Structuration of Micro-fluidic Devices Based on Low Temperature Co-fired Ceramic (LTCC) Technology

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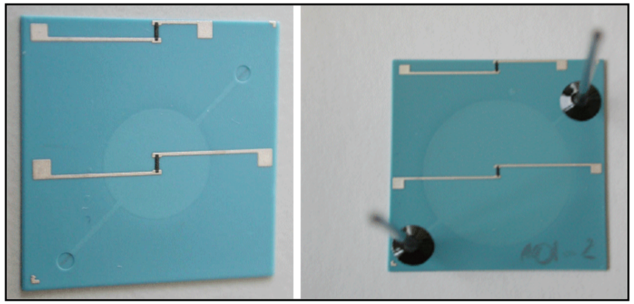
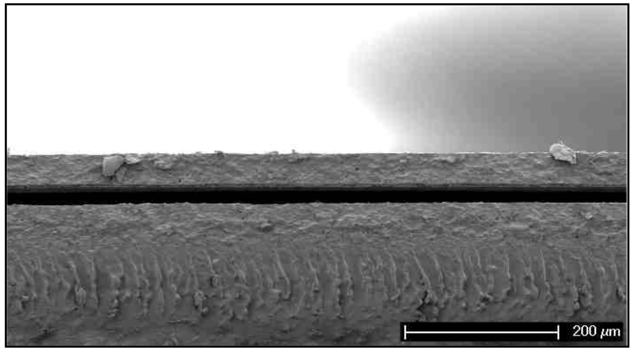
PURPOSE OF THE PRESENTATION

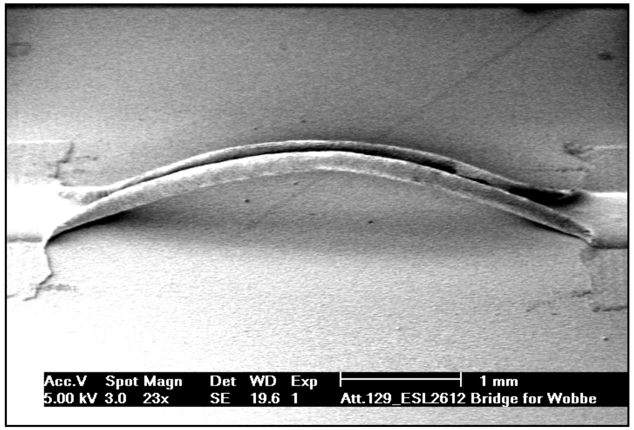
- Preparation of graphite-based sacrificial layer for microstructuration of LTCC



- To demonstrate the fabricated structures; membranes



- To explain the processing conditions and their effects on final device properties



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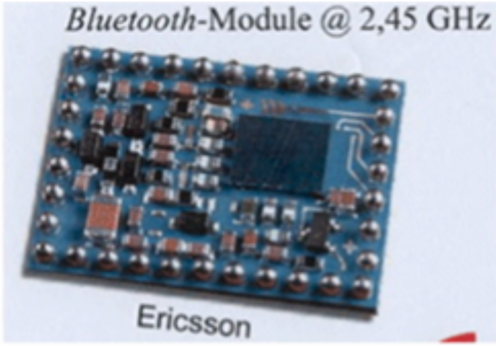
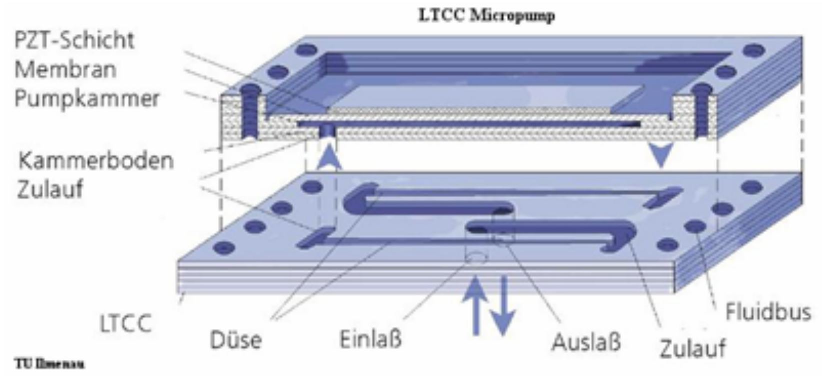
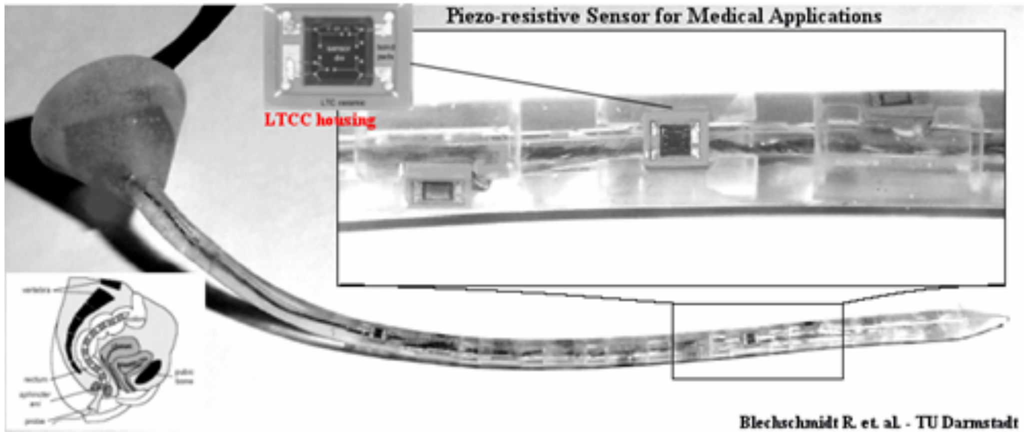
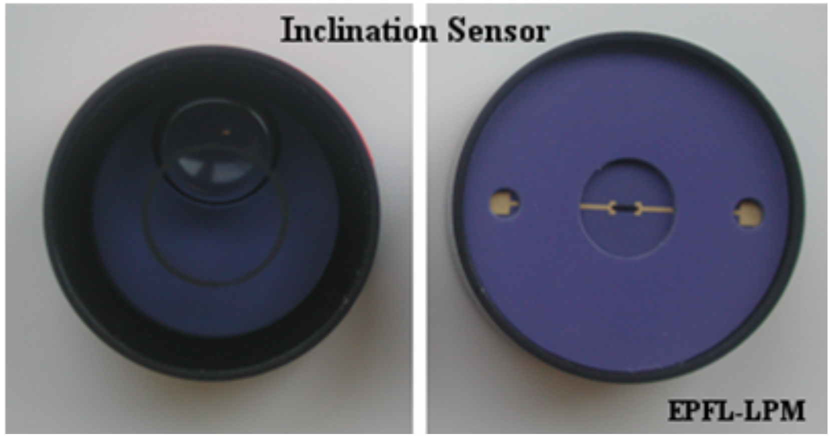
Application areas of LTCC technology have diversified









→ What are the challanges and solutions for 3-D structuration?

OUTLINE OF THIS PRESENTATION

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LTCC Technology for Micro-fluidic Sensor Applications

→Introduction

→Advantages

→Challenges

3-D Structuration of LTCC

→Carbon-sacrificial paste preparation

→ Fabricated Structures

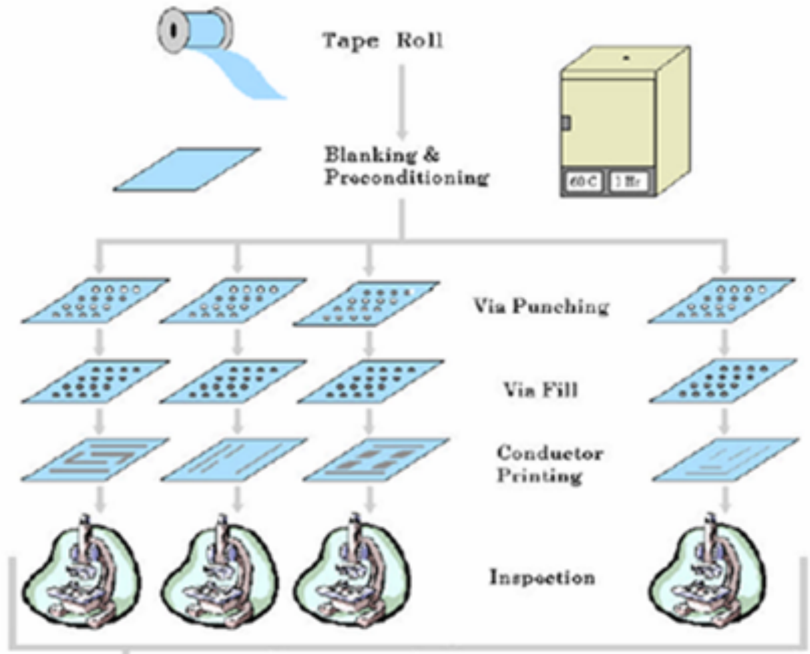
Discussions

→Material Properties

→Effects of processing conditions on structure

→Conclusions and next steps

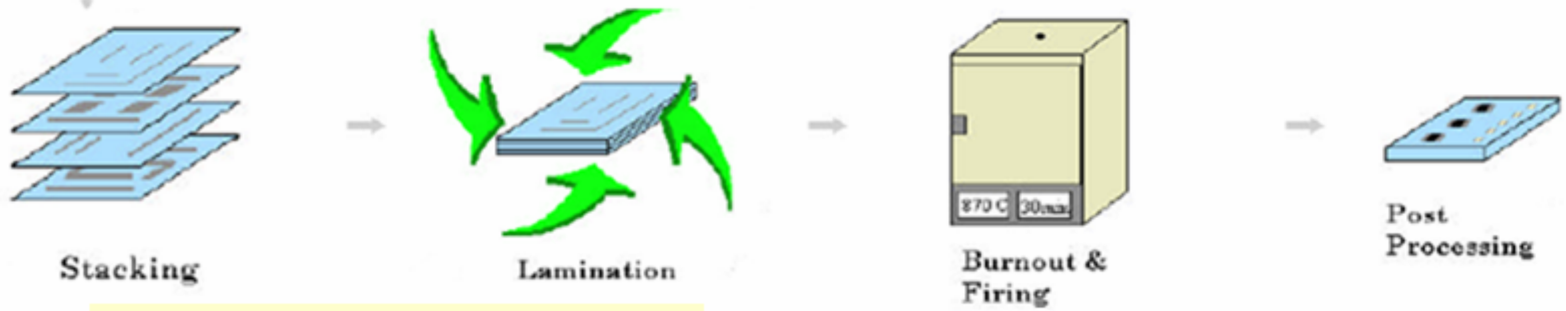
INTRODUCTION: LTCC MATERIALS SYSTEM



Ceramic / glass mixture blended in organic vehicle & cast into thick-film sheets (LTCC tapes: 30-350 um)

Layers processed by
- cutting,
- screen-printing pastes

→CO-FIRING & COMPATIBILITY with thick-film technology



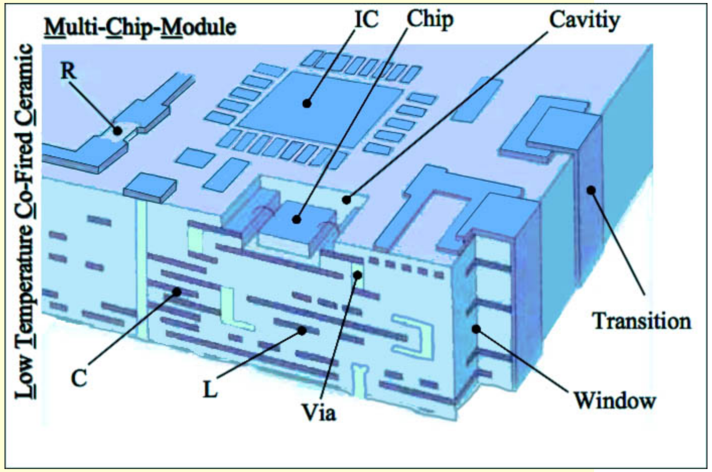
Lamination up to 80 layers

Firing < 900°C

by Heraeus

ADVANTAGES OF LTCC FOR MICRO-FLUIDIC APPLICATIONS

- Excellent chemical / thermal stability
- Ease of machinability of tapes
- Cost effective
- High density packaging
- Hermeticity of the structures



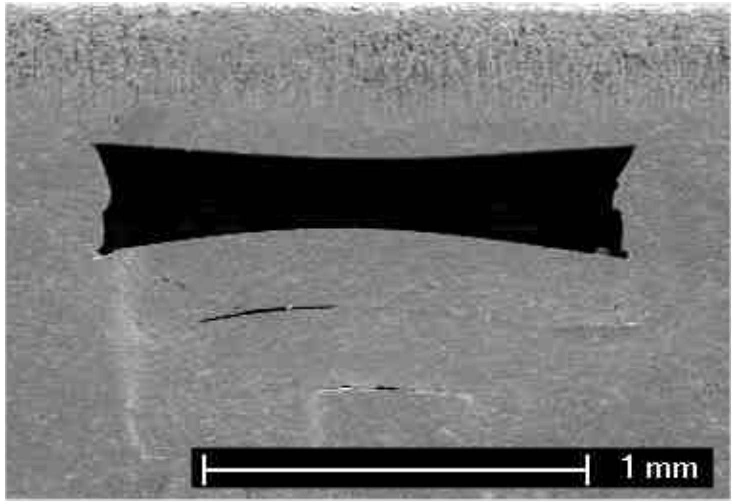
- Mechanical and electrical functions in one system

CHALLANGES

Sagging

Unsupported cavity is deformed during:

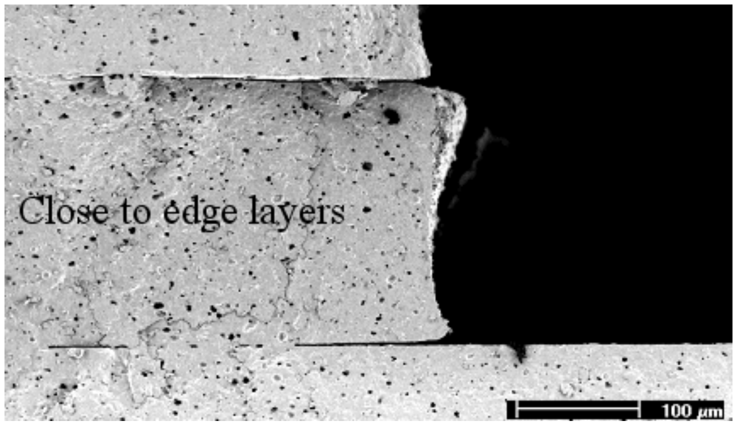
→Lamination (lamination stress)
→Sintering (over Tg)



Delamination / Disintegration

Occurs due to:

→Poor lamination
→Geometrical constraints



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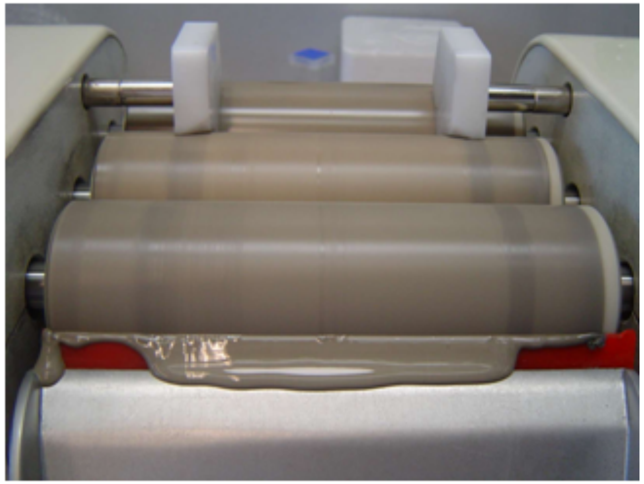
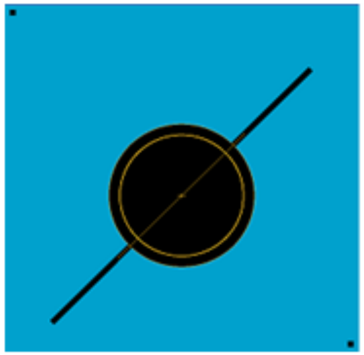
CARBON SACRIFICIAL PASTE PREPARATION

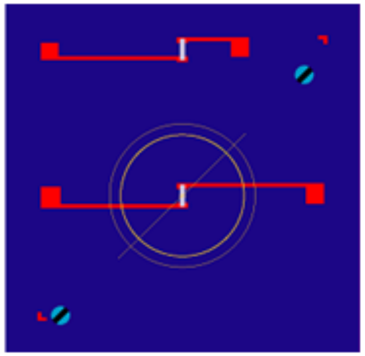
Product	Function	Specification	Supplier
Graphite	Sacrificial	d_{50} : 1-2μm (used lot) ★	Aldrich, 28,286-3
		d_{50} : 11μm	TIMCAL, Timrex-KS25
		d_{50} : 15. 3μm ★	TIMCAL, Timrex-KS5-25
Ethyl cellulose	Binder	control of rheology	Aldrich, 43,383-7
Terpineol	Solvent	slurry viscosity	Fluka, 86480
Acetyl acetone	Dispersant	dispersing additive	Sigma-Aldrich, P775-4

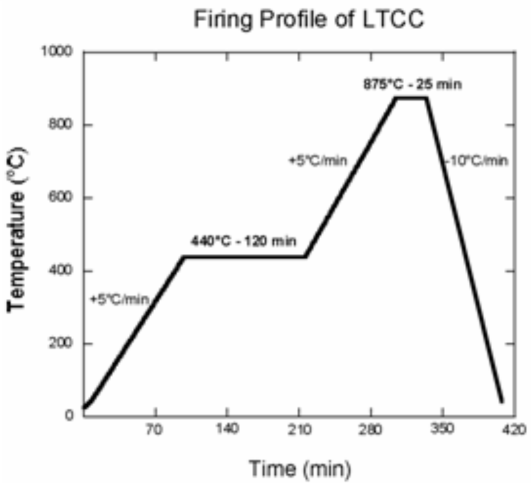
Graphite 26 wt%

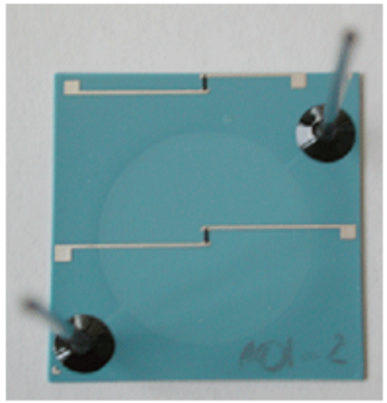
Organics 74 wt%



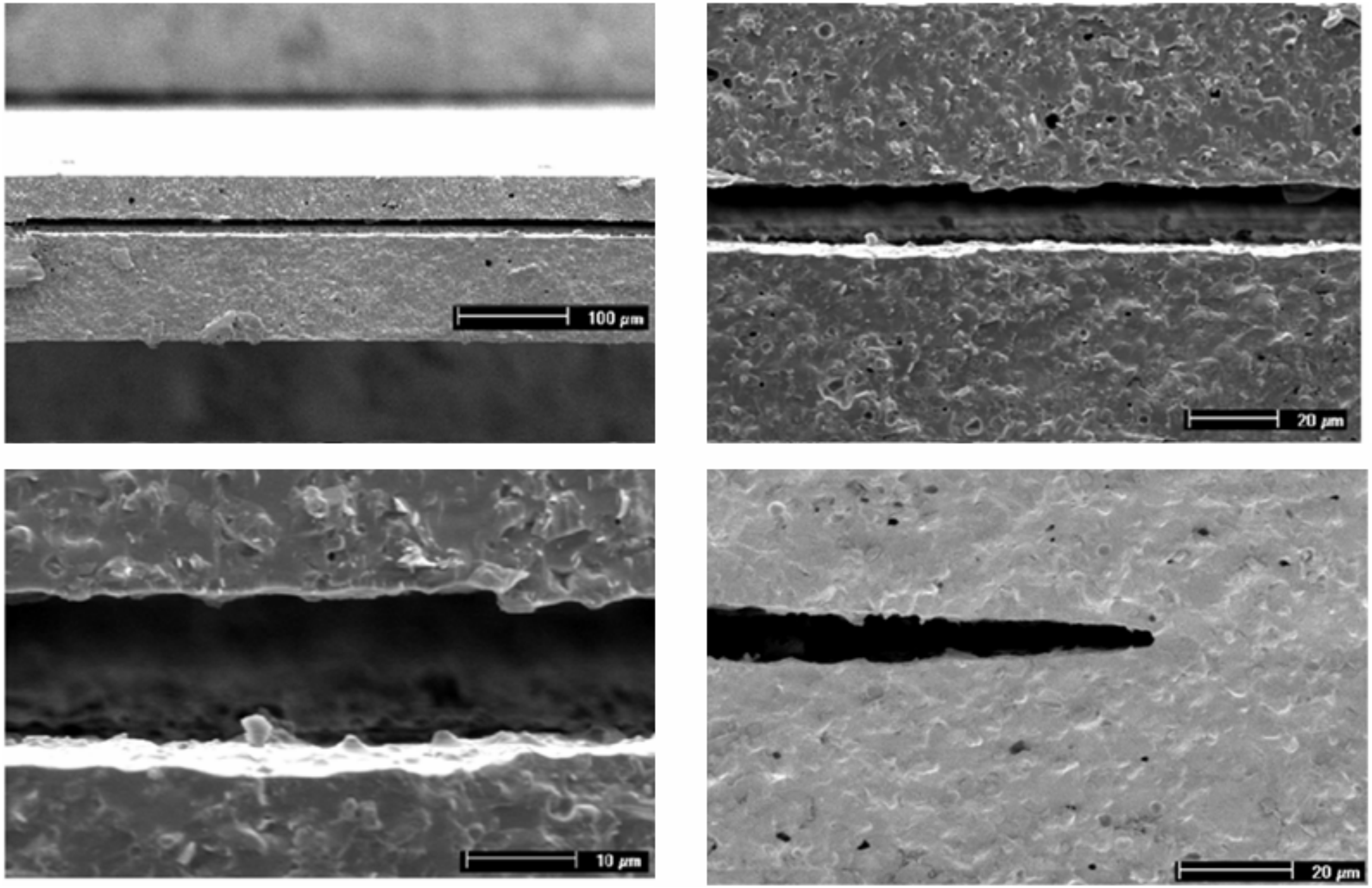






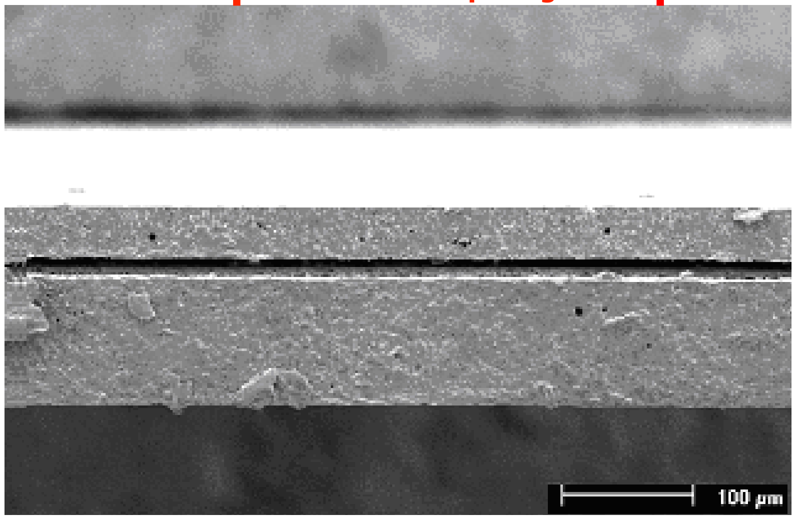


FABRICATED STRUCTURES

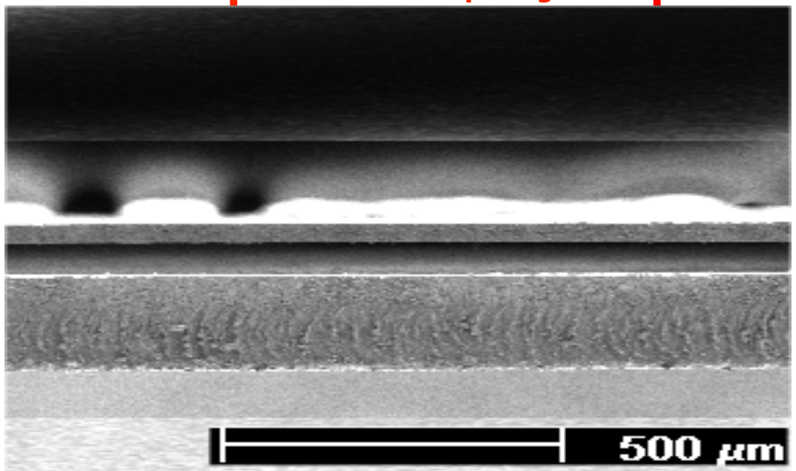


FABRICATED STRUCTURES

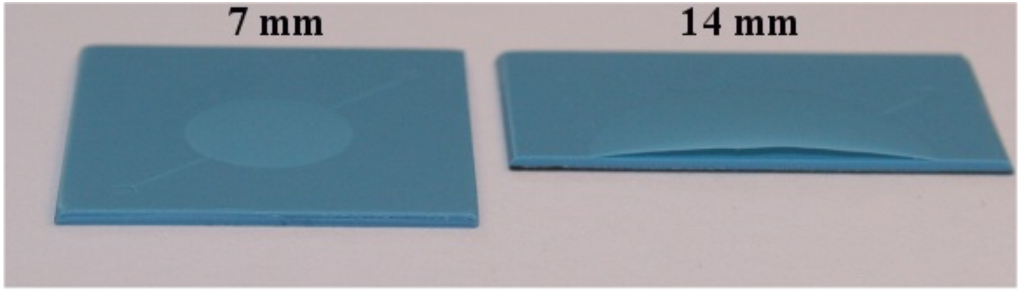
d_{50} ~2µm ⟶ $t_{spacing}$ ~13µm

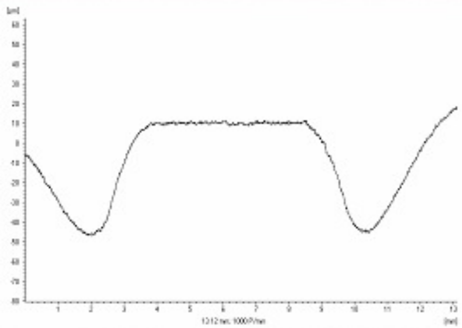


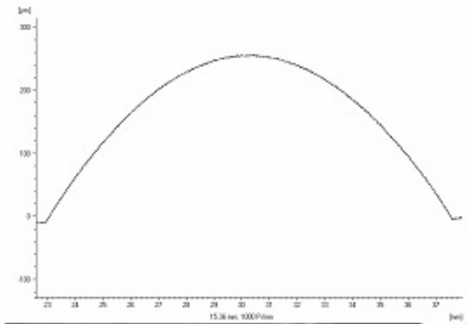
d_{50} ~15µm ⟶ $t_{spacing}$ ~60µm

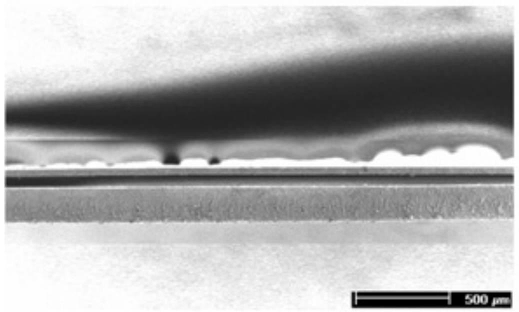


d_{50} ~15µm → <u>**Swelling**</u>









CORRELATION

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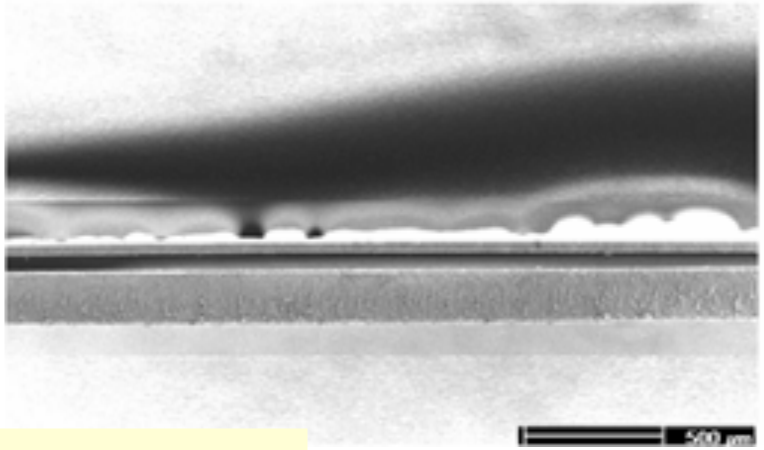
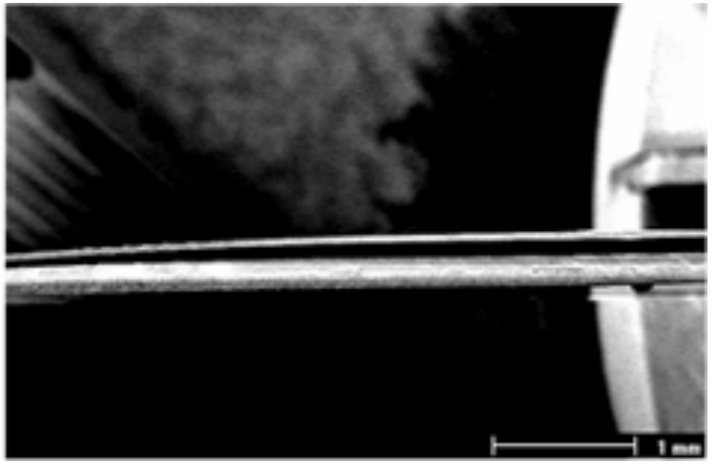
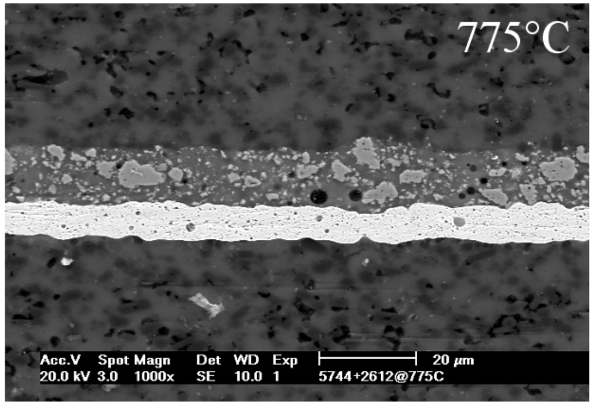
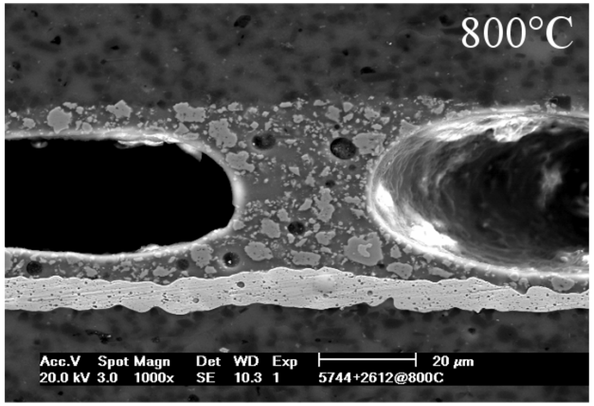
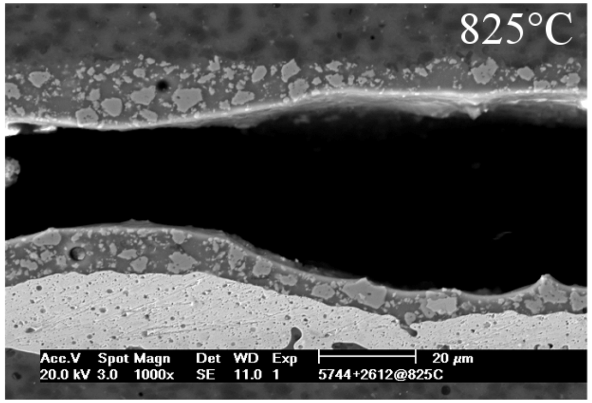




Membranes







Buried TFR

→ **What is the origin of swelling (at 750-800°C) ?**

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CHARACTERSTICS OF GRAPHITE and LTCC

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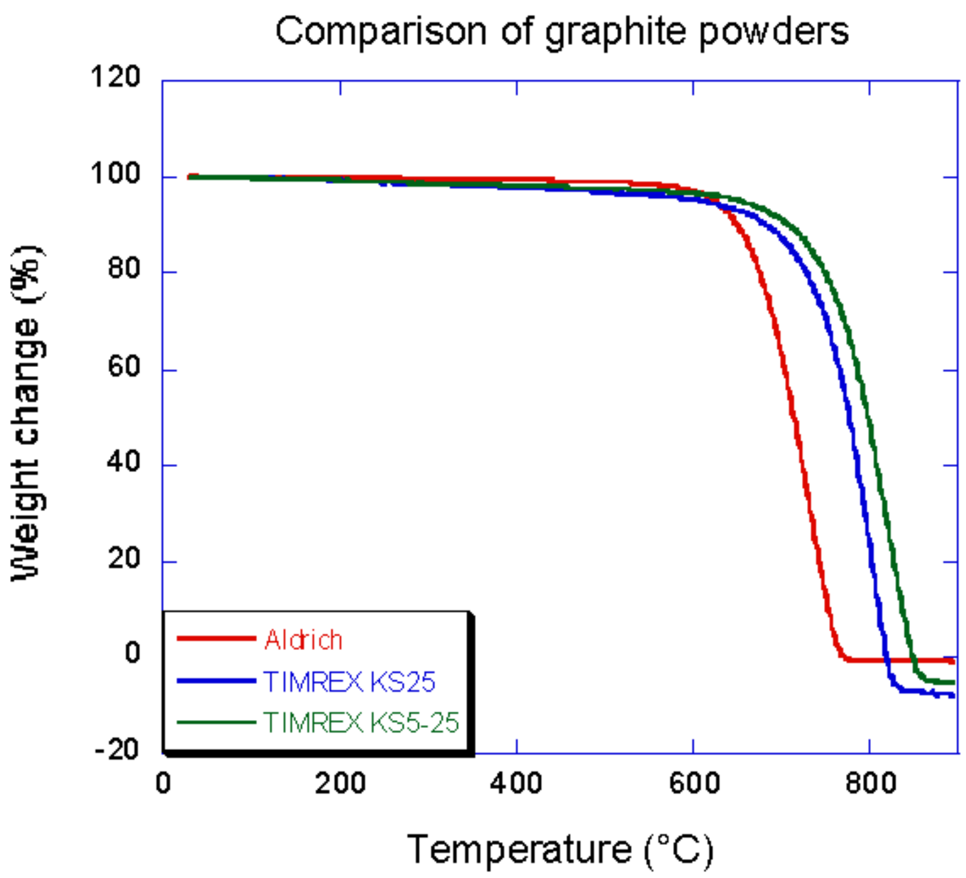

→ *Heating rate of 10°C/min in air!*

Burnout temperature of graphite;

d_{50} ~2µm → 770°C

d_{50} ~15µm → 860°C

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Ideal graphite burnout reaction;

$C(s) + O_2(g) \rightarrow CO_2(g)$

What is the final temperature for full-degassing of burnt products?

OR

What is the temperature for elemi-nation of LTCC open-porosity?

DETERMINATION of LTCC OPEN-POROSITY ELEMINATION TEMPERATURE

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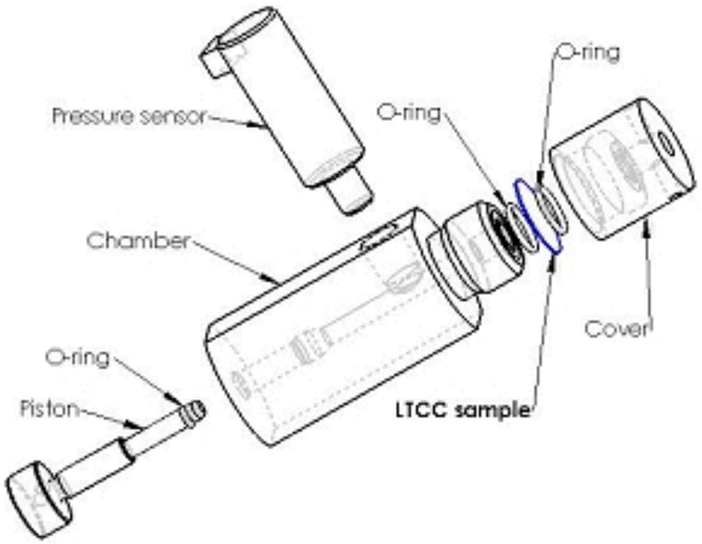
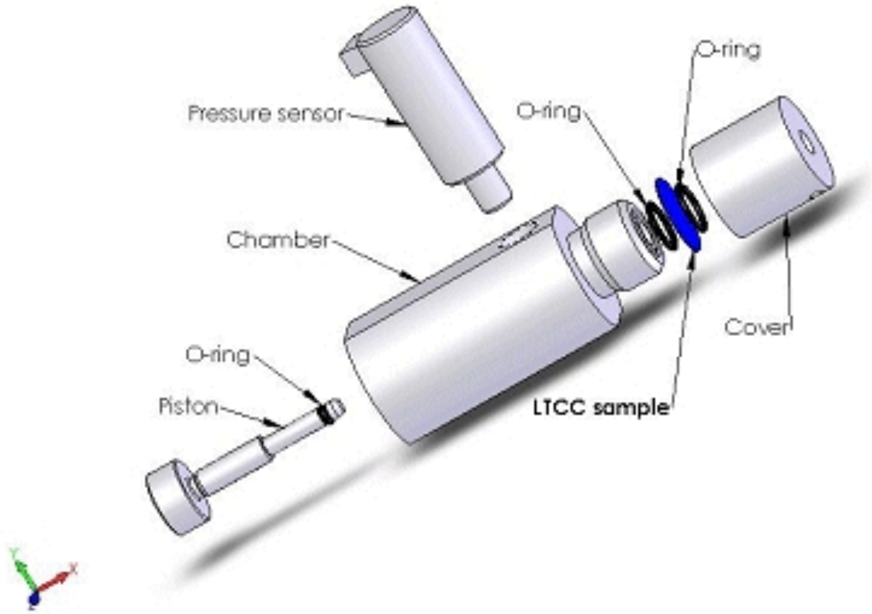
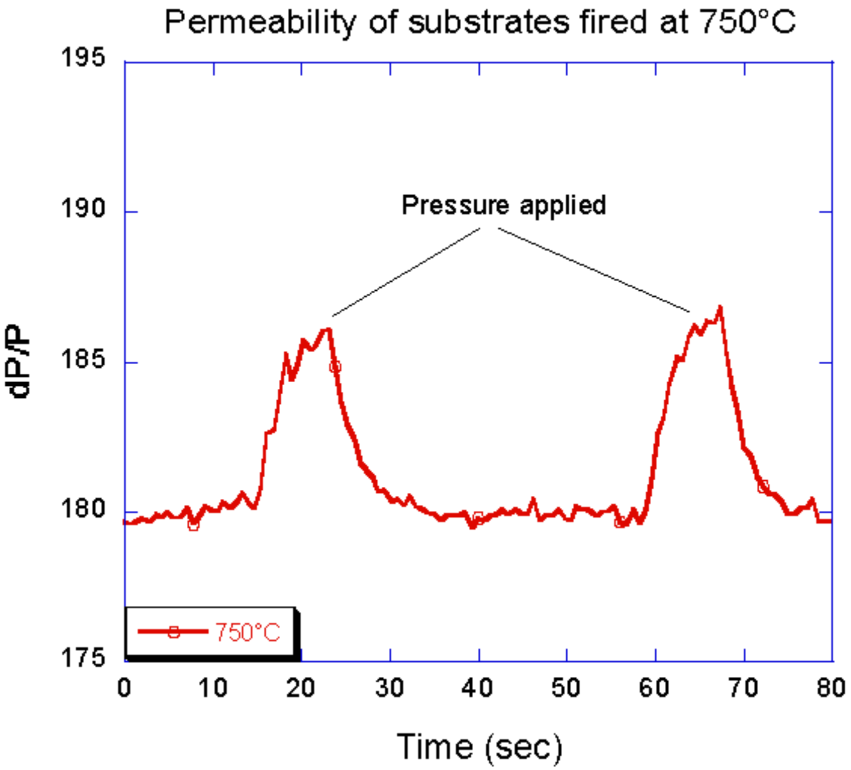
Closed-chamber for determination of open-porosity elemination temperature

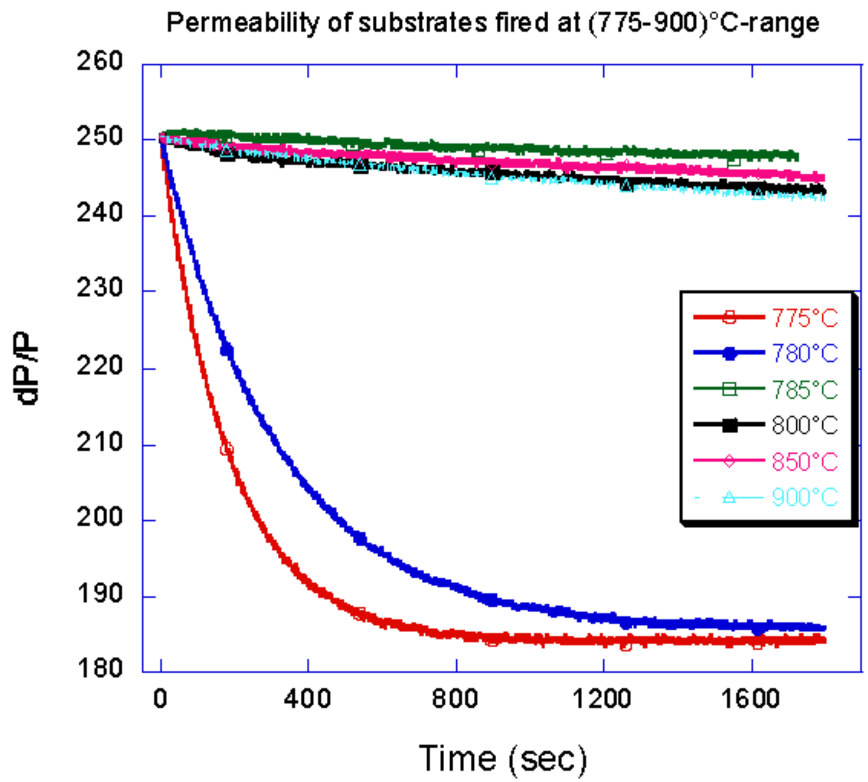




Air leakage through LTCC is detected via presure-relaxation time

DETERMINATION of LTCC OPEN-POROSITY ELEMINATION TEMPERATURE





Permeable substrate at 750°C

Open-porosity eleminated at ~ 785°C

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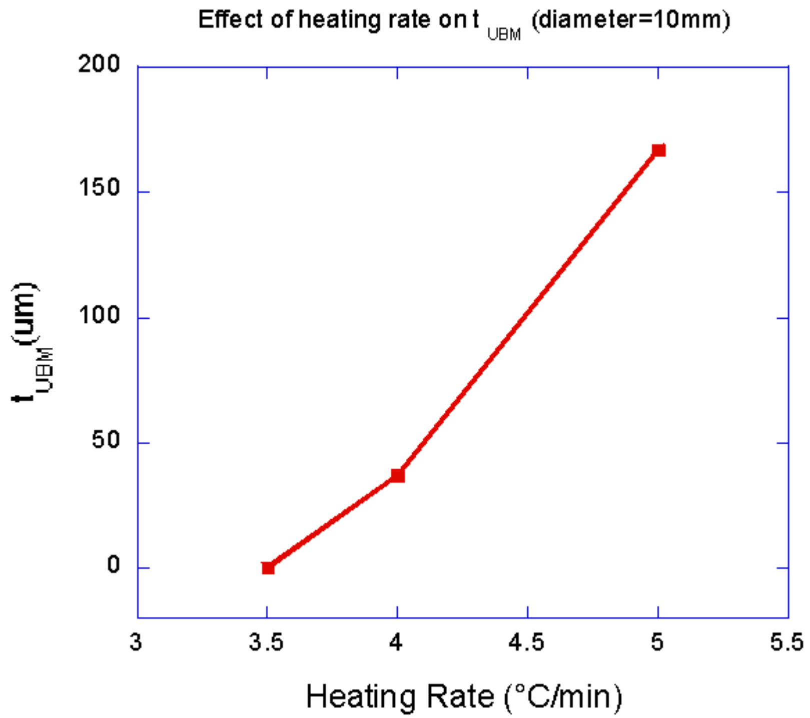
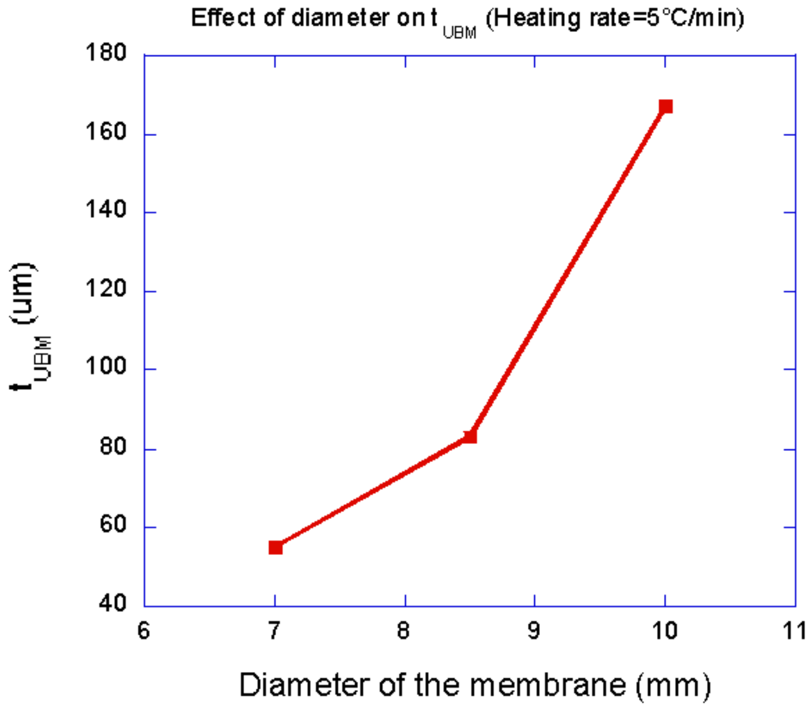
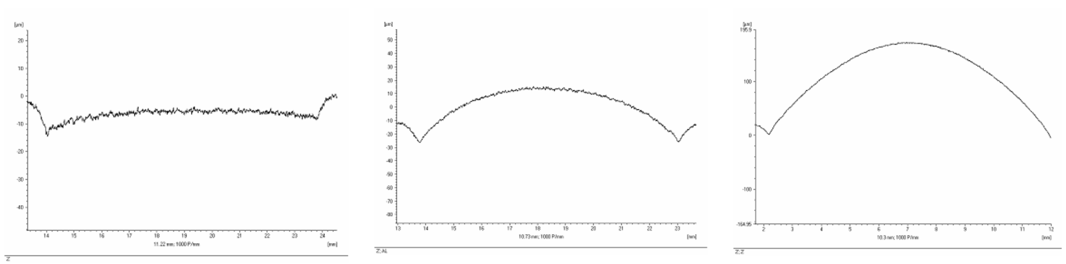
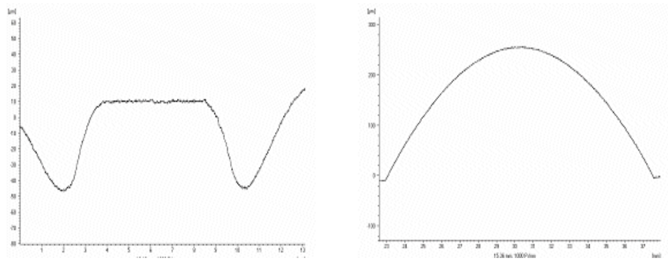
EFFECT OF PROCESSING CONDITIONS ON STRUCTURE









ORIGIN OF MEMBRANE CHARACTERISTICS

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Graphite powder	$T_{burnout}$ (°C)*	$T_{LTCC\text{-}open\text{-}pore\ elimination}$ (°C)+	Unburned (%)
Fine (d_{50}~2µm)	770	785	0
Coarse (d_{50}~15µm)	865		less than 55

* : *Heating in air at 10°C/min rate*
\+ : *Heating in air at 5°C/min rate*

The spacing and membrane flatness is determined by the competition between the kinetics of

- the graphite burnout
- LTCC sintering

→ The chemistry,
→ Particle size (d50),
→ Heating rate,
→ Membrane diameter,
→ Thickness

Closure of LTCC porosity leads to depletion of oxygen to burn the graphite, which shifts the CO/CO_2 equilibrium according to

→ **$C(s) + CO_2(g) \rightarrow 2CO(g)$**

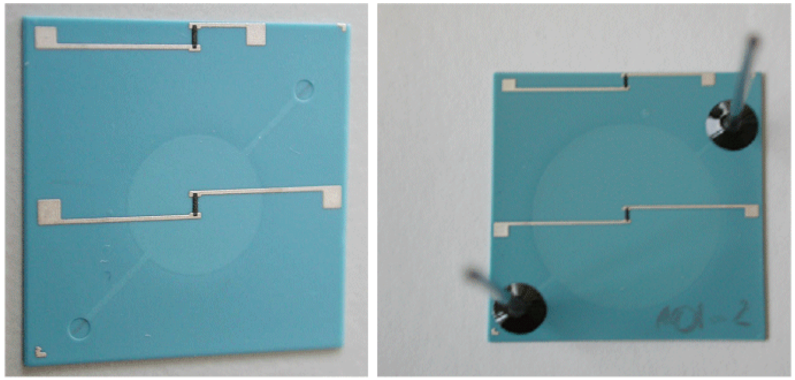
CONCLUSIONS

- Carbon sacrificial pastes effectively used for fabrication of membranes/channels

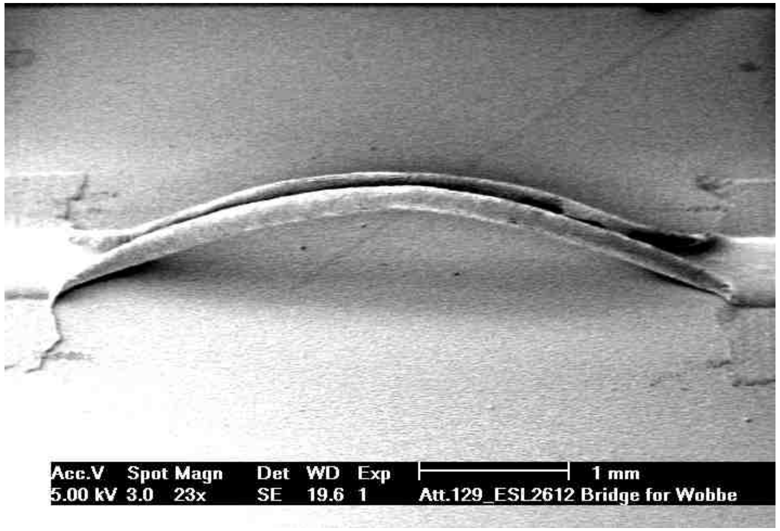
- Membranes produced with
  - → thickness: of <u>40µm</u>
  - → diameter: 7,10, 15, <u>18mm</u>
  - → spacing: (<u>10-100µm</u>)

- Final membrane features dependent on graphite powder and LTCC properties

  → Desired structures can be fabricated selecting the right processing parameters



14mm-diameter-membrane with PTC resistors



PTC free-hanging bridge on LTCC

NEXT STEPS

- Investigation of different paste compositions (permanent sacrificials)
- Improving the lamination technique
- Application of non-destrcutive testing methods e.g. ultrasonic microscope, for examing the entire structure
- Measurements with the prototypes