Rapid Detection of Fentanyl using a Multifunction Nanostructured Substrate

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Definitions

Chromatography: technique use in laboratory to separate 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.
GIAD(glancing angle deposition): is an extension to oblique angle deposition where the substrate position is manipulated during film deposition.

1. Introduction

1.1 Acknowledgement

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 Problem and project statement

Our design project is for creating a device for detecting fentanyl. As we knew, fentanyl has become the most common drug involved in drug overdoses. Fentanyl is often mixed with heroin or cocaine without user knowledge. To prevent the overdose of fentanyl, there is an urgent need to detect fentanyl in a mixture of chemicals. Our goal is to investigate a novel photonic sensor to separate and quantify fentanyl.

Our plan is to make a novel photonic sensor to separate fentanyl, meanwhile, we will use the arduino to take pictures to observe the result. Finally, we will have a complete device with arduino, photonic sensor and chemical solvent which contain fentanyl. Then we will see how the separation performance from a computer.

1.3 Operational Environment

The device will be located anywhere away with water, fire, extreme low/high temperature. The device will be operated in the factories where needs to detect fentanyl.

Users will use it by a computer so they will see the pictures on their screen. The UV light is needed depends on the solvent. We will try to adjust our device so that could transform and receive data on any computers or laptops.

1.4 Intended Users and Uses

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. In addition, the device could be calibrated to detect other chemical components and our device has to be reliable, easy to carry and easy to use.

1.5 Assumptions and Limitations

Assumptions:

Our assumption is that the device will be used by the law enforcement at airports and borders checking points to detect illegal trafficking of fentanyl. The user will have a safe and easily way to detect the fentanyl and prevent the overdose and illegal trafficking of fentanyl.

Limitations:

The device must be operate with a computer.
The retail price of the device can not be less than one hundred.
The product must be created before Dec 2019.
Away from fire or water when using.
Ultraviolet light may be needed

1.6 Expected End product and Deliverables

The product will be an L shape frame as shown in figure 0 below. At this point we do not have actual frame yet but we are working on one the 3D prototype. The chemical which contain the fentanyl will be dropped on the chromatography paper (other method of separation can be used) and the arduino will take the pictures to keep track of the movement of the compound while the separation process is been perform. The this process is done the device will be able to tell if the chemical mixture contain fentanyl base on analysis of the those pictures.

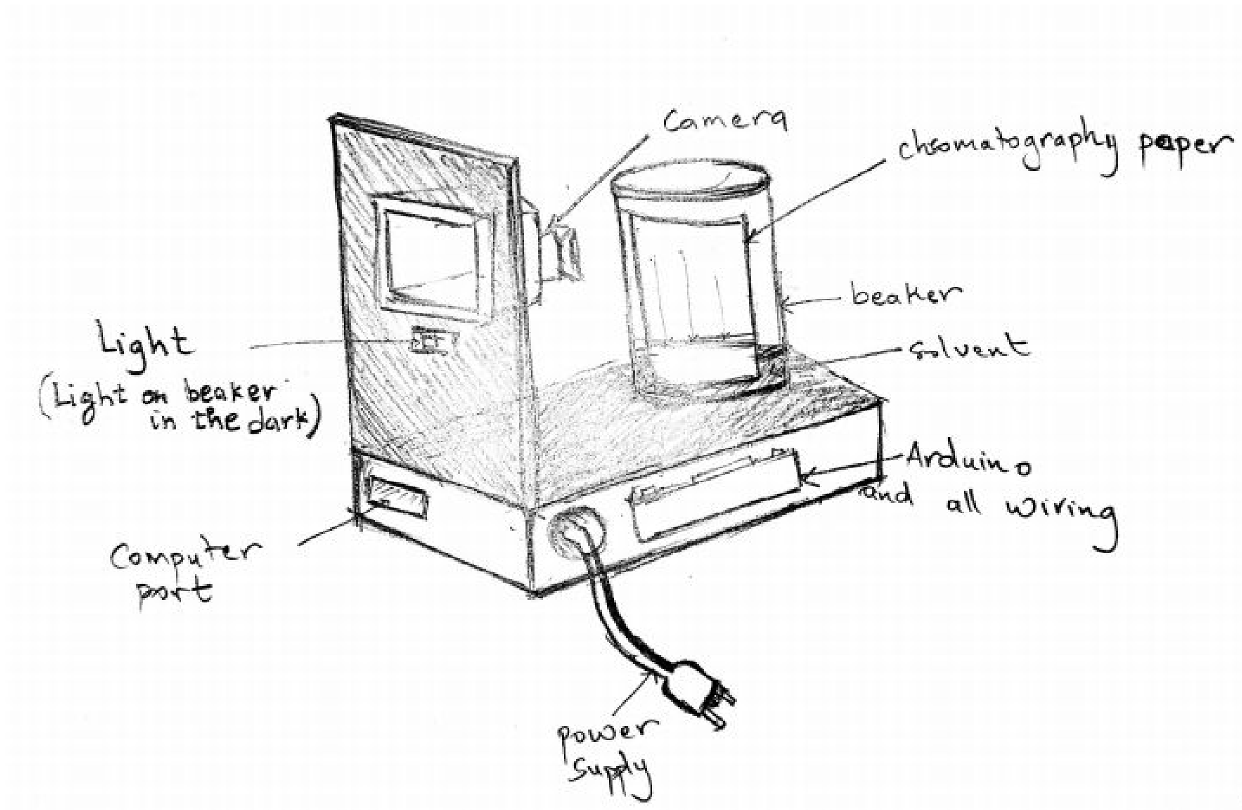


Figure 0: sketch of the expected product

First semester Deliverables

1. Paper Chromatography test
This step is the first step we need to do, that will help us better understand the theory of chromatography test and let us knew how to improve our strategy of making the photonic sensor.

2. Ultra Thin film nanostructure layer fabrication
The whole team will go to learn the fabrication process and the fabrication group will create the thin film to separate the mixed dye.

3.Arduino
The instrumentation group will write a code for the arduino to capture as many pictures within a certain timeframe. The team will make sure the speed and format of the data matches on the windows/mac system.

4. Ultra Thin film nanostructure separation (Photonic sensor)

The team will work on the nanostructure thin film separation by a chemical solvent which contain fentanyl instead of dye.

<u>Second semester Deliverables</u>

1. Device Instrumentation

The team will work on combination of arduino and photonic sensor in a removable box.The box will be designed humanized with Solidworks, 3D printer such design tools.

2. Revise/improve later semester's problem

The three small groups in the team will take their own advantages to work for fixing and improving exist problems.

3. Finalize the project requirement

This step is our final step to finish the project, the whole team will communicate with our advisor(client) Prof.Meng Lu to do the final revision.

2. Specifications and Analysis

2.1 Propose design

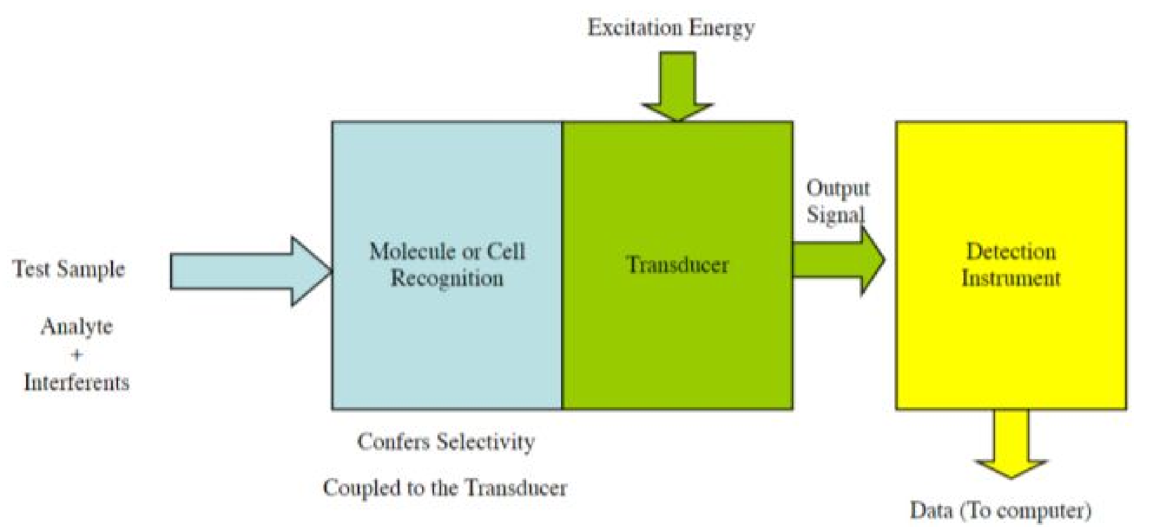
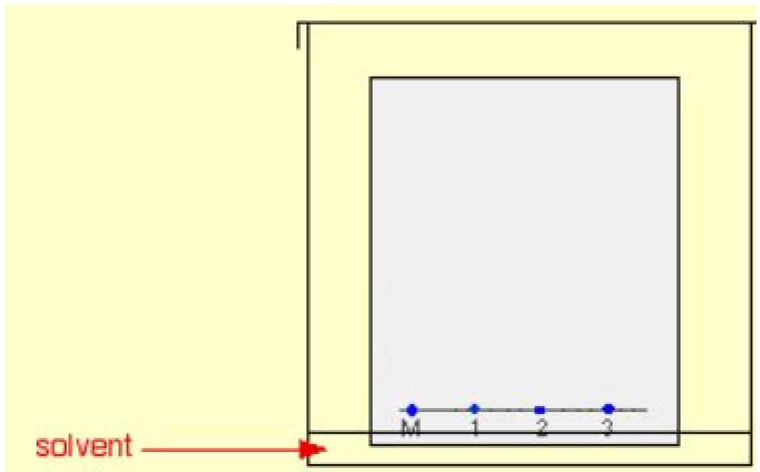


Figure 1: system principle

Figure 2: The separated components



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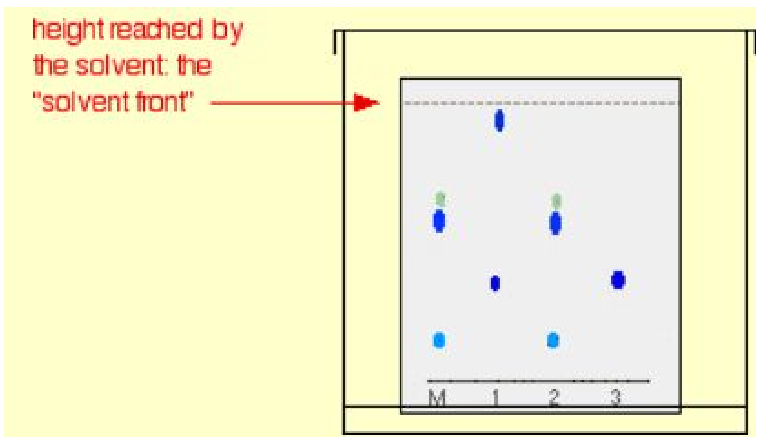

Figure 3: Separation process on chromatography paper

The method of fentanyl detection has been determined. The project was barely in embryo, but the system operation principle is shown in **figure 1**.
In ultra-thin layer chromatography(UTLC), the test sample should go upward though the plate when the bottom of the chromatography plate soak in the solvent, but the sample cannot touch with the solvent. After few minutes, the separation of sample will be completed, the components should be separated in different position of the result has been shown in **figure 2** and **figure 3**. Because some of the separate components has no color, the UV needs to make the components visible. So that the camera will record the image of this separation and analyze where the fentanyl stays on the plate.
Before we make further decision on design, we have to ensure the material for the chromatography plate and the appropriate components for the solvent. The relationship between the plate material and the solvent will highly affect the rate of separation and

quality of the separation result. The inappropriate solvent will lead to unsatisfactory result, such as the boundary between each component become unclear, or the sample aways stay in the bottom, never go upward. To do this, we will try several different types of material of stationary phase, TiO_2 and SiO_2, with mixture of the ethyl acetate,methanol and deionized water. But the result is still not good enough, so we will keep going and make the material and solvent invariant as many changes as possible.

<u>Instrumentation</u>

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.

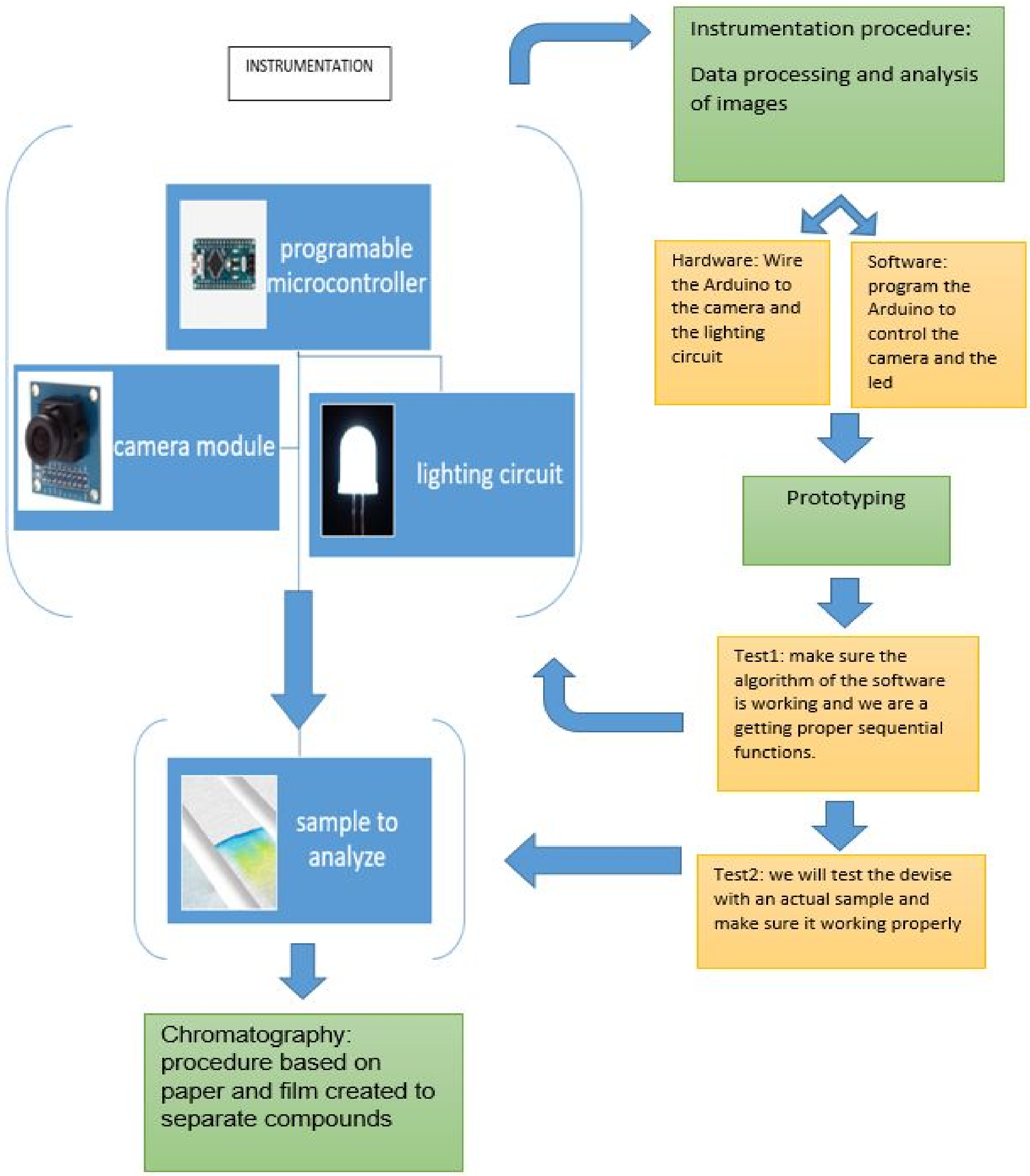

Figure 4: Instrumentation overview

The hardware and camara description used are provided below.

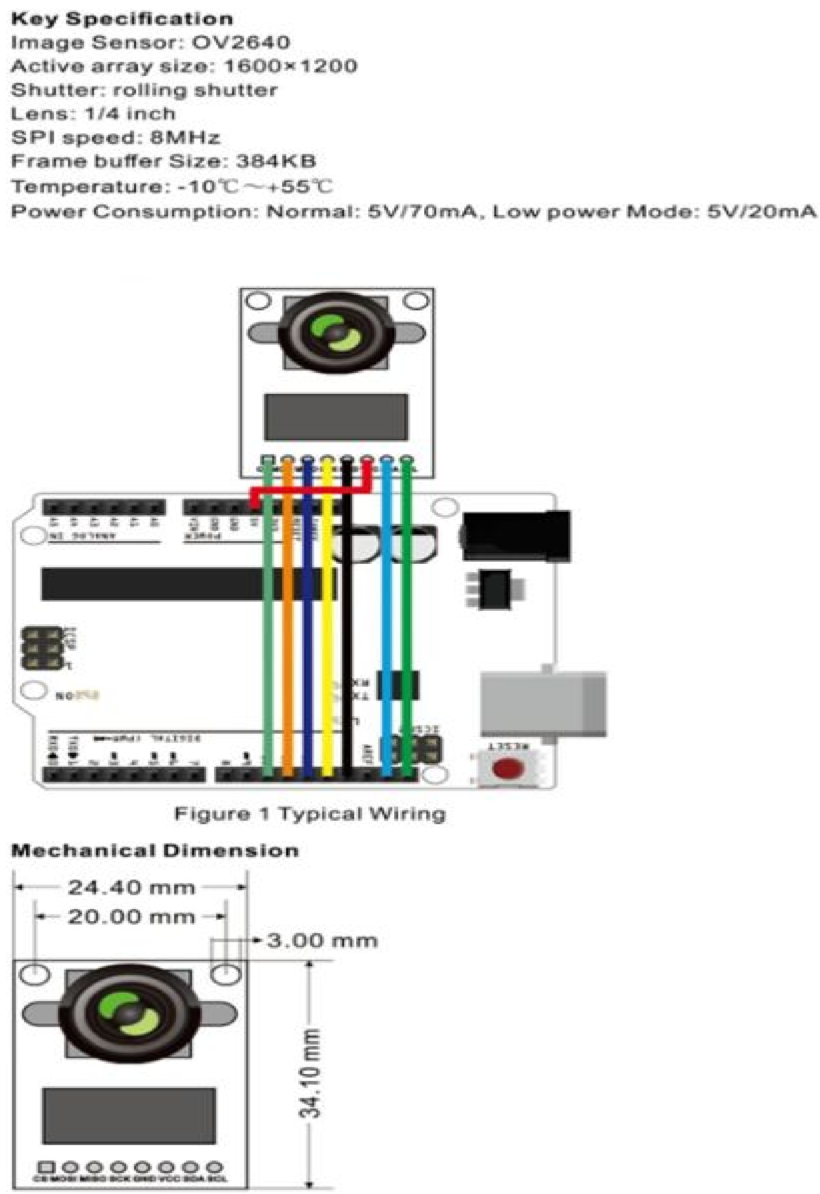

Figure 5: Arducam specification

<u>Software</u>

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.

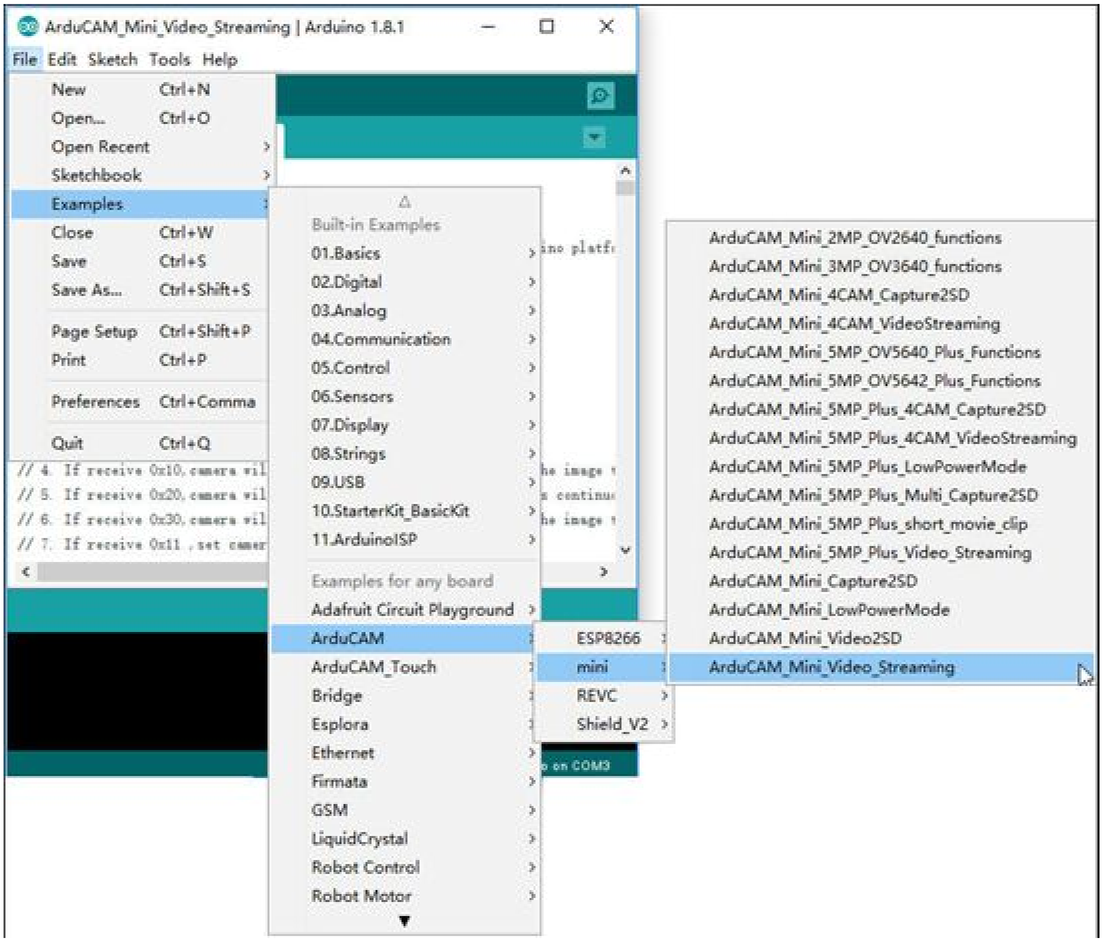

Figure 6: Software for Arducam

2.2 Design analysis

We design the chromatography plate by using the glacial angle deposition (GLAD) miniaturized layer fabrication. Then we analyze material and solvent. For the material, we choose the material by analyze its capillary action.

$$h = \frac{2\gamma \cos\theta}{\rho g r}$$

The equation for capillary action has shown above.

γ is the liquid-air surface tension(force/unit length) θ is the cont contact angle, ρ is the density of liquid (mass/volume), g is the local acceleration due to gravity (length/square of time), r is the radius of tube.

From what we know, on the surface of chromatography plate, there are plenty of the column structure to form the channel, and the capillary action occur on these channel. From the equation above, we figure out the relationship between the radius of tube(

channal) and the height *h* of the liquid column. Higher height means the stronger capillary action occur, lead to a quicker chromatography separation rate and the clearer boundary between the each components, So, we will choose the material by analyze its distance between each column structure.

And for the solvent, it include the mobile phase and stationary phase.The mobile phase flows through the stationary phase, and carries the components of mixture with it. And the different components travel through the chromatography plate in different rate and stop in different position.

Generally, the mixture components separated on the chromatography plate based on each component's affinity for the mobile phase and stationary phase. The component will move through the surface of chromatography plate faster than others due to the components are of different polarities and a mobile phase of a distinct polarity is passed through the chromatography plate. And for the stationary phase, different components carried by the stationary phase with varying degrees depending on each component polarity and its unique structural characteristics. That is the reason why components travel at different rates, separated in different color and stay in different position.

So, we will choose the solvent by analyze the polarity of the mobile phase and the stationary phase.

Instrumentation

Our design will be powered at 5V to 12V DC source or battery. It will wait to be turn on that will need couple seconds to reboot. A white LED will shine to allow the camera to take clear pictures.

Our system will be taking pictures every set amount of time and analyze it base on the color of pixel. Since we know what the chromatography paper should contain, the algorithm in our code that is checking for colors should detect if there is a change in the area of the paper corresponding to the retention factor (Rf value that we know).

If there is a sign of color in the area corresponding to the fentanyl Rf value, that will be an output from Arduino that the substance been tested contain the fentanyl drug.

For the overall shape of the system we are thinking about putting in the "L" shape plastic frame. All wiring will go in the bottom part and will have a flat surface what can hold the paper. The camera will be attached to the stand and can be adjust to look down or on the side to perform correctly.

3. Testing and Implementation

3.1 Interface Specifications

The project requires both hardware and software components. The arduino is a very useful hardware tool. In addition, we need a camera which will be integrated with the arduino. The software is matlab which will be used to transfer data from arduino to the computer.

3.2 Hardware and software

Instrumentation

We will test the circuit connections between the microcontroller and the camera module, the circuit connection between the lighting circuit, and the microcontroller. Our last testing will be if the whole system is doing what it is supposed to do. We will be testing with and without the chromatography paper to monitor the behavior of the system. In addition, we will also need to test with different compound that the fentanyl which mean we will have to recalibrate our system by changing the Retention factor (RF) in our code to see it with a little tweak it can detected other compounds as well.

3.3 Functional Testing

The designed device will be tested by dropping the fentanyl (liquid state) on the device. The device contains the pictures taken rates, the speed of separation. Position of the fentanyl on the thin film layer plate The main purpose of these tests are testing for the utilizing of the device.

3.4 Non functional testing

Finally, we will test the practicability and adaptability of the device. The process will be done by testing it on different computer and different places. Finally we will record the different users satisfaction of the device.

3.5 Process

We will following below steps to finish the whole process.

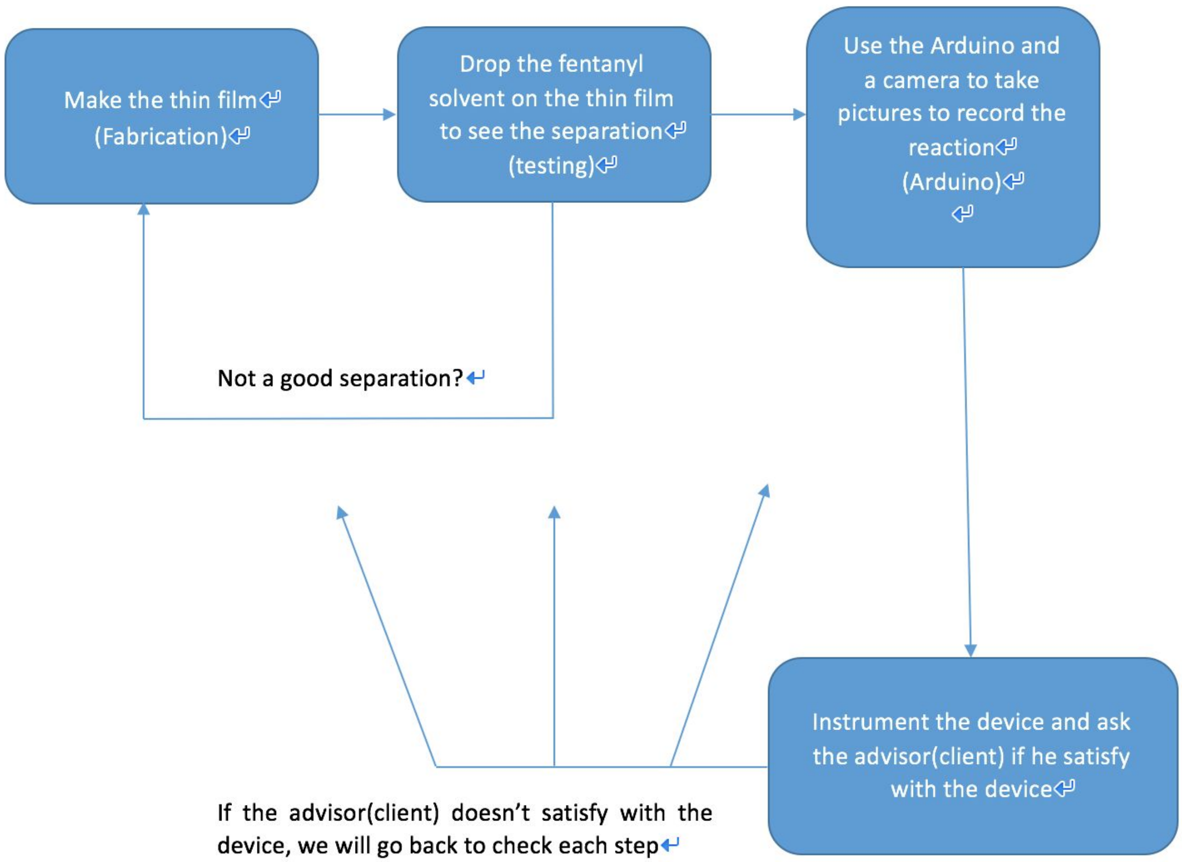

Figure 7: Whole design overview

3.4 Results

[For this section, we haven't finished working on the entire device yet but we got the result of the paper chromatography test which is the first step of our experiment. Also, we got the result of the ultra thin layer film but it's not so perfect. We can see them below.]

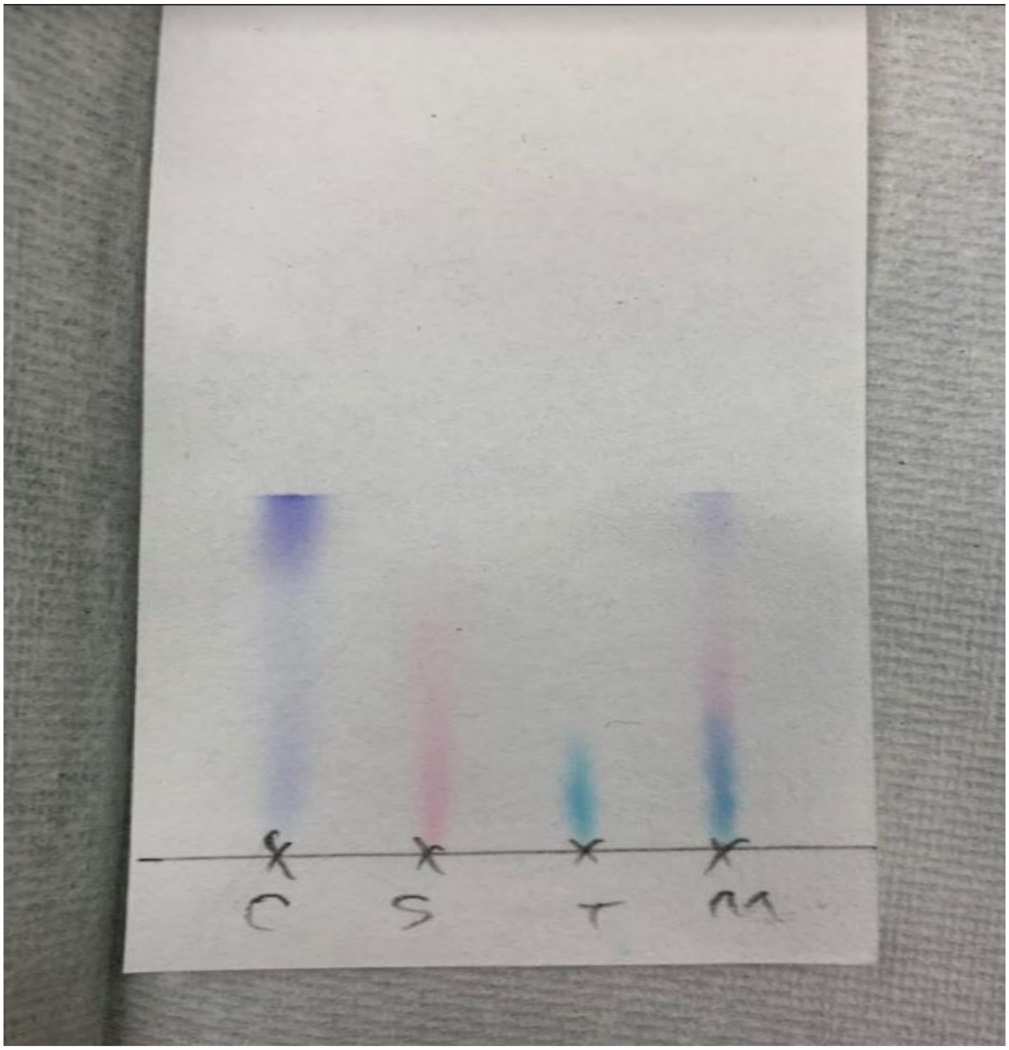

Figure 8: Paper chromatography test result

Figure 9: Ultra thin film chromatography test result

4. Closure materials

4.1 Conclusion

Conclusively, in order to make this design a reality, we would be working with our client, Meng Lu, along with some of his graduate students in the fabrication lab to achieve our goal. The project is split into different phases in order to make it more feasible. Our deliverable this semester is to be able to get good separation of any given mixture on the Ultra thin layer chromatography(UTLC) plate, which would be fabricated in the microelectronics research center. In February, we started out testing using paper as a stand in for the UTLC plate ,as we sought to understand the basic principles of chromatography. This month, we began fabricating silicon dioxide ultra thin layer plates to use to replace the paper in separation experiments. The silicon plates were not able to soak up the liquid hence we could not achieve separation. As a result, we recently tried Titanium dioxide plates and were able to get the fabricated titanium plates to soak up liquid and we are currently working on figuring out the right mixture of solvents to use to give the best separation of spotted mixtures on the titanium plates

4.2 References

Jim Clark. “Paper Chromatography.” *Paper Chromatography*, July 2016, www.chemguide.co.uk/analysis/chromatography/paper.html.

Libretexts. “Liquid Chromatography.” *Chemistry LibreTexts*, Libretexts, 23 Feb. 2019, chem.libretexts.org/Bookshelves/Analytical_Chemistry/Supplemental_Modules_(Analytical_Chemistry)/Instrumental_Analysis/Chromatography/Liquid_Chromatography.

ArduCAM. “ArduCAM/Arduino.” *GitHub*, 15 Mar. 2019, github.com/ArduCAM/Arduino.

Apffel, Brinkman, and Frei. "Micro Post-column Extraction System for Interfacing Reversed-phase Micro Liquid Chromatogrphy and Mass Spectrometry." *Journal of Chromatography A 312.C* (1984): 153-64. Web.

Burger, Wilhelm., and Mark J. Burge. Digital Image Processing An Algorithmic Introduction Using Java / by Wilhelm Burger, Mark J. Burge. 2nd Ed. 2016.. ed. 2016. Texts in Computer Science.book

Shen, and Maa. "A Camera and Image Processing System for Floc Size Distributions of Suspended Particles." *Marine Geology 376* (2016): 132-46. Web.