Group 1
An Implantable Wireless Glucose Sensor

Problem Statement

Diabetes is a disease caused by either a reduced production of insulin or a weak response to insulin by the body. Since insulin is the hormone that controls blood glucose levels in the organism, glucose monitoring is an essential process in the treatment of diabetes. Current techniques involve bedside devices that can measure glucose concentration under clinical conditions as well as the “finger-pricking” method, which is rather painful and inconvenient through the daily routine of an individual. An implantable wireless glucose sensor that would allow continuous monitoring of blood sugar levels without disrupting the patient at risk is highly desirable.

Your task in this project is to investigate and suggest how MEMS technology and micromachining can provide solutions for this application. In particular, you should design a wireless microsystem implantable in the body that will measure glucose concentration and send a signal to an external data recording device. Your system should include a sensor element, the necessary components for sampling of the fluids in the body and electronics for data acquisition and communication. You may use monolithic or hybrid integration of the individual chips, however, you have to make sure that the full assembly will not interfere with operations in the body or set the patient at risk in any way.

Design Specifications

- Components should be compatible with batch fabrication.
- Overall size of the implant should not exceed 1 cm² in area and 2 mm in thickness (there is no limitation in geometry).
- The sensor should show linearity in a glucose concentration region of 2 mM – 20 mM at least (assuming that for healthy individuals the values are between 4-6 mM)
- Response time should be ~20 sec at maximum.
- Data should be collected at least 6 times a day.
- Your selection of materials should be limited to biocompatible materials, such as polymers, inert metals etc. In any case, the packaged microsystem should not interfere with or harm any body functions.
- A calibration scheme for the sensor and testing of all components before implantation should be proposed.

Additional Specifications

NOTE: These specifications are NOT critical in evaluating the group’s success in completing the project; however they pose very important concerns in a real-life application and should be taken into consideration and addressed to the largest extent possible. Qualitative information is expected, while any additional calculations and/or numerical/simulation data will be viewed positively.

1) Implantation stability and lifetime: Since the motivation behind implantable microdevices is to impose minimal disturbance to the patient, it is highly desirable that the sensor will operate properly for the longest period of time possible. The group should take this into consideration at the design stage and try to address it accordingly. There is no particular requirement however for the scope of this project; as an estimate, replacement of the implant every 2-3 months would be considered ideal.
2) **Interference reduction:** As with most sensor applications, selectivity for the substance of interest is of significant importance. In this case, false signals from other sources such as ascorbic or uric acid may exist. Your primary task remains detection of glucose in the range of interest; however you should provide as much information as possible regarding how such interference could be eliminated.

**Overview of Design Process**

You should start with an extensive literature search and identify the individual components of your system. There is plenty of published data available regarding glucose sensors, implantable devices and wireless microsystems. After you have decided on your general approach, you should allocate specific tasks to each member and try to meet the specifications.

**Sensor**

The sensing principle for glucose detection is not limited to a single method. You should try to find the one that suits the application better, come up with a design, and remember to always explain your choices. Simulation tools are available if they would help the group in meeting the specifications and/or defining the specific geometry.

**Sampling**

Given the specifications for minimal interference with flow or other functions in the body as well as maximum sensor lifetime, the design of a sampling component is necessary. This could include microfluidic components such as channels, reservoirs, valves or it could be part of the package.

**Electronics and Wireless Communication**

Do not underestimate this part as it is fundamental in any MEMS device operation! Your sensor/sampling elements might require power and you will definitely need signal processing electronics and wireless communication circuitry. There is no limitation in your approach (for example on-chip powered or battery-less systems are both acceptable); keep in mind the overall size specification. Simulation data and calculations will be necessary to show proper operation.

**Packaging and Implantation**

Your system will consist of multiple components so your interconnection and packaging approach is very important, especially under the requirements of biocompatibility and stable operation. Also depending on the implantation site, stress and strain considerations might have to be considered and modeled. All in all, specific materials have to be used and fabrication processes will need to be implemented or adjusted. Finally, do not neglect to suggest a specific location for your implant and provide all necessary information – this will actually be a step that you will have to take early in the process.

**Process Flow and Device Fabrication**

Design a detailed process flow to fabricate each component of your device. It is often useful to sketch your process flow in cross section and (if possible) a three-dimensional schematic. Bear in mind that your process steps should be compatible with ALL of the materials in use as well as batch processing. There is no limit to the number of process steps and the equipment that you (theoretically) have access to; however, trying to keep your design as simple as possible is always a better approach. Complete a layout of the device using an appropriate CAD program.
Remember that as with any engineering task, there may be a number of compromises that need to be made for device functionality and simplicity. Be sure to explain why you have decided on a particular design and if any of the specifications cannot be made, provide all relative information why this was not possible.