

# Rapid detection of Fentanyl using a multifunction nanostructured substrate

## Project Plan

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## List of 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 Introductory Material

## 1.1 Acknowledgement

**Team Client:**Meng Lu

**Team Advisor:** Meng Lu

The senior design team would like to appreciate Dr. Lu, for his funding and willingness to providing the team with the technological guidance and equipments necessary to successfully complete the project.

## 1.2 Problem Statement

Fentanyl is a potent, synthetic opioid analgesic - excellent for controlling serious pain, but also with huge abuse potential. It is 80 to 500 times stronger than morphine. From 2013 to 2016, nearly 10,000 Americans died as result by using overdose fentanyl. 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.

### **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 GIAD 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.

### **1.3 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 with placing it in the temperature condition, which might cause the detection of sensor become sensitive or slow, and lead to a inaccuracy 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.

#### **Limitations**

The fentanyl detector is designed for the detection of fentanyl but can be calibrated to detect some other chemicals. Theoretically, it can be used for the detection and separation for other kinds of chemical mixture. But our testing result will only be based on the data of fentanyl. Its accuracy measuring other chemicals will be limited.

### 1.6 Expected End Product and Deliverables

- a) The objective of the task is the detection of fentanyl using multifunction nanostructured substrate.
- b) To detect the fentanyl, we need to put it in a liquid form first, drop just a little of the liquid form on a chromatography paper, and develop a part of it in a solvent.
- c) After a couple of hours, we should see the liquid of fentanyl moving at a certain speed and stop at a certain point.

### 1.7 Project Description

Since fentanyl has become a serious problem throughout all over the U.S., our fentanyl detector fills the empty market. We find out that the Chicago airport is one of the largest airports in the U.S., so we decide to put fentanyl detectors there to see if they work well and we will improve them in the future by recording the data of our product.

## 2 Proposed Approach and Statement of Work

### 2.1 Objective of Task

We are required to design a device that can detect fentanyl. To successfully operate this project, a list of goals needs 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 shown below.

	Fabrication	Chromatography test	Instrumentation
February	Learn the principle of glancing angle deposition	Learn and play using the commercial kit	Buy the arduino and the camera, and document on them.
March	Fabricate the ultra thin plate	Test Chromatography on GLAD	Coding and using optical

	by electron beam in MRC		detection to analyze the feature of fentanyl
April	Test the ultra thin plate by UTLC	Test Chromatography of PC+GLAD	implement a system that analyze the Chromatography data

Table 1

## 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 lighting 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 needs 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 come up with some combination of UV light to make the compound deposition on the paper visible and at the same time make sure the camera luminosity is not affected by the UV light.

## 2.5 Proposed Design

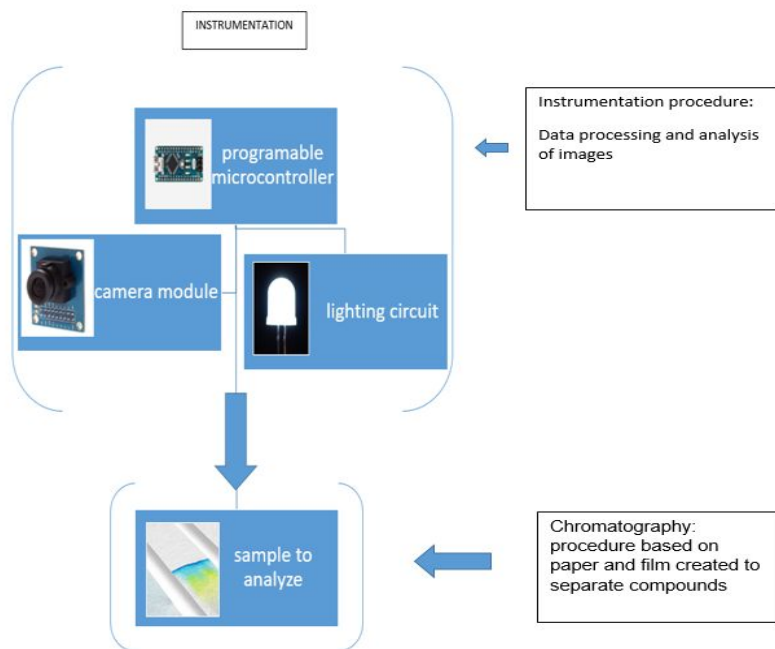
### **GLAD deposition**

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 developed 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 station 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 we assigned the chromatography test to our project is because the way already became a simple and useful way to separate the fentanyl compared to other ways.

### **Instrumentation**



Our design proposal is made of the a 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. Their is a diagram below showing an overview of the design.

## 2.6 Technology Consideration

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

## 2.7 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 when do the lab. Keep in mind avoid touching 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.

## **2.8 Task Approach**

### **Chromatography test**

First, we will use the purchased chemical kit to try out the paper chromatography test. Then test chromatography on GLAD using food dye. Finally test the PC and GLAD.

### **Instrumentation**

- a) We will do the circuit connections first. It will go as follows:  
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 is responding properly.
- d) we can now assemble our chunks of program to test the functions of the whole system.

## **2.9 Possible Risks And Risk Management**

### **Chromatography test.**

We have to carefully measure the distance and record the time during the lab. Different data may cause error when we analyze the result. On the other hand, we need to approve the tightness of the cover on the testing breaker so that the solvent wouldn't dry during the experiment.

### **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.

## **2.10 Project Tracking Procedures**

### **GLAD deposition**

Through group meetings, slack and weekly meetings to report team members.

### **Chromatography test**

Using the groupme, slack and meetings to keep everyone on the same track.

### **Instrumentation**

Project tracking consists of comparing the “project timeline” below 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.

## **2.11 Expected Results and Validation**

### **GLAD deposition**

We expect the layer height is round 10 micrometer, majority number column growth in expect angle, and less column extinct.

### **Chromatography test**

The expectation is to have good separation on the chromatography paper of the fentanyl mixture for each trial run

### **Instrumentation**

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.

## **2.12 Test Plan**

### **Chromatography test**

According to the timeline that our client assigned to us, we needs to be done with the simple paper chromatography test at end of February. We will test chromatography on GLAD at march and Test chromatography of PC and GLAD at April.

### **Instrumentation**

We will be test 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**

## **February**

- Step 1: Study theory of chromatography
- Step 2: Carry out simple chromatography experiment

## **March**

- Step 1: Test drug separation on chromatography paper
- Step 2: Fabrication of GLAD film
- Step 3: Fabrication of PC
- Step 4: Design read-out instrument and algorithm

## **April**

- Step 1: Test chromatography on GLAD film
- Step 2: Test chromatography on PC-GLAD

## **May**

- Step 1: Optimize experiments and GUI

### **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.

### **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

With the help of our advisor, we have ordered some test chromatography kits to begin testing regular dye samples and get some good practice with chromatography. We will also purchasing a camera that will be set up with an arduino to help monitor testing in the lab over long periods of time.

## 4 Closure Materials

### 4.1 Conclusions

Even though fentanyl is good for controlling pain, people also use it at recreational drug. Fentanyl is sometime mixed with heroin and cocaine without the knowledge of the user. The overdose of fentanyl is causing many death in the USA and across the world. Therefore, the need of detecting fentanyl in a mixture of chemical is needed. 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

The result we are supposed to have is the speed and the distance traveled by the liquid fentanyl on the chromatography paper.

### 4.2 References

Wikipedia contributors. (2019, February 21). Fentanyl. In *Wikipedia, The Free Encyclopedia*. Retrieved 01:56, February 22, 2019, from <https://en.wikipedia.org/w/index.php?title=Fentanyl&oldid=884394909>

Wannenmacher, J., Jim, S. R., Taschuk, M. T., Brett, M. J., & Morlock, G. E. (2013). Ultrathin-layer chromatography on SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, TiO<sub>2</sub>, and ZrO<sub>2</sub> nanostructured thin films. *Journal of Chromatography A*, 1318, 234-243.

“Chromatography.” *Wikipedia*, Wikimedia Foundation, 15 Feb. 2019, [en.wikipedia.org/wiki/Chromatography](https://en.wikipedia.org/wiki/Chromatography).

“Photonic Crystal.” *Wikipedia*, Wikimedia Foundation, 10 Jan. 2019, [en.wikipedia.org/wiki/Photonic\\_crystal](https://en.wikipedia.org/wiki/Photonic_crystal).

### 4.3 General Information from Wikipedia

According to wikipedia, fentanyl is an opioid used as a pain medication and anesthesia. It is often mixed with cocaine or heroin and numerous people use it illegally as a drug. As claim by wikipedia, there is many effects and serious side effect of fentanyl on human body. Some undesirable effects about fentanyl are vomiting, constipation, sedation, confusion, and hallucinations. Serious side effects of fentanyl are slow and ineffective breathing, serotonin syndrome, low blood pressure, addiction. 20,000 deaths was reported back in 2016 in the United State because of the overdose of fentanyl.

Chromatography is a technique used in laboratory to for separation of mixture. The mixture then get transform into fluid. A separation of the constituent of the mixture happened after they travelled at certain speeds. Note that all mixture in fluid form traveled at different speed on a chromatography paper.

Photonic crystal is a periodic nanostructure that impact the motion of photons. Photonic can be found as a natural form and is very useful in many application.

### 4.4 Appendices

The kit we are using for the project are from the supplier call Innovation Science.

## Electrochemical Cells

The tendency of oxidation-reduction reactions is to proceed to an equilibrium state. These reactions occurring in electrochemical cells provide another way for us to express the driving force in chemical reactions. When reagents that accept or donate electrons are arranged so that the electrons can enter or leave the reaction through a metallic conductor, an electrochemical cell is established. A half-cell contains a metal in contact with a solution of its salt. Each metal will develop a different electrical potential based on its electron configuration. The standard reduction potential listed in various references is the voltage that a half-cell develops when combined with a hydrogen half-cell. First, construct a simple chemical battery and determine from the standard reduction potentials what the output of the battery will be (if a voltmeter is available the actual and theoretical voltages can be compared). Second, construct an electrolysis cell and demonstrate how hydrogen and oxygen can be produced from the electrolysis of water.

Kit Includes:  
 2 x 500mL Cupric Sulfate, 0.5M Solution  
 25mL Bromothymol Blue, 0.04% Solution  
 8 x 500mL Sodium Sulfate, 1M Solution  
 Pkg. of 15 Copper Metal Strips  
 Pkg. of 15 Magnesium Metal Strips 5"UN1869  
 Pkg. of 15 Dialysis Tubing Strips 6"

DOT Info:  
 Small quantity exemption 173.4  
 THIS PACKAGE CONFORMS TO 49 CFR 173.4 for domestic highway or rail transport only

**WARNING:** This product can expose you to chemicals including Strong inorganic acid mists containing sulfuric acid, which are known to the State of California to cause cancer. For more information go to [www.P65Warnings.ca.gov](http://www.P65Warnings.ca.gov).



**IS8016**

**\$45.99**

## Thin Layer Chromatography

**Chromatography** is an analytical tool used to separate similar compounds. Thin-layer chromatography utilizes a sheet coated with silica gel. The samples are applied to the silica gel sheet and separated by migrating an appropriate solvent up the sheet. This type of separation is called adsorption chromatography because the separation of similar compounds is based on the selective adsorption of the compounds on the silica gel solid phase.

In this lab samples of various plant leaf materials may be extracted or the red and green leaf extracts included may be used. The samples of extracted leaf pigments are applied to a silica gel sheet and separated using a mixture of organic solvents.

Kit Includes:  
 2 x 10g Alfalfa Powder  
 2 x 25mL Red Extract  
 Pkg. of 15 Chromatography TLC Sheets  
 6 x 250mL Chromatographic Solvent  
 2 x 50mL Isopropyl Alcohol, 70%

DOT Info:  
 UN1230, Methanol, 3, PG II, Ltd Qty  
 UN1219, Isopropanol, 3, PG II, Ltd Qty  
 UPS HAZARD CHARGE APPLIES

**WARNING:** This product can expose you to chemicals including Methanol, which is known to the State of California to cause birth defects and reproductive harm. For more information go to [www.P65Warnings.ca.gov](http://www.P65Warnings.ca.gov).



**IS8017**

**\$79.95**

## Determination of the Molecular Mass of a Liquid

A volatile liquid is placed in a test tube and the tube is closed with a stopper with a hole in it. The test tube is placed in a hot water bath. The liquid vaporizes and excess vapors escape through the hole. The tube is then placed in an ice bath to quickly cool the vapor and cause it to condense. The mass of the tube is determined.

Kit Includes:  
 2 x 25mL Methyl Alcohol UN1230  
 2 x 25mL Isopropyl Alcohol UN1219

DOT Info:  
 Small quantity exemption 173.4  
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**WARNING:** This product can expose you to chemicals including Methanol, which is known to the State of California to cause birth defects and reproductive harm. For more information go to [www.P65Warnings.ca.gov](http://www.P65Warnings.ca.gov).



**IS8018**

**\$39.15**

## Thermochromism

The way in which light is absorbed or reflected by a crystalline material is determined by the structure of the crystal. This crystal structure can be changed by the application of heat. In some cases this change is reversible and the original structure, and therefore the original color, returns upon cooling. Two compounds are formed when metal salts are reacted with the  $[Hg_4]^{2+}$  ion. Each compound is heated on a hot plate and a change in color is noted. The initial color of the compound returns upon cooling.

Kit Includes:  
 3 x 25g Mercury (II) Chloride UN1624  
 3 x 25g Potassium Iodide  
 15g Silver Nitrate UN1493  
 2 x 25g Copper (II) Chloride, Anhydrous UN2802

DOT Info:  
 Small quantity exemption 173.4  
 THIS PACKAGE CONFORMS TO 49 CFR 173.4 for domestic highway or rail transport only



**WARNING:** This product can expose you to chemicals including Mercury/mercury compounds, which are known to the State of California to cause birth defects and reproductive harm. For more information go to [www.P65Warnings.ca.gov](http://www.P65Warnings.ca.gov).

**IS8019**

**\$89.95**



