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Materials Chemistry and Physics 89 (2005) 56–63
MATERIALS CHEMISTRY AND PHYSICS
www.elsevier.com/locate/matchemphys

Molecular Weiss domain polarization in piezoceramics to diaphragm, cantilever and channel construction in low-temperature-cofired ceramics for micro-fluidic applications

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Received 2 August 2004; received in revised form 8 August 2004; accepted 24 August 2004

Abstract

This paper presents the efforts made to study the process of comminution to Weiss domain polarization and phase transition in piezoceramics together with the versatility of low-temperature-cofired ceramics-based devices and components for their ready adoption for typical applications in the area of micro-fluidics. A conceptual micro-fluidic module has been presented and few unit entities necessary for its realization have been described. The purpose of these entities is to position the sensors and actuators by using piezoelectric materials. Investigations are performed to make useful constructions like diaphragms and cantilevers for laying the sensing elements, cavities for burying the electronic chip devices, and channels for fluid transportation. In order to realize these constructions, the basic step involves machining of circular, straight line, rectangular and square-shaped structure in the green ceramic tapes followed by lamination and firing with post-machining in some cases. The diaphragm and cavity includes one or more un-machined layer stacked together with several machined layers with rectangular or square slits. The cantilever is an extension of the diaphragm creation process with inclusion of a post-machining step. The channel essentially consists of a machined green ceramic layer sandwiched between an un-machined and a partially machined layer. The fabrication for all the above constructions has been exemplified and the details have been discussed.

Keywords: Ceramics; Multilayers; Piezoelectricity; Crystal symmetry

1. Introduction

Micro-electromechanical systems and micro-system technologies provide the means for system integration with increased performance and reliability and decreased size and cost. There is a rising demand of micro-fluidic systems in chemical, semiconductor and bio-technology sector with requirements as reduced size, high effective volumes, small response time, low power consumption, multi-sensor and fluidic integration, reduced cost and on-line or web monitoring. The development in this field has shown steady growth, driving the frontiers of new materials, processes and technologies for applications like micro-systems for chemical analysis, drug delivery, environmental data acquisition and micro-total analysis systems [1–4].

The low-temperature-cofired ceramics (LTCC) technology is an efficient and convenient medium for the manufacture of integrated fluidic systems. It has been used in the past for manufacturing monolithically packaged interconnects and hybrid microelectronics circuitry. These tapes are normally available in the form of thin sheets in the pre-fired green state. The green tapes are essentially glass–ceramic composite materials consisting of alumina and glass particles held together in an organic binder. The glass frit binder lowers the processing temperature as well as renders the material compatible with the conventional thick-film technology and the organic vehicle is responsible for binding and viscosity

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0254-0584/$ – see front matter
doi:10.1016/j.matchemphys.2004.08.023

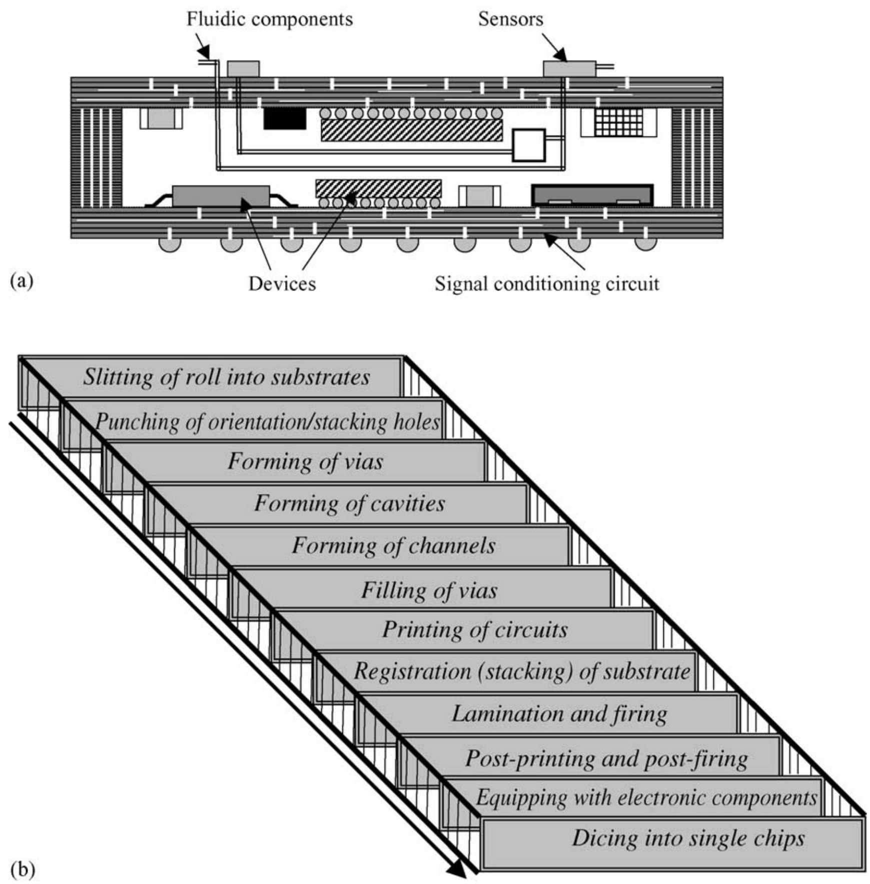

Fig. 1. Schematic representation of the micro-fluidic system (a) and brief description of the process (b).

control. The green tapes are processed in three basic steps: punching by conventional methods to create via holes in order to create vertical interconnects, patterning of individual layers with conductive, resistive and via-filler formulations, collation and lamination of the same under moderate pressure and temperature followed by co-firing to sinter the material.

This paper presents a conceptual micro-fluidic system and the fabrication of unit elements for positioning sensing or actuating films of piezoelectric materials or directly positioning piezoceramics, which is basically the building block of this system. But before going into the depth of fabrication of unit entities of the fluidic block it is important to have an overview of the micro-fluidic system, the basic piezoelectric building material and its physical principles of operation.

2. Conceptual micro-fluidic system and piezoceramics materials

2.1. Micro-fluidic structure

A representative micro-fluidic system is presented in Fig. 1a with a brief and self-explanatory description of the process in Fig. 1b. The micro-fluidic structure consists of various elements which include:

- sensing elements for pressure, temperature or flow, positioned on the top layers;
- fluid handling and control part consisting of fluidic channels, mixing chambers, pumps and valves embedded at the centre region;
- signal conditioning circuit;
- microcontroller and memory devices;
- drives connected externally.

The sensors are placed on the top layer so that they are exposed to the measurand and interact freely with it. These sensors are normally for measurement of pressure and temperature and in some cases for the flow measurement. In case of flow measurement they have to be integrated with the fluidic flow system. The temperature and pressure can be measured either in absolute values or relative to certain value depending upon the specific application. In order to make the sensing elements more effective they are fabricated on a diaphragm or a cantilever structure, which is fixed at one end and freely suspended on the other. A major task in the fabrication of a fluidic block is the integration of the sensing and actuating elements at various locations. These sensors and actuators are normally fabricated by depositing a piezoelectric film using piezoceramics target materials or by using piezoceramics itself. Weiss domain polarization and stress-induced