American University in Cairo SensUs Team

American University in Cairo

Team Members:

- Omar El-Sayyad
- Marie Gamal
- Karim Rafik
- Asser Hangal
- Manar El Naggar
- Namir Elkhouly
- Mohamed Saeed

Supervised by:

- Dr. Hassan Azzazy

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1. Introduction

We are a group of 7 members with backgrounds in Chemistry (2), Computer Science, Electronics Engineering, Mechanical Engineering (2) and Nanotechnology.

Our device is built around the principles of light absorption by molecules (spectrophotometry). A light source is placed in front of a detector. The sample to be analyzed is placed between the detector and light source. Different concentrations of Vancomycin in the blood affect the light intensity that passes through it. Using that, a correlation is established and used to program the device.

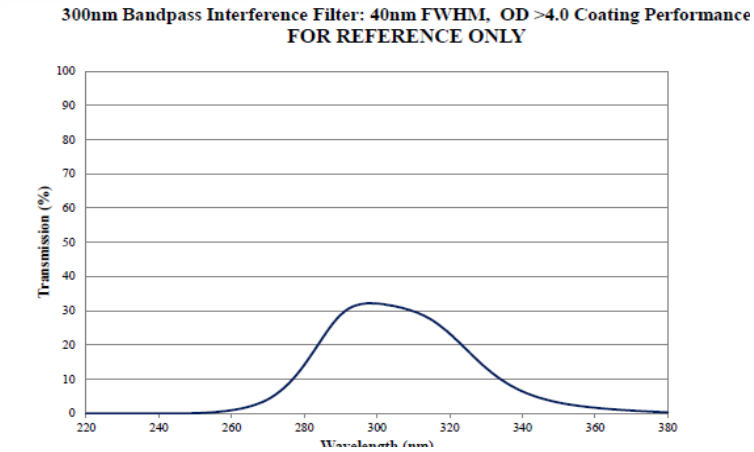
The design and assembly of the device were fully original and did not use previously published designs. This led to a greater number of obstacles that were tackled with teamwork and research. Production of the prototype was done at the American University in Cairo campus, whilst, some optical and electrical components were purchased from abroad.

Most importantly, all team members were fully indulged in completing the task and benefited significantly by working with others studying different courses in achieving the same task.

2. **Biosensor System and Assay**:

2.1

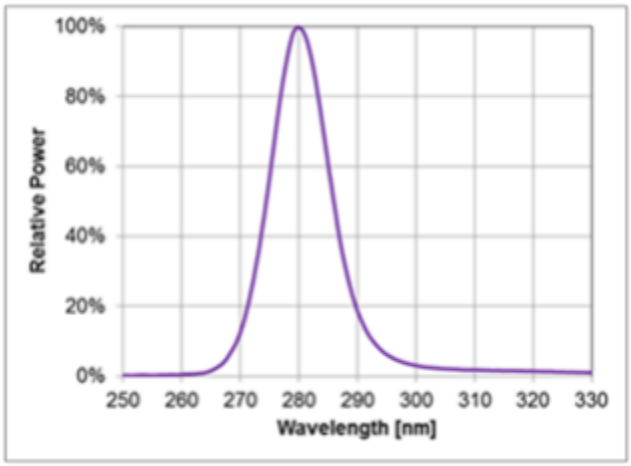
The device built is an absorption spectrophotometer. The device takes a sample of blood plasma spiked with vancomycin in a quartz cuvette on which a UV light (in the wavelength range of 280 nanometers) is emitted. The light coming out of the sample is passed through an optical filter (bandpass filter with center wavelength 300 nanometers) which then falls on a silicone detector to determine its intensity.



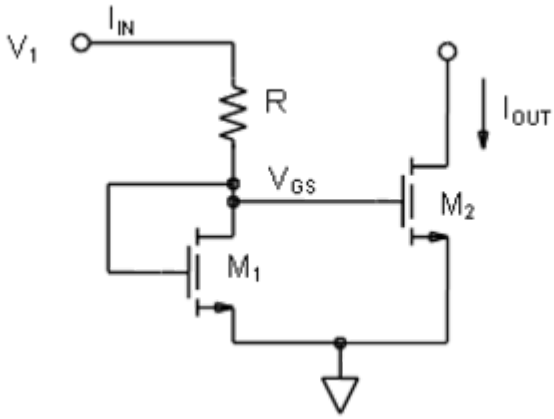
Absorption spectrophotometer block diagram

2.2 The circuitry involved:

There are two main parts of the circuit not including the power supply. The first part is the biasing circuit of the UV LED and the second part is the silicone detector and its amplifying circuit. The UV LED emits light in the wavelength range of 280 nanometer as shown by the graph below. The biasing circuit used is a current mirror which forces a steady 100mA to be sourced from the supply and through the LED. Also the voltage applied to the LED is approximately ... thus operating at its nominal current and voltage characteristics. As shown in the diagram of the current mirror, the resistance R controls the amount of current that will be passed through the LED. For the purpose of biasing the LED a resistance value of … was chosen to allow the desired value of 100mA to be passed through the LED. The second main part of the circuit is the amplification part connected to the output of the silicone detector. It is a simple negative feedback amplifier using an operational amplifier. The output of the opamp is then connected to one of the analog inputs of an arduino board to be processed and the displayed on the LCD.



UV LED's output power vs. wavelength



Current mirror circuit

2.3 Assay:

We start with pure plasma which is then spiked with freshly prepared Vancomycin in distilled water. To the previous mixture, trichloroacetic acid (TCA) is added and all the mixture is then centrifuged at 15000 rpm for 3 mins to separated proteins from plasma. Then, we separate the supernatant from the precipitated proteins, and we dilute it in 1:10 volume ratio. Finally, the diluted mix is ready to be transferred to the quartz cuvette and hit by the beam of light to detect the concentration of Vancomycin.

3. Analytical Performance:

The detection method is based on the absorbance properties that Vancomycin possesses. As UV light is directed at a sample containing Vancomycin, some of it is absorbed depending on the concentration of Vancomycin present in solution. A detector is then in line to receive the remaining light and convert it to an electric signal. A correlation is established between the concentration and the electric signal, which is then programmed on the device.

All in all, the time needed for one test is 5 minutes. With volume sample ranging from 20 – 200 ul. We prepared 4 testing sets each with original sample volume 20 ul and concentrations of Vancomycin 0, 25, 50 and 100 ug/ml. First set (I) with no dilution. Second set (II) with 1:1 dilution. Third set (III) with 1:2 dilution. And last set (IV) with 1:10 dilution. We exposed it to UV light and got readings in voltage (Taking into consideration that the baseline output is 0.38).

Initial Conc (ug/ml)	**Output (Voltage)**			
	I	**II**	**III**	**IV**
0	0.46	0.75	0.88	0.89
25	0.42	0.44	0.49	0.95
50		0.42/0.43	0.45/0.46	0.73/0.74
100	0.39	0.42/0.43	0.44	0.74

4. Novelty and Creativity:

4.1. Already available

The concept behind our biosensor is the excitation of the desired molecule, Vancomycin, by a certain wavelength and then, the presence and the amount of the desired molecule can be detected. We made use of the UV-Vis spectrometer provided by the University to make sure of the validity of the theory behind the biosensor. The Vancomycin powder was provided by the University. Our device consists of a pure aluminum cylinder in which all the optical components, detector and wavelength filters, electrical component, the excitation source, LED lamp are hold. All the optical components were ordered from Edmund, and the LED lamp from DigiKey. Moreover, a quartz cuvette was ordered as well, and is hold in the aluminum cylinder. We had to use pure aluminum to avoid any UV absorption which was provided by the University.

4.2 New developments

Making a fluorometer on small scale is what we really as a team is proud of as well as, discovering new effective and time saving techniques to separate proteins from plasma as they are inhibiting vancomycin absorption. The device design is very innovative where all the components are hold in the pure aluminum cylinder. The electrical circuit is imbedded within the device to make it safe and easy to use.

5. Translation Potential:

5.1. Stakeholder Desirability

Our major stakeholders are as follows.

This group of stakeholders will interact directly with the product. Their major role is being able to operate the device as a black box, they are not required to fully understand its architecture but rather give it inputs and be able to infer conclusions from the resulting output.

1. Patients:

The patients' only role is to just follow the doctor's' instructions whenever they need to draw blood.

2. Hospitals & Medical Institutes:

Hospitals & Medical Institutes will be the ones dealing with the device most frequently because the number of patients there needing the device is much bigger than any other entity. They have the largest interest in the device because with it, they will be able to easily determine what dose to prescribe for their patients.

3. Researchers:

This group of stakeholders will have a major role in the device's manufacturing as in they will look at new technologies that may emerge and help in optimizing the device's way of detecting the concentration. Researchers also include those involved in the medical aspect of the project (chemists and biologists) which may discover new ways of the the synthesis of blood sample. Along with the manufacturing, they were able to create a functional biosensor.

4. Manufacturers:

The manufacturing process of the device is really important and must be done very carefully. It would probably happen in a clean room because the chambers holding the blood and carrying it through the device will have to be as clean as possible to produce the most accurate results. Manufacturers are considered very powerful stakeholders because they are the essence of the device and without them the device would never be realized, a mere conceptualizing of the device is never enough.

5. Distributors:

Any device being manufactured will need distributors to distribute the device to the different medical entities that will use the device. This will represent their only role and it is an important one because proper distribution will ensure the biggest outreach possible.

In terms of gain creators, the device will provide smart and remote data access to speed up medical intervention so our key advantage is the cutting down of detection time of course as well as increasing its availability. We must not drift off from this objective which is the detection of Vancomycin in Hospitals in a time and cost-effective method is a critical issue to keep high quality patient care.

5.2. Technical Feasibility

An advantage our biosensor has is that it is a handheld device, so operating it can be done from the patient's room. Moreover, its ease of usability will allow any nurse to operate it without the need for intense training. In terms of user experience, the doctor will be able

to view all his patients' records on a platform installed on the hospital's system. Once the nurse administers a device, the reading is automatically sent along with a unique ID to the patient to be recorded forever. All these features contribute to the usability of our biosensor.

As far as we know, in Egypt, there are no handheld devices to measure the concentration of vancomycin in the blood. Currently, the process goes as follows, a patient's blood sample is taken to a lab on a different floor, gets processed for a certain amount of time and the results are brought back to the doctor. This time can be cut down by more than half with the use of such a device, so its availability is necessary.

Due to the lack of resources in Egypt and problems with logistics, the final product wasn't close to what we envisioned. The features that follow the capturing of the reading are there, but as far the detection process, it's still not reliable. This inconvenience is further explained in section 2 of this document.

As far as commercialising the product, we'll first start by getting funding (explained in section 5.3). After getting a proper starting capital, we'll estimate our demand. We'll start off distribution with one or two hospitals, these will require light duty manufacturing. Then, when we're ready to expand, we will increase our manufacturing and buy more capacity to keep up with the demand of more hospitals and clinics.

5.3. Business Viability

The approximate prices of the components for our device are as follows:

Cuvette	100$
300 nm filter	130$
Detector	80$
UV Source	10$
Pure Aluminum tube	5$
3D Printing	5$
Circuit components	20$
Total	**350$**

These prices are the prices we paid when buying each product alone. When mass producing this product, the prices will much more less than what are paid. An approximate price for total cost if we're going to mass produce the device will be around 300$ per device.

We came to that price by asking the technicians and markets we bought from if we bought a hundred of each component.

300$X100=30,000$
30,000$= 534,000EGP

Our plan if our product becomes successful is to partner up with the venture lab at AUC to help us grow our business. The venture lab at our university is an association that helps students with startups and helps them fund their projects and business. If we need more capital to fund our business we'll seek the help of a private bank to take a loan. The venture lab is willing to help us with the funds up to 200,000EGP. So we'll need around 334,000 from the private bank. Private banks in egypt provide loans with an interest rate of 20%. So the cost of the bank loan after interest will be 400,000 EGP.

We're hoping to target private hospitals because according to our market in Egypt they will be willing to invest more in our product than the public ones according to our research of our market. Were going to set a price of 15,000EGP for our product which is the equivalent of 830$. This is not a big amount for hospitals to pay with comparison to the medical devices they pay for which are measured in millions. So this is why we are very optimistic in selling our device very easily. But also our device is used for a very specific reason so we should also put that into consideration. There are around 300 private hospitals in egypt that could use our device. Our target will be 100 hospitals, this will allow us to dominate the market because we'll probably be the only ones in Egypt selling such a biosensor.

6. Team and Support

6.1. Contributions of the team members

Omar El-Sayyad (Chemistry), Marie Gamal (Chemistry), Manar El Naggar (Nanotechnology)
Mostly involved in preparing the needed materials (chemicals) to carry out the assay and working on ways to improve accuracy and results. Worked heavily on limiting and eliminating the interference caused by blood plasma with light to allow for more consistent results. Worked on different assays in parallel (other than fluorescence) to help identify the most suitable and accurate method.

Asser Hangal (Computer Science)
Work was significantly involved with programming the device by writing a program that would automate the displaying procedure making it more user friendly. Cooperated mostly with Karim Rafik (Electronics Engineering) by assisting and suggesting new ideas with the circuit. As well as that, he contributed ideas to the design of the device.

Namir Elkhouly (Mechanical Engineering), Mohamed Saeed (Mechanical Engineering)
The production spine of the team. Used computer programs to design the device, make alterations and finally 3D print different prototypes to be tested for suitability and accuracy. Heavily involved in the inner and outer design of the device, whilst communicating with all different sectors of the team to try and put everything together (e.g. working with electronics engineering member to fit circuit stably)

Karim Rafik (Electronics Engineering)
Worked on developing the electric circuit for the device and fitting in the electrical components. Made adjustments to the power supply to try and improve performance, as well as reducing fluctuations (improving consistency of results). Had the greatest background in optics and was relied upon in optical-based problems.

6.2. People who have given support

Dr. Hassan Azzazy (Chemistry Professor)
Our supervisor for the competition and involved with making sure the team was on track. Added to that he provided funds and resources to help make this whole project possible.

Dr. Tamer Shoeib (Chemistry Professor)
Minor consultation with instrument design.

Dr. Hatem Tallima (Chemistry Professor)
Involved with pre-sample treatment and limiting protein interference with measurements.

Dr. Anwar Abdelnasser (Chemistry Professor)
Contributed to initial plan using fluorescence which was then changed to spectrophotometry.

Dr. Mohamed Serry (Mechanical Engineering Professor)
Provided guidance with the machinery of the device.

Samir Nabhan (Chemistry Research Assistant)
Assisted dealing with blood plasma to ensure safety of all team members.

7. Final Remarks

The device that the team has designed is based on the science of spectrophotometry and radiation. Therefore, the only material that our device could have been made out of is pure aluminum, so that it does not absorb any of the radiation. That being said, even though the aluminum will not absorb any of the radiation, there are factors that could greatly affect the result of the experiment. When using the device or if similar models are made in the future, it should be noted that any gaps or holes left in the device could affect the results. Therefore, the user or designer should make sure that when all the components are placed there are no gaps that could lead to the light escaping. In addition, the device should be as stable as possible so that the light would not be scattered inside the device.

The device the team has designed would not have been possible if it wasn't for the support that The American University in Cairo has given us. We would like to thank the University for providing us with the finances and the equipment needed to be able to participate in this competition. In particular we would like to thank Dr. Azzazy, Chair of the Chemistry department in The American University in Cairo, for constantly providing us with support both scientific and moral. We would not have been able to design this device without
his help.

8. References

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