Biomedical Instrumentation

How electrical engineering can cure you

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The interaction between electrical engineering and bio-medicine can be traced back centuries to the discovery that muscles work with electrical pulses. However, these early experiments did not lead to direct medical applications. The era of microelectronics has brought many new medical applications, from devices to improve the quality of life, such as hearing aids, to live saving devices for the operating theatre.

Hearing aids, in the form of cones, have been used since pre-historic times. Modern hearing aids are small devices which fit into the ear to amplify the incoming signal, as shown in figure 1.

When the patient is totally deaf, a direct connection with the nervous system may be required (although this will not solve all forms of deafness). The cochlea implant is a device which is inserted into the cochlea and stimulates the nerves directly (figure 2). This requires a microphone, transmitted and finally the flexible probe which is inserted into the cochlear. A project in Delft, together with the LUMC and Advanced Bionics, is working towards improving the sound quality of such devices [1].

Figure 3: Minimal invasive surgery

In-vivo sensors have brought about major advances in surgical aids and long term monitoring. Minimally invasive surgical techniques allows treatment/analysis to be performed with minimal damage to healthy tissue, which leads to faster recovery time and lower costs. However, this means that the surgeon requires micro-sensors and actuators to perform these tasks, since direct line of sight and touch is no longer available.

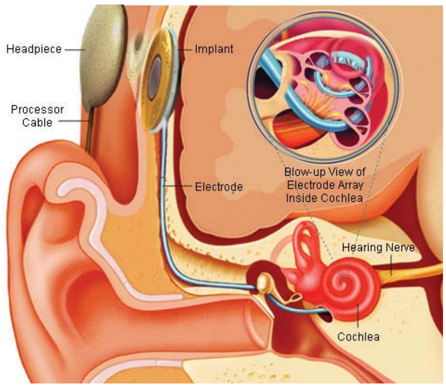

Figure 2: Cochlea Implant

One of the first devices for developed for catheters was the pressure sensor, which could be reduced in size to fit the catheter. One such example is given in Figure 4

Using silicon, this can be expanded with more sensors on a single chip, while maintaining a low device area. In catheter applications the main limitation is the width of the device. An example of a multi-sensor, developed in Delft, is given in Figure 5 [2]. Similar technologies have also been used for cardiac output devices [3].

Figure 1: Examples of modern hearing aids

Implants present new challenges for these devices since they have to remain in contact with the tissue for longer periods without causing adverse effects, and also maintain functionality. The pacemaker is an example of a long term implant. Although the main function of the pacemaker is actuation, many systems include sensors to enable the device to best estimate the requirements of the user. Other devices can be used for medium term to monitor or treat the patient. Two examples from recent Delft projects are tissue vitality after an operation and the photo dynamic therapy device. Tissue vitality shows the surgeon that the tissue is healing correctly after the operation and there are no infections to cause complications. One application for this is for after a colon operation. When part of the colon is removed it is essential that the colon

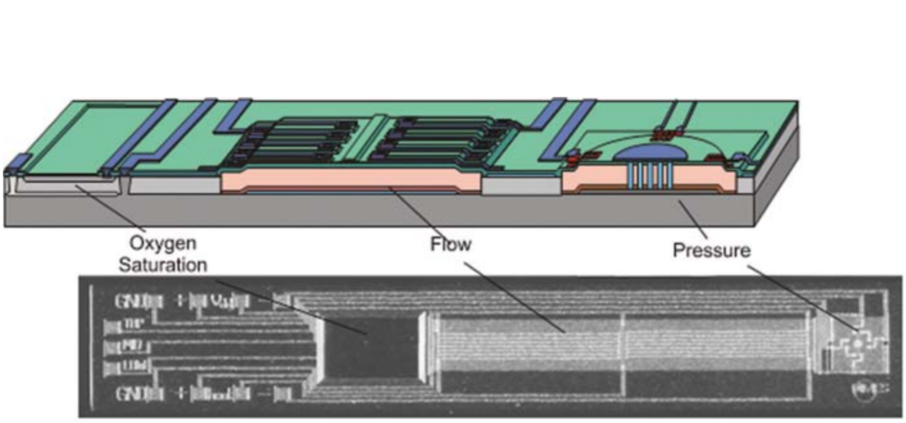

Figure 5: Multi catheter sensor

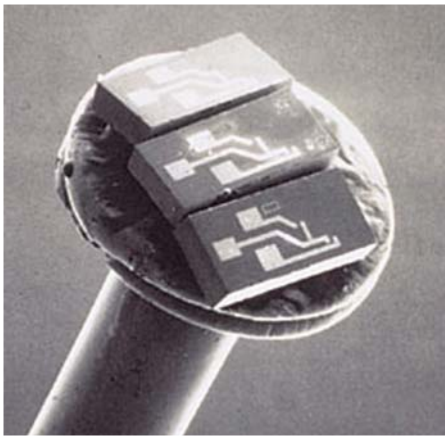

Figure 4: Pressure sensor from Lucas NovaSensor

is re-connected and heals quickly without infection or leakage. Measuring O2, CO2 and temperature, can give this vital information to the surgeon. A cross-section of the final proposed device, and results from O2 measurements in the kidney, when the blood supply is periodically interrupted, are given in Figure 6 [4].

The above device is for monitoring, and warning the surgeon of complications. Implanted wireless devices can also be used for treatment. Photo-dynamic therapy is a technique where visible light is used to selectively kill cancer cells. With brain cancer, there is a need to be able to access the area after the operation to prevent any re-growth of a tumour. One device under development to address this problem is shown in Figure 7. This device is intended to be implanted during an operation for a brain tumour and can be used in the months after the operation to ensure that to new tumour can develop [5]. The device has wireless power and wireless communication.

As we see above, optical techniques can measure many parameters in medical applications. this is also the case for in-vitro devices. Optical waveguides can be used to detect bacteria [6]. A micromachined waveguide has traps on the surface to capture the bacteria of interest. Once trapped, this will interact with the light wave allowing its presence to be measured. The basic structure of the device is given in Figure 8. Also in figure 8 is a microchannel for separating individual cells [7]. Once separated they can be further analysed.

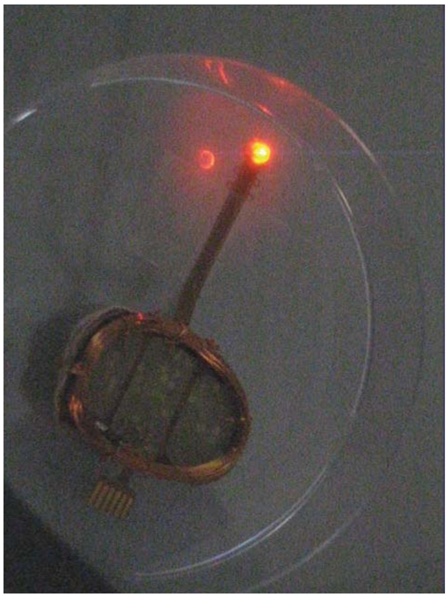

Figure 7: Wireless PDT device for brain implants.

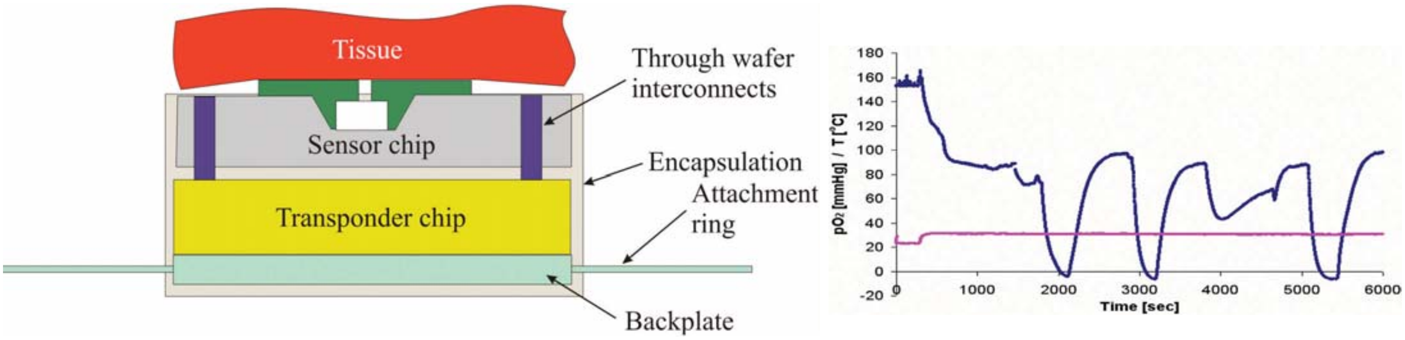

Figure 6 (left): cross-section of O2/CO2 optical sensor (right): measured O2 levels in the kidney during periodic brief disruption of blood supply

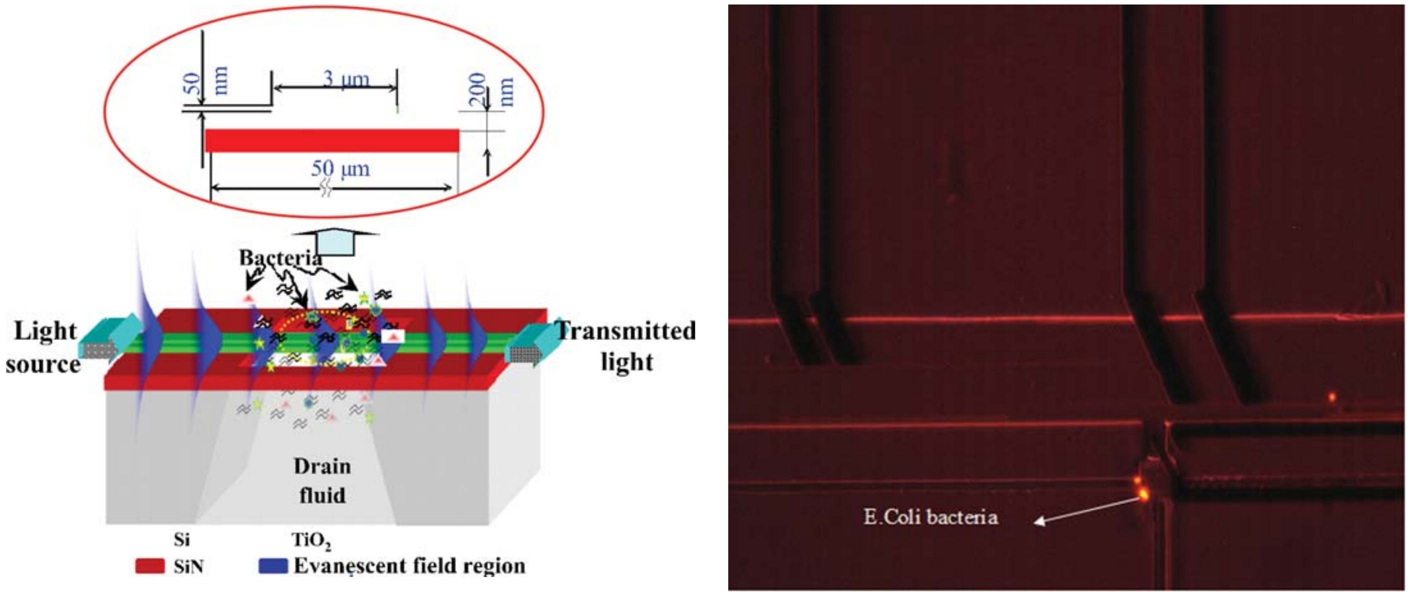

Figure 8 (left) Optical waveguide for detecting E-coli (right) microchannels for isolating e-coli for further analysis

This article has shown just a few examples of silicon sensors for medical applications. These devices are making operations safer and cheaper and also allowing treatment which was previously not possible. In the field of analysis micro-devices are able to speed up the analysis, so yielding faster information to the medical staff. They also mean that the size of the sample required can be much smaller. There remain many opportunities for expanding micro-sensors into the medical field, which is itself an expanding market.

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