2016

Biopsy-Implantable Chemical Sensor for Monitoring and Adjusting Cancer Treatments

RESEARCH PAPER

FIELD: MEDICINE & BIOMEDICAL ENGINEERING

AHMED A. EL DEMERDASH
HASSAN S. HASSAN

ahmed14010@stemegypt.edu.eg
+20-111-211-274-7

STEM HIGH SCHOOL FOR BOYS 6TH OF OCTOBER | hassan59010@stemegypt.edu.eg
+20-127-118-745-4

Contents

1- Abstract

"In the battle against cancer, which kills nearly 8 million people worldwide each year, doctors have in their arsenal myriads of powerful weapons, including various forms of Chemotherapy and Radiation. What they lack, however, is good reconnaissance — a reliable way to obtain real-time data about how well a particular therapy is working for any given patient. That's why, a tiny biochemical sensor that is implanted in the cancerous tissue will be made; the sensor then wirelessly sends chemical measurements to an external "reader" device, allowing doctors to better monitor a patient's progress and switch therapies accordingly. This device boosts treatments' efficacy while reducing patients' exposure to serious side effects. "

Design requirements are critical for the success of any project. And so, accuracy and cost are considered the main design requirements of our project. A simple prototype has been crafted in order to test the mechanism of our idea. Dissolved Oxygen (DO) and pH levels are measured, and a simulation has been made in order to mimic the environment of the tumor. In conclusion, our smart device offers an opportunity to accurately monitor the state of the cancerous tissues with a quite low cost.

Key Words

Cancer, Dissolved Oxygen, Acidity Level, PEEK, nRF Module, and MRI

This project is a continuous integration of development for monitoring the cancerous tumor inside the body. We have used some useful resources especially the MIT website, because they have worked in this field before. This approach leads to significantly reduced integration problems and allows a team to develop cohesive results more rapidly.

2- Purpose

Magnetic resonance imaging and other scanning technologies can indicate the size of a tumor, while the most detailed information about how well a treatment is working comes from pathologists' examinations of tissue taken in biopsies. Yet these methods offer only snapshots of tumor response, and the invasive nature of biopsies makes them a risky procedure that clinicians try to minimize.

Now, we are developing a tiny biochemical sensor that can be implanted in cancerous tissue during the initial biopsy. The sensor then wirelessly sends data about telltale biomarkers to an external "reader" device, allowing doctors to better monitor a patient's progress and adjust dosages or switch therapies accordingly. Making cancer treatments more targeted and precise would boost their efficacy while reducing patients' exposure to serious side effects.

We wanted to make a device that would give us a chemical signal about what's happening in the tumor. Rather than waiting months to see if the tumor is shrinking, you could get an early read to see if you're moving in the right direction.

3- Hypothesis

When cancerous tissue is under assault from chemotherapy agents, it becomes more acidic. Many times, you can see the response chemically before you see a tumor actually shrinks. In fact, some therapies will trigger an immune system reaction, and the inflammation will make the tumor appear to be growing, even while the therapy is effective.

Oxygen levels, meanwhile, can help doctors gauge the proper dose of a therapy such as radiation, since tumors thrive in low-oxygen (hypoxic) conditions. It turns out that the more hypoxic the tumor is, the more radiation you need. So, these sensors, read over time, could let you see how hypoxia was changing in the tumor, so you could adjust the radiation accordingly.

4- Control

Design requirements are one of the most important factors that strongly lead to the success of any project. So we have to determine them before doing or performing anything in the project. Also these design requirements must be classified as the importance of each one. Every solution has different design requirements. Theses design requirements determine the ability of the project to solve our problems and grand challenges of our country.

Accuracy

The accuracy of any medical project is the most important design requirement, because it determines further steps regarding the patient and his life. Therefore, it has been chosen to be one of our main design requirements. There are many projects that tried previously to monitor the cancer within the body. However, their findings might be misleading and give inaccurate evaluation of the environment inside the tumor.

In order to measure this design requirement, we have to:

1- Use an accurate measuring tools (In our case pH & DO Sensors).
2- Perform a detailed task analysis of the work to be performed.

3- Compare the results we have gotten to results already known to measure how accurate is the device.
4- Depend upon genuine determiners of the evolution inside the tumor by means of measuring chemical contrasts such as PH and DO levels

So we can conclude this design requirement as:

a- Using most accurate measure tools.
b- Comparing our results to standard readings.

Safety

One of the main design requirements that are considered in any project is Safety. Our project is totally considered safe, because the device doesn't harm any of the organs that the device is implanted into. So how can we measure the safety of the project?!

1- We will perform some experiments on pets at first in order to test our device.
2- We will check if the device causes any harm to the organs within the body.
3- After that we can be sure that the device is totally safe to use.

Speed

The device is considered to be a tiny biochemical sensor that can be implanted in cancerous tissue during the initial biopsy. The sensor then wirelessly sends data about telltale biomarkers to an external "reader" device, allowing doctors to better monitor a patient's progress and adjust dosages or switch therapies accordingly. Making cancer treatments more targeted and precise would boost their efficacy while reducing patients' exposure to serious side effects.

Therefore, the device is extremely fast as it depends on the wireless technology, but how can we measure it?!

1- We will measure the time in which the response show up after adjusting the device.

2- Then, we will compare that time to the time needed in the regular biopsy and MRI.

As result, we will observe that our project holds the projects so quickly.

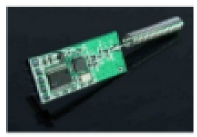
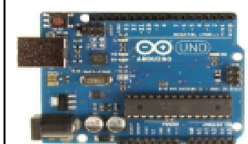
Cost & Sustainability

Compared to the other means of monitoring the cancerous tumor, our chemical sensor is very cheap and effective. In other words, MRI machines are very expensive to make and also they require a great room and time to get results from one sample. On the other hand, our tiny cheap implantable chemical sensor provide a real time data from the environment inside the tumor

In addition , We're making these sensors out of materials that are in the kinds of long-term implants, and given that they're so small. Also the device will depend on Lithium Batteries that have a long-live period. Therefore, it is rechargeable and can last for a long period of time.

5- Materials List

In order to turn our notion into a tangible model, efficient materials that well describe the project as a whole have been used.

Materials	**pH Electrode**	**DO Sensor**	**nRf Sensor**	**Monitor**	**Arduino**	**Projector**
Cost (L.E)	**From Chem Lab**	**64**	**75**	**Mobile Phone or Laptop**	**From FabLab**	**From FabLab**
Illustration						
Use	**Observes the pH level inside the tumor**	**Measures the amount of Dissolved Oxygen within the tumor**	**Wirelessly sends the measurments from the dvice inside the tumor to an external monitoring device**	**Recieves data from the device inside the tumor so that doctors can better diagonse the condition of the patient**	**Converts the measurements taken from the pH Electrode and the DO Sensor into a readable data**	**Makes a simulation for the environment inside the body.**

The pH electrode and DO sensor were tested in a temperature of about (36°: 45°) and pressure of about (760_{mmHg}:880_{mmHg}) to make sure that the sensors will not give misleading results in the varying conditions inside cancer tumors when exposed to different therapies. Also, the same experiment was done to test the durability of the Polyether Ether Ketone to the conditions of the body.

A test was made on a real tumor by implanting the sensor in it. The behavior of the tumor was observed towards the device so that we can know if the sensor has a bad effects on the body or not. Moreover, two experiments were made with different materials, one made of plastic and the other is made of Polyether Ether Ketone so that we can see which one is more efficient than the other.

A genuine comparison was made between our device and prior solutions, in order to calculate the difference of cost and the ability of our device to be applied in a large scale.

6- Procedure Steps

We have followed some Methods to perform our test plans:

I. The device is composed of a pH Electrode and a DO Sensor so that we can specify an accurate readings for the Acidity level and amount of Dissolved Oxygen inside the tumor.
II. The device is then implanted inside the tumor using a medical needle as the one used in insertion or remove of any substance inside the body.
III. The pH Electrode and the DO Sensor then accurately read the pH level and amount of Dissolved Oxygen inside the tumor.
IV. The device employs an nRF Module that deliver the readings wirelessly to an external monitor outside the body.
V. The physicians then use the findings in order to determine the condition of the patient. As a result, they can adjust the amount of dosage needed in order to cure the patient.

7- Results

7.1 Data Table

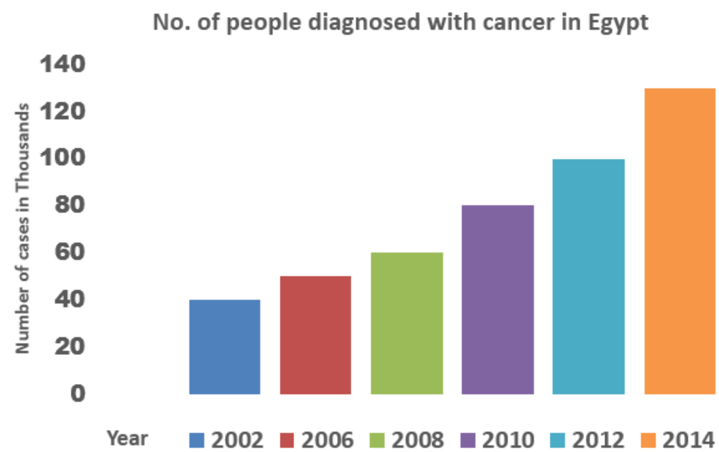
After we have performed our test plan, the results from different tests were as the following:

Physical Results: The pH of Acetic Acid (CH_3COOH) and the DO of water filled with Yeast were measured in various temperatures (36°C: 45°C) and pressures (760_{mmHg}:880_{mmHg}). The findings in figure [5] were compatible with the standard numbers of these two environments, having a slight error value. And so, the pH electrode and the DO sensor will work properly in the varying conditions inside the cancer tumors.

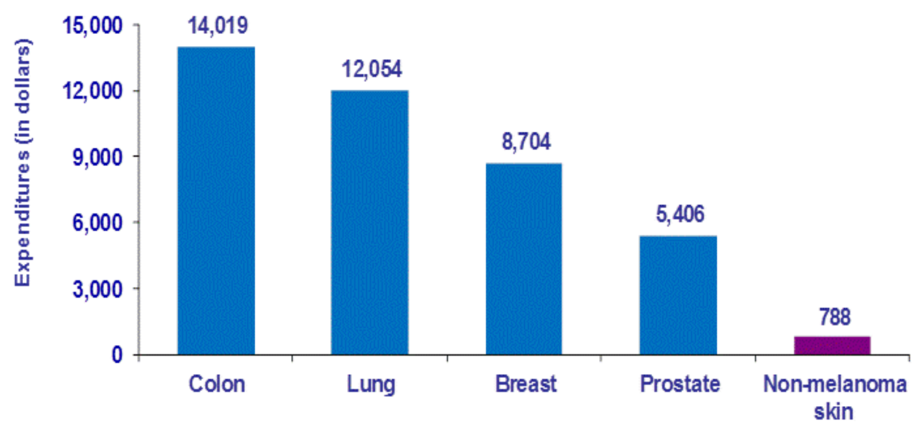
Temperature 36° & Pressure 760_{mmHG}			
	Real Measures	Standard Measures	Error Value
pH of 1.0 M CH_3COOH	2.3:2.5	2.4	±0.1
pH of 0.1 M CH_3COOH	2.81:2.93	2.88	±0.05
pH of 2.0 M CH_3COOH	1.9:2.1	2	±0.1
DO of H_2O tested	14.3:14.9	14.6 (mg/L)	±0.3

7.2 Graphs

Number of People diagnosed with Cancer in Egypt

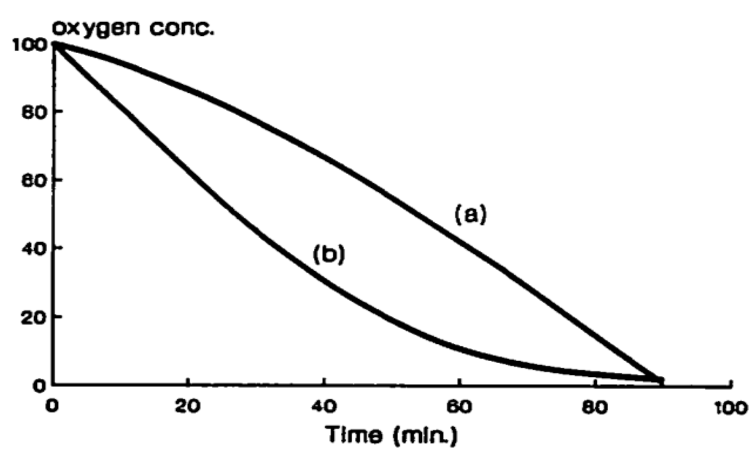


Economic Difficulties



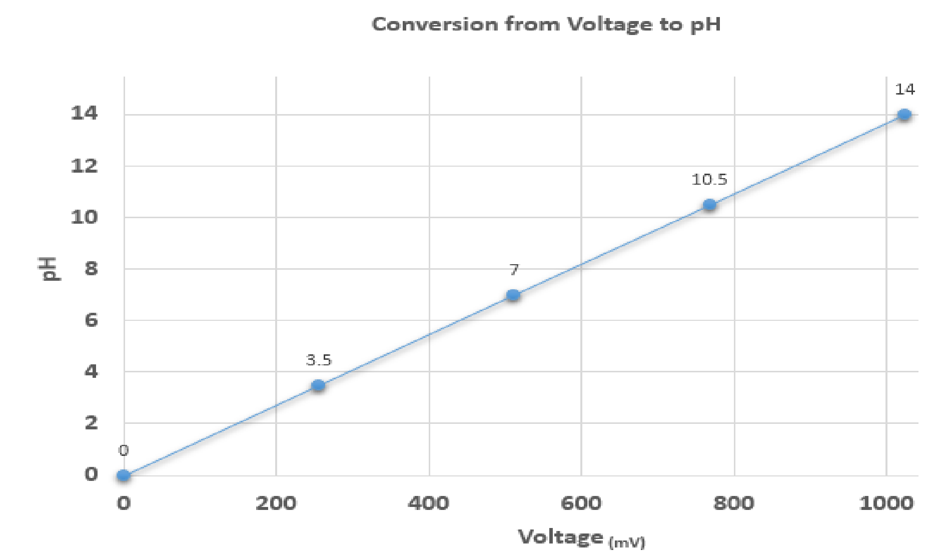
The DO concentration in water is inversely proportional to the amount of Yeast, because it exhausts Oxygen within the water

(b) has more Yeast than (a)



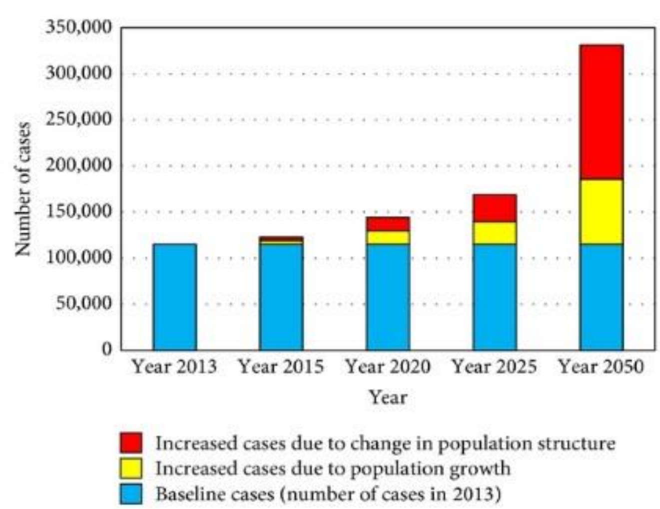
When connecting the pH electrode to the Arduino, the measuring was in the form of voltage change ranging from 0mV:1023mV

An equation has been made in order to convert the voltage variance to a change in the pH.



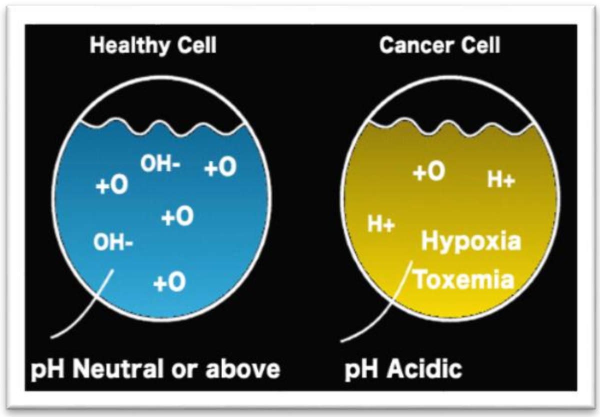

```
int x=0;          int pH=0;        void loop(){ x=analogRead(A0);
if ( x >512 && x <= 1023){ pH=map (x,512,1023,8,14); Serial.println(pH); delay(1000);}
if (x > 0 && x <= 512 ){ pH=map(x,0,512,0,7);Serial.println(PH); delay(1000);}
if (x==0) { pH = 0; Serial.println(PH); delay(1000);}
```

Cancer Spread in the Future



8- Analysis of Results

The biosensor works by monitoring two biomarkers: pH (a measure of acidity) and DO. These are valuable indicators of how well the tumor is responding to treatment. In fact, when chemotherapy or, any therapy, begins to take effect, the tumor becomes less acidic.



Also, by measuring dissolved oxygen, the biosensor helps doctors determine the appropriate dose for treatment, since tumors thrive in low-oxygen (hypoxic) conditions. Specifically, oncologists can determine and alter the dosage based on the dissolved oxygen level inside the tumor.

The Cost: MRI machines are too expensive. The one costs about $3.5 million. It requires a lot of space and time to provide information that may be misleading. On the other hand, our Biochemical Sensor costs far less than MRI, and it helps the economy in Egypt in a marvelous way. When manufactured, it would cost about $60 (DO probe $18 + pH probe $19 + wireless reader $10 + $13 chamber material (Polyether Ether Ketone) to provide all-time data about cancer tumors.

9- Conclusion

Over time, cancer will spread tremendously through whole Egypt due to the increasing of population. It may lead to a serious problems in many fields, such as Economy, Industry, etc...

To monitor a cancer's response to treatment, doctors currently rely on the results of magnetic resonance imaging (MRI) and tissue analysis of biopsies.

However, these methods can only offer a snapshot that is already history by the time the results are analyzed. Also, in the case of biopsies, there is a limit to how many times you can invade the body with risk. On the other hand, our implantable Device promises to provide readings about the state of a tumor as it happens. Such a device would give doctors a chance to change therapy dosing, and potentially reduce unnecessary side effects.

Biopsy has a great chance of bleeding, infection, or wound healing problems. Also it may leave a permanent scar on the body.

10- Recommendation

A natural extension of this work is to create a system that does not require advanced knowledge on the part of the user. The pH and oxygen sensors were demonstrated separately but could be combined into a single sensor. The sensor chamber is a very clean environment in which to perform spectroscopy, especially compared to tissue. Moreover, it would be possible to build a wearable reader that the patient could use at home. It can detect early warning signs and inform the patient to visit the doctor before it is too late

11- Literature Cited

- V. H. Liu, C. C. Vassiliou, Y. Ling, and M. J. Cima, "Implantable dissolved oxygen sensor and methods of use," Filed 04 May 2010. Patent application 61/331,236.

- Cancer facts and figures | World Cancer Research Fund International. (n.d.). Retrieved January 3, 2016, from **http://www.wcrf.org/int/cancer-facts-and-figures**

- D. Lindner and D. Raghavan, "Intra-tumoural extra- cellular pH: a useful parameter of response to chemotherapy in syngeneic tumour lines," Britishjournal of cancer, vol. 100, pp. 1287-1291, Mar. 2009

- Zumdahl, S., & Zumdahl, S. (2007). World of chemistry. Evanston, Ill.: McDougal Littell.

- (n.d.). Retrieved January 3, 2016, from **http://www.smcegy.com/site/about.aspx?par=6&id=0**

Under the direction of