Low Cost Solution for Air-Water Surface Pressure Sensor for Langmuir Trough

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ABSTRACT

The air-water surface pressure sensor plays a major role in monolayer deposition using Langmuir-Blodgett (LB) technique. The barrier mechanism and the deposition mechanism of LB through is controlled, by considering the air-water surface pressure, which creates by the surfactants pushed by the barriers of the LB through. Over pressuring and less pressuring on surfactants may totally destroy the film structure. So, the surface pressure sensor may the one who makes the film fabrication process a success by keeping the surface pressure at a suitable constant value. Unfortunately the cost of a surface pressure sensor is typically lager than $9000 at most manufactures. This research is focused on developing a low cost surface pressure sensor which can be used as an alternative for LB through. The sensing mechanism is based on the Electro Magnetic (EM) theory and Pulse width Modulation (PWM) which used with a commonly available PIC Microcontroller based control circuit.

KEYWORDS: Langmuir-Blodgett, Electro Magnetic Theory, Pulse width Modulation, PIC Microcontroller, Wilhelmy Plate, Pressure Sensor, Surface Pressure

INTRODUCTION

A monolayer can be considered as a two-dimensional film of material having a thickness of only one molecule. These films have very large surface area to volume ratios and are typically confined to within a single number of nanometers in the third dimension. Under these conditions, materials will often behave very different from bulk materials.

The types of molecules best suited to forming monolayers are those that prefer to sit at the interface between air and water. These molecules are called amphiphiles as they usually contain a hydrophilic part that resides within the water and a hydrophobic part that is repelled from the water. Any molecule that sits at the water surface may also be called a *surfactant*, from 'surface active agent'.

The idea of a Langmuir-Blodgett (LB) film was first proven feasible in 1917 when Dr. Irving Langmuir showed that single water-surface monolayers could be transferred to solid substrates. 18 years later, Dr. Katherine Blodgett made an important scientific advance when she discovered that several of these single monolayer films could be stacked on top of one another to make multilayer films. Since then, LB films (and subsequently the troughs to make them) have been used for a wide variety of scientific experimentation, ranging from 2D crystallization of proteins to Brewster angle microscopy. The LB troughs general objective is to study the properties of monolayers of amphiphilic molecules. An amphiphilic molecule is one that contains both a hydrophobic and hydrophilic domain (e.g. soaps and detergents). The LB trough allows investigators to prepare a monolayer of amphiphilic molecules on the surface of a liquid, and then compress or expand these molecules on the surface, thereby modifying the molecular density, or area per molecule. This is accomplished by placing a subphase (usually water) in a trough, spreading a given amphiphile over the surface, and then compressing the surface with barriers.

The monolayer's effect on the surface pressure of the liquid is measured through use of a Wilhelmy plate, electronic wire probes, or other types of detectors. An LB film can then be transferred to a solid

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substrate by dipping the substrate through the monolayer.

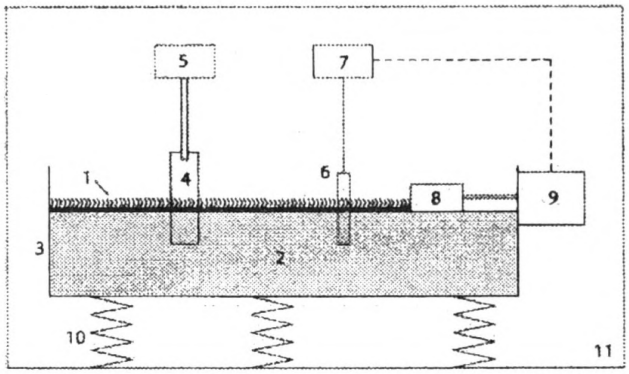

Figure 1: A schematic of a Langmuir Blodgett trough

1-Amphiphile monolayer, 2-Liquid subphase, 3-LB Trough, 4-Solid substrate, 5-Dipping mechanism, 6-Wilhelmy Plate, 7-Electrobalance, 8-Barrier, 9-Barrier Mechanism, 10-Vibration reduction system, 11-Clean room enclosure

An important property of the system is its surface pressure (the surface tension of the pure subphase minus the surface tension of the subphase with amphiphiles floating on surface) which varies with the molecular area. The surface pressure – molecular area isotherm is one of the important indicators of monolayer properties. Additionally, it is important to maintain constant surface pressure during deposition in order to obtain uniform LB films. Measurement of surface pressure can be done by means of a Wilhelmy plate or Langmuir balance.

The Wilhelmy method consists of a plate partially immersed in the liquid connected to an electronic linear-displacement sensor, or Electro-balance. The plate can be made of platinum or filter paper which has been presoaked in the liquid to maintain constant mass. The plate detects the downward force exerted by the liquid meniscus which wets the plate.

The sensor used to measure the surface pressure which uses Wilhelmy plate method is a very sensitive and expensive device which approximately cost $ 9,000 (Rs. 1,000,000 approx). The objective of this project is to introduce an alternative sensor which can use as a replacement of expensive commercial sensor that capable of fulfills our laboratory requirements.

The one of main objectives of this research is to minimize the cost by introducing alternative mechanism for surface pressure sensor using day to day components.

SENSOR DESIGN

The Air-Water Pressure Sensor Consist of following blocks as shown in the figure 2.

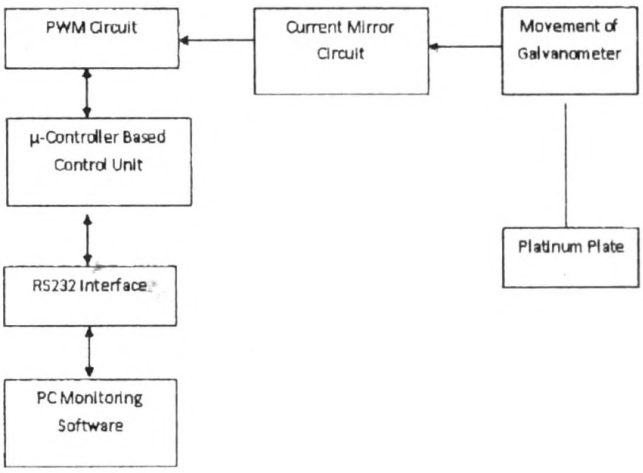

Figure 2: Block diagram of the Surface Pressure Sensor

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Platinum plate is used for measure the surface tension using Wilhelmy Plate Technique. As an alternative we may use thin glass plate to obtain the same results. The plate is connected to the movement of a galvanometer using a thin string.

Movement of a Galvanometer is based on the theory of Electro Magnetic Induction, is a very sensitive for typically smaller currents or voltages. That capability is used to measure smaller weights that act a force on the pointer of the movement due to gravity which can be easily calculated using Newton Mechanics. Also a Galvanometer movement is a very inexpensive and easily available component in the Market which is common in most analogue display units.

Current Mirror circuit is used to control the current flowing through the Galvanometer

Movement Coil. The mirror is consist of Current Limiting Resistor Parallel with Movement coil, two High Frequency NPN Bipolar Junction Transistors which glued face to face configuration, and a PN junction rectifier diode to control the self induced current effect to the Movement coil. Also we can use Transistor Array IC to achieve the requirements. The main advantage of this circuit is to control the current through the Coil and to Control the Temperature effects on the constant current flows through the coil.

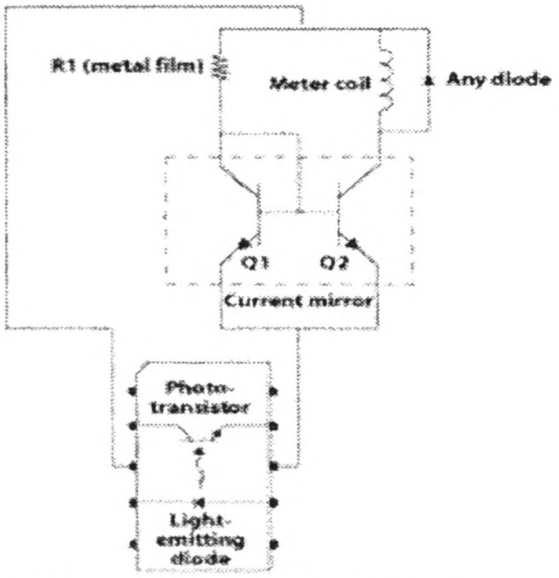

Figure 3: Current Mirror Circuit

PWM is an inbuilt function of a PIC microcontroller. Where PIC16F877A microcontroller used in this project have two built-in PWM modules. So we do not need any external circuit to control PWM signal. The current mirror circuit can directly interface with the PWM circuit of PIC microcontroller.

The control unit of the Sensor is consisting with PIC 16F877A Microcontroller with 8MHz clock rate. It also programmed with MikroC® C compiler on MikroC IDE v.8.1. The algorithms are used to control the current which passes through the D/A Converter to current Mirror circuit by running along with the pointer location feedback mechanism designed with photo transistor and a LED. Control unit also used RS232 Protocol to communicate with the PC Monitoring Software through the RS232 Interface circuit which is built as a part of LB System control Software.

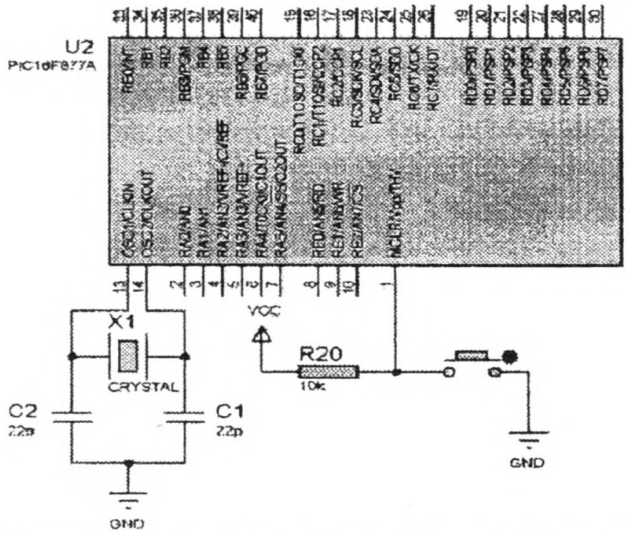

Figure 4: µ-Controller Based Control Circuit

RS232 Interface Circuit is used to link communication between PIC Microcontroller and PC Monitoring Software through RS232 Protocol suit. The circuit is based in common IC MAX232 from MAXIM®. It also buffer the voltage difference between PC Serial Port (COM Port) and PIC Microcontroller's RS232 Interface. The circuit is configured to use 9600 baud rate for safer communication.

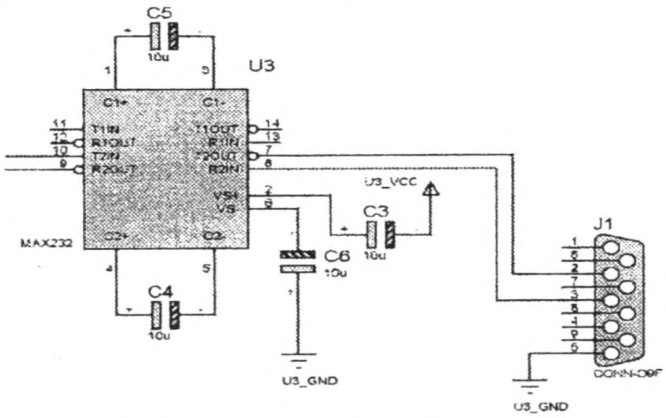

Figure 5: RS232 Interface Circuit

PC Monitoring Software is a part of LB Deposition system Control software which able to control the dipping and floater control mechanism speed for maintain the quality of the deposition of the monolayer.

DISCUSSION

While it is possible to design and build a Langmuir trough and components by hand, this generally requires significant machining abilities, access to raw materials and advanced programming skills. As an alternative, a large fraction of laboratories purchase them prebuilt from companies that specialize in such instruments. A few of the major companies are Nima Technology, Kibron Inc, and KSV instruments. Some of these companies, such as Nima Technology, focus mainly on making troughs for solid substrate deposition, offering several different models that allow for horizontal, vertical, and alternate layer dipping. Others like Kibron and KSV instruments provide "all in one" portable troughs that not only allow for substrate deposition, but also double as tensiometer and surface force measuring devices. These packages generally allow for high customizability by offering different software and hardware options such as bigger or more complicated troughs.

Main advantage among developing a custom sensor is that we can reduce huge cost for Industry made components and can use for measure surface pressure for any liquid surfaces by customizing or calibrating the custom sensor.

As the components and circuitry only used easily available economical apparatus. So on any failure of the sensor can be easily recovered by replacing the components necessary.

Also the mechanism and techniques are simple to understand and can be improved easily. The sensor sensitivity can be easily increase by expanding the frequency range, which only require few modifications on control circuit and the software.

The Main disadvantage of the sensor is that it's very difficult to calibrate with standard weighs because it require microbalance and have to use micro level weights which cause difficulties when handle in manually.

We can develop a high resolution sensor to measure the surface pressure which requires more resolution by increasing the resolution of PWM Circuit and changing the algorithm which used in the micro controller for smoother operation. Also we can develop a data logging facility using inbuilt EEPROM of the micro controller as this system is open for high customization.

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