SAND2022-14590C

Sandia National Laboratories

Soldered Tensile Failure Stress of Ceramics in Multilayered Ceramics Capacitors

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Background

- Weibull strength-size scaling can be used to predict the tensile strength of a ceramic part (Eq. 1).
- It is uncertain whether this approach can be used for joined ceramics that have complex thermal-residual stress fields.

$$P_f = 1 - exp\left[-k_A \times A\left(\frac{S}{S_{OA}}\right)^m\right] \quad \text{(Eq. 1)}$$

Objective

- Determine if Weibull statistics can be used to predict the tensile strength of a ceramic that contains a thermal residual stress field through experimental and computational analysis.

Experimental Procedure

Sample Preparation

- Tape cast specimens (25x25x1.5 mm) were acquired from AVX (X7R-dielectric $BaTiO_3$).
- Silver ink from Heraeus was screen printed to the specimens and fired at 800 C for 6 minutes.
- Oxygen Free Highly Conductive Copper discs (4mm diameter x 0.5 or 1.0 mm thick) were soldered to the metallized surface with 73Pb37Sn solder (either ink, Heraeus Item No: 1847, or solid preforms).

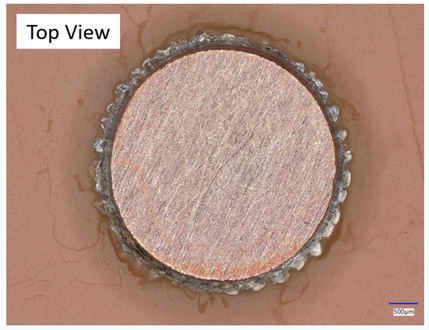

Figure 1: Copper Soldered Sample

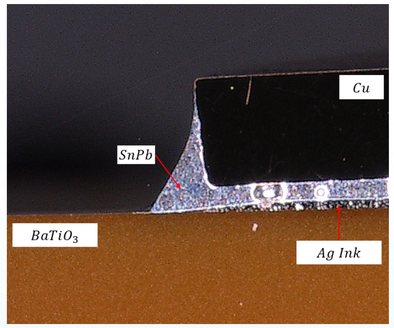

Figure 2: Cross Section of Copper Soldered Sample

Strength Testing

- Ring on Ring fixture (9.5/19 mm load/support rings) was used to measure the tensile strength of specimens according to ASTM C1499.
- Soldered copper disc was oriented on the tensile side of the specimen within the load ring (Fig. 3).

Computational Procedure

- The silver ink and solder processes from the experimental procedure were simulated in Sierra finite element software utilizing a viscoplastic model for the solder process.
- A quarter symmetry model was then loaded under the same load as the experimental procedure.

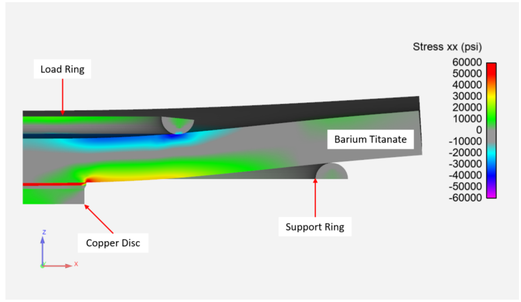

Figure 3: Finite Element Analysis of Experimental Model

Experimental Results

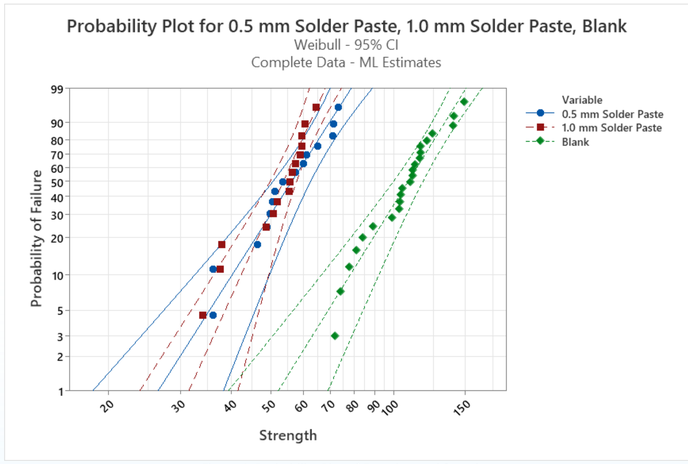

Figure 4: Probability Plot of Experimental Samples

Variable	0.5 mm Solder Paste	1.0 mm Solder Paste	0.5 mm Preform	1.0 mm Preform	Blank
Weibull Modulus	5.6	7.92	4.54	3.46	5.76
Characteristic Strength (MPa)	60.085	56.214	57.285	54.089	115.787
Average Strength (MPa)	10.9	8.7	13.1	15.4	20.2
Standard Deviation (MPa)	11.45	7.92	52.84	48.65	21.56

Table 1

- The ceramic strengths decrease as a result of a solder process.
- Thicknesses of copper did not affect the strengths.

Experimental and Computational Comparison

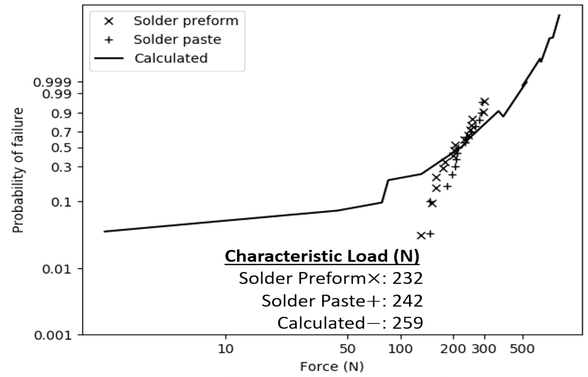

Figure 6: 0.5 mm Solder Experimental and Computational Comparison

- Similar results are at intermedial loads, however, the spread between Weibull fit and model varies at low and high loads.

Fractography

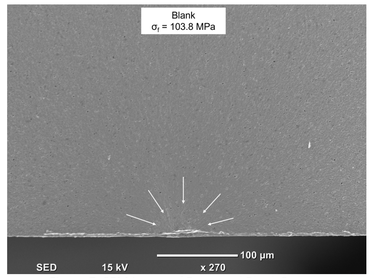

Figure 7: SEM Image of Fractured Blank Sample

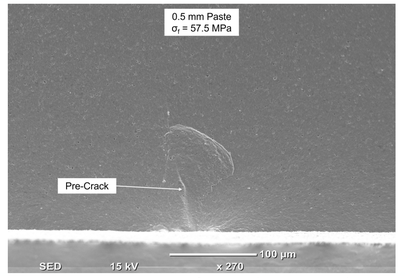

Figure 8: SEM Image of Fractured Ceramic Sample

- Fractography showed that cracks from soldering process were present prior to strength testing.
- The different flaw source is likely the discrepancy between model and experiments.

Summary and Further Work

- The soldered ceramics failed at the high solder stress regions as expected, however, cracks from soldering process were observed and likely why experiments and model differ.
- Different shape and size copper pieces are to be tested to try and prevent solder cracks for direct model comparison.

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