Rapid detection of Fentanyl using a multifunction nanostructured substrate

Project Plan

Client: Meng Lu

Team Members:

Yifu Zhang
Zheyuan Tang
Hao Wang
Ugerah Abalu
Kossi Egla
Olouwole Eteka

Team Email: sddec1907@Iatate.edu
Team Website: http://sddec19-07.sd.ece.iastate.edu/
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List of Definitions

Chromatography: Chromatography is a laboratory technique used for the separation of mixtures into their components. The mixture is dissolved in a solvent, called the mobile phase, and spotted another material called the stationary phase. The mobile phase carries and separates the mixture

Fentanyl: a powerful opioid drug used in the treatment of severe pain.

UTLC(ultra thin layer chromatography): is a chromatography technique used to separate non-volatile mixtures. The mobile phase has different properties from the stationary phase. For example, with silica gel, a very polar substance, non-polar mobile phases such as heptane are used.

PC(photonic crystal): is a periodic optical nanostructure that affects the motion of photons in much the same way that ionic lattices affect electrons in solids.

GLAD(glancing angle deposition): is an extension to oblique angle deposition where the substrate position is manipulated during film deposition.

PET(Polyethylene terephthalate): A type of thermoplastic polymer

1 Introductory Material

1.1 Acknowledgement

Team Client: Meng Lu
Team Advisor: Meng Lu

We would like to express our special thanks of gratitude to our advisor and client Dr Meng Lu who is helping us to acquire equipment and materials for our project. Also, we would like to send a special appreciation to our professor Dr Daniel as well as Electronics Technology Group (ETG) who are providing us with in class resources and electronics for the success of our project.

1.2 General Information about Fentanyl

Fentanyl is a potent synthetic opioid drug approved by the drug and food administration for use as a pain medication and anesthetic. Fentanyl is stronger than many other drugs on the market. It is 100 times more potent than morphine and 50 times more than heroin. There are many effects and serious side effect of fentanyl on human body. Some overdose effects about fentanyl are hallucinations, unconsciousness, cold and clumsy skin, drowsiness, dizziness respiration failure that can lead to death. According to the USCDC, the rate of drug overdoses involving the fentanyl raised about 113% each year from 2013 to 2016 and resulted
in over 10,000 overdose deaths in 2016.

1.3 General Problem Statement

The purpose of the project is to design a system that can detect fentanyl in a mixture of chemicals by separating compounds. The system will use “thin layer chromatography” to separate the compounds using an optical instrument that detects the existence of fentanyl.

General Solution Approach

The project is split into three smaller design tasks. The first task is to fabricate the chromatography paper and the GLAD film. The task will be accomplished as followed:

The first task will be chromatography

a) Research the appropriate material and solvent for mobile phase and stationary phase, to separate the fentanyl out from component obviously.
b) Using glancing angle deposition to fabricate the ultra thin layer plate by electron beam.

The second task is to test the chromatography based on paper and film created on first task.

a) Test the chromatography on GLAD film
b) Test the chromatography on PC-GLAD

The third task will be the instrumentation and combine all the part together

a) Test the system of instrumentation (data analysis)
b) Test the system as a whole.

Operating Environment

The fentanyl detector will be designed to detect fentanyl in a chemical mixture such as the drug and medicine. To prevent the fentanyl border crossing, the main concern is placing it in the right temperature condition. Failure to do so might result in the detection of sensor become sensitive or slow, and lead to an inaccurate result. Our recommendation is use this type of biologic sensor in room temperature.

1.4 Intended User(s) and Intended Use(s)

The fentanyl detector is a low cost measurement instrument instrument that can detect and measure fentanyl. It can be used by individuals or corporates involved in detecting and measuring fentanyl. The fentanyl detector can have it applications in the pharmaceutical area to measure the dosage of fentanyl in substances. It can be used by the law enforcement at airports and borders checking points to detect illegal trafficking of fentanyl. It can also be used in laboratories for experiment with fentanyl compounds.

1.5 Assumption and Limitations

Assumption

Our intention is to make the fentanyl detector affordable, compact and easy to carry, and with high accuracy. Our product would mainly be divided into two sections: the chromatography section and detection section. We expect the chromatography section to be removable, which is easy to connect with other terminal to detect it. Based on our cost estimate for the materials, we assume that our final product would be relatively inexpensive.

Limitations

There are 2 possible limitations on this project. Firstly, the chromatography may hard to separate the test sample which contains much more type of chemicals and they have similar retention value with fentanyl. Although we can use extra fentanyl as reference, it still hard give better resolution of chromatography. Secondly, the camera we are using cannot detect reflected lights of wavelength below 800 nm. The grating separation on the titanium dioxide plate we are currently using is 2um. Hence, it might be difficult for the camera to really capture good clear images coming from the plate during the experiment.

1.6 Expected End Product and Deliverables

a) The objective of the task is the detection of fentanyl using a multifunction nanostructured substrate.

b) To detect the fentanyl, we need to put it in a liquid form first, drop a small amount of measured fentanyl in liquid form on a chromatography paper, and deep a part of the paper in a solvent.

c) After couple hours, we should see the liquid of fentanyl moving at certain speed and stop at a certain point on the chromatography paper.

The product will look like the sketch in Fig1. The Fig 1A is call the photonic holder. It will hold the photonic crystal sensor(figure 3) that will be deep in the solvent contained in the whole inside the box(figure 1C). The solvent will be put in a cylindrical beaker that will be placed in the Fig 1 B diagonally. The large circle hole is for the is where the camera will be placed and the small hole is for the infrared LED. The LED will emit infrared light that will hit the photonic crystal and reflect on the camera. The camera (can detect infrared above 800 nm wavelength) will take a series of pictures to keep track of the movement of the compound

while the separation process is been perform and send it to a computer to be analysed. After analysis, we should tell if the mixture contain fentanyl.

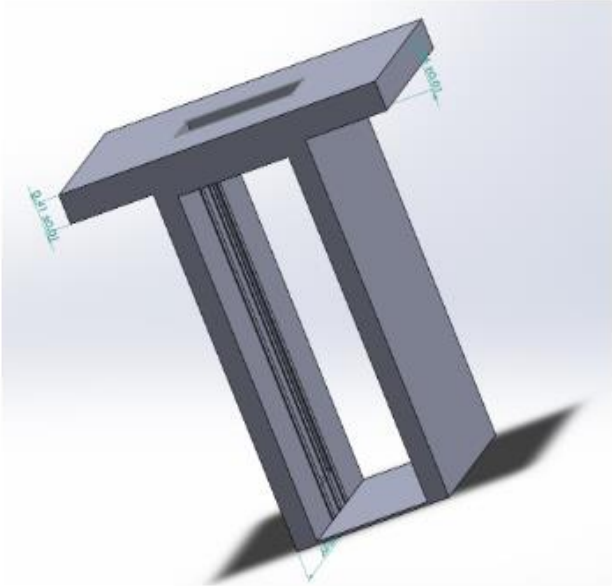


Fig 1 A

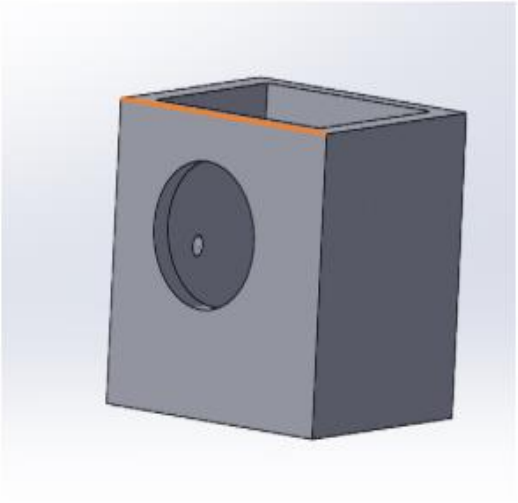


Fig 1 B

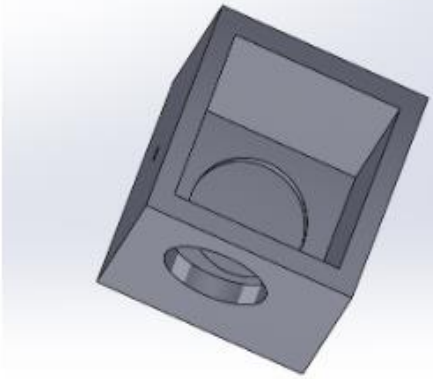


Fig 1C

Figure 1: sketch of the expected product

1.7 Project Description

The goal for the this project is to create a convenient and affordable fentanyl sensor. Our project made up of two critical components.

Chromatography

The Ultra thin layer chromatography plate is made up of PET plastic material in the bottom. The photonic crystal periodic optical nanostructure as the second layer. The third layer will be the TiO2 which is coating through glancing angle deposition to form the nanorow.

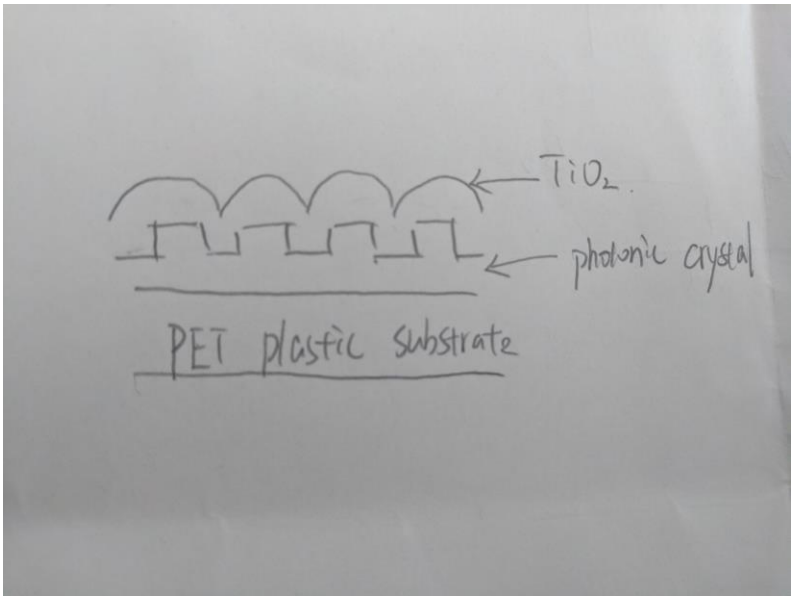


Figure 2 : Pet Plastic Substrate

This structure will have a groove on the surface and have strong enough capillary force to ensure liquid flow on it surface and separate .During the chromatography process,the mobile phase solution, chromatography photonic sensor plate and test sample will be considered as the influence factor.

Arduino camera

The arduino camera is build to capture the process of separation. The first thing to do is wire the camera with the laptop, then set its wavelength to meet the wavelength requirement for photonic crystal.

For the first semester, our main task is to collect more data as possible as we can, such as what type of combination between the material of chromatography plate and composition of solvent can get the clear separation for test sample. And for the Next semester, we will use these data to create a real product.

2 Proposed Approach and Statement of Work

2.1 Objective of Task

We are required to design a device that can detect fentanyl in any given mixture. To successfully operate this project. A list of goals need to be accomplished.

1. We divided the team into three small groups(Fabrication, Chromatography test, instrumentation) and each group should accomplish their own goals.
2. We will discuss the difficulties between groups.
3. Effective time management is required.
4. Each group will need to follow the proportional plan shows below.

	Fabrication	Chromatography test	Instrumentation
February	Learn the principle of glancing angle deposition Start some Chromatography experiments	Learn and play using the commercial kit	Buy the arduino and the camera, and document on them.
March	Fabricate the ultra thin plate by electron beam in MRC	Test Chromatography on GLAD	Coding and using optical detection to analyze the feature of fentanyl
April	Test the ultra thin plate by UTLC	Test Chromatography of PC+GLAD	Start the 3D design of the frame Implement a system that analyze the Chromatography data

Table 1 : schedule of semester one

2.2 Functional requirements

For this project, we are required to have three major skills, Fabrication(sensor fabrication skills), Chromatography test(chemistry skills), instrumentation(programing and hardware design skills). We have to

follow the requirements shown below as subsets of our skills. In addition, we use google documents, our website, and powerpoints to communicate and for documentations.

Fabrication

a) Glancing angle deposition(GLAD): The glancing angle nanostructure layer will be fabricated by electron beam processing.
b) Photonic crystal sensor : Principle, structure, and application

Chromatography test

a) Experiment testing: Perform the chromatography experiment using dyes as a sample before moving on to fentanyl mixture
b) Use GLAD and food dye to test
c) Test the GLAD with fentanyl solvent

Instrumentation

a) Designing a system to read and analyze the result of the chromatography process.
b) Optical analysis with image processing and shape recognition.
c) Designing a controlled lightning module to allow the camera to take clear pictures in order for the microcontroller to analyze them.

2.3 Constraints Considerations

Chromatography test

The main constraint for the chromatography is the relationship between the concentration of the solvent and the materials of the stationary phase. Different materials of the stationary phase need different concentration of the solvent to separate each dye.

Instrumentation

The main constraint is that the fentanyl liquid does not have a color so the paper to be analyzed will not show any color so we will have to use an infrared LED to shine on the photonic crystal and read the amount of reflection on the camera. We will need make the angle at the reflection point 90 degree.

2.4 Proposed Design

GLAD deposition

For fentanyl drug, we assume that more than 10 chemical compounds will be mixed in sample. We will deposit a 10 micrometer thick layer on the plate which has a structure of a glancing angle columns. Compare with paper chromatography and thin layer chromatography, the UTLC will have shorter development time and higher resolution of compound separation. The purpose of GLAD nanostructure is to have better result of separate fentanyl compound out in short time

Chromatography test

The chromatography test step is designed for testing the stationary phase with solvent to see if there's fentanyl or not. We are supposed to use different kind of materials to test with different types of dyes to prove there's a separation between fentanyl and other chemical substances or dyes. The purpose of using the chromatography test to our project is because it is very simple and easy to use.

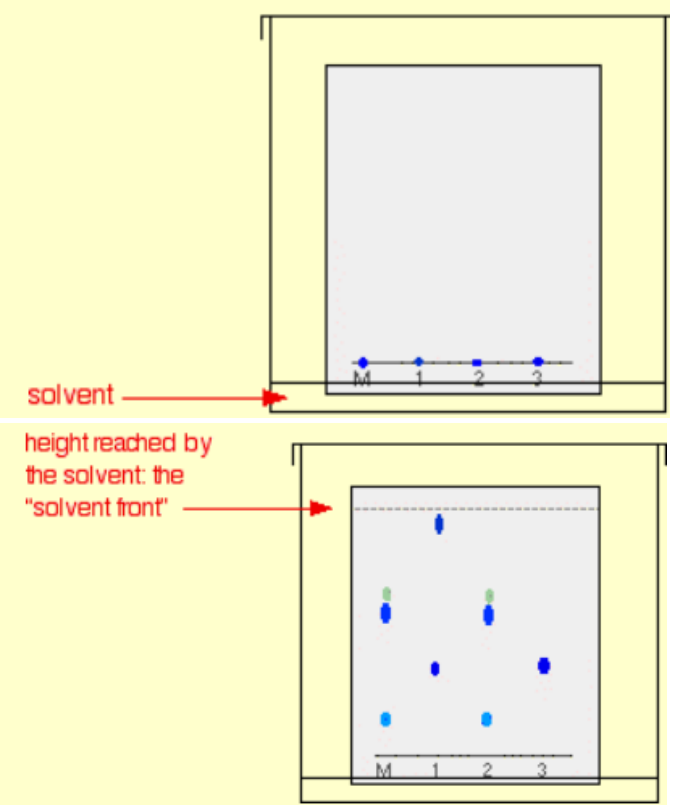


Figure 3: Pictorial and real representation of chromatography separation

Instrumentation

Our design proposal is made of the Arduino microcontroller that will be controlling a camera and a lighting circuit to take a pictures of the chromatography paper. The microcontroller will analyze the picture taken and will display whether the paper shows a sign of fentanyl or not. There is a diagram below (figure 4) showing an overview of the design. The whole system will go into a frame. We are thinking of making it an "L" shape (figure 0) where all the circuit will go into the bottom part and the camera attached to the stand. The system level diagram is showing bellow and we will be working on the frame once our design is functional.

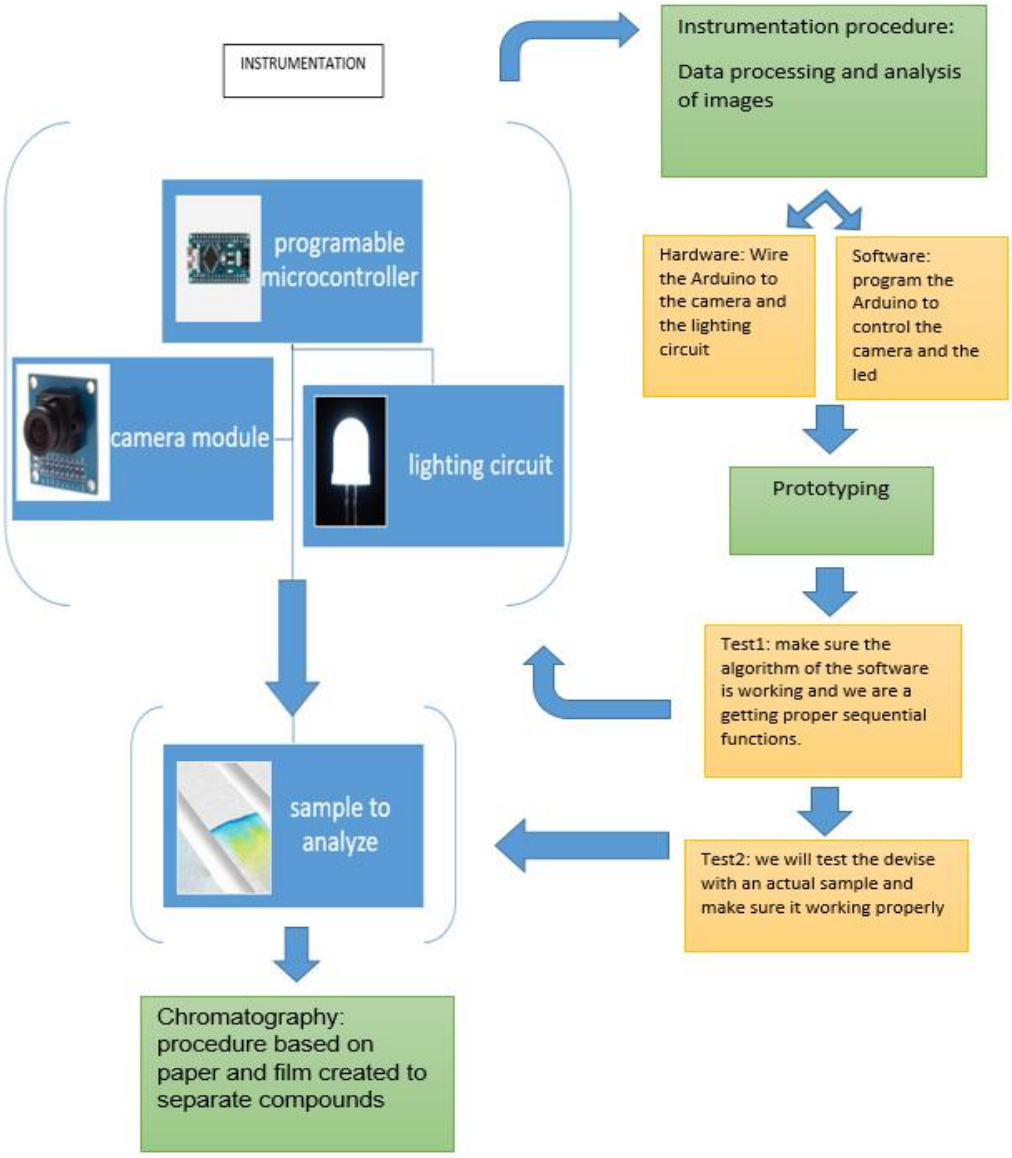


Figure 4: Instrumentation overview

The hardware and camara description used are provided below.

Key Specification
Image Sensor: OV2640
Active array size: 1600×1200
Shutter: rolling shutter
Lens: 1/4 inch
SPI speed: 8MHz
Frame buffer Size: 384KB
Temperature: -10℃～+55℃
Power Consumption: Normal: 5V/70mA, Low power Mode: 5V/20mA

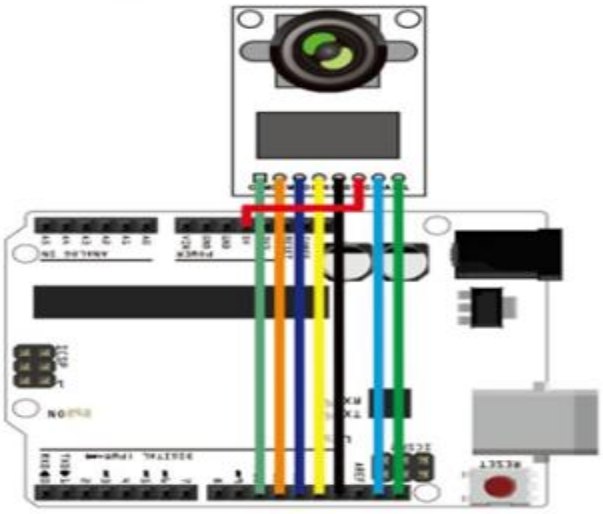


Figure 1 Typical Wiring

Mechanical Dimension

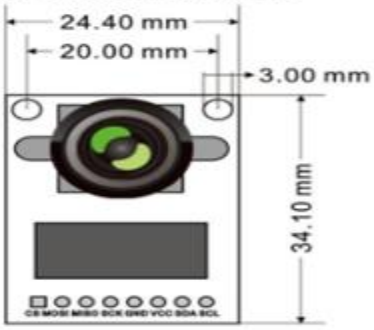


Figure 5: Arducam specification

Software

There is a built in library which comes with the Arducam that can allowed us to stream image when we installed it. We then needed to tweak the code to be able to send data to our computer. For accuracy purposes will be analyzing those picture with another software (Matlab or JAVA) as well to see if we will get the same results. The procedure to get the Arducam library is provided bellow.

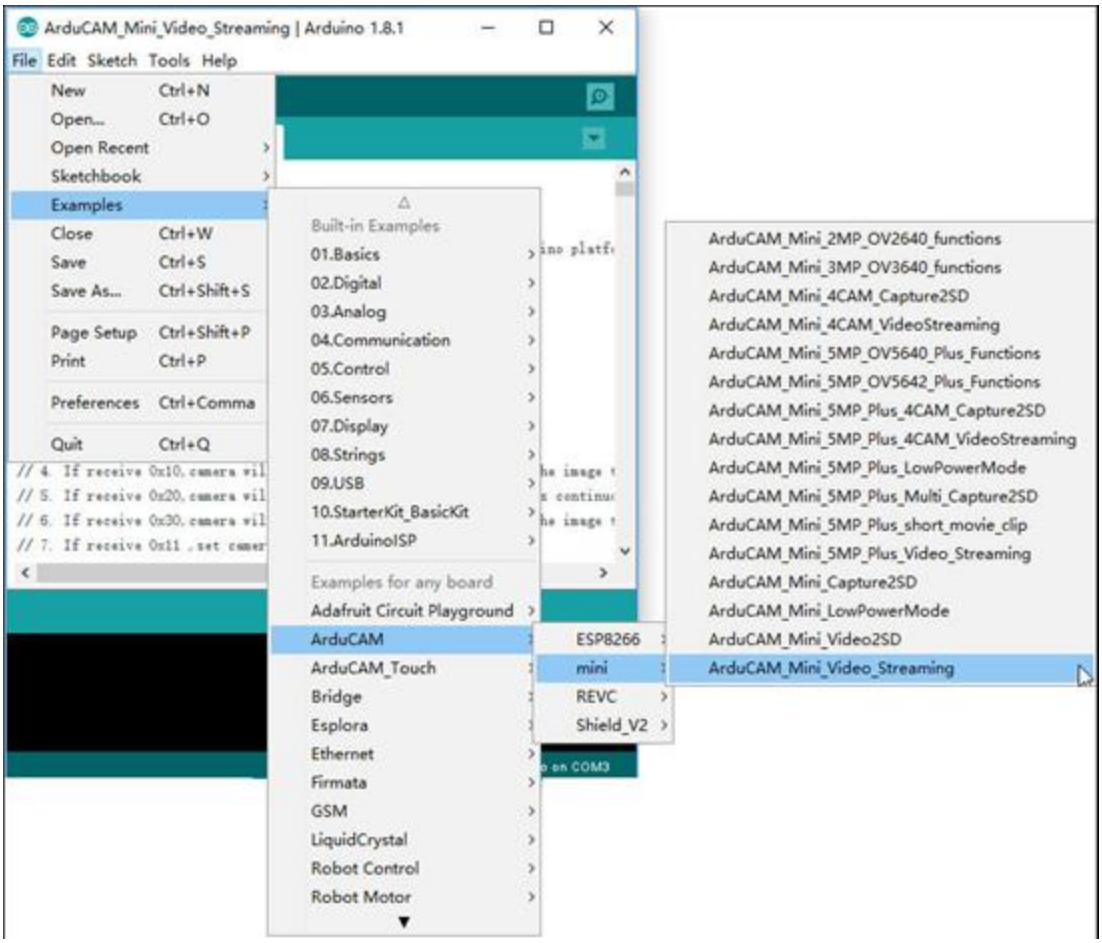


Figure 6: Software for Arducam

2.5 Technology Consideration

Our two main technologies considerations for this project will be the use of advances chromatography sensor, and arduino technology and MATLAB.

chromatography sensor:

The chromatography photonic sensor used for the plate of the chromatography process. We will use the chromatography photonic sensor to first separate the composition of the fentanyl. Afterwards, we will then use the infrared light source to irradiate on the plate and reflect the light back to camera. Thus we can detect the wavelength of the reflect light so that give the result.

Arduino technology and MATLAB:

Arduino is an open-source electronics platform based on easy-to-use hardware and software. We will use it as a microcontroller with a camera to take picture of the chromatography sensor, to power the infrared LED. We can program the arduino to coordinate the light and the pictures and save them on a computer. We will then use MATLAB to analyse the picture. MATLAB is a software with matrix-based language allowing the most natural expression of computational mathematics. It pretty popular for image analysis, pixels

analysis, and matrices work. In our case we will be using it to analyse a picture in order to determine the retention value of the fentanyl base on compounds separation.

2.6 Safety Considerations

Chromatography test

Make sure teambers in the chromatography test group has passed the safety online training course. Students who enter the chemical lab should wear the lab uniform and lab goggle while performing any experiments. Students will also take care to avoid spilling toxic chemicals in the lab.

Instrumentation

The important safety measure in this part is to make sure the extension cord to the wall outlet is completely insulated. Also to make sure the outlet is not overloaded and avoiding touching naked wires.

2.7 Task Approach

Chromatography test

First, we will use the purchased chemical kit to try out the paper chromatography test. This would give us some good practice with understanding the basics of the chromatography separation process. We would try out food dye separation on the paper chromatography to see a good example of mixture separation. After successfully completing this, we would then move on to testing the food dye separation using the UTLC plates made through GLAD using food dye. If successful, we would begin trail using actual mixtures that contain fentanyl in them to see how we can seperate the fentanyl from the mixture

Instrumentation

a) We will do the circuit connections first.It will go as follow:
Connection and implementation of the camera module circuit to the microcontroller.
b) Program the microcontroller and make sure it is working properly with the camera module.
c) connect our lighting circuit with microcontroller, program it and make sure it responding properly.
d) we can now assemble our chunks of program to test the functions of the whole system.

2.8 Possible Risks And Risk Management

Chromatography test.

We have to carefully measure the distance and record the time during the lab.Inconsistent data could lead to error during result analysis.Also, we need to improve the tightness of the cover on the testing breaker so that the solvent wouldn't dry during the experiment. To do this, we are using Aluminium foil paper to cover the beaker that contains the solvent.

Instrumentation

We have to consider that we need to implement a camera that is compatible with the microcontroller we are using. We also need to keep in mind that the resolution of the camera we are using should be enough to detect the data we want to analyze on the paper.

2.9 Project Tracking Procedures

Project tracking consists of comparing the "project timeline" that will be shown in Section 3, with the actual advance in the instrumentation part of the project. We should be done by the end of the third month to leave place for testing. We will create a tracking record to make sure we are meeting the deadline of the project.

2.10 Expected Results and Validation

We expect our system to take clear picture with all the visible trends already given to the program and make the decision of whether the substance contain fentanyl or not. The system must be able to compare accurately the image taken and existing image embedded in the program. The camera must detect traces of infrared reflexions from the infrared LED through the photonic crystal on the chromatography sensor. We then calculate the concentration of compound on the photonic crystal and figure out what kind of compound is it. We also expect to have very good separation on the UTLC plate for each sample chromatography test of the fentanyl mixture.

2.11 Test Plan

We will be testing as we go. We will test the circuit connections between the microcontroller and the camera module, the circuit connection between the lighting circuit, and the microcontroller and our last testing will be if the whole system is doing the job it is supposed to do.

3 Project Timeline, Estimated Resources and Challenges

3.1 Project Timeline

Figure 7: Grantt Chart (2019 spring)

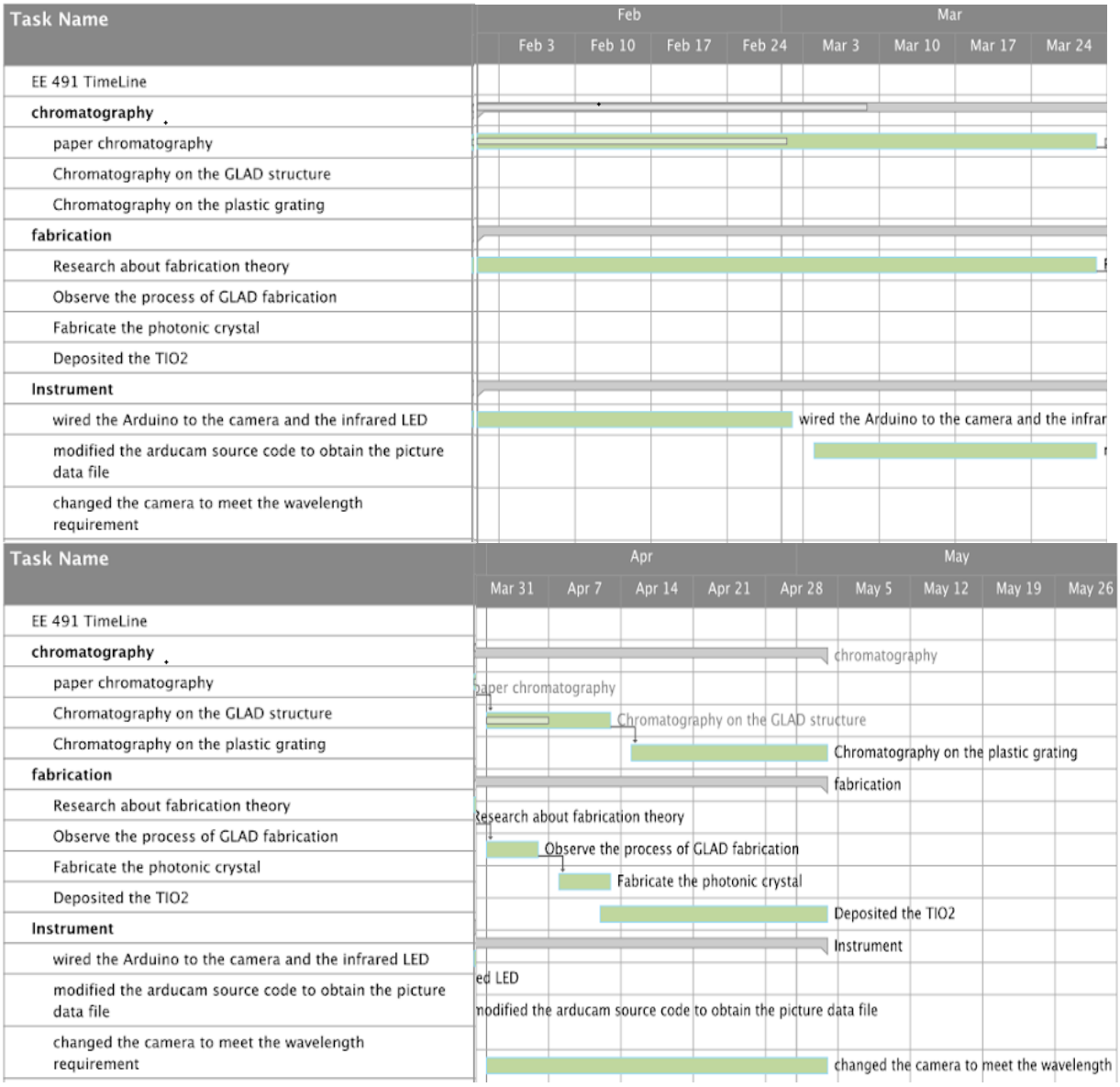
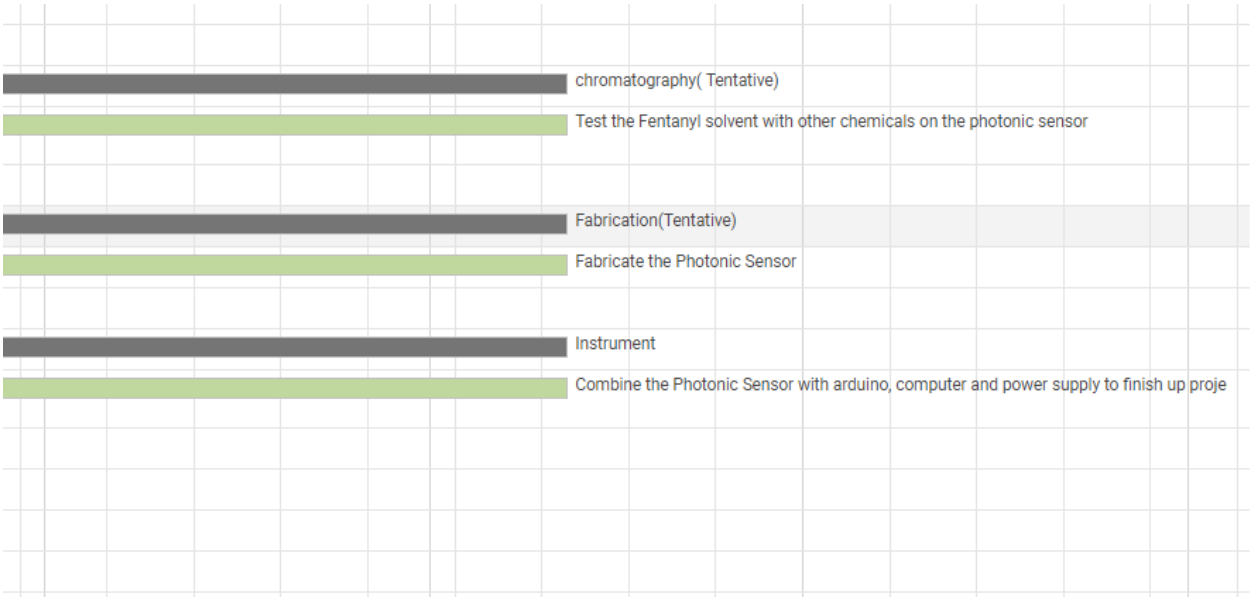


Figure 8: Tentative Grantt Chart (2019 fall)

EE491 Timeline(Fall)		
chromatography(Tentative)	**08/26/19**	**11/11/19**
Test the Fentanyl solvent with other chemicals on the photonic sensor	08/26/19	11/11/19
Fabrication(Tentative)	08/26/19	11/11/19
Fabricate the Photonic Sensor	08/26/19	11/11/19
Instrument	08/26/19	11/11/19
Combine the Photonic Sensor with arduino, computer and power supply to finish up project	08/26/19	11/11/19



EE491 Timeline(Fall)			
chromatography(Tentative)	**08/26/19**	**11/11/19**	chromatography(Tentative)
Test the Fentanyl solvent with other chemicals on the photonic sensor	08/26/19	11/11/19	Test the Fentanyl solvent with other chemicals on the photonic sensor
Fabrication(Tentative)	08/26/19	11/11/19	Fabrication(Tentative)
Fabricate the Photonic Sensor	08/26/19	11/11/19	Fabricate the Photonic Sensor
Instrument	08/26/19	11/11/19	Instrument
Combine the Photonic Sensor with arduino, computer and power supply to finish up project	08/26/19	11/11/19	Combine the Photonic Sensor with arduino, computer and power supply to finish up proje

3.2 Feasibility Assessment

The feasibility of this project is good. We are working with a few graduate students with extensive experience in semiconductor fabrication to guide us in the making of the sensors. We have also properly organised the timeline and split into sub groups so we can effectively work on the testing of the samples, fabrication of the semiconductor and building the tool to read the sensors simultaneously. In addition, we will be following the process outlined below:

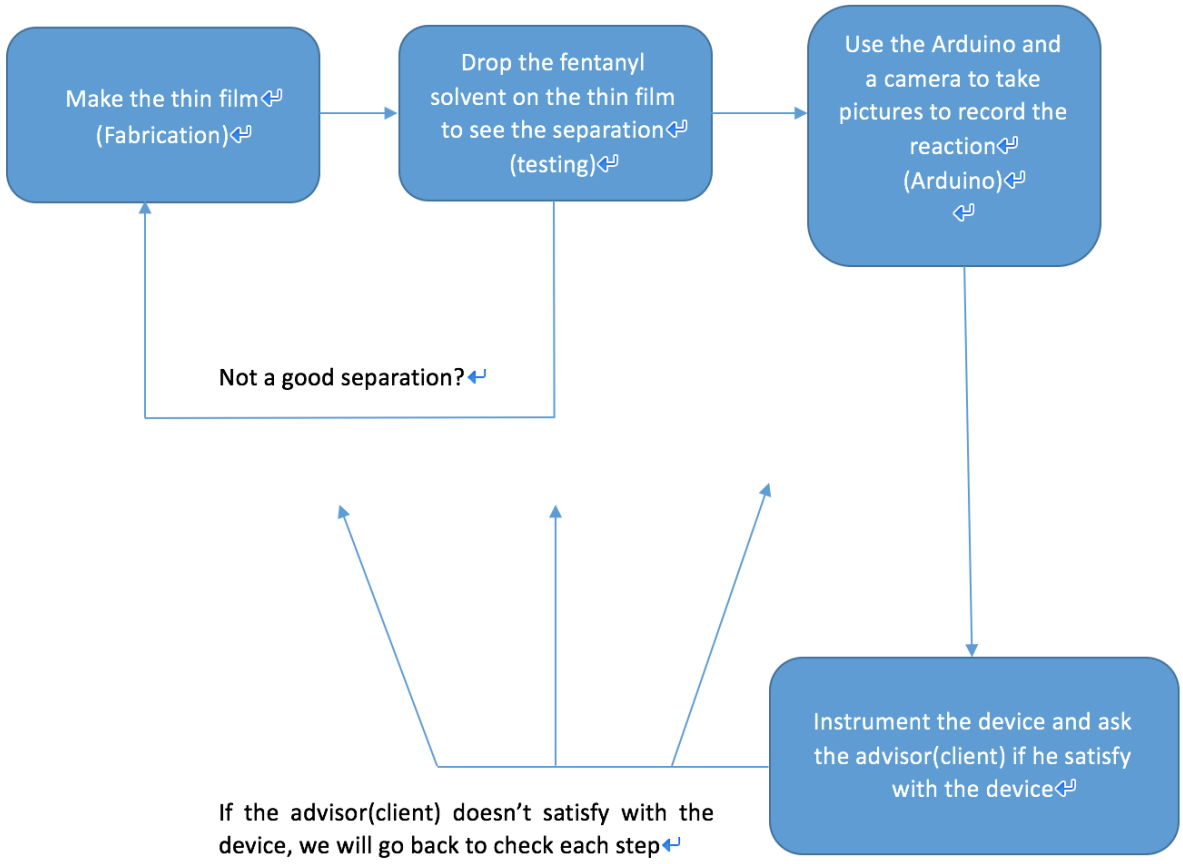


Figure 9: Design overview

3.3 Personnel Effort Requirements

Fabrication group: The fabrication group would be using glancing angle deposition to fabricate Ultra thin layer plate by electron beam in MRC. The 2 team members in the group will spend an average of 12 hrs a week working on this section of the project.

Testing group: As the “middle” process in the project, the testing group will test the sensors made by the fabrication group and supply data to the instrumentation group. The 2 team members in the group will spend an average of 10 hrs a week working on this section of the project

Instrumentation group: The instrumentation group will design physical hardware that is capable of analyzing data from the thin layer chromatography paper (TLCP). The 2 team members in the group will spend an average of about 10 hours working on the image processing and data collection section of the project.

3.4 Other Resource Requirements

Some additional resources that we would require for the project are listed below:

Paper chromatography
1. Kit
2.Ethanol

For Glancing Angle Deposition(GLAD)
3. Titanium
4.Aluminum
5.Silicon
6.Mobile phase(ethyl acetate/methanol/water)
7. New test sample(Brilliant Black BN , LissamineTM Green B,tartrazine , and Acid Red 14)
Glass backing

For fabrication of photonic crystal
8.Photonic crystal

Hardware and software required for detection of fentanyl in mixture
9.Arduino
10.Camera
11.Infrared LED
12. Switches
13. C programming and MATLAB

4 Closure Materials

4.1 Conclusions

Even though fentanyl is good for controlling pain, people also use it at recreational drug. Fentanyl is sometimes mixed with heroin and cocaine without the knowledge of the user, which makes it even more potent. The overdose of fentanyl has caused an increase in mortality rates in the USA and across the world. Therefore, there is an important need for detecting fentanyl in a mixture of chemicals . To do so, our team come up with the following approach:

- 1st task: fabricating of the chromatography paper and the GLAD film
- 2nd task: testing of the chromatography based on paper and film created on first task.
- 3rd task: will be the instrumentation and combination of all the part together

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