FABRICATION ISSUES USING LTCC TECHNOLOGY FOR FIA WATER QUALITY SYSTEM

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Abstract—**The focus of the present paper is the Low Temperature Co-fired Ceramics (LTCC) technology and its utilization for the fabrication of 3-D hydraulic (manifold and micro-channels) and packaging (silicon sensor encapsulation) structures for a On-line water monitoring system. Fabrication issues as the sagging problem in LTCC is addressed for these devices and some results are discussed.**

Index Terms— **LTCC, Micro-channels Sagging control, FIA, Meso- systems.**

I. INTRODUCTION

IN the chemical, semiconductor & biotechnology industries there are increased needs for microfluidic systems with several requirements as smaller sizes, lower dead volumes, shorter response time, lower power consumption and integration of several fluidic devices with multi-sensor possibilities and low cost. The brief description given here demonstrates how LTCC technology is a suitable material system for the fabrication of Meso Analytical system components for water in situ analysis of heavy metal contaminants in drinking, industrial and natural water [1].

A FIA (Fluid Injection Analysis) system can be used to fabricate such system and consists of a fluidic manifold; reservoirs, valves and pumps, micro-channels, chemical sensors and electronics interface for communications. In this technique a sample is injected in a continuous flowing carrier and is transported downstream into a detector. On its way to the detector, the sample fluid is mixed with the carrier and reagent solutions and is dispersed in a reaction coil. A detector measures the result of this reaction by means of an electrochemical sensor and the operation can be repeated all over again. Most of the modules needed for a FIA system such as manifold, micro channels and fluid management devices can be fabricated and integrated using the LTCC green ceramic tapes associated with silicon technology.

In this paper we present the development a sagging compensation technique applied to micro-channel and cavities fabrication.

II. LTCC TECHNOLOGY [2]

One of the important features of green tape technology is the possibility of fabricating three-dimensional structures using multiple layers. The Green tapes are glass-ceramic composite materials. They are commercially produced in flat tapes of various thicknesses but usually in the range of 100 to 300 μm. They are called green ceramic tapes because they are manipulated in the green stage; that is before firing and sintering.

The processing of the green ceramic tapes is usually done in three basic steps:

- Patterning of individual layers with via holes, resistors, conductors, dielectric pastes, depending on application;
- Collation and lamination of the tapes under pressure and temperature;
- Co-firing of the entire laminate to sinter the material.

The typical processing schedule for LTCC electronic packages is shown in Figure 1.

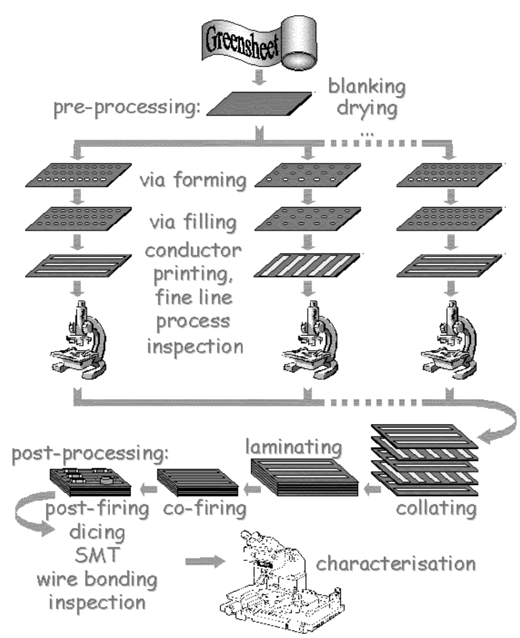

Fig. 1. Complete LTCC processing steps.

III. CONTROL OF SAGGING IN LTCC [3]

Sagging of suspended or laminated structures is a common problem in LTCC processing. These materials are subject to plastic deformation upon lamination or under the stress of

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body forces once the glass transition temperature of the glass binder is reached during sintering.

There are three main strategies used to compensate or reduce the sagging problem:

- Deposition of thick films to compensate auto-supported structures;
- Use of sacrificial materials
- Use of fugitive phases

The use of fugitive phase materials that may disappear or flow during sintering is the strategy utilized at this time.

It is possible to use graphitic carbon black as fugitive phase when sintering is accomplished in a neutral or just slightly oxidizing atmosphere. The gasification of the graphitic carbon (reaction with oxygen to form carbon mono, and dioxide) is slow and little graphite is lost before the bridging or suspended ceramic structure becomes rigid.

After that point, one can open the furnace to air and burn-off the graphitic carbon. Samples were fired with structures where the feature size is large enough for the sagging to be evident and easily measured.

IV. Experimental Procedure

Micro-channels using LTCC can be implemented in a simple way, in this case three layers are enough to fabricate the channel. Top layer makes media interconnection, middle layer makes the channel itself (that could be straight, in L, Y, U, spiral or any desired complex shape); bottom layer makes the device base, as shown in Fig. 2 below.

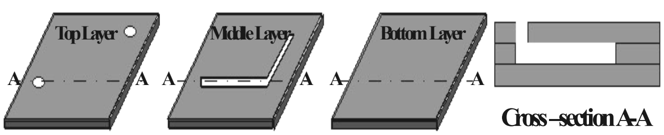

Fig. 2. Micro-channel implementation using LTCC

Several micro-channel and cavity configurations had been tested specially for large hydraulic and aspect ratio in order to test the compensation scheme.

For processing devices, individual layers are stacked, registered, and laminated to yield the desired structure. Heat and pressure are applied to the stack to complete the lamination process using pressures of 3000 PSI, at 90°C.

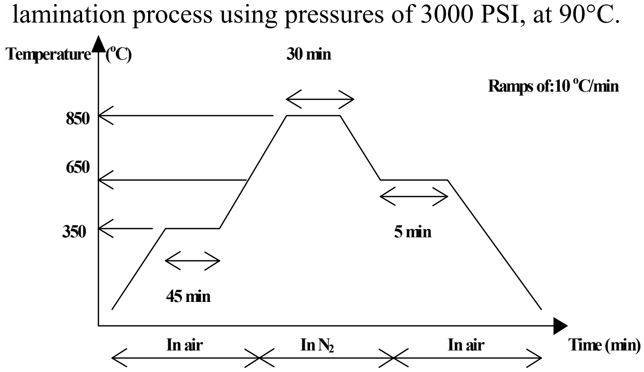

Fig. 3. Sintering profile for sagging control

The laminates are then ready for sintering, which is done with a special sintering profile. During the sintering process the tapes shrink in all dimensions. DuPont 951 tape shrinks 14 % in the x, y plane and 15 % along the z-axis and this can be compensated for in the design process. The sagging compensation can be accomplished by changing the temperature sintering profile and the furnace atmosphere controlling the air/nitrogen ratio. A possible sintering profile modification for sagging control is shown in Fig. 3.

V. Results And Discussion

Several processing tests were worked-out in order to verify compensation latitude. Various cavities and micro-channels with different aspect ratio from 1-10 to 1-60 were tested showing the great compensation potential of the technique. In Fig. 4. is depicted a photo of a sintered cavity without and with carbon black paste.

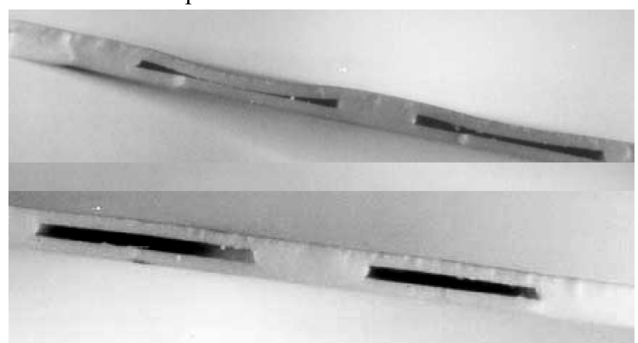

Fig. 4. Sintered cavity without and with carbon black paste.

Straight Micro-channels were successfully fabricated using the carbon black paste compensation technique, in Fig. 5. is presented a set of micro-channels with different aspect ratio.

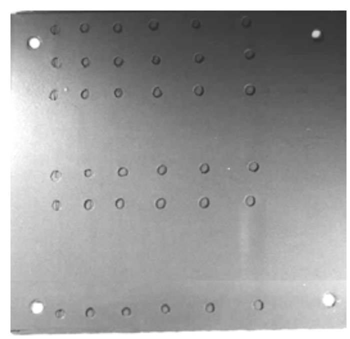

Fig.5. Fabricated LTCC straight Micro-channels

VI. Some Applications

Let's take as an example of LTCC hybrid technology application in meso-systems, a well known analytical technique: FIA. In this technique a sample is injected in a continuous flowing reagent then mixed and transported downstream into a detector. At this time we will show how the sagging prevention technique can contribute to the fabrication of one important part of the FIA system: the sample-reagent mixer device.

Measurements performed by Moon in straight conduits display linear pressure drop for low Reynolds numbers [4].

Micro-channels displays low Reynolds numbers so liquids fall in a laminar regime and they mix mainly by diffusion. When a bend is added to the micro channel it behaves as a passive mixer, because of a local turbulent flow in the bend, so a meander coil of micro-channels will mix liquids quite well in a moderate time, figure 6. depicts a LTCC based 3D passive mixer. The majority of these micro-mixers are designed to mix compounds for performing reactions in micro chemical systems.

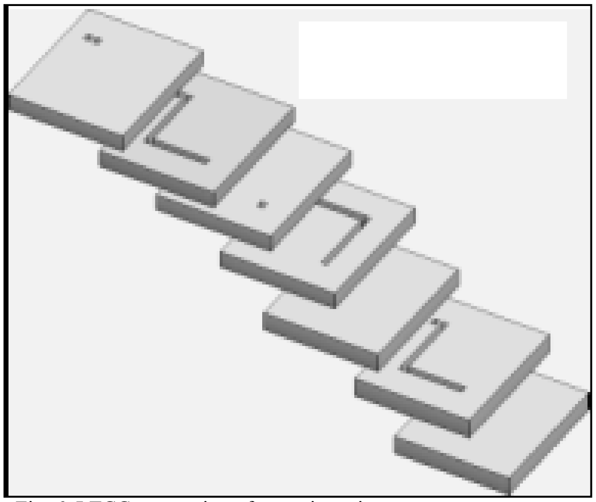

Fig. 6. LTCC conception of a passive mixer.

In order to have homogeneous mixing and known flow in micro-channels we must have controlled dimensions, obtained using the carbon black paste sagging compensation technique.

In other applications when cavities are needed this technique can be successfully applied. Micromixers can also play a role in the study of reactions on the mili-second time scale. Here, a micro-mixer is presented in which a vortex is employed to decrease mixing times by reduction of diffusion distance. This device currently in evaluation is a vortex passive mixer, that can mix liquids very fast with low pressure drop. The geometry of such device can be seen in figure 7.

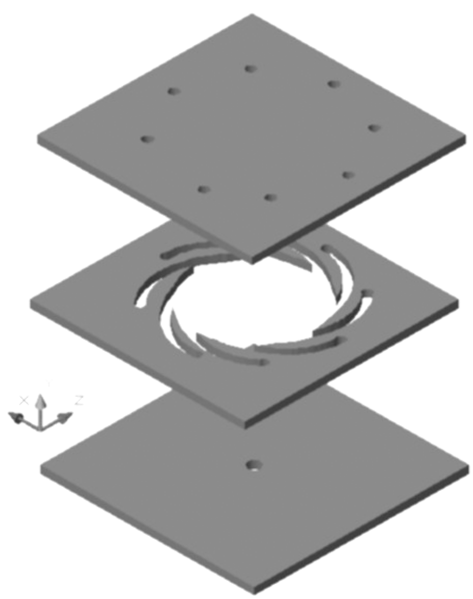

Fig. 6. LTCC conception of a passive vortex mixer

Geometry control and sagging prevention in cavity is mandatory for this device.

The vortex mixer work as follows: fluids sample and reagent are alternately applied to 8 tangential inlets, the liquids to be mixed enter at high speed into the vortex chamber. Due to the high injection speed, in the vortex chamber, a rotational flow field is induced reducing the diffusion distance, as a result mixing times can be significantly decreased.

VII. Conclusions

Water quality assessment today is a necessity; this work is contributing to the technical feasibility of an On-line water monitoring system. Fabrication issues related to sagging problem in LTCC processing was discussed, some compensations possibilities were explored and some applications were presented

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