

Abstract

Free sintered **Low Temperature Cofired Ceramics (LTCC)** substrates are often assessed in their dimensional accuracy concluding that the overall x/y-shrinkage and tolerances at sintering might be responsible for component assembly problems. The tolerance effect increases in relation with substrate size.

That's why in the last years different new sintering methods for LTCC improve on importance.

The paper describes results of our investigations concerning the shrinkage behaviour of substrates made out of varying tape material counts of DuPont 951, *Ceramtek Ceramtape* and *others* using release tape 953A6 following the pressure less and especially the pressure assisted sintering procedures.

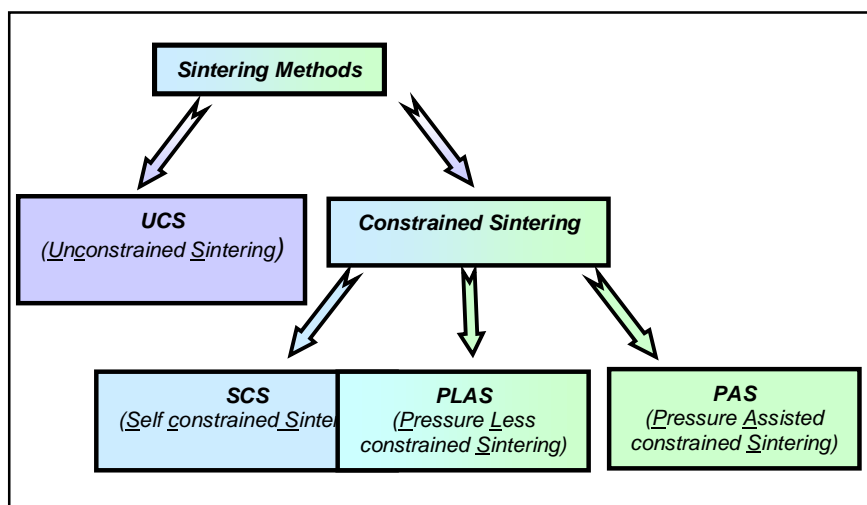


Fig. 01: Sintering methods for LTCC

Sintering methods

Free sintering is the most used method for production of substrates, one may also call it the „**Unconstrained Sintering**“ (**UCS**) method.

The most talked about disadvantage of this inexpensive LTCC sintering process is the shrinkage of tiles in all directions with relative high tolerances of up to $\pm 0.5\%$. The typically achieved $\pm 0.3\%$ for x- and y-direction still causes problems for device mounting and requires post processing to provide acceptable catch pad tolerance.

Additionally module waviness caused by TCE mismatch of conductor inks lead to more problems at assembly. The relative high lamination pressure often generates deformation of cavities and holes.

Constrained sintering essentially almost eliminates the x/y-shrinkage. Three constrained sintering processes are known. The **Self constrained Sintering (SCS)**, the **Pressure Less constrained Sintering (PLAS)** and **Pressure Assisted constrained Sintering (PAS)**. Besides the costs of additional release tapes and their removal after sintering, the installation of a special hot pressure-sintering furnace have to be considered. Advantages (+) and disadvantages (-) and some technical characteristics are listed in figure 02.

Sintering process	main advantages and disadvantages
UCS	<ul style="list-style-type: none"> + cheapest way, modules immediately finished for post processes + cofired conductors on surfaces possible + full standard ink system exists + cavities, holes, channels and mouldings possible - lamination pressure 3000psi - high absolute shrinkage: x, y = $12,7 \pm 0,3$ %; z = 17 % - full conductor layers in cofiring impossible
SCS	<ul style="list-style-type: none"> + limited shrinkage in x/y direction (~ 0.3 %) + cofiring of inlays nearly and nearly full conductor layers in cofiring possible + no sacrificial layer necessary - not available yet - limited ink system (via conductors and postfired resistors very critical) - no tape material with low loss features available
PLAS	<ul style="list-style-type: none"> + lamination pressure down 1000psi + limited shrinkage in x/y direction (~ 0.3 %) + nearly full conductor layers in cofiring possible - sacrificial layer and often removal process is necessary - shrinkage nearby edges therefore limited number of layers - limited ink system cofire prints on surface are critical
PAS	<ul style="list-style-type: none"> + lamination pressure down 1000psi + shrinkage controllable to 0.0% + full conductor layers and inlays possible in cofiring possible + better accuracy of cavities possible - sacrificial layer and often removal process is necessary - limited ink system, cofire prints on surface are critical

Fig. 02: Features of the Sintering processes for LTCC

Pressure Furnace

This paper discusses results of our investigations using PLAS and especially PAS methods and possibilities of overcoming some of the mentioned problems. A special furnace was used for the PAS process. Modules of up to 4 inches can be sintered under pressure. A uniaxial force of up to 50 kN can be applied during sintering.

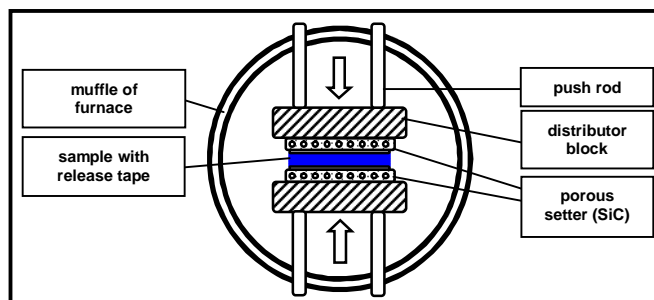


Fig. 03: Furnace for the PAS process

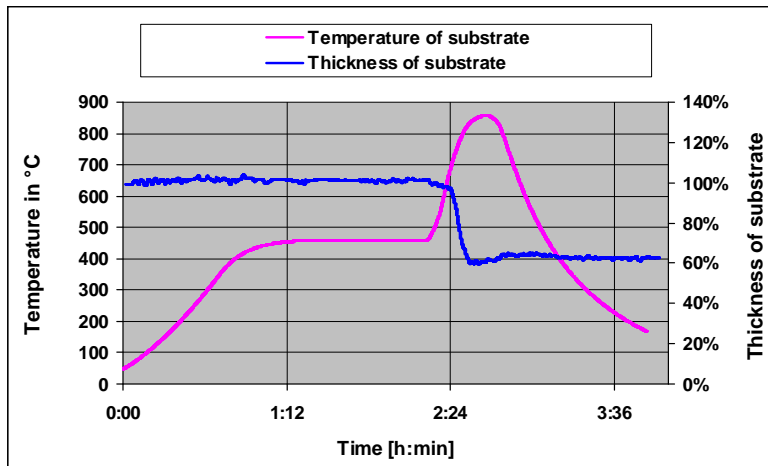


Fig. 04: Temperature profile and changes of the substrate thickness during the sintering

Influence of PAS to the Substrate Thickness

Fig. 05 shows the shrinkage in z-direction. As expected it depends on the sintering pressure and is about the volume shrinkage.

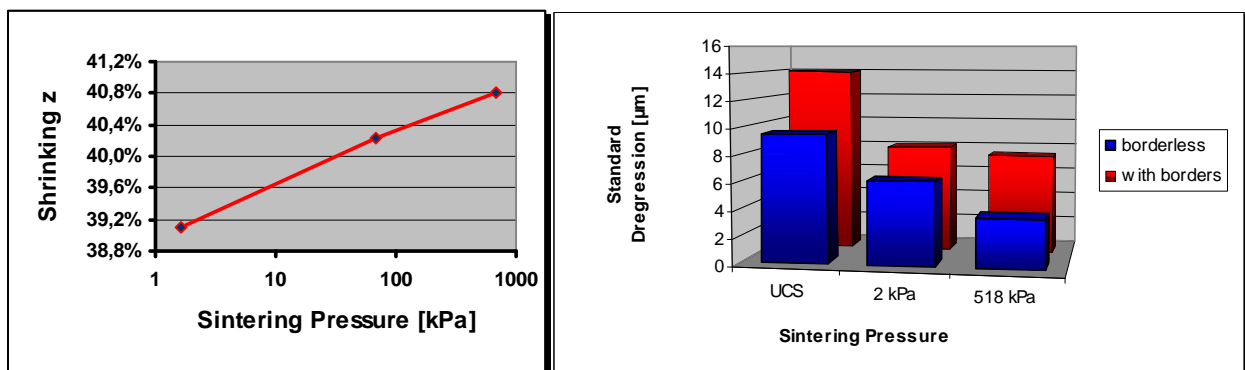


Fig. 05: Substrate shrinking and tolerances of thickness after sintering at different pressures (6- layer substrates)

Shrinkage Behaviour

(DuPont 951, other tapes (Ceramtape, Heratape) will follow soon **are under way**)

Experimental Procedure

The investigation of the shrinkage behaviour was realised on modules of 6 layers of LTCC with top and bottom layer of release tape. Silver filled vias in different distances arranged around a centre via were used for the measurement procedure. The vias positioned in the middle layers were measured before and after the sintering process using an X-ray microscope.

Investigated Shrinkage

A disadvantage of the UCS- process is high absolute shrinkage and especially the tolerance of 0.2%. Additional influence caused by conductor TCE-mismatch enlarges the problem.

The investigation shows that the absolute shrinkage with the PLAS process is restricted to under 0.3%, whereby the PAS process controls the shrinkage by use of the pressure (Fig. 04). If the pressure is too high then the module expands in x- and y-direction.

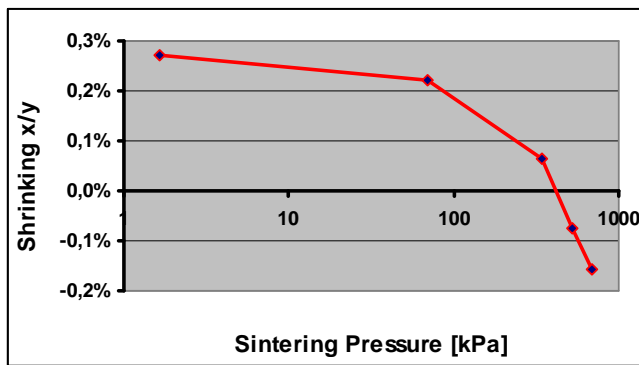


Fig. 06: Effect of applied sintering pressure on via location (inner layer)

Not all areas are shrinking with at the same rate.

At lower pressures the rate is nearly constant, at higher pressures differences between inner and outer areas rises (Fig. 07).

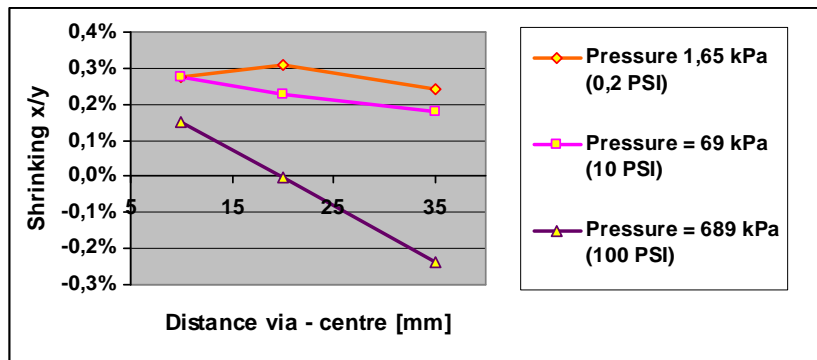


Fig. 07: Effect of distance from centre for shrinkage (negative value = expansion)

Constrained Sintering and Cavity Formation

An advantage of the constrained sintering processes is the lower lamination pressure in use. It leads to lower tolerances after lamination. Besides the loading of edges is strongly sinking. This leads to better results in realizing of cavities or holes. But one problem of the PLAS is that edges and nearby placed vias become concave. The effect is restricted to the area of more than 2 mm around the edge.

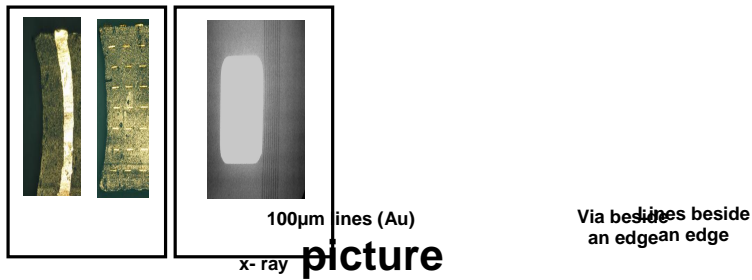


Fig. 08: PLAS - Effects of shrinkage nearby edges

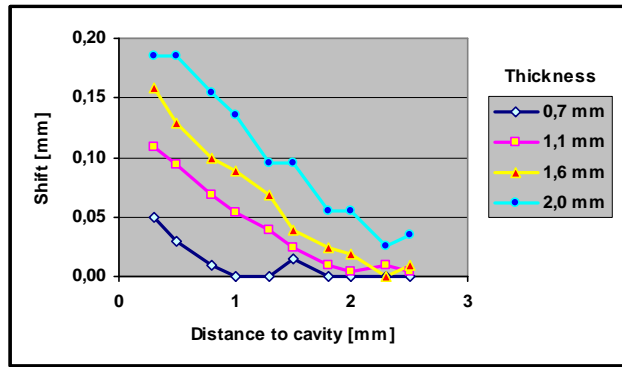


Fig. 09: Effects of shrinkage nearby edges are restricted to an area of 2,5 - 3,0mm

Using the PAS process this problem can be avoided. The PAS process offers additionally the control on edge deformation. The shape of vertical edges is directly dependent on the applied sintering pressure.

An example is a module with 6 layers. At no pressure during the sintering, a strong shrinking of the inner layers is visible. The best result was achieved at a pressure of 10 psi (0.7 bar), at a pressure of 100 psi (7 bar) bulges show up. The optimal pressure depends on the LTCC material and the number of layers.

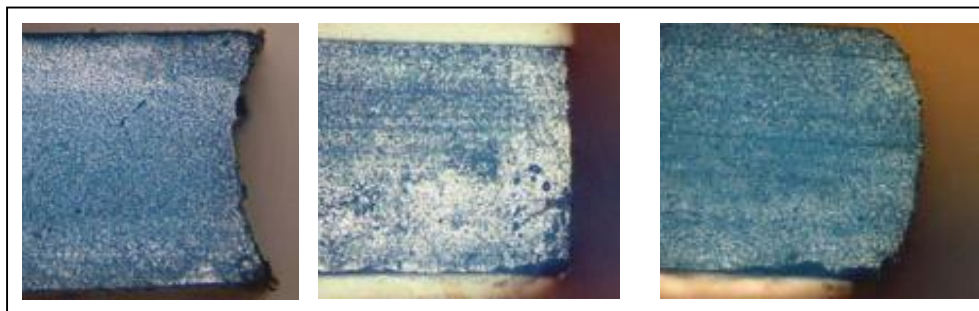


Fig. 07: Forming of vertical edges in perforations dependent on the sintering pressure (module of 6 layers; sintered thickness 0,9 mm)

Integration of Inlays in LTCC

Constrained sintering and especially PAS leads to new perspectives to realise inlays. Especially inlays with low heights (foils, wires) are qualified. However one problem remains is the different TCE in case of using metals or variant glasses and ceramics. Therefore only the PAS process is usable for larger inlays. Without external pressure during sintering the thermal mechanical forces destroy the module.

Summary

Every sintering method has special advantages. The PAS is the most expensive procedure but offers some unique advantages.

- Substrate thickness with low tolerances
- Low loss tapes usable
- Shrinkage controllable to 0.0%
- Inlays are possible

Besides the costs of additional release tapes and their removal after sintering, the installation of a special hot pressure-sintering furnace have to be considered. Advantages (+) and disadvantages (-) and some technical characteristics are listed in figure 01:

Fig. 01: Advantages and disadvantages of the different sintering processes [1-4]

This paper discusses first results of our investigations using PLAS and PAS methods and possibilities of overcoming some of the mentioned problems. A special furnace was used for the PAS process; modules of up to 4 inches can be sintered under pressure. A uniaxial force of up to 50 kN can be applied during sintering.

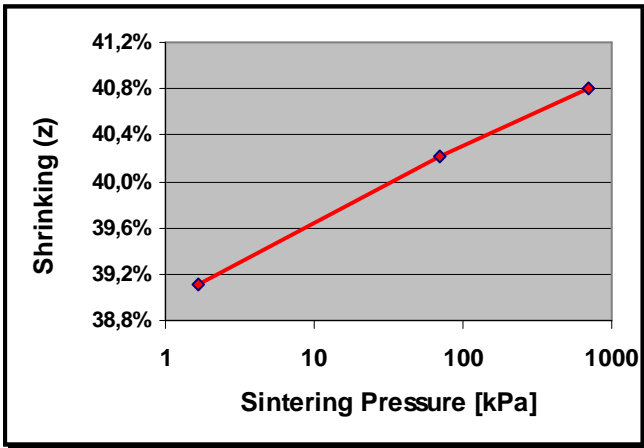
Summary

The main advantage of the 0-shrinking processes is lower shrinkage tolerances. This initial work confirms the expected behaviour and one can say that the PLAS process can be used to control shrinkage to better than 0.3%. The PAS process allows control of the shrinkage below 0.1% whereby the tolerances behave similarly.

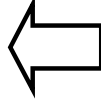
Besides the 0-shrinking technologies, especially the PAS process offers new possibilities by realisation of edges and holes. Modifications in uniaxial lamination technology and applying release tapes lead to improved manufacturing of cavities. In addition it allows new kinds of inlay integration.

References

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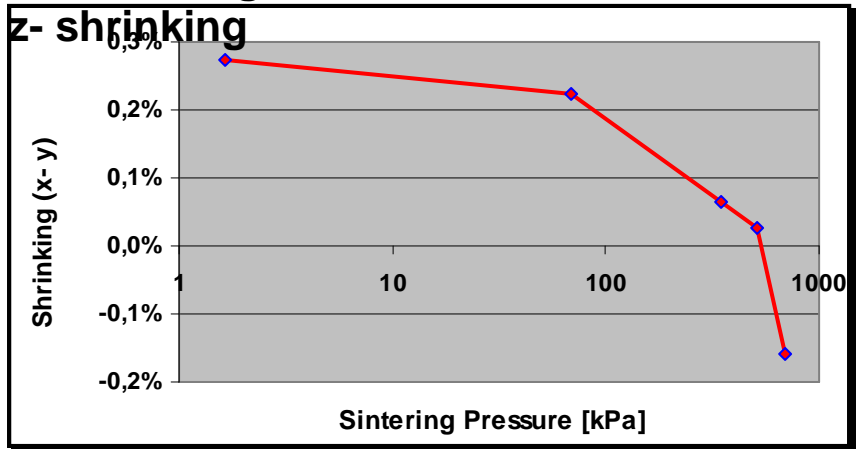


With growing pressure the tolerances (shown as area) increase.

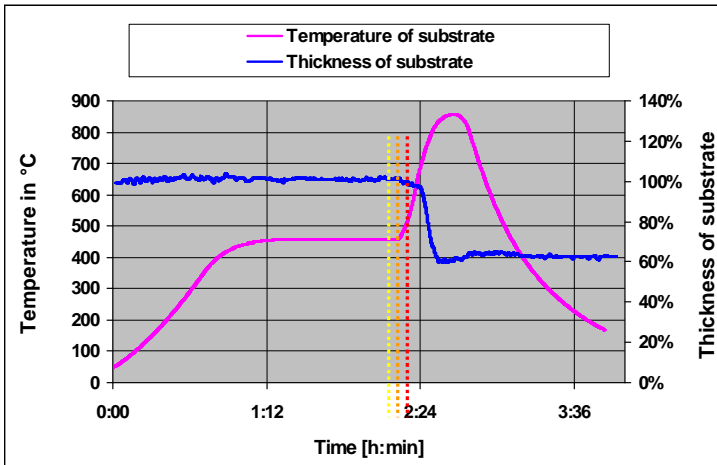


Effect of applied sintering pressure on z- shrinking

Shrinkage differences between inner and outer areas rise at higher pressure.



Effect of applied sintering pressure on via location (x- y- shrinkage)



The shrinkage happens in a short part of the sintering process. The pressure in this time and directly after, influences shrinkage and tolerances.

Influence of pressure reduction at three different times.

