is determined using the **Ball-on-three-balls** (B3B) test.

Testing conditions: 0.5 mm/min, 21°C and 23% relative humidity.

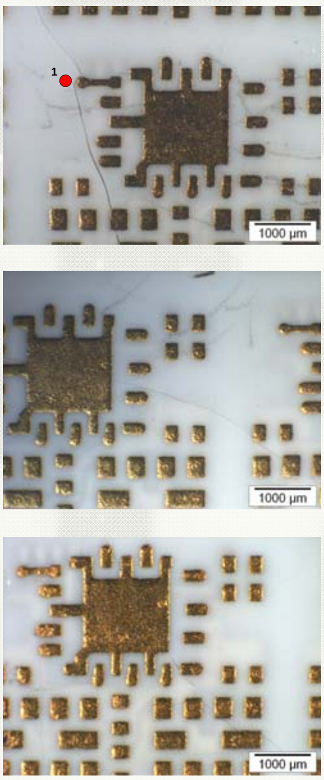
The failure stress (*equiv. tensile stress*) is calculated with FEA:

$$\sigma_{eq,max} = \left[2.58 - 0.67 \cdot (t/t_0 - 1)\right] \cdot \frac{P}{t^2}$$

P = Fracture load (N), t = thickness (mm), t_0 = 0.43 mm

Mechanical strength results

Fracture features of the tested LTCC surface at different locations



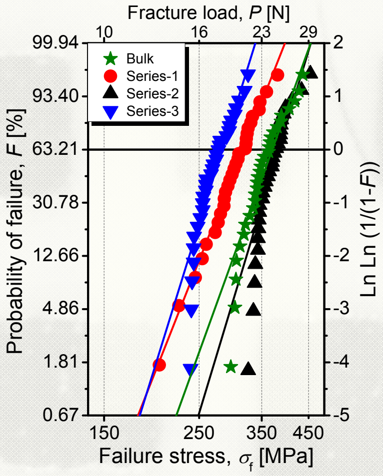


Fig. 1: Probability of failure vs. failure stress of LTCC and bulk material under biaxial flexure.

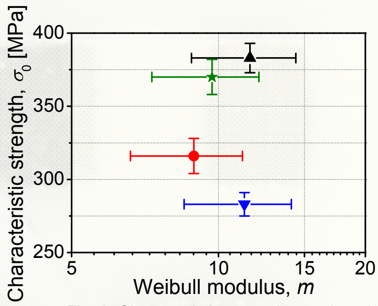


Fig. 2: Characteristic strength, σ_0 plotted versus the Weibull modulus, m, for LTCC components and bulk material.

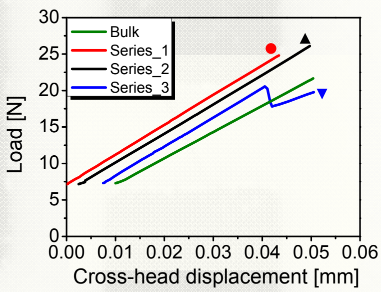


Fig. 3: Load vs. displacement curves for different locations in the LTCC. Step-wise fracture in 3 indicates interaction with metal electrode.

Estimation of critical defects

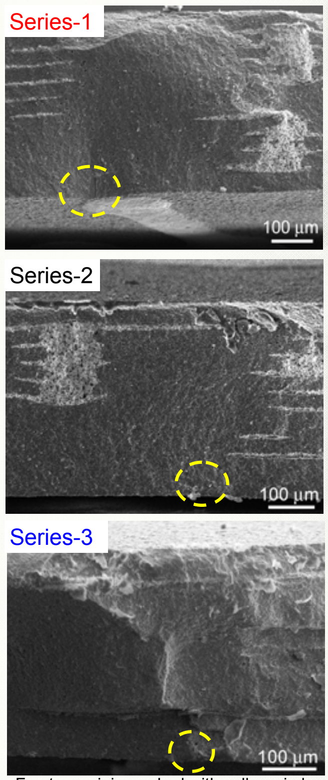
$$a_c = \frac{1}{\pi} \cdot \left(\frac{K_{Ic}}{Y\sigma_f}\right)^2$$

$$a_c = 4 - 20\ \mu m \ [1]$$

Y = 1.128 (Surface flaw); $K_{Ic,SEVNB}$ = 1.8 ± 0.1 MPa·m$^{1/2}$

[1] R. Bermejo, P. Supancic, I. Kraleva, R. Morrell, R. Danzer, "Strength reliability of 3D low temperature co-fired multilayer ceramics under biaxial loading", *J. Eur. Ceram. Soc.* **31** (2011) 745-753.

SEM micrographs of LTCC fracture surfaces at different locations



Fracture origin marked with yellow circle

Summary

+ The **mechanical strength** of LTCC components depends on the surface features (metallisation, vias, etc.)
+ The **internal architecture** of the component has an effect on the **resistance to crack propagation** of the material

Acknowledgements

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