MEMSPlant Sense—Miniaturized Implantable Pressure Sensor

R. Jose James, M. Fretz, G. Spinola Durante, P. Niedermann, L. Löfgren, J. Schleuniger, J. Gobet, T. Parkel, M. Sénéclauze, C. Bosshard, R. Eckert, M. Despont, S. Mohrdiek

The project focusses on developing a platform for long term implantable miniature wireless sensors. The sensor targeted here is an implantable wireless pressure sensor for blood pressure monitoring of patients with e.g. acute heart diseases. The challenges of developing miniature active implantable medical devices (AIMD) are numerous including the limited number of materials, low temperature packaging, miniaturization of electronics, powering, and leak and long term reliability testing. This project addresses each of these challenges.

Memsplant Sense project focuses on technologies needed for developing a miniature long term AIMD. The AIMD developed is an implantable pressure sensor. Potential applications of the demonstrator are in-vivo pressure monitoring in hypertension patients and in the brain. The main technologies developed in the project are the miniaturization of the electronics and wireless units, the packaging of the electronics with long term biocompatible materials, non-destructive leak testing, energy harvesting and long term reliability testing.

There are two pressure sensing concepts developed here, thermal proximity and mechanical coupling based pressure sensing (Figure 1). The thermal proximity sensor works on the principle of deflection measurement of a biocompatible membrane using a proximity sensor using silicon micromachining techniques at CSEM. The mechanical coupling method (patent pending) works on the principle of coupling between a biocompatible membrane and a pressure sensor membrane using a polymer material. The principle was demonstrated with a sensitivity of 40 µV/mbar (Figure 2).

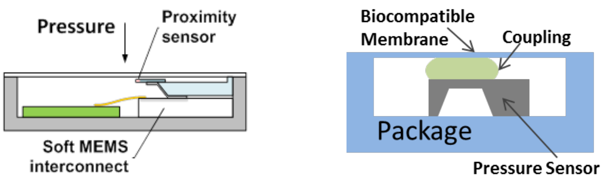

Figure 1: Thermal proximity (left) & mechanical coupling (right) pressure sensing concepts.

The package and membrane are made from sapphire. The cavities of the package are manufactured on wafer level. Sealing of the pressure sensor is done using a laser based bonding technique. This low temperature sealing (< 100°C) was tested to be leak tight (<10^{-12} mbar*l/s) with a good shear strength (110 MPa), and a good yield (> 90%). The fine pitch (< 400 µm) feedthroughs developed here are also leak tight (<10^{-12} mbar*l/s) with good shear strength (110 MPa). The feedthroughs are fabricated using pins made of materials that are usually used for biocompatible feedthroughs like platinum and alloys. The via of the feedthrough has been tested to have low contact resistance (~1 Ω) with a via diameter as low as 100 µm. An example of a sealed package is displayed in Figure 2.

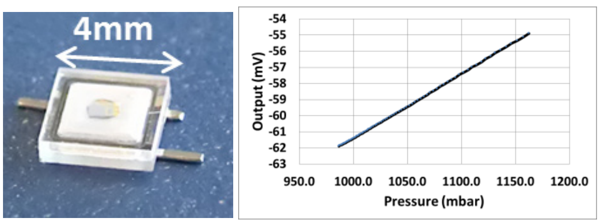

Figure 2: Implantable pressure sensor (left) and its sensitivity (right).

The wireless powering and data communication is implemented using two options, 1) using a miniature passive RF chip with a size of 2.5 mm x 2.5 mm and 2) using the Icycom platform which is capable of processing and storing data. The passive RF chip has been demonstrated with the pressure sensor. Work is going on to increase the communication range with the use of a miniature antenna.

A non destructive hermeticity test method based on FTIR quantitative measurement of the ingress of a tracer gas into the cavity was implemented. For the package the results were in good agreement with the conventional membrane deflection method while showing a lower detection limit, presently estimated at 2 x 10^{-12} mbar*l/s (Figure 3). This opens the way to the individual control of manufactured chips to ascertain a 10-year life time in the body.

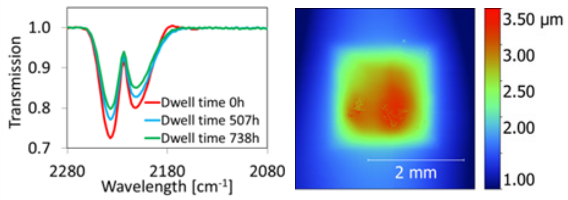

Figure 3: FTIR N_2O absorption spectra in the cavity (left) and deformation of the membrane (white light interferometry) (right).

The concept of energy harvesting, by implanting packaged photovoltaic (PV) devices directly under the skin has been studied. The optical properties of different artificial skin models (Figure 4) have been measured and a skin model with skin-like optical properties has been selected for the purpose of PV testing. Figure 4 shows estimated power densities of a set of PV technologies under standard sun spectra, as seen through 1.5 mm of fair skin.

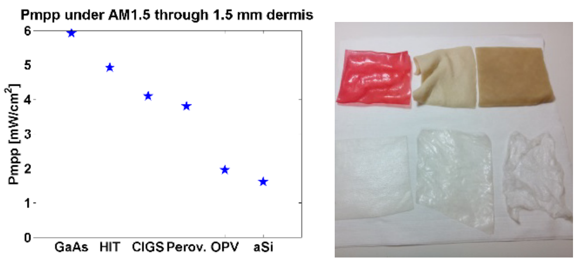

Figure 4: Maximum power density under standard sun spectra as seen through 1.5 mm skin (left); Skin models (right).

In summary, a platform for the miniaturization of AIMD has been developed. The required technologies can be adapted for many different in-vivo wireless sensing applications.

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