IMPEDANCE SPECTROSCOPY MICROFLUIDIC MULTICHANNEL SENSOR PLATFORM FOR LIQUID ANALYSIS

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ABSTRACT

The presented microfluidic sensor system includes a novel impedance spectroscopy multichannel microfluidic sensor chip and additional components (signal pre-coupling electronic, microreservoir, micro-pump with controlling) in a complete platform. The sensor system has a rectangular size of 55 mm x 115 mm and is based on a Molded Interconnect Device (MID). The MID technology enables a low cost fabrication process and unlocks the implementation of microfluidic structures. Measurements of the S21 parameter of water/ethanol mixture have shown a working sensor platform with a significant signal correlation to the ethanol concentration in a frequency range of 0.25 - 250 MHz.

KEYWORDS: Impedance Spectroscopy, Microfluidic Sensor, Ethanol Concentration Measurement, Flip Chip, Electromagnetic Shield, Silicon, SU8, Process Monitoring, Molded Interconnect Device

INTRODUCTION

Most of the former developed microfluidic impedance spectroscopy sensors contain a system of planar electrodes that are convenient from the point of following connection to the measuring circuit but in most cases they remain “open” for external electromagnetic field [1-6]. Complicity in creation of multichannel sensor chip with reasonable size due to neighboring chip interference on a platform that integrate all the connections including fluidic, requires application of alternative approaches.

THEORY

The four channel microfluidic sensor chip is based on Silicon/SU8 and has a rectangular size of 20 mm x 55 mm. All electrical connections (ground electrodes, shield pads, contact pads) are on one chip side and enable a flip-chip solder assembly. The interference-free multichannel measurement is enabled by an innovative sensor chip design which contains a 3D electromagnetic shielding of the measurement electrodes.

Figure 1: Simulation of flow and pressure distribution in microfluidic chip with ANSYS 14.5 CFX

The design of the microfluidic sensor chip was developed under the help of the simulation tools Comsol Multiphysics 4.3b and ANSYS 14.5 CFX. The fluidic structures were stressed with a maximum water pressure of 40 kPa. The result of the microfluidic simulations demonstrate uniform velocity and pressure distribution in the sensor channels, as shown in Figure 1. The fluidic structure generates no
pressure surges and prevents additional vapor generation which is important for a significant and unaltered sensor signal.

Design and simulation of 3D shielding for sensor chip have been performed with Comsol Multiphysics 4.3b. Due to opposite electrodes design the localization of electromagnetic energy is confined directly in microfluidic channels, reducing aside field propagation and affording to cut down the distance between neighboring channels without affecting entire chip field distribution or rising of interference effects. Enclosing each of the channels with a 3D shielding provided by grounded side walls between separate channels that connecting top shield and bottom grounded electrodes considerably improve the external field protection. Remained open parts of microfluidic channels are protected by top and bottom grounded electrodes providing external field decay more than five orders of magnitude. Figure 2 shows the simulation results of the electrostatic field distribution.

![Simulation of electrostatic field distribution with COMSOL 4.3b: a) electrostatic field distribution in microfluidic chip; b) electrostatic field intensity distribution across the channels; c) electrostatic field intensity distribution along the channels.](image)

**EXPERIMENTAL**

The sensor system is based on a low cost and mechanical robust Molded Interconnect Device (MID). The MID establish a mounting plate for all integrated components (signal pre-coupling electronic, microreservoir, micropump with controlling) and mechanical, electrical and fluidic connections.

The MID substrate allows minimizing tube management combining fluidic and electrical interconnections in one platform and offers higher components density serving at the same time as a holder for the whole sensor device. The Combination of laser drilled through holes and adapted plating technology enables the possibility for double-sided device interconnections. Technologically developed electroless plating steps afford to produce microfluidic sensor with contact pads allowing performing sensor direct soldering to MID platform without additional intermediate wire bonding.

The internally developed signal pre-coupling circuit reduces further noise effects and enables a reprocessing of all four different signal channel data. All components and the microfluidic sensor chip, Figure 3 a), were attached with lead-free flip chip solder process or glued on the MID platform, Figure 3 b).

![Microfluidic structures of the sensor chip a) and Microfluidic Sensor Platform b)](image)
RESULTS AND DISCUSSION

The actual results of the fabrication development are demonstrated in Figure 3. The sensor platform was connected to the FPGA based network analyzer which is developed by the research partner TEPROSA GmbH. A mixture of water and ethanol (5 - 10 Vol%) was analyzed in a frequency range of 0.25 - 250 MHz. The measured $S_{21}$ parameters showed a significant signal correlation to ethanol concentration, as shown in Figure 4.

Figure 4: Water/ethanol sensor $S_{21}$ measurements in a frequency range 0.25 - 250 MHz

CONCLUSION

The presented microfluidic multichannel sensor platform demonstrate advantages and results of combined MID-MEMS technologies. The designed sensor provide high level of external field protection and demonstrate considerably high sensitivity analyzing binary mixtures of water and ethanol. The current contribution shows an alternative approach of building an integrated low cost sensor devices for liquid mixtures analysis.

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REFERENCES


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