Nanotechnology and Nanosensors

(Technion - Israel Institute of Technology)

Nanosensors in the Service of the Internet of Things (IoT)

Application of Health monitoring and diagnosis using nano sensors implanted inside human body

Author: Isuru Kalhara

Education: B.Sc. Eng. (Honors) in Electronic and Telecommunication, UoM, Sri Lanka
Reading for M.Sc. in Artificial Intelligence, UoM, Sri Lanka

Country : Sri Lanka

Introduction

The Internet of Things (IoT), built from inexpensive microsensors and microprocessors paired with tiny power supplies and wireless antennas, is rapidly expanding the online universe from computers and mobile gadgets to ordinary pieces of the physical world: thermostats, cars, door locks, even pet trackers. New IoT devices are announced almost daily, and analysts expected to up to 30 billion of them to be online by 2020.

The explosion of connected items, especially those monitored and controlled by artificial intelligence systems, can endow ordinary things with amazing capabilities—a house that unlocks the front door when it recognizes its owner arriving home from work, for example, or an implanted heart monitor that calls the doctor if the organ shows signs of failing [1].

Rationale: For medical condition monitoring such as blood glucose, cholesterol and other complex measurements such as hormones need invasive methods and lot of expensive testing. Lot of controllable deaths and accidents can be reduced if we are capable of doing real time monitoring of these indexes.

Objective: Propose an IoT system which is using implanted nano sensors that are capable of real time monitoring of critical human blood ingredients and communicate them to a health care provider through a bio-cyber interface. This system can identify possible health problems and give required medical solutions gathered from experience medical officers.

Literature Review

IONT (Internet of Nano Things) consists of few main parts described below [2]

1) Nano-Nodes: Machines that accomplish numerous errands as in transmission and computation if the data are over small distances and have a smaller amount of memory storage. As for Body Sensor Networks (BSNs), organic sensors fixed in Human Body represent Nano-Nodes.
2) Nano-Routers: They possess huger computational power than nano nodes and they represent aggregators of coming information from nano-nodes.
3) Nano-Micro interface gadgets: These gadgets have the responsibility of data accumulation initiating from nano-switches and send it to the microscale machines.
4) Gateway: It facilitates the regulation of all-inclusive nano things network over the Internet.[3]

IOBNT(Internet of Bio Nano Things) can be identify as synthetic biology and nanotechnology tools that allow the engineering of biological embedded computing devices [4]. Main components of IOBNT can be identified as,

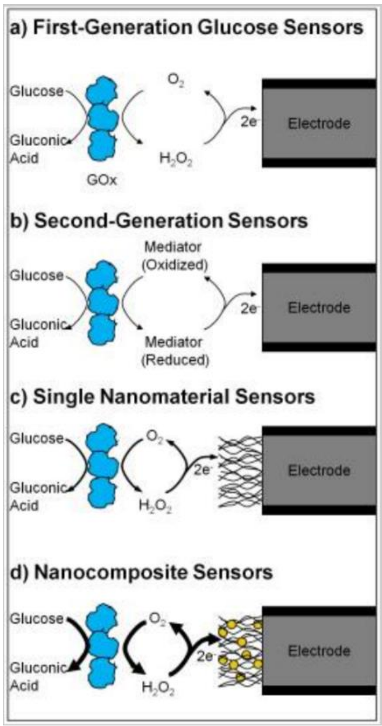
1) Intra-body sensing and actuation, where Bio Nano Things inside the human body would collaboratively collect health-related information, transmit it to an external healthcare provider through the Internet, and execute commands from the same provider such as synthesis and release of drugs.
2) Intra-body connectivity control, where Bio Nano Things would repair or prevent failures in the communications between our internal organs, such as those based on the endocrine and the nervous systems, which are at the basis of many diseases.

3) Environmental control and cleaning, where Bio Nano Things deployed in the environment, such as a natural ecosystem, would check for toxic and pollutant agents, and collaboratively transform these agents through bioremediation, e.g. bacteria employed to clean oil spills [4]

Discussion about available sensors and researches for sensing glucose and cholesterol are discussed below.

Glucose Measurement using Nanosensors

Nanosensors and nanomaterials for monitoring glucose are described by Kevin J. Cash and Heather A. Clark [5].

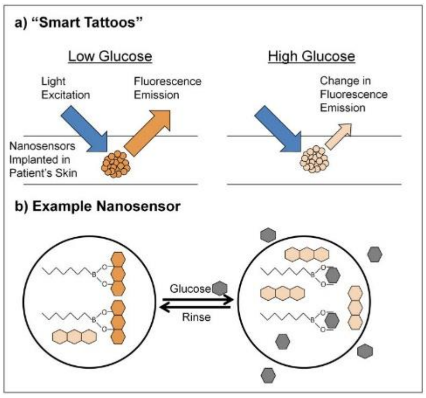


This figure describes how glucose sensor evolved with each generation. And it describes how nanocomposite glucose sensor works.

The nanoscale properties of these modified systems have several advantages, including higher surface areas (yielding larger currents and faster responses) and improved catalytic activities. These sensors, owing to their size, would be implanted similar to current technology if used for continuous monitoring. Accordingly, these sensors could experience the same drawbacks as current sensors, including sensor fouling and decreased sensor life as a result of immune foreign body response.

Secondly, nanofabrication techniques can generate glucose sensors that are nanoscale in all dimensions. These sensors offer some advantages over traditional sensors for continuous monitoring: these sensors would be injectable, which could lead to more facile administration of the sensing system than the current implantation approach. Additionally, because of the small size of these sensors, they could potentially avoid the foreign body response of the immune system and, therefore, have longer useful lives. However, these sensors are a radical change from current continuous monitoring sensors and there is little clinical data on these systems, so further research is needed before these nanosensors can be of use to patients.[5]

Designing of Smart tattoos is described below for glucose measurement.



Electrochemical detection technologies represent a large portion of research into glucose detection and dominate the field of commercially available sensors. However, for in vivo continuous monitoring, fluorescence-based sensors offer several advantages. Chief among them is the ability to optically interrogate the sensors through the skin rather than having an electrode system implanted. This approach often involves a "smart tattoo" for the patient, as sensors would be implanted into the skin of the patient similar to regular tattoos

Cholesterol Measurement using Nanosensors

High sensitive amperometric cholesterol sensor development is discussed by Mashkoor Ahmad at Beijing NCEM [6]. The development of a cholesterol biosensor is important due to the prevalence of cardiovascular diseases as a major health threat around the world. The concentration of cholesterol in blood is an important parameter for the diagnosis and prevention of disease. Nanomaterials provide high surface areas for higher enzyme loading and a compatible microenvironment helping the enzyme to retain its bioactivity. Besides this, they provide direct electron transfer between the enzyme’s active site and the electrode.

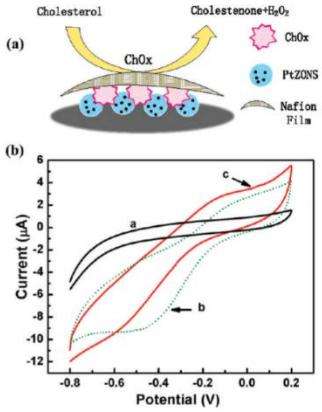
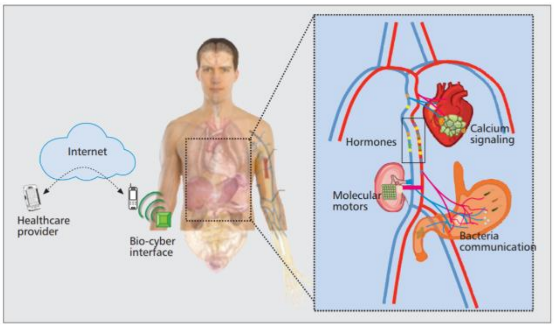


Figure describes schematic of modification of glassy carbon electrode with Pt-incorporated fullerene-like ZnO nanospheres, ChOx, and Nafion for efficient detection of cholesterol. (b) Cyclic voltammetric sweep curve of the Nafion/ChOx/PtZONS/GCE electrode in the absence (CV a) and in the presence (CV c) of 100 μM cholesterol in PB solution (pH 6.8) at a scan rate of 50 mV/s; CV curve of the Nafion/ChOx/ZnO/GCE electrode in the presence of 100 μM cholesterol (CV b) in PB solution (pH 6.8) at scan rate of 50 mV/s.[6]

Methodology

Solution suggests a complete IoT system that is capable of identifying anomalies of blood, communicate the data to center system and suggest possible precautions and medicine to the patient.

System can be described as follows[5].



Here a nano sensor array consists of sensors which can measure blood glucose, cholesterol and hormone anomalies is implanted to the human. The implanted system will power up using thermal power harvester. Collected data is directly transmitted to the smart phone using bio cyber interface. Smart phone app should able to filter the data and record them to the cloud service which is able to predict and diagnose possible diseases using machine learning algorithms with previous data.

Conclusion

Overall system should be biocompatible and capable of doing all the data transmission and processing for the lifetime of the patient without any replacement. Energy harvesting and using of non-degrading batteries or supercapacitors are needed.

Patients with these devices can have daily report of the fluctuations of each blood parameter and interactive suggestions for future exercise routines and schedules.

References

[1] The internet of things goes nano; https://www.scientificamerican.com/article/the-internet-of-things-goes-nano/

[2] Abdulkareem, Zahraa. (2018). Review about effects of IOT and Nano-technology techniques in the development of IONT in wireless systems.

[3] Nayyar, V. Puri, y D.-N. Le, "Internet of Nano Things (IoNT): Next Evolutionary Step in Nanotechnology," Nanosci. Nanotechnol, vol. 7, no. 1, pp. 4-8, 2017.

[4] Akyildiz, Ian & Pierobon, Massimiliano & Balasubramaniam, Sasitharan & Koucheryavy, Yevgeni. (2015). The internet of Bio-Nano things. IEEE Communications Magazine. 53. 32. 10.1109/MCOM.2015.7060516.

[5] Cash KJ, Clark HA. Nanosensors and nanomaterials for monitoring glucose in diabetes. *Trends Mol Med*. 2010;16(12):584–593. doi:10.1016/j.molmed.2010.08.002

[6] Ahmad, Mashkoor & Pan, Caofeng & Gan, Lin & Nawaz, Zeeshan & Zhu, Jing. (2010). Highly Sensitive Amperometric Cholesterol Biosensor Based on Pt-Incorporated Fullerene-Like ZnO Nanospheres. Journal of Physical Chemistry C. 114. 243-250. 10.1021/jp9089497.