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LTCC, New Packaging Approach for Toxic Gas and Particle Detection

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Abstract

Packaging of chemical sensors is still an area, which is not much explored. Low temperature co-fired ceramic, LTCC, packaging offers large advantages in terms of 3D design, integration of advanced functionality and fast processing. SiC based FET gas sensors are possible to integrate directly in the LTCC co-firing process at 850°C, whereby both high temperature and other advanced applications like ultra-low detection of toxic gases are greatly improved. The LTCC packaging is also used for development of particle detectors as well as packaging for an electrical method to detect toxic effect on cells by particles.

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1. Introduction

Low Temperature Co-fired Ceramic, LTCC, is a sophisticated packaging technology developed since the 1980's and now used for embedded electrical circuits, buried passive components in applications such as automotive, telecommunication and hand-held electronics [1]. Continuous material and processing development offers benefits like parallel processing, hermetic packaging, resistance to harsh environments and high temperatures and cost

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effectiveness e.g. through fast processing. The technology is based on commercially available green tapes where e.g. conducting lines, finger electrodes and cavities are processed. Recently a tape, HeraLock 2000 (Heraeus GmbH, Germany), with almost no planar shrinkage during the firing process was discovered [2], whereby also bulk materials may be integrated within the LTCC package [3]. One of the advantages of the LTCC is the integration of electrical connections eliminating wire bonding and encapsulation. For the SiC-FET gas sensors the LTCC packaging is suitable for gas sensing in high temperature and corrosive environment as well as many other applications.

The new generation of SiC-FET gas sensors [4] have been commercialized for control of small and medium sized bioheaters (www.sensic.se). Several applications have been demonstrated for harsh environment and high temperature such as an ammonia sensor for control of the selective catalytic reduction, SCR, a process where urea is introduced in a diesel engine exhaust system for reduction of nitric oxide gases [5]. Recently it has also been shown that the SiC-FET devices, for example utilizing a porous Ir gate, are able to detect ultra-low concentrations, in the low parts per billion (ppb) range, of indoor toxic gases like formaldehyde, benzene and naphthalene [6].

Not only gas molecules but also particles show adverse effects on our health and need to be controlled. Commercial detectors are e.g. based on charging of the particles and separation of them in an electric field. The LTCC technology has the potential to provide portable and cheap particle detectors [5].

A so called cell clinic was developed for electrical monitoring of cell activity using a capacitance sensing CMOS chip [7]. This method is developed for measuring cell activity during particle exposure in order to determine toxic effect of particles on cell growth. A LTCC housing has been developed for the CMOS chip.

Here we report on the use of the LTCC packaging for SiC-FET gas sensor devices and an example of gas sensing by these devices. Furthermore, we report about the potential use of LTCC packaging for a particle detector and its use as a housing for a CMOS chip for capacitive measurements of cell growth to monitor the influence of particle exposure on cell viability.

2. Experimental

For the LTCC packaging the green tape HeraLock 2000 (Heraeus GmbH, Germany) has been used. More details can be found in a paper by M. Sobocinski et al, this proceeding.

The SiC-FET devices are designed by SenSiC AB and processed by ASCATRON AB, Stockholm, Sweden [4].

More details about the LTCC packaged CMOS chip used for capacitive monitoring of cell growth during particle exposure is found in a paper by N. Halonen et al, this proceeding.

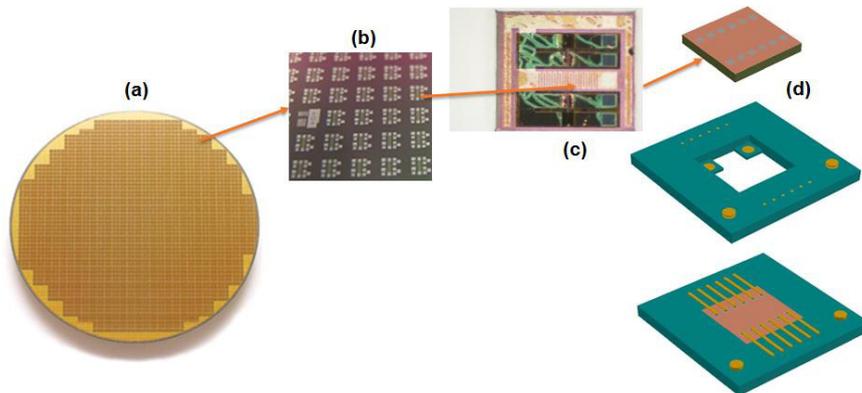


Fig. 1. (a) SiC FET devices processed on 4" SiC wafer (design SenSiC AB, processing ASCATRON AB, Sweden), (b) close up of the wafer showing several sensor chips, (c) one sensor chip hermetically integrated in the LTCC packaging, (d) schematic picture of the LTCC package

3. SiC-FET sensors

The SiC-FET device has been integrated in a LTCC package in one processing step, M. Sobocinski et al, this proceeding. This is possible due to the material properties of silicon carbide and the sturdy design of the transistor based sensor chips. The IV curves were slightly changed after the processing but the devices were still fully functioning also as gas sensors. Except for eliminating the tricky bonding step for the SiC-FET devices, the LTCC packaging also has big advantages like easy integration of functionality in the packaging, see schematic pictures in Figure 1 and 2.

The silicon carbide based transistors function as gas sensors due to the catalytic gate metal, normally porous, which is utilized as the sensing layer. Gas molecules adsorb and react on the catalytic metal surface, reaction products charge the insulator surface exposed in the pores of the catalytic metal. The formed electric field influences the current through the transistor and this change in current is the sensor response to gas molecules.

The LTCC packaging increases the commercial potential of the SiC-FET technology in many different areas. Applications are possible at high temperature as well as room temperature. Indoor atmosphere contains volatile organic compounds, VOC, such as formaldehyde, benzene and naphthalene, which are toxic already at ppb levels [8]. The SiC-FET devices in the laboratory successfully detected these three gases also in an atmosphere of high humidity with a detection level of 1 ppb for benzene, 0.5 ppb for naphthalene and 10 ppb for formaldehyde.

4. Particle detectors

The LTCC technology is also being developed for detection of particles, since these may be a threat to our health. Parameters that influences the toxic effect of particles are e.g. the size, shape, concentration and content or adsorbents on the particles. Particles may be collected and separated by applying a low temperature and/ or an electric field and also a magnetic field will give information, see Fig. 2. Finger electrodes may be used for resistivity measurements or impedance spectroscopy and has the potential to detect size and concentration of the particles. Heating the particles and detection of the emissions has been demonstrated to detect ammonia released from ash particles that originates from a power plant with an SCR system to reduce nitric oxide gases [9].

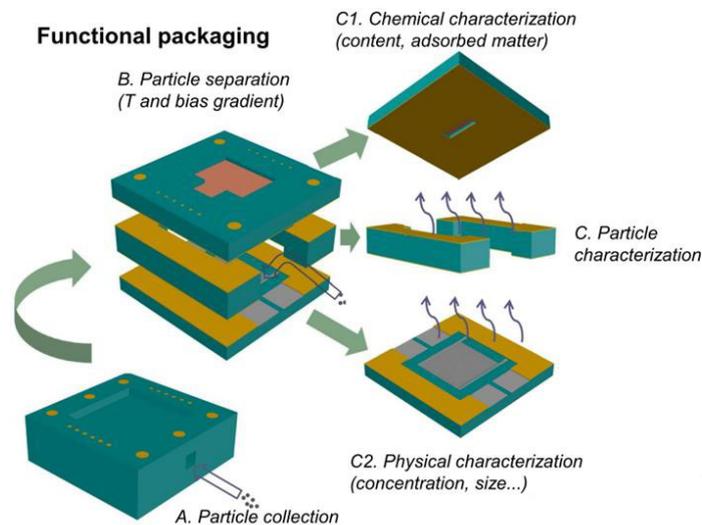


Fig. 2. Schematic picture of a particle detector based on LTCC technology. A and B. Particles are collected by a low temperature and separated by electric fields. C1 and C2. Particles are heated and the emitted gases detected by an integrated gas sensor (or gas sensor array). Finger electrodes are used for impedance spectroscopy of the particles.

5. The toxic effect of particles on cells

A CMOS chip has been developed to perform capacitive measurements of the viability of cells [7]. The method is extended to an electrical method to detect the influence of particles on cells. For this the CMOS chip is packaged using LTCC technology, see Fig. 3. The green tape used for this is the HeraLock 2000, which is considered not biocompatible. A special mounting solved this, see N. Halonen et al, this proceeding. Cell growth was normal in the final device. Many different particles are interesting to test and a mammalian cell culture is used for the experiments, which are performed in an incubator. The goal is to develop this method to also function outside the incubator, to make it a compatible method for studying toxic effects on cells by particles.

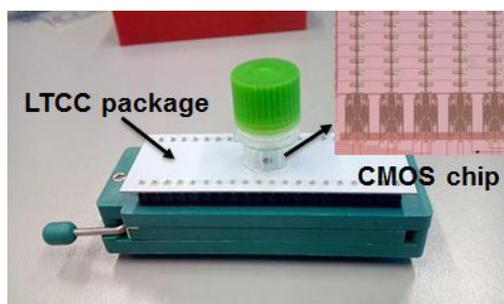


Fig. 3. CMOS chip (insert) glued to the LTCC package. Cavity for cell growth media and preliminary testing of particles. The LTCC substrate is connected to zero insertion force (ZIF) connector

6. Conclusion

The LTCC packaging technology is very interesting for both gas and particle detection because of easy 3D processing and possibility to include several kinds of functionality. We have demonstrated integration of a SiC-FET gas sensor in a one-step firing process. The LTCC is also developed for particle detection and analysis and as an electrical method to study the influence of particles on cells.

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