SWTEST

PROBE TODAY, FOR TOMORROW

2024 CONFERENCE

# Newly developed low CTE LTCC material for ST substrates

Nippon Electric Glass


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# Overview

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- Introduction
- Sample preparation
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- Summary

# Motivations

## Background

- Demands for ST (Space Transformer) substrates for probe cards
  - ✓ CTE of the material is close to that of silicon wafers.
  - ✓ Low electrical resistance conductors can be used.
- LTCC has an advantage over HTCC.
  - ✓ LTCC can use conductors with lower electrical resistance.

## Targets

- Development of low expansion LTCC material for ST substrates
- Properties beyond existing low expansion LTCC materials
  - ✓ Bending strength
  - ✓ Fracture toughness
  - ✓ Share strength

# Introduction

**Raw material composition)**
**Existing LTCC materials**
**MLS-26 ： Glass + Alumina**
**MLS-28 ： Glass + Alumina + Willemite ($2ZnO \cdot SiO_2$)**

| | MLS-26 | MLS-28 |
|---|---|---|
| Bending strength (MPa) | 375 | 311 |
| Fracture toughness $K_{1C}$ ($MPa \cdot m^{1/2}$) | 2.3 | 1.9 |
| Coefficient of thermal expansion (ppm/℃) @-40～125℃ | 4.7 | 3.7 |

# Introduction

Raw material composition)
Newly developed LTCC material
New LTCC ：Glass + Alumina + Cordierite ($2MgO \cdot 2Al_2O_3 \cdot 5SiO_2$)

| | Cordierite | Willemite |
|---|---|---|
| $K_{1C}$ ($MPa \cdot m^{1/2}$) | 2.0～3.0 | ＜1 |
| CTE (ppm/K) | 1.5～2.5 | 3.2 |

Addition of cordierite as a filler

- ✓ Lowering CTE of LTCC by adding small amounts
- ✓ Increase of fracture toughness of LTCC

# Sample preparation

## Newly developed LTCC material

Slurry

glass, alumina, cordierite
binder, plasticizer

↓

Green sheet

doctor blade method

Optimization of the glass ratio (different glass volume ratios)

- ✓ Bending strength measurements (Three-point bending test)
- ✓ Fracture surface observations

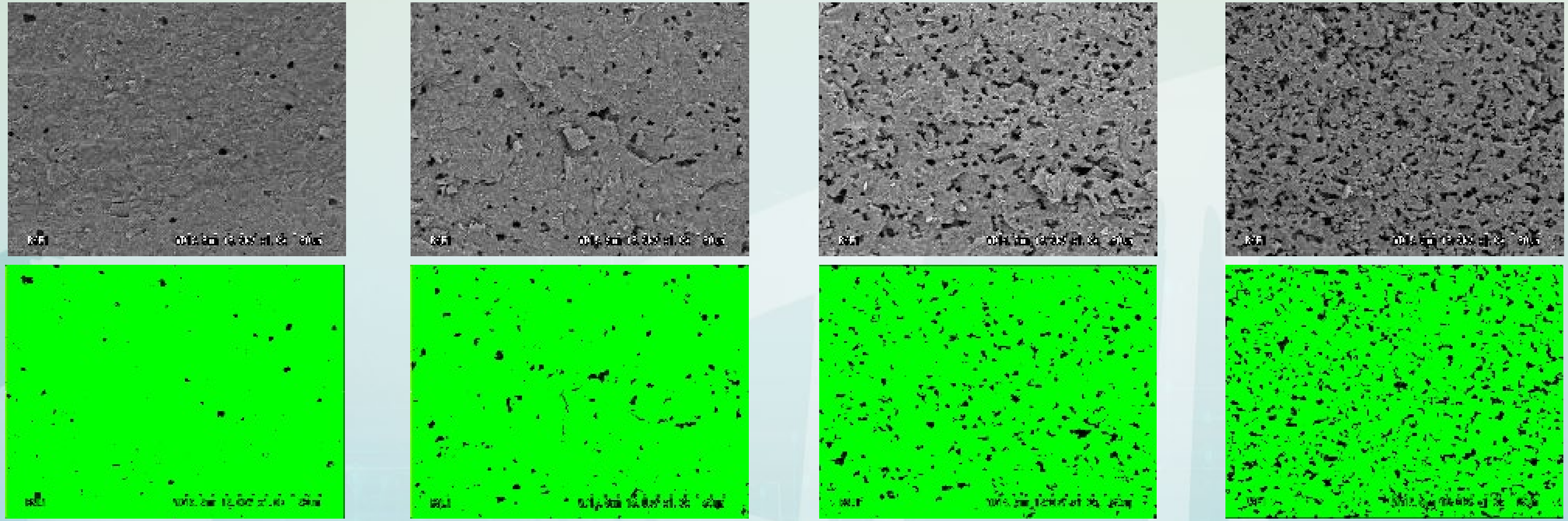
# Results and discussion

## SEM observation of fracture surfaces of LTCC

- ✓ Calculation of void area by image processing

X: normalized glass volume fraction

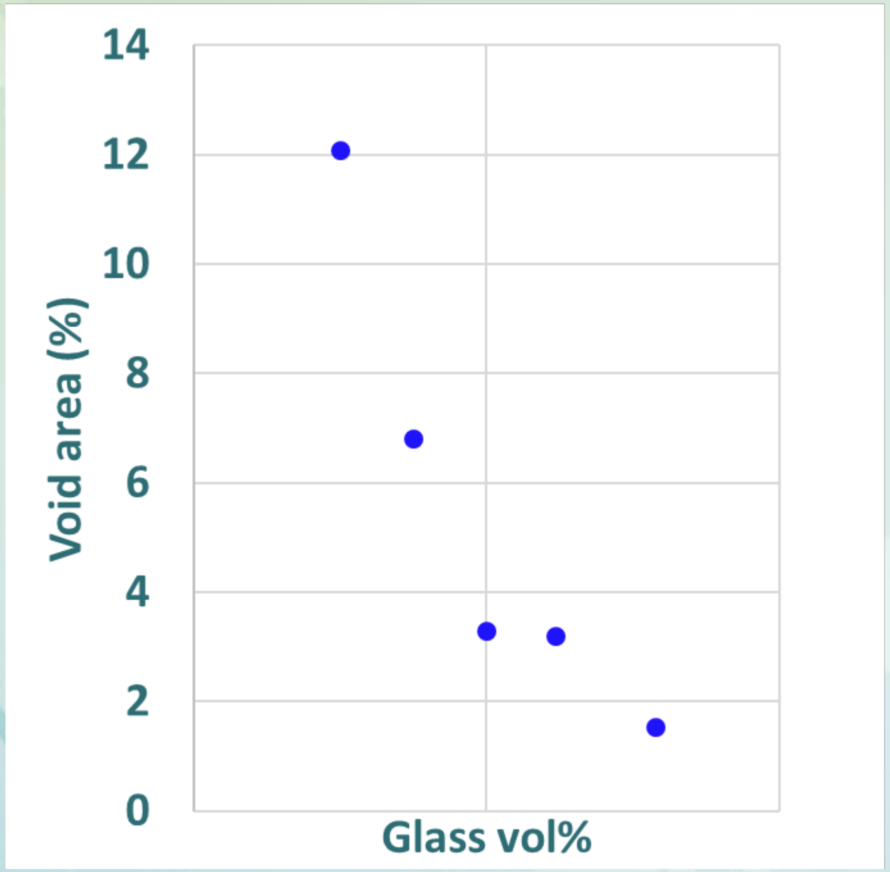
| Glass 1.5X vol% | Glass 1.3X vol% | Glass 1.1X vol% | Glass 1.0X vol% |
|---|---|---|---|

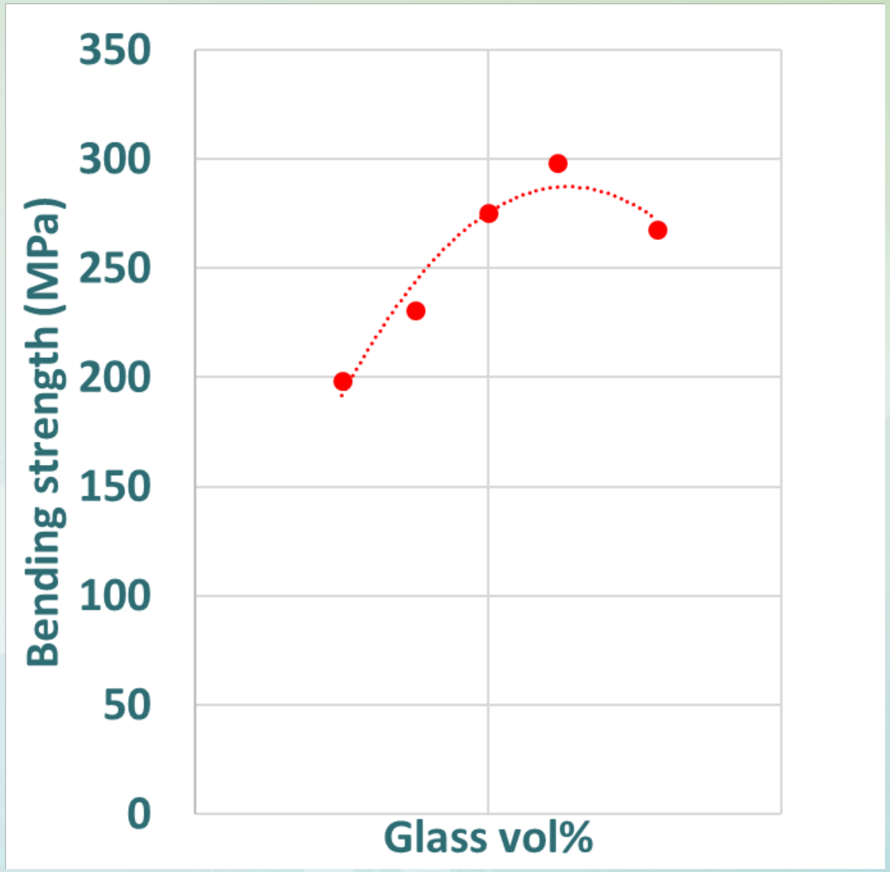


| Void area 1.5% | Void area 3.3% | Void area 6.8% | Void area 12.1% |
|---|---|---|---|

# Results and discussion

## Relationship between void area, bending strength and glass volume ratio

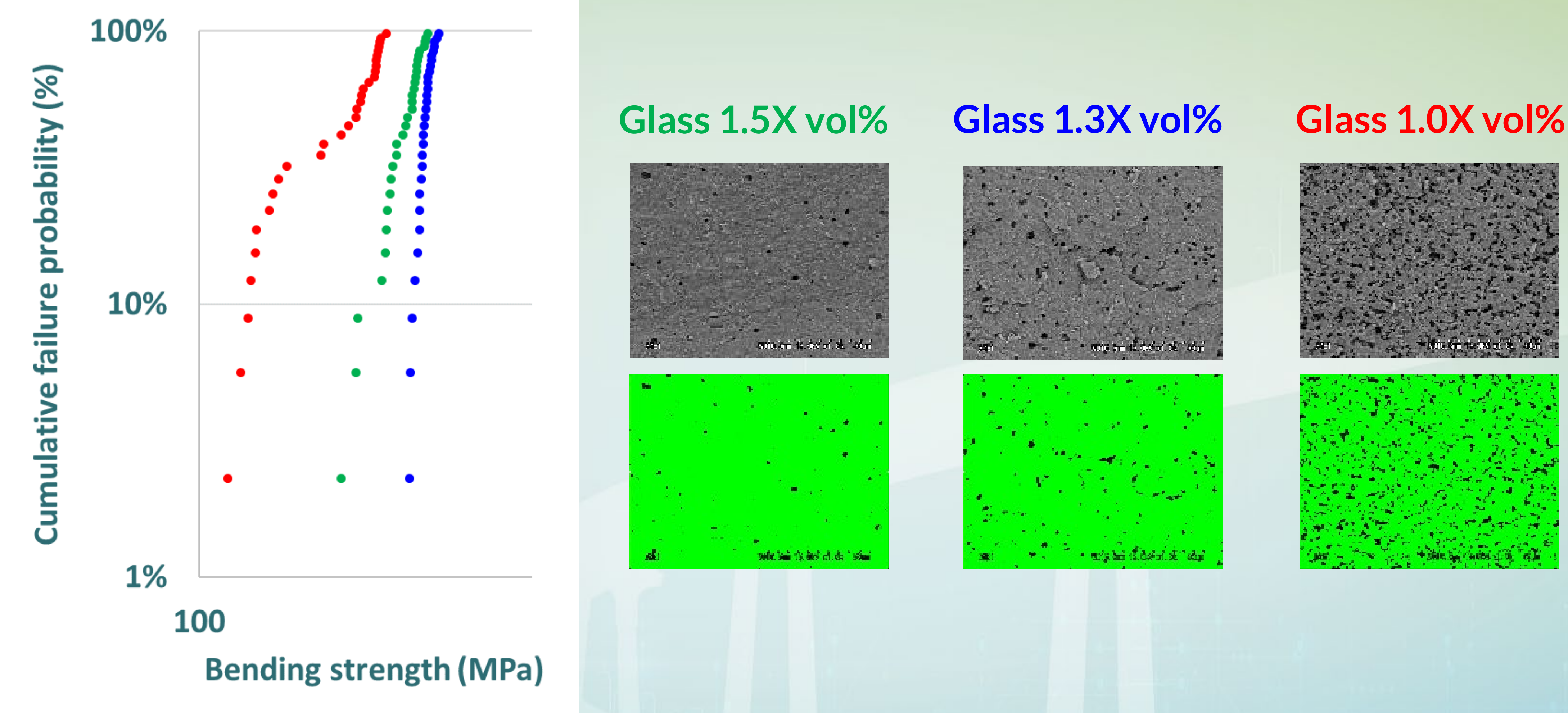



- ✓ Void area decreases with increasing glass volume ratio.
- ✓ Bending strength is maximum at specific glass volume ratios.

# Results and discussion

## Impact of glass volume ratio on bending strength

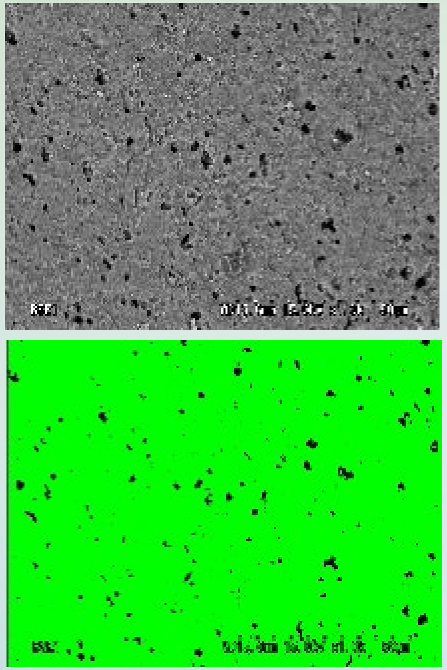



- ✓ Bending strength decreases with increasing voids (Glass 1.0X vol% region).
- ✓ Bending strength is low due to the low strength of the glass itself (Glass 1.5X vol% region).

# Results and discussion

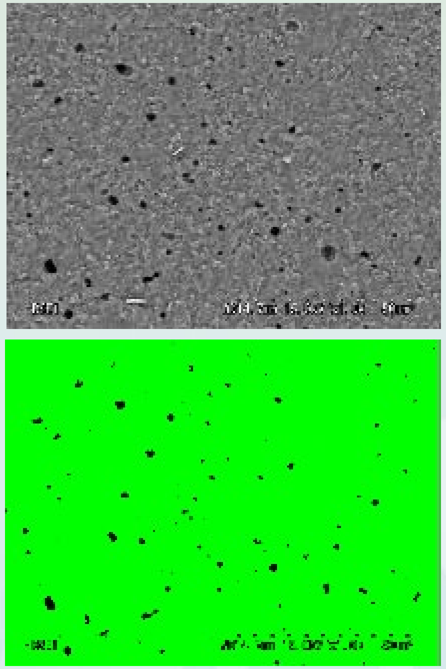
## Impact of particle size of glass powders on bending strength

Glass $D_{50}$ α um



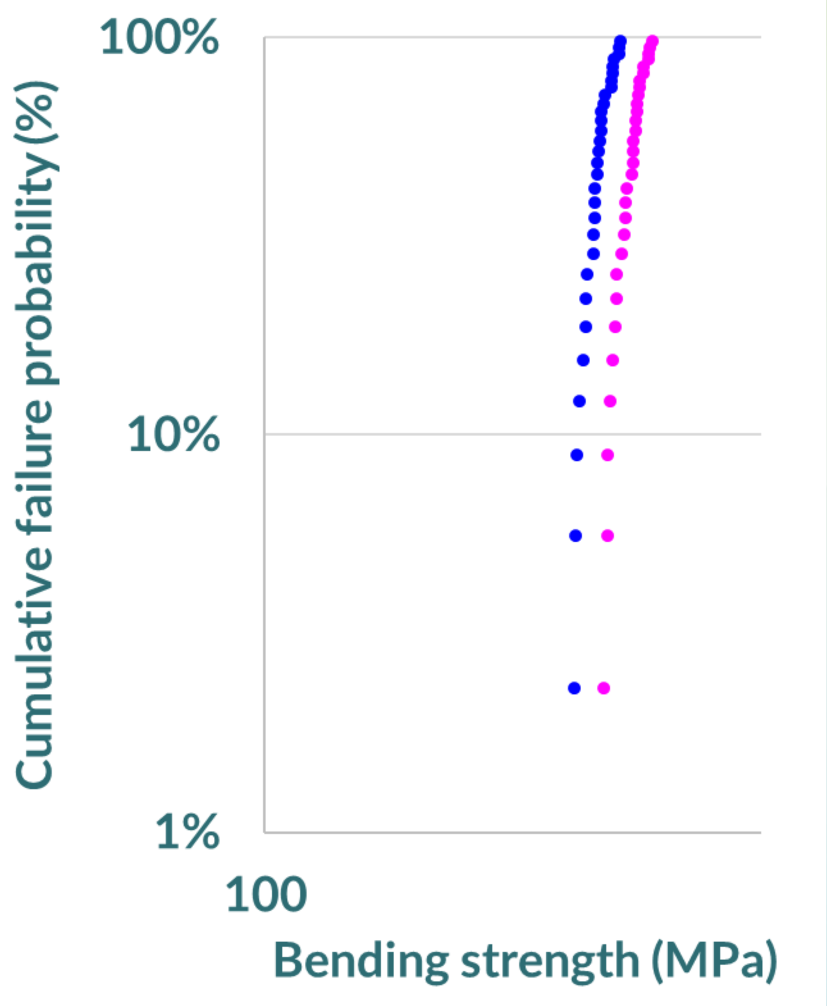
Void area 3.2%

Glass $D_{50}$ β um



Void area 1.9%

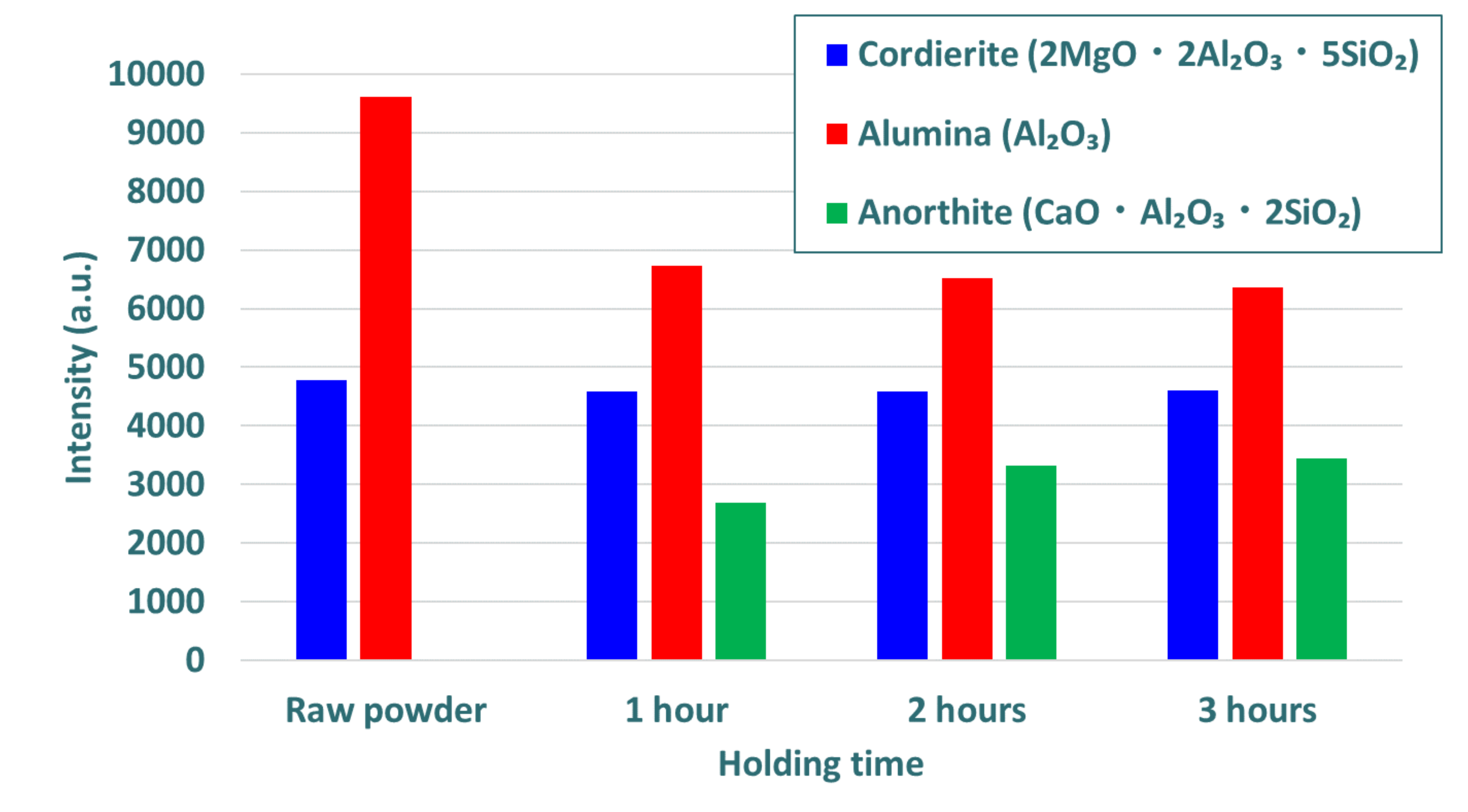
α um > β um




As the average particle size of the glass powders decreases, the void area decreases and the bending strength increases.

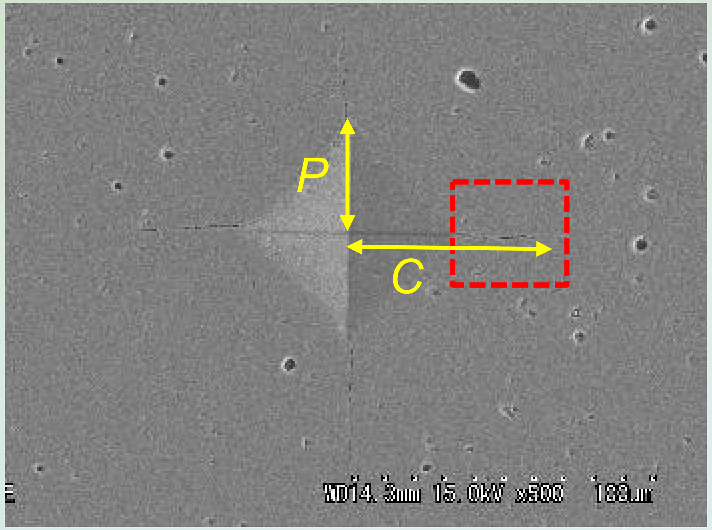
# Results and discussion

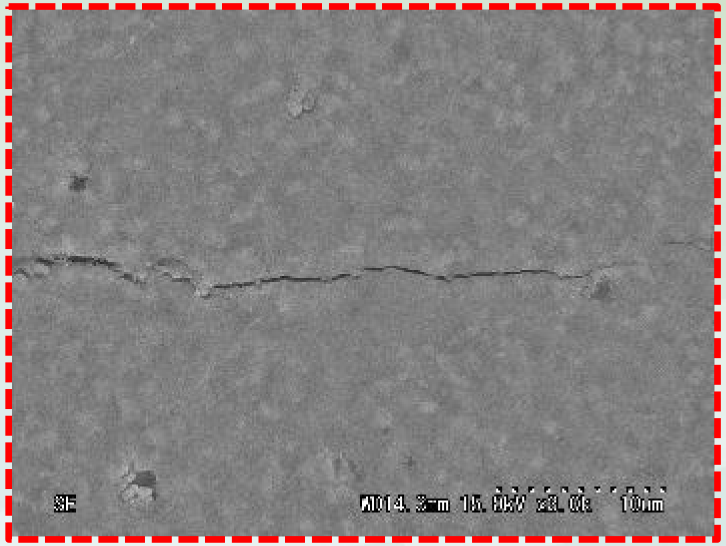
## XRD evaluation




Anorthite precipitates as holding time increases.
Anorthite is derived from alumina, not cordierite.

## Fracture toughness evaluation



### Indentation fracture method

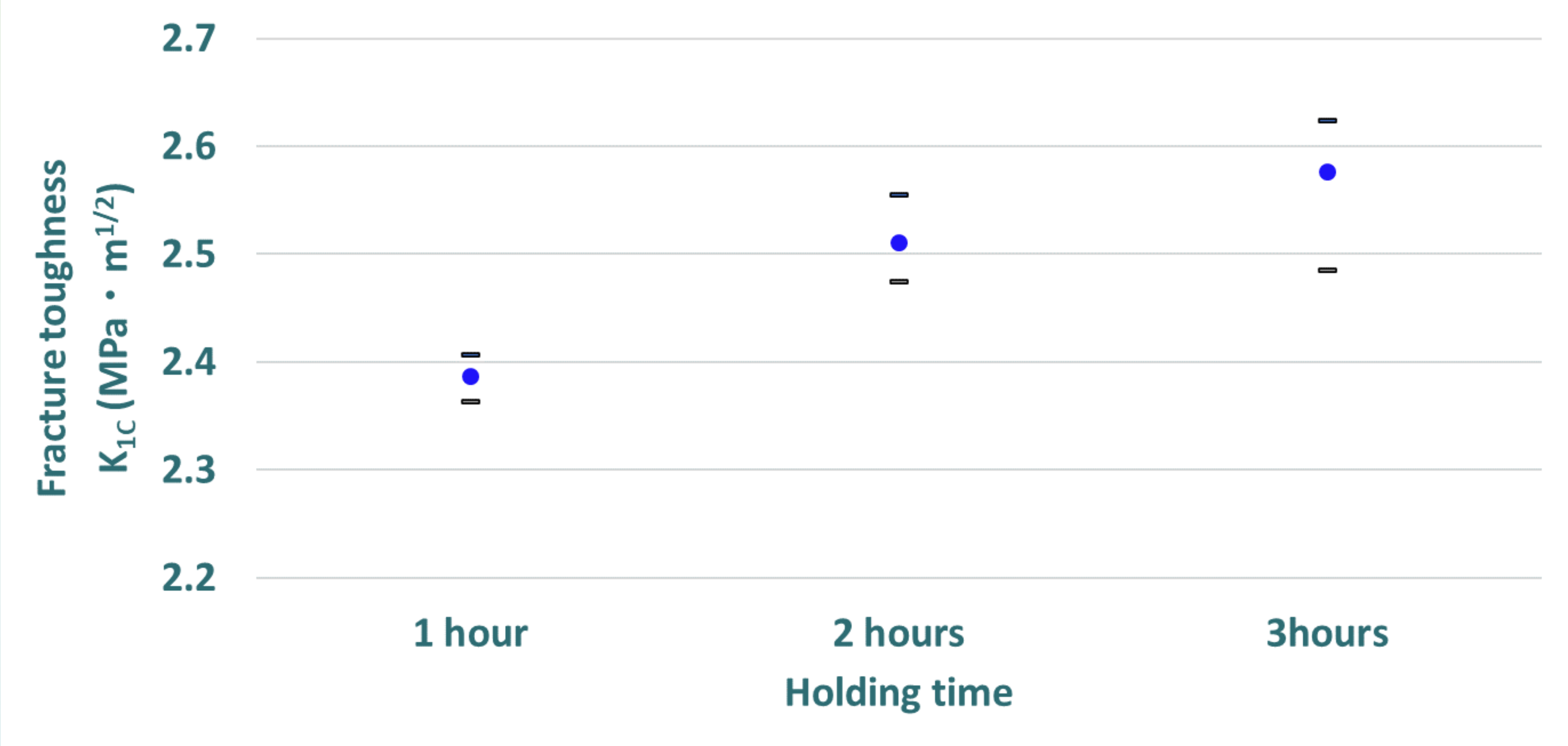
Fracture toughness was evaluated by the following equation.

$$K_{1C} = 0.018\left(\frac{E}{H}\right)^{1/2}\left(\frac{P}{C^{3/2}}\right)$$

*E*: Elastic modulus, *H*: Vickers hardness, *P*: Half of indentation length, *C*: Half of crack length

# Results and discussion

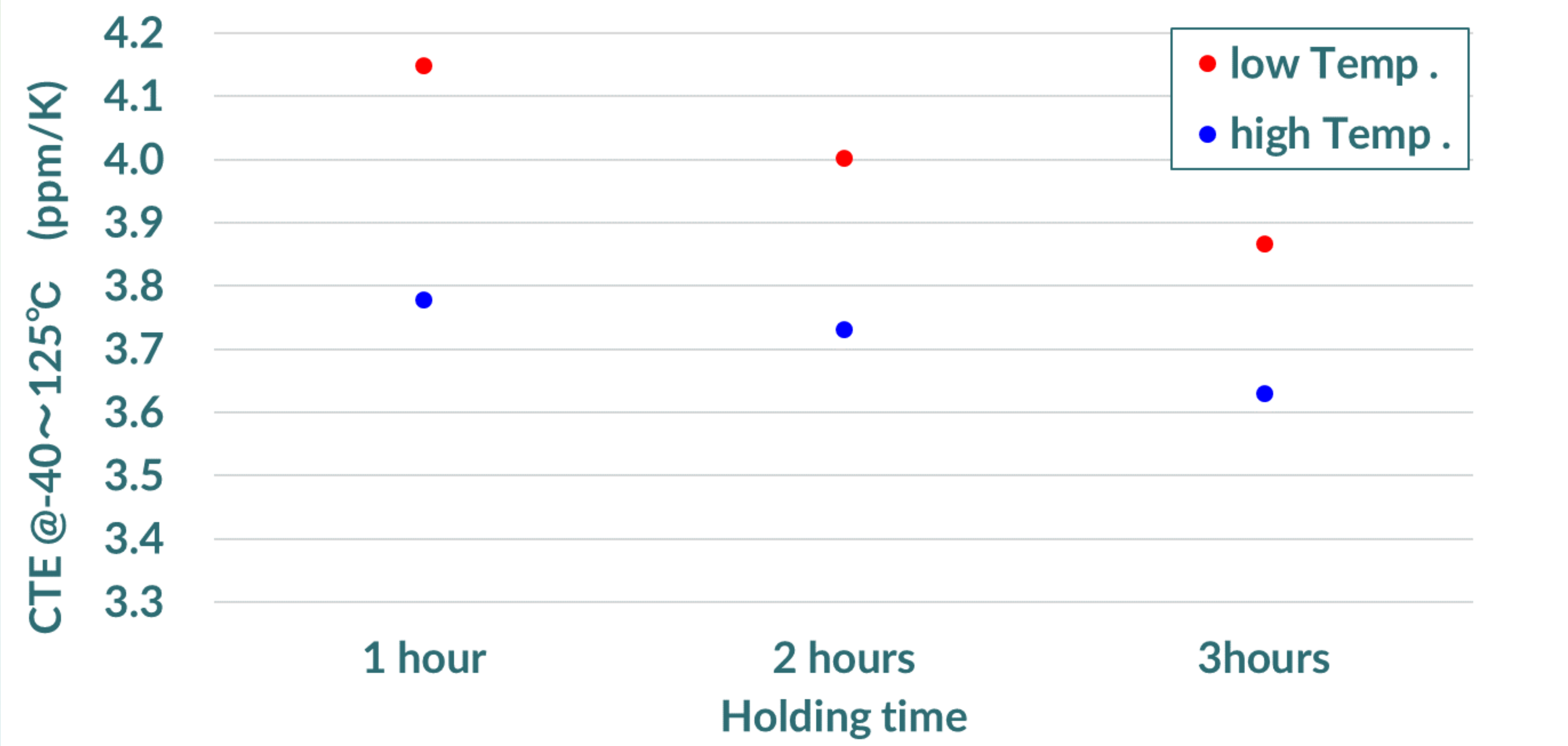
## Impact of holding time on fracture toughness




We believe that the improved fracture toughness is due to the anorthite precipitated in the glass region.

# Results and discussion

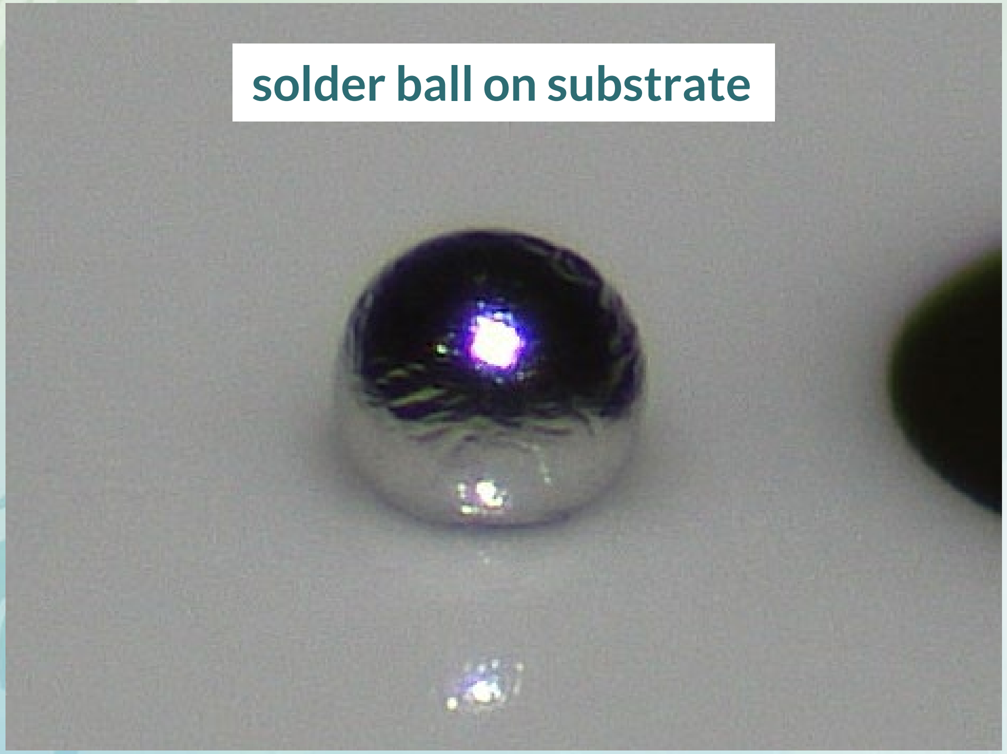
## Impact of sintering temperature and holding time on CTE

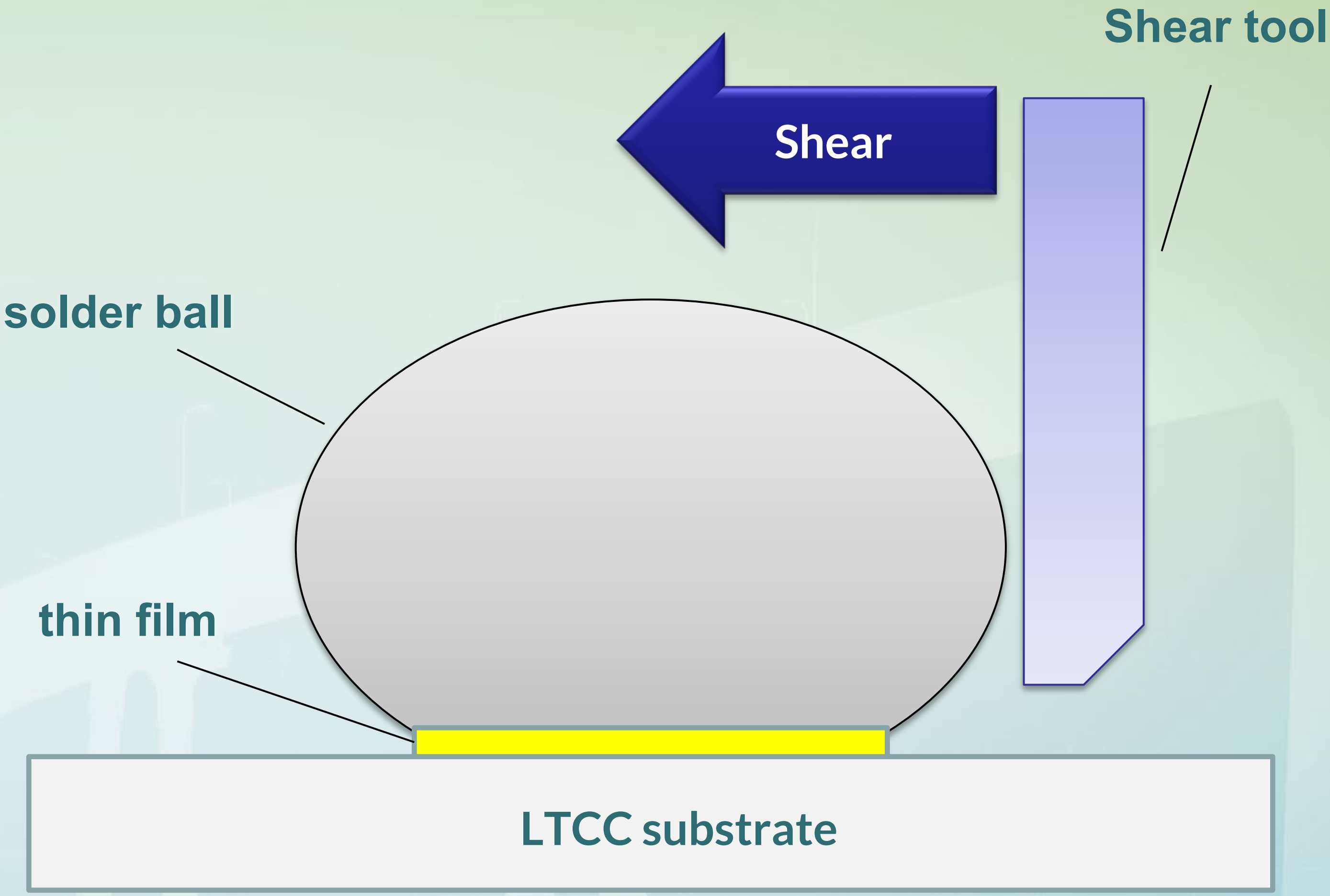



- ✓ The higher the sintering temperature, the lower the CTE.
- ✓ CTE decreases with increasing holding time.
- ✓ Decrease in CTE is attributed to the reduction of alumina with high CTE.

# Results and discussion

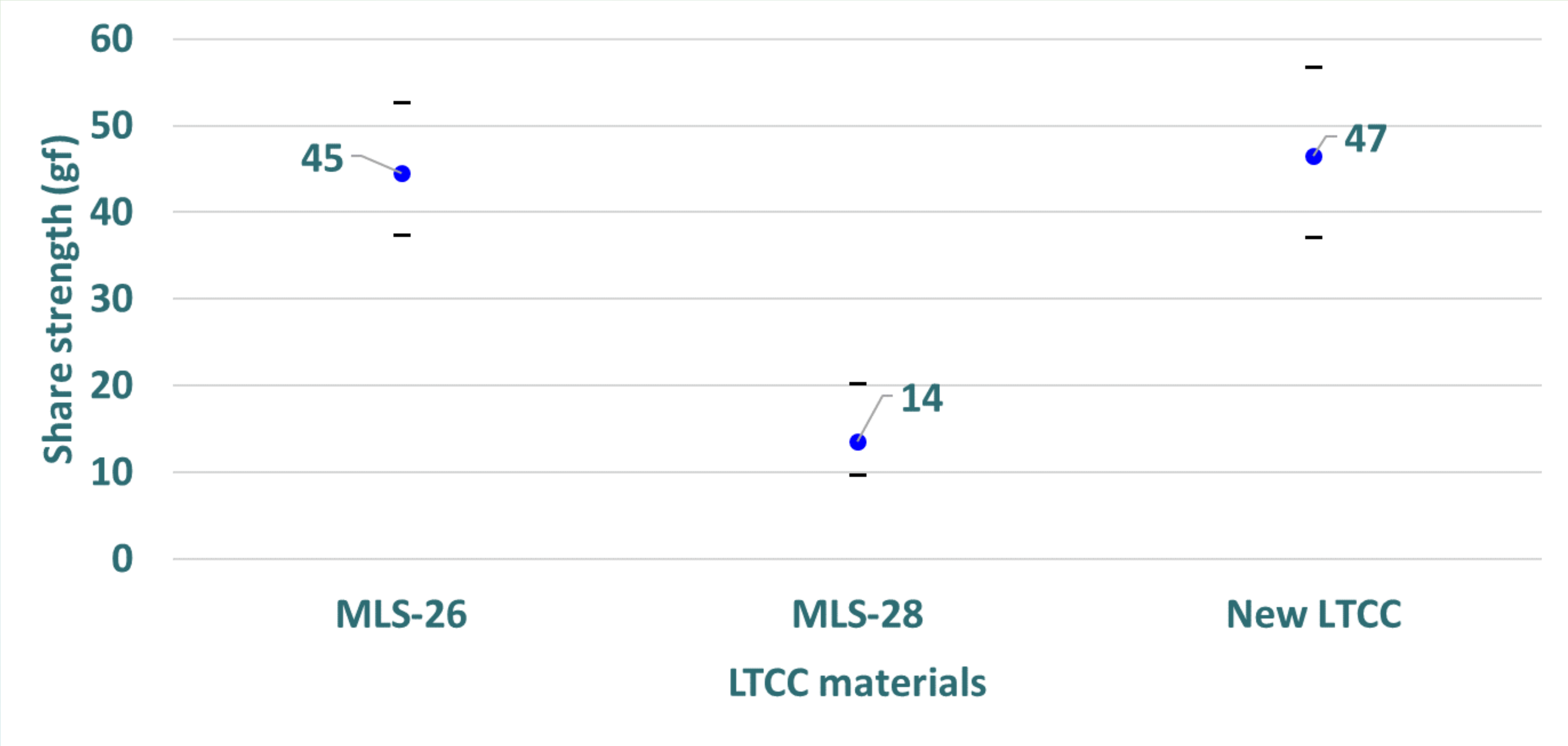
## Share strength evaluation



# Results and discussion

## Share strength evaluation




Compared to existing materials,
The shear strength of New LTCC was equivalent to MLS-26 and approximately three times that of low-expansion MLS-28.

# Summary

**A new LTCC material for ST substrates with the desired CTE, high strength, and high fracture toughness was developed.**

**Raw material composition**

- ✓ Selection of cordierite, a low expansion filler
- ✓ Optimization of glass volume ratio and glass particle size

**Sintering conditions**

- ✓ Optimization of sintering temperature and holding time

| | MLS-26 | MLS-28 | New LTCC |
|---|---|---|---|
| Bending strength (MPa) | 375 | 311 | 350 |
| Fracture toughness $K_{1C}$ (MPa・$m^{1/2}$) | 2.3 | 1.9 | 2.6 |
| Coefficient of Thermal Expansion (ppm/℃) @-40～125℃ | 4.7 | 3.7 | 3.6 |