Concept for Packaging of a Silicon based Biochip

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Abstract

We report on a concept for packaging of a silicon-based biochip for integration with a fluidic cartridge, thus forming a lab-on-chip (LOC). The biochip, which has dimensions of 2 mm x 2 mm, comprises a central membrane having a diameter of 200 µm, and 20 bond pads with metal tracks leading to the membrane. The packaged biochip provides a fluidic interface to the cartridge as well as electrical interfaces to the biochip electronics being located in a readout instrument. The packaging method ensures the strict separation between the wet sensing area and the electrical contacts. The challenge is that the biochip has a freely moving membrane, additionally with a delicate biological coating, and this membrane is positioned on the same side of the silicon chip as the bond pads for the electrical interconnection. For packaging, the biochip is mounted into a recess of a rigid printed circuit board (PCB). The biochip is electrically connected with the PCB using a proprietary MicroFlex interconnection (MFI) technology, thus resulting in a flat surface towards the reaction chamber of the fluid cartridge. After the realization of the electrical contacts between the sensor chip and the PCB, the entire chip is encapsulated with an epoxy layer, leaving the membrane of the biochip uncovered. To protect the membrane against the fluidic epoxy, a specially shaped silicone casting-mould is used. In a last step, the biochip with the epoxy layer is glued on the bottom side of the cartridge.

Keywords: biochip packaging, lab-on-chip

1. Introduction

Here, we report on the packaging concept for a silicon biochip fabricated by MEMS (micro electro mechanical system) technology. The biochip's sensing element is a freely moving membrane, which is coated with a special polymer in order to bind the biological species to be detected. Both, excitation and detection of the membrane oscillation is done electrically. This so-called circular disc resonator (CDR) sensor has been developed by Newcastle University, UK, and will be described elsewhere. The packaging technologies as described in this paper represent important steps in developing a user-friendly, practically usable LOC device from a bare biochip. This development aims at a prototype device that can be applied for the evaluation of the biochip's analytical properties and the implementation of suitable assays in the field of medical diagnostic testing.

Normally, for the electrical connection of silicon dies in semiconductor device fabrication, silicon micro technology offers a number of well-established solutions, the most common thereof being wire bonding technologies and flip-chip-technology. However, the problem-free application of these technologies presumes, that the only integrated functional unit is electronic circuitry – in case that there are parts on the chip, which potentially have to undergo mechanical, chemical or biological interaction with the environment, electrical interconnection and encapsulation tend to become a challenge. This difficulty in finding suitable interconnection and encapsulation solutions is one of the main reasons, why the majority of biochip prototypes, which have been developed in scientific laboratories during the last decade, did not come up to capture the market, yet.

Similar considerations apply to the CDR-sensor: The challenge is that it has a freely moving membrane, additionally with a delicate biological coating, and this membrane is positioned on the same side of the silicon chip as the bond pads for the electrical interconnection. Standard interconnection technologies, as listed above, cannot be used, as the bond connections and their encapsulations, respectively, would hinder the flow of the analyte towards the sensor membrane.

2. Packaging and integration concept

2.1. Packaging of the biochip

An overview of the packaging concept is depicted in Fig. 1. The CDR-sensor will be mounted into a

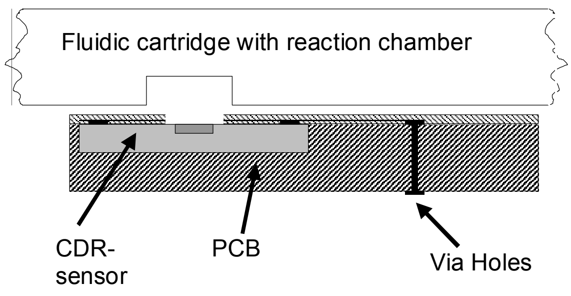

Fig. 1. Packaging concept. The packaged CDR-sensor will finally be bonded against the fluidic cartridge.

recess of a rigid printed circuit board (PCB), with its sensor surface being flush with the surface of this PCB. The CDR-sensor is electrically connected with the PCB using IBMT's MicroFlex interconnection technology, thus resulting in a flat surface towards the sensor chamber of the fluid cartridge. Via holes in the PCB provide electrical feed through to the backside of the PCB, thus allowing for an electrical connection between contact pads on the biochip's front side to those on the backside of the PCB. After the realization of the

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electrical contacts between the sensor chip and the PCB, the entire chip is encapsulated with an epoxy layer, leaving the membrane of the CDR-sensor uncovered. In a last step, the CDR-chip with the epoxy layer is glued against the bottom side of the cartridge. In this way all electrical connections are reliably separated from the fluidic interface.

A detailed description of the MFI technology can be found in [1]. In brief, gold balls produced by a standard ball bonder are used to mechanically and electrically connect the bond pads of the chip to the bond pads of an extremely thin micromechanically produced polyimide substrate. The polyimide substrate is bonded to the CDR chip first, and to the rigid PCB afterwards. The substrate is composed of two individual polyimide layers, each having a thickness of 5 µm. In-between, a structured metallic layer electrically connects the contact pads, which will be bonded to the sensor chip, to those bond pads provided for connection to the PCB. A very low overall height of the assembly can thus be achieved. Furthermore, this method is very robust because no mechanically fragile bond wires are used.

The described concept is illustrated in Fig. 2. The depicted design of the PCB supports the possibility for the integration of three CDR-dies in total.

We produced a tailored support for gluing CDR chip and PCB and we developed a special silicone mould for the casting of the CDR chip – PCB assembly with a suitable biocompatible epoxy coating (Fig. 3). The purpose of this mould is to guarantee the conformity of the coated PCB with the CDR test cartridge, which has been produced by MiniFAB Ltd, Victoria, Australia, and to prevent the CDR chip membranes from being wetted by the epoxy coating. This is achieved by pressure sealing of the CDR membrane surrounding area with the specially shaped silicone mould (Fig. 4). One part of the mould is made of transparent material in order to allow for optical control of the casting process.

To validate the feasibility of the packaging process, a PCB insert was assembled with special CDR dummy chips having the same dimension as the future CDR-chip. They are completely made of silicon with gold bond pads and a gold structure marking the position of the CDR membrane – however, they do not feature a real membrane or any functionality. The chips were integrated and electrically connected like described above. The resulting packed CDR-sensors are shown in Fig. 5. Microscopic inspection showed that the coating did not contain any imperfections and that the

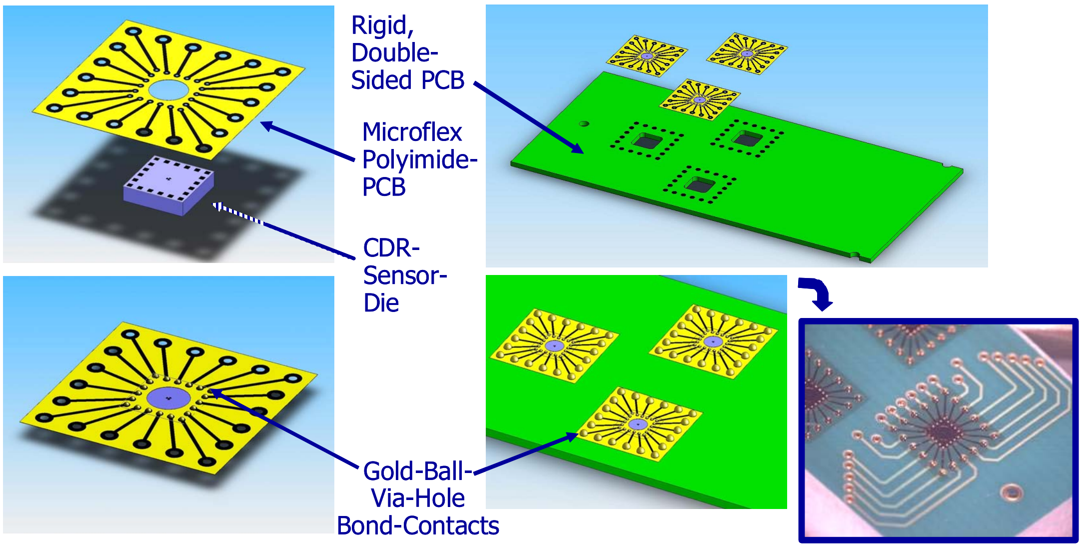

Fig. 2: Electrical interconnection and assembly of the CDR sensors to the PCB

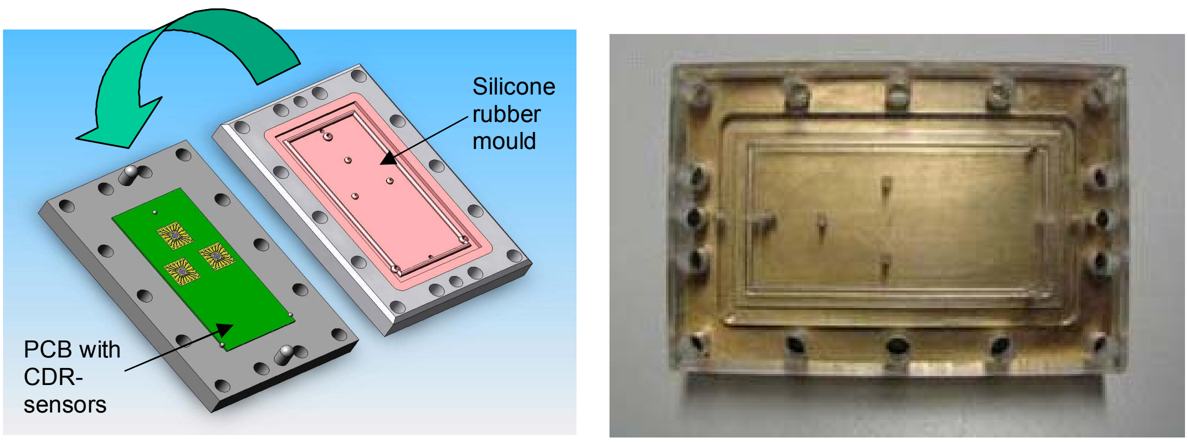

Fig. 3: Device for the coating of the CDR PCB carrier with epoxy, while leaving the CDR sensor membranes uncovered. Left: schematics. Right: Photograph of the mould. One part of the mould is transparent in order to allow checking for air bubbles

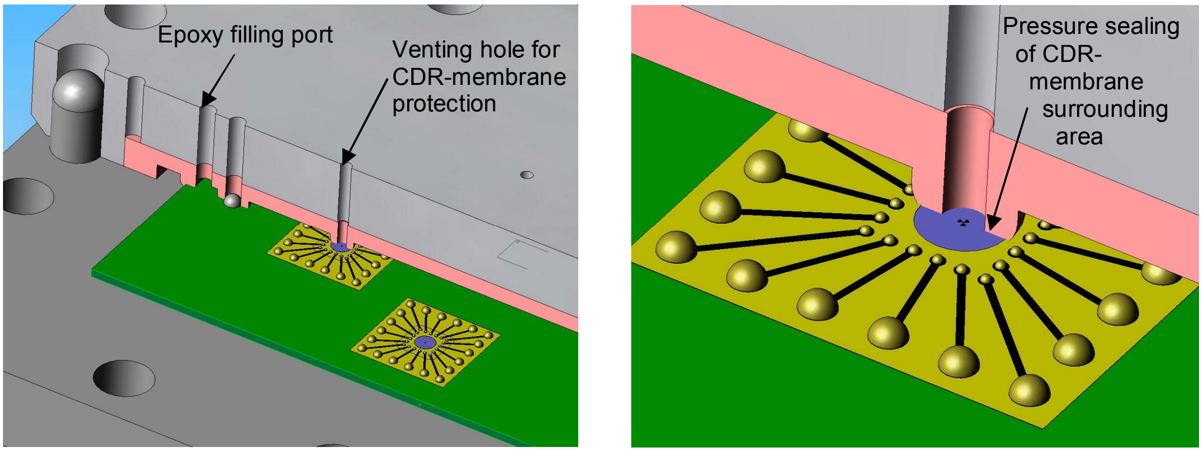

Fig.4: Details of the casting concept and device

membrane area, as desired, actually could be kept free of coating material.

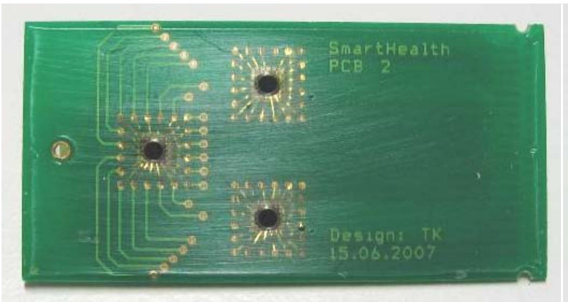

Fig. 5: Photograph of a coated PCB containing three CDR-chips.

2.2. Electrical connection to readout instrument

All electrical contacts on the backside of the PCB are led to one edge of the PCB. Once inserted into the readout instrument, the electrical contact between the PCB and the instrument is established by a pogo-pin connector (Fig. 6).

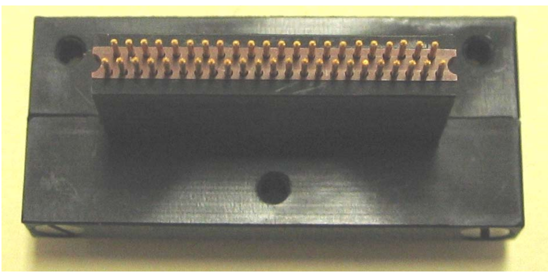

Fig. 6: Photograph of the pogo-pin connector.

The 48 Pogo-pins have a pitch of 0.8 mm. They are double-side spring loaded, thus allowing a pressure-initiated electrical connection to the PCB as well as to the signal processing board of the readout instrument. The alignment of the connector towards the respective PCBs is guaranteed by semi-circular grooves in its front side and by dowel pins at the back. The elaborate, multi-component design of the connector and its precise implementation allows adhesive connections to be avoided. Thus, single pogo-pins, which are delicate parts, can be replaced in case of damage.

The whole connector arrangement between the PCB, which has been integrated in the fluidic cartridge, and the electronics board of the readout instrument is depicted in Fig. 7.

Electrical measurements on the CDR test assembly have been performed in order to validate the quality of the electrical connection achieved with the MicroFlex method. For this purpose, some of the CDR dummy chips were completely covered with a gold layer on their surface, and then integrated and connected to the PCB as described above.

After having made the MicroFlex electrical interconnections between the chip surface and the PCB, the resistance of each of the 20 bond pad connections was measured. This was achieved by measuring the resistance between the gold surface in the centre of the dummy chip towards the pogo-pin-connection pad of the PCB, which is connected to the respective bond pad. The results showed that the resistance for a successful bond connection is less than 7 Ω, with an average of 5.27 Ω.

3. Summary and Outlook

A concept for packaging of a MEMS biochip as well as a method for its integration to a LOC has been presented. The packaged biochip provides a fluidic interface to the fluidic cartridge as well as electrical interfaces to the sensor electronics located in a readout instrument. The packaging method ensures the strict separation between the wet sensing area and the electrical interconnection area. Dummy sensor chips have been packaged in order to demonstrate the feasibility of the described packaging method. A pogo-pin connector has been fabricated and tested with a packaged dummy sensor chip.

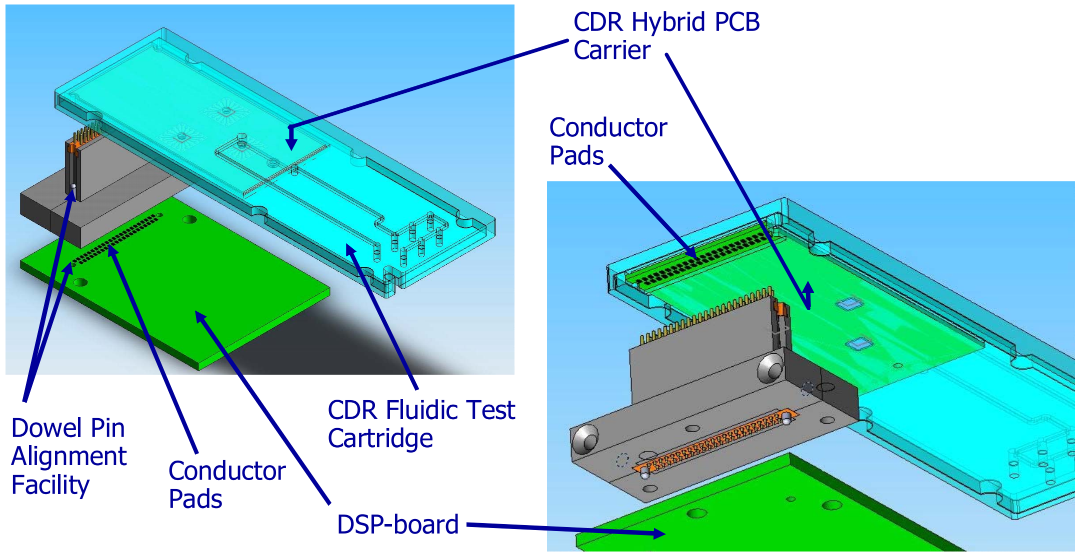

Fig. 7: Connector arrangement between PCB in fluidic cartridge and electronics board of the readout instrument

It remains to be proven that the described casting procedure ensures a robust and reliable protection of the electrical interconnects against the liquids, which will be in contact with the sensor's membrane area.

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