DEVELOPMENT OF INNOVATIVE SELF-FABRICATE CONTACT ANGLE MEASUREMENT TOOLS FOR HYDROPHOBICITY ANALYSIS

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This report is submitted

In fulfilment of the requirement for the degree of

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Faculty of Mechanical Engineering

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DECLARATION

I hereby declare that this project report entitled "Development of Innovative Self-Fabricate Contact Angle Measurement Tools for Hydrophobicity Analysis" is the result of my work except as cited in the references.

Signature :

Name : MUHAMMAD SYAFIQ BIN ISKANDAR

Date :

APPROVAL

I have checked this project report that it is sufficient in term scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Hons) and can be submitted to JK-PSM.

Signature :

Name of Supervisor : PROF. DR. GHAZALI BIN OMAR

Date :

DEDICATION

I would like to dedicate to my parent, my fellow friends and my supervisor, Professor Dr Ghazali Bin Omar their full support encouragement and inspired during this project.

ABSTRACT

Hydrophobicity is the physical property of a surface that avoid water. Basically, carbon and hydrogen atoms are the only molecules in the hydrophobic surface. This surface cannot interact favourably with water and repel water that make a contact with the surface. This property of the surface can be measured or classified by referring to the contact angle of the droplet on the surface. Contact angle is the most important criteria to analyse the wettability of the surface. Small contact angle is smaller than 90º it show high wettability, whereas large contact angle which exceed 90º correspond to low wettability. Contact angle can be describe as the angle formed by meeting of liquid with solid surface. The shape of the liquid drop to be measured as contact angle is determined by surface tension of the liquid. The purpose of this project is to develop an innovative contact angle measurement tools for the hydrophobicity analysis with low cost of manufacturing proses but get the high accuracy of the result. Since the previous product on market has high cost to buy it and also used advanced technology and advanced software which make users complex to handle the equipment. Furthermore the product is quiet big and stationary and only can be used in the laboratory only which is cannot be move from a place to another place. After complete the product, a few series of testing was conduct to test the accuracy of the result and compared with the previous study with high technology method. Then the result will validate using Minitab software to conduct the test for One Sample T Test and Normality Test for both samples.

ABSTRAK

Hidrofobiciti ialah keadaan fizikal suatu permukaan yang mampu menjauhi atau kalis air. Asasnya, hanya atom karbon dan hydrogen yang terdapat pada permukaan hidrofobik. Permukaan ini tidak bertindak balas dengan air dan menolak molekul air yang berada pada permukaan. Ciri permukaan ini boleh dikenal pasti dan diukur melalui cara mengira sudut titisan cecair dengan permukaan. Sudut titisan cecair ialah kriteria yang penting dalam menganalisis kadar kelembapan suatu permukaan. Jika sudut titisan cecair ialah lebih kecil daripada 90 ˚ maka ia menunjukkan kadar kelembapan yang tinggi, manakala sudut titisan cecair yang melebihi 90 ˚ menunjukkan kadar kelembapan yang rendah. Sudut titisan cecair boleh diterangkan sebagai sudut yang terbentuk apa bila cecair bertemu dengan permukaan pepejal. Bentuk cecair yang dikira sebagai sudut titisan ditentukan oleh tekanan pada permukaan cecair. Tujuan utama projek ini ialah untuk menghasilkan alat untuk mengukur sudut titisan cecair untuk tujuan hidrofobik analisis dengan mengunakan bahan yang murah dan berpatutan tetapi boleh memberikan hasil yang tepat. Disebabkan oleh produk yang berada dipasaran sekarang mempunyai harga yang mahal dan juga mengunakan teknologi yang termaju yang mampu memberikan kesusahan kepada pengguna untuk mengendalikan alat tersebut tanpa selian daripada orang yang bertanggungjawab. Selain itu alat itu juga hanya boleh digunakan didalam makmal sahaja kerana saiz yang besar dan berat untuk dialihkan dari satu tempat ke suatu tempat. Selepas menyelesaikan produk ini, beberapa siri kajian telah dijalankan untuk melihat sejauh mana ketepatan dapatan kajian daripada alat yang dihasilkan dan dibandingkan dengan kajian yang dijalankan dengan mengunakan alat yang berteknologi tinggi. Selepas itu keputusan eksperimen di sahkan dengan menggunakan Minitab software untuk menjalankan Ujian Satu Sampel T dan Ujian Normal.

ACKNOWLEDGEMENT

Alhamdulillah, all praise and thankfulness to almighty Allah S.W.T, The Most Gracious and The Most Merciful, the final prophet Muhammad S.A.W and his relatives, all his companions and those who have followed finally I have completed this Final Year Project.

The deepest appreciation and gratitude to my supervisor, Professor Dr Ghazali Bin Omar for his valuable advice, guidance, understanding, support and constant encouragement throughout the course of my final year project.

Lastly, appreciation to my beloved family and fellow friend who always support me throughout the year. I also would thanked to Solehah Bt Jasmee, Master student in Structure and Material who gave advice and guidance for me to finish this report.

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LIST OF ABBEREVATIONS

LED	=	Light emitting diode
DIY	=	Do It Yourself
CATIA	=	Computer aided three-dimensional interactive application
PC	=	Personal Computer

CHAPTER 1

INTRODUCTION

1.1 Background

The contact angle is the angle which is conventionally measured through the fluid, where the liquid-vapour interphase meets a solid surface. It quantifies the wettability of a solid surface by a liquid via the Young equation. A given system of solid, liquid, and vapour at a given temperature and pressure has a unique equilibrium contact angle. However, in practice contact angle hysteresis is minimal contact angle. The equilibrium contact is within those values and can be calculated from them. The equilibrium contact angle reflects the relative strength of the liquid, solid and vapour molecular interaction.

The hydrophobic coating is the earlier stage of water repellent coating before achieve a superhydrophobic coating. (Bhushan & Jung, 2011) states that hydrophobic is usually used to define the contact of a solid surface with any liquid. The surface will have low energy and build of non-polar molecules. The properties of hydrophobic coating can be improved to become a superhydrophobic are by increasing the surface roughness and lower the surface energy. The contact angle of hydrophobic coating is greater than 90º and lower than 150º so that make this coating have a good wettability properties (Kubiak & Mathia, 2014)

Superhydrophobic coating is inspired by the unique structure of the Lotus leaf refers to self-cleaning mechanism. The lotus effect is occurred only due to low energy surface topography with hierarchical morphology. A hierarchical morphology allows the formation of air pocket that reduced the contact area between an applied water droplet and the surface

(Mahadik,et al 2013). A superhydrophobic surface are water repellent with large water static contact angle above 150º and low sliding angle lower 10º .The superhydrophobic provides the surface with various used in many application such as self-cleaning, anti-biofouling, anti-icing, drag-reducing, and corrosion resistance.

There are many strategies that have been develop for coating technologies to aluminium and glass material to prevent it's from harmful effect of water and moisture in the environment. Aluminium is widely used in many industrial fields as a basic material because it's good properties in excellent thermal and electrical conductivity but poor in corrosion resistance. So that the aluminium with hydrophobic coating can improved the corrosion performance for the material.

The properties of hydrophobic and superhydrophobic coating such as contact angle, surface morphology and its oxidation can be analysed on the substrates temperature of the thin film hydrophobic coating. The main criteria for hydrophobic coating to protect the coating from undergoes oxidation and resistance to the corrosive is high temperature resistance.

The ideas come out after a few testing done by manually drop by hand is quite tough and take a few time for the next drop let can be put. With the automatic tools we can run the test just by pressing the on off button and it is reduces time wasting. The measurement tools sure can be functional like the advanced technology tools but we just make it as portable and easy to used but the result will be same.

1.2 Problem Statement

Superhydrophobic and hydrophobic coating has the application of water proofing, self-cleaning, anti-corrosion and anti-icing. These hydrophobicity concepts have been applied in textiles, paints, electric devices, automotive industry and car glass. In order to check the hydrophobicity we need to measure the contact angle of the specimen. For liquid moving quickly on the surface, the contact angle can be altered from its value at rest.

Contact angle measurements are often used to estimate surface and liquid cleanliness and the effects of surface treatment developed as a part of fundamental research in surface science as well as for industrial applications. The advancing contact angle will increase with speed, and the receding contact angle decrease. In industry there are many method that have been develop but all of those method using expensive and high cost of testing tools. The product also stationary and complex to handle by the beginner. So we need to develop the measurement tools which is using the low cost but have high efficiency in order to measure the contact angle.

1.3 Objective

The objectives of this project are as follow;

i. To develop an innovative and portable contact angle measurement equipment tools for hydrophobicity analysis with low-cost manufacturing process and easy to handle.

ii. To verify and validate the measurement data accuracy of the contact angle using Minitab Software.

1.4 Scope

The scope of the study is the development in order to measure the contact angle with lower cost of equipment. The development on tools is made by low cost of material but the result is efficient for the measurement and also self-fabricate manufacturing process. The specimen is based on the type of surface which in different roughness which is lotus leaf and silica carbide.

1.5 General methodology

The working procedures that need to be done to achieve the objectives are listed below

1. Problem statement

The problem will be analysed and investigated to find the best solution in the project to get the better result and finding.

2. Literature review

Review the article, journal, finding on internet and older experiment to get the information about the project

3. Design product

The stage and box for the measuring equipment of contact angle will be design in a few type of design to get the good result.

4. Fabrication product

After get the design actual product will be fabricated and prepared for the experiment of testing.

5. Sample preparation

Each sample will be prepared in specific properties which is different type of surface.

6. Testing of sample

All the sample will be tested to get the image of the contact angle of the droplet

7. Analysis and result

After get the result will be analysed on the different type of surface and the contact angle measurement.

8. Suggestion and recommendation

Suggestion will be proposed based on the result and analysis

9. Report writing

A report writing on this study will be written at the end of the project.

The methodology of this project is summarized in the flow chart as shown in the figure below

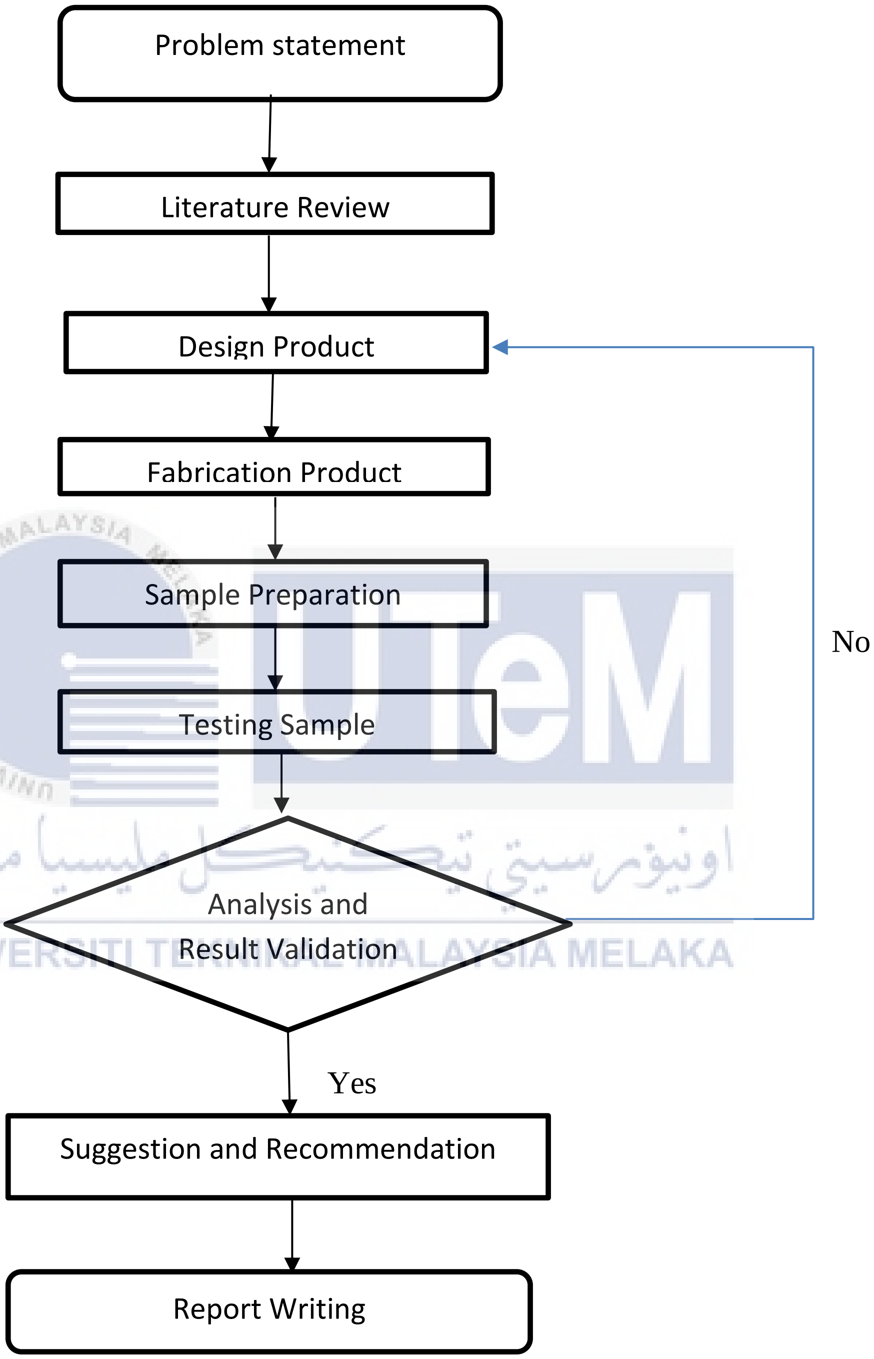


Figure 1.1: Flow chart of General Methodology

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter present the review cases study of the development tool in order to measure the contact angle. It includes the hydrophobicity properties which is super hydrophobic and hydrophobic and also contact angle properties.

2.2 Contact angle

Contact angle is the most important criteria to analyse the wettability of the surface. Small contact angle is smaller than 90º it show high wettability, whereas large contact angle which exceed 90º correspond to low wettability. Contact angle can be described as the angle formed by meeting of liquid with solid surface. The shape of the liquid drop to be measured as contact angle is determined by surface tension of the liquid.

In liquid state the net force is zero because each of the molecules in the bulk is pulled equally in every direction by neighbouring liquid molecules. The molecule that exposed at the surface does not have neighbouring molecules and creating an internal pressure. Therefore the liquid will contract its surface area to maintain the lowest surface free energy (Yuehua Yuan and T. Randall Lee, n.d.).

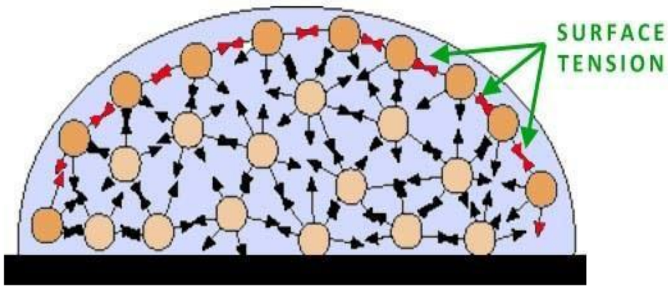


Figure 2.1: Surface Tension in water droplet

Based on the past study by Thomas Young(1804), he were proposed treating the contact angle of a liquid with a surface as the mechanical equilibrium of a drop resting on a plane solid surface under the restrains at three condition of surface tension. From the study it form "Young Equation", where the angle formed by the solid surface and the tangent of the drop is called as a "contact angle". Each combination of a solid and a liquid, there is an appropriate angle of contact between both surfaces that exposed to the air and to the solid

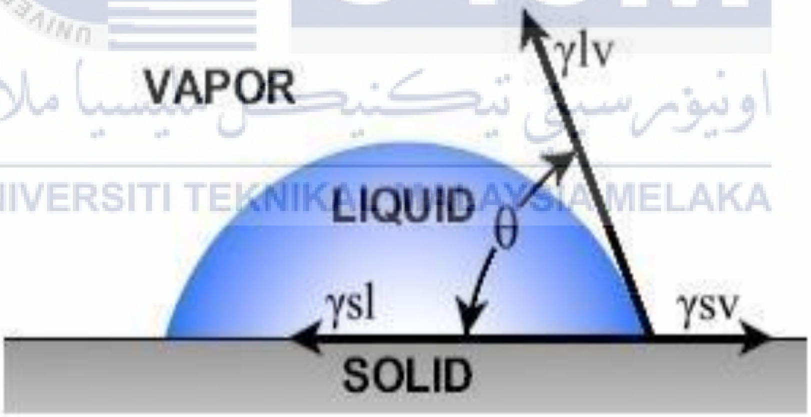


Figure 2.2: Contact angle according to Young Equation (Mittal and Robert, 2014)

$$\gamma SV = \gamma Sl + \gamma lV \cos\theta \qquad \text{Eq. (2.1)}$$

Where: γlV - Liquid-vapour, γSV - Solid-vapour, γSl - Solid-liquid, θ – Contact angle

Equation 2.1 is relates to the contact angle to the surface free energy of a system containing solid(S), liquid (L), and vapor (V) phases, it referred as Young's equation. (Lamour et al., 2010)

The contact angle hysteresis played an important role in the system is get when Young's equation applied to a specific liquid-solid system, three parameters, γSV,$\gamma Sl\ and$ γlV determine a single and unique contact angle θ. The phenomenon of wetting is more than just a static state. The liquid moves to expose its fresh surface and to wet the fresh surface of the solid in turn. The measurement of a single static contact angle to characterize wetting behaviour is no longer adequate. When in actual motion, the contact angle produced is called a "dynamic" contact angle (Young, 1804).

According to (Bhushan & Jung, 2011), Wenzel was formulating a simple model predicting that the contact angle of a liquid with a rough surface is different with smooth surface. Cassie and Baxter present that water vapor which is normally called as "air" in gaseous phase in the literature, may be trapped in the cavities of a rough surface. Therefore, it form solid-liquid-air interface, it opposed to the homogeneous solid-liquid interface. These two theories explain two condition wetting regimes or state: the homogeneous (Wenzel) and the composite (Cassie-Baxter) regimes.

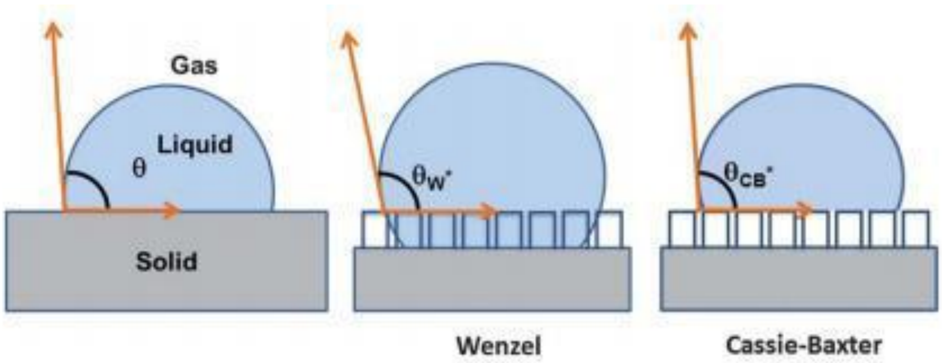


Figure 2.3: Water droplet in Wenzel state and Cassie-Baxter states (Nuraje,et al 2013)

This two equation are explained about contact angle of liquid with rough surface. The Wenzel Equation, Eq (2.2) states that the water droplet is in full contact with the surface and is amplified by a roughness parameter. Hydrophobic can be obtained when is larger than 90º, with Hysteresis, H and sliding angle, due to the increase in the solid-liquid interface. It show that the value of contact angle of a rough surface is depend on the value of the contact angle.

$$\cos\theta = r\cos\,\theta Y \qquad \text{Eq. (2.2)}$$

The Cassie-Baxter equation, Eq (2.3), indicate the water droplet is suspended on a composite interface made of solid and air trapped between the droplet and the surface. Hydrophobic can be assumed when H is low and is low due to the increase in the solid-vapor interface. It describe the superhydrophobic surface with contact angle is not dependent to the roughness where is the fraction in the contact liquid or solid. Wetting in the Cassie Baxter state is more suitable to be considered for achieving superhydrophobic rather than Wenzel state (Zheng & Lü, 2014)

$$\cos\theta = \varphi s(\cos\theta y + 1) - 1 \qquad \text{Eq. (2.3)}$$

2.3 Hydrophobicity properties

Hydrophobicity is the physical property of a surface that avoid water. Basically, carbon and hydrogen atoms are the only molecules in the hydrophobic surface. This surface cannot interact favourably with water and repel water that make a contact with the surface (Law, 2014)

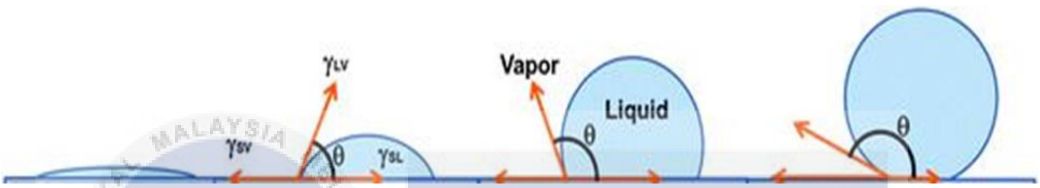
2.3.1 Definition

The term hydrophobic is from word “hydro-“means water and “-phobia” means fearing or hating in Greek. It refer to fearing condition and used to define the contact of solid surface with any liquid (Bhushan & Jung, 2011). Hydrophobicity is a tendency of water molecules to minimize their contact with hydrophobic molecules. In other word is a nonpolar substance that does not combine with water molecules. Hydrophobic molecules tend to be nonpolar and, thus, prefer other neutral molecules and nonpolar solvents. Hydrophobes do not dissolve well in the water molecules are polar. Hydrophobic molecules in water often to group up together, forming micelles and show a high contact angle.

Superhydrophobic is described by materials that having surfaces that are very difficult to wet, and the surface with contact angle between 150º to 180º. Figure 2.4 show the differences between super hydrophilic, hydrophilic, hydrophobic and superhydrophobic. It exhibit very low water contact angle, smaller than 10º. This causes the water droplet rolling and bouncing from the surfaces. It also will remove contaminants on the surface due to self-cleaning properties of superhydrophobic coating. Water drop are able to capture the dust and dirt particle, while moving on the surface, and can easily remove particle contaminants from the solid surface (Bernagozzi, Antonini, Fabio, & Marengo, 2014).

Superhydrophobic coating is a coating that exhibits the extremely high water repellence. The degree to which a solid repels a liquid depends on two factors which is surface energy and surface morphology. Once the surface energy is lowered, hydrophobicity is enhanced. In superhydrophobic coating, the surface morphology plays an important role in wettability.

The main parameter to characterize the wetting is the contact angle. There are several factors that can influence the contact angle such as surface energy, surface roughness and its cleanliness. Roughening a coating not only enhances its hydrophobicity due to the increase in that solid-liquid interface but also when air is trapped on a rough surface between the surface and the liquid and the droplet (Mohamed, Abdullah, & Younan, 2015).



(a) (b) (c) (d)

Figure 2.4: Contact angle to determine hydrophobicity (Nuraje et al., 2013)

Where: (a) Super hydrophilic that have contact angle below 5°, (b) Hydrophilic that have angle < 90°, (c) Hydrophobic that consist of angle = 90°-150°, and (d) Superhydrophobic which is angle = 150°-180° .

There are many methods that have been develops to formulate a superhydrophobic coating such as electrospinning technique, layer-by-layer, spray coating, sol-gel method and electrochemical deposition. All of the following method is conducted by constructing hierarchical nano/ microscale binary structure or modifying a rough surface with low surface free energy materials. (Tang et al., 2014).

Many application of superhydrophobic in daily life such as self-cleaning windows, textiles, medical devices and electric devices. Typical application of hydrophobic coating are condenser, filtration part and food processing parts.

2.3.2 Hydrophobicity phenomena in nature

There are many phenomena that always observed in nature but the most popular is the great water repellence by *Nelumbo nucifera* (Lotus plant). But there are other plant that have the same type of the water repellence properties such as *Pistia stratiotes* (water cabbage), and *Colocasia esculenta* (wild taro) that shown in Figure 2.5.

(a) Lotus leave **(b) Water cabbage** **(c) Wild taro**

Figure 2.5: Example of plants (a) Lotus leave (Mohamed et al., 2015), (b) Water cabbage, (c) Wild Taro

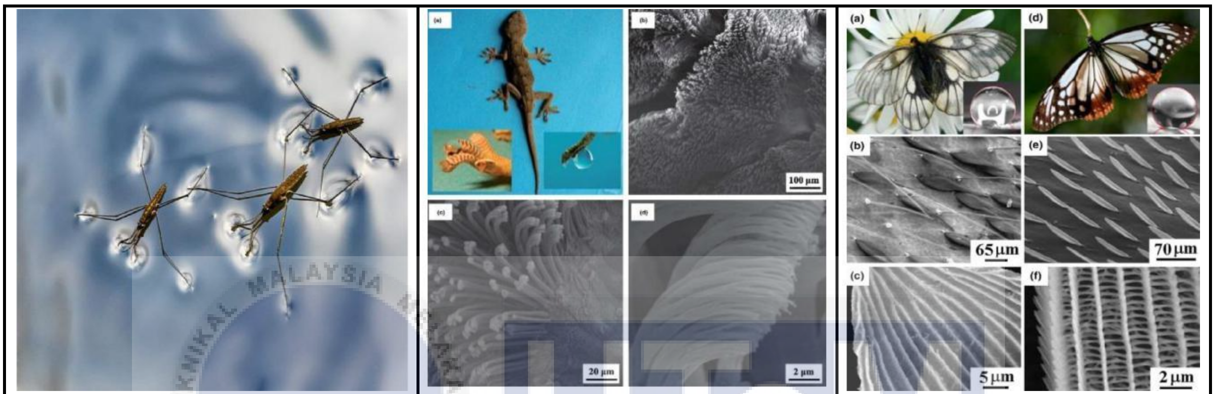
Lotus leaves have become a famous example for Superhydrophobicity and self-cleaning surfaces, and have led to the concept of the ‘Lotus effect’. Even many other plants have superhydrophobic surfaces with almost similar contact angles; the lotus shows greater stability and perfection of its water repellence according to (Mohamed et al., 2015). This type of surface make the lotus easy to repel water and gave some advantage because it only can be found at the pond of river only.

The high surface tension of water made the droplets to assume a closely spherical shape, since a sphere has lower surface area, and along these lines requests slightest strong fluid surface vitality. Adhesion forces are the result in wetting when contact with the surface. Whichever finish alternately inadequate wetting might happen relying upon the structure of the surface and the liquid pressure of the droplet. The cause of self-cleaning properties is the hydrophobic water-repellent double structure of the contact surface. This graded double structure is made out of a characteristic epidermis (its outermost layer called the cuticle) and the wrapping waxes. The epidermis of the lotus plant possesses papillae with 10 µm to 20 µm in height and 10 µm to 15 µm in width on which the so-called epicuticular waxes are imposed. The second layer of the double structure forms because these superimposed waxes are hydrophobic. This bio-chemical property may be answerable for the working of the water repellence of the surface (Hans J Ensikat, 2011).

Besides, there are some creature that also evolved with superhydrophobic property such as water strider. The Gerridae are a family of insects in the order Hemiptera, usually known as water striders, water bugs, pond skaters, water skippers, or jesus bugs. By having the unique ability to walk on water, the gerrids consistent with the classification as true bugs suborder Heteroptera, have mouthparts evolved for piercing and sucking, and distinguish themselves. Gerridae, or water striders, are anatomically manufactured should shift their weight will have the capacity with run on highest priority on the water's surface. For sure, one could find water striders in any pond, river, or lake as demonstrated on Figure 2.6 (a) (Guittard, 2015).

The legs of water strider are responsible for their water resistance due to the layer of minute hairs that coated on the leg. The resulting large contact angle that will allows surface tension to support the animal walk on water surface. Thierry and Frederic (2015) states that many insect are superhydrophobic such as gecko which has solid-solid adhesion that makes them able to climb on vertical surface. It sue to the well-aligned microscopic hair, called setae on their feet as shown in Figure 2.6 (b).

The group of Goldwyn studied the structures of different butterflies having hydrophobic or superhydrophobic properties and different colours. While the scales of the transparent butterfly wings of the genus *Parnassius glacialis* (Papilionidae) show no clear pattern, the white translucent regions of *Parantica sita* (Nymphalidae) were highly ordered and organized in lines forming periodic and parallel porous microstructures. Also demonstrated that the colour of twelve butterflies (lepidopteran species) is due to appropriate nanostructures in their scales producing visible colours, such as blue, green, or violet. Moreover, at the microscale, the scales of butterflies, such as *Morpho aega*, overlap in only one direction. (Guittard, 2015



(a) Water strider **(b) Gecko** **(c) Butterfly**

Figure 2.6: Examples animal with superhydrophobic properties (a) Water strider, (b) Gecko, (c) Butterfly. (Guittard, 2015)

As the references in developing the measuring tools for contact angle, the standard that been referred is *ASTM D5725-99-Standard Test Method for Surface Wettability and Absorbency of Sheeted Materials Using an Automated Contact Angle Tester* (ASTM), 2011), *ASTM D7940-13-Standard Test Method for Measurement of the Surface Tension of Solid Coatings, Substrates and Pigments using Contact Angle Measurements* (ASTM, 2013) and *ASTM D7334 − 08 (Reapproved 2013) Standard Practice for Surface Wettability of Coatings, Substrates and Pigments by Advancing Contact Angle Measurement*. The studies was conducted on the three standards to make sure all the properties is following the international standard.

2.4 Measurement tools of contact angle

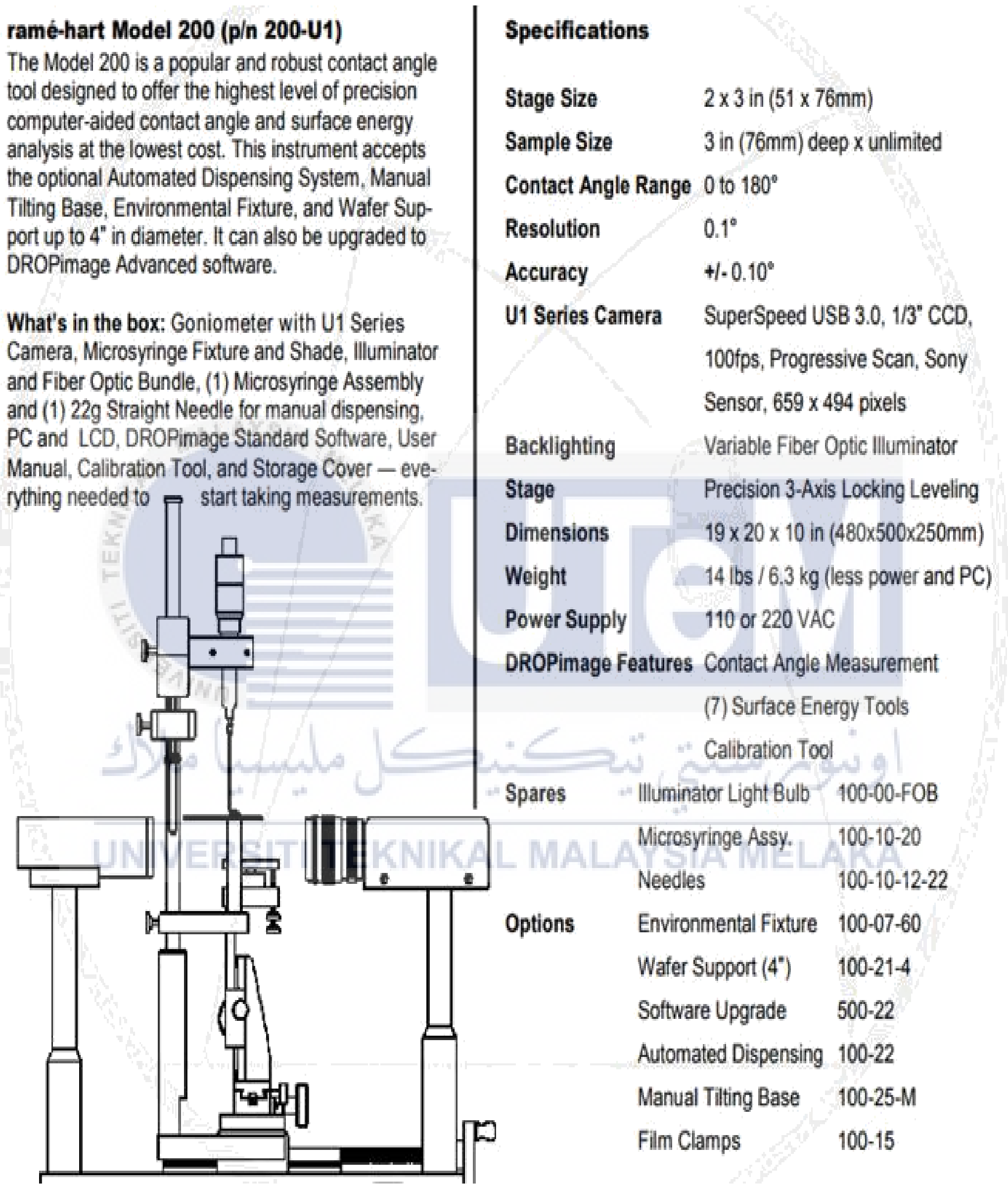
For the many research that have done, they used variety of measurement tools that can get at the market nowadays. All of the equipment was completely appropriate and suitable to measure the contact angle. Those samples of measurement tools were describe below.

2.4.1 Ramé – hart Model 200: Standard Contact Angle Goniometer with DROP image Standard

Figure 2.7: Ramé – hart Model 200

The first commercial contact angle goniometer was design by W.A Zisman that was manufactured at Ramé-hart instrument company in early 1960s. Ramé-hart has been the pioneer and premier manufacturer of contact angle goniometers and tensiometers for over 45 years. Ramé-hart Instrument Company is the largest company in the world dedicated solely to the production, sales, and support of contact angle and surface tension tools. In excess of four and large portion decades, a many Contact Angle Goniometers numerously would at present being used today that might have been fabricated by Ramé-hart shares of the organization.

Then Phillips and Riddiford as well McIntyre have analysed sessile drop profile photograph with a tools called tangentometer that comprise on mirror mounted toward those benchmark of the drop.(Yuehua Yuan and T. Randall Lee, n.d.)



ramé-hart Model 200 (p/n 200-U1)
The Model 200 is a popular and robust contact angle tool designed to offer the highest level of precision computer-aided contact angle and surface energy analysis at the lowest cost. This instrument accepts the optional Automated Dispensing System, Manual Tilting Base, Environmental Fixture, and Wafer Support up to 4" in diameter. It can also be upgraded to DROPimage Advanced software.

What's in the box: Goniometer with U1 Series Camera, Microsyringe Fixture and Shade, Illuminator and Fiber Optic Bundle, (1) Microsyringe Assembly and (1) 22g Straight Needle for manual dispensing, PC and LCD, DROPimage Standard Software, User Manual, Calibration Tool, and Storage Cover — everything needed to start taking measurements.

Specifications

Stage Size	2 x 3 in (51 x 76mm)	
Sample Size	3 in (76mm) deep x unlimited	
Contact Angle Range	0 to 180°	
Resolution	0.1°	
Accuracy	+/- 0.10°	
U1 Series Camera	SuperSpeed USB 3.0, 1/3" CCD, 100fps, Progressive Scan, Sony Sensor, 659 x 494 pixels	
Backlighting	Variable Fiber Optic Illuminator	
Stage	Precision 3-Axis Locking Leveling	
Dimensions	19 x 20 x 10 in (480x500x250mm)	
Weight	14 lbs / 6.3 kg (less power and PC)	
Power Supply	110 or 220 VAC	
DROPimage Features	Contact Angle Measurement	
	(7) Surface Energy Tools	
	Calibration Tool	
Spares	Illuminator Light Bulb	100-00-FOB
	Microsyringe Assy.	100-10-20
	Needles	100-10-12-22
Options	Environmental Fixture	100-07-60
	Wafer Support (4")	100-21-4
	Software Upgrade	500-22
	Automated Dispensing	100-22
	Manual Tilting Base	100-25-M
	Film Clamps	100-15

Figure 2.8: Description on Ramé-hart model 200

2.4.2 Drop Shape Analyzer – DSA100

Figure 2.9: Drop Shape Analyzer – DSA100

Drop Shape Analyzer – DSA100 is our high-quality framework result for just about all assignments in the dissection from claiming wetting and bond with respect to solid surfaces. Starting with the fundamental unit to exact estimation of the contact point of the fully programmed master instrument flying for serial estimation for surface free energy (SFE) they need the suitableness DSA100 for special requirements. It precisely match those individual, adaptable also dependable segments of the surfaces and forms. Even though the specification is the best for the measuring contact angle, the market price is at $8,000.00 USD.

Measuring methods and options

1.) Contact angle between a liquid and a solid

2.) Surface free energy from contact angles of several test liquids using all common models

3.) Static contact angle, advancing angle and receding angle

4.) Roll-off angle on hydrophobic and superhydrophobic surfaces

5.) Measurement of surface tension and liquid-liquid interfacial tension using the Pendant Drop method

6.) Temperature-controlled measurements from -30 to 400°C

7.) Measurements at controlled humidity

2.4.3 SI-CAM2000D contact angle measuring instrument

Figure 2.10: SI-CAM2000D contact angle measuring instrument

SI-CAM2000D contact angle measuring instrument for measuring the contact angle of a liquid on a solid, that is a liquid wet ability on solid, can also measure the contact angle of the liquid external phase. Contact angle measuring instrument is a commonly used instrument in universities, research institutes and manufacturing enterprises. Based on user test conditions, objects, corresponding to the requirements of different model range, difficult for users to choose.

The instrument can measure a variety of liquid contact angle of various materials, such as bulk materials, fibre materials, textile materials; powder samples after making into the tablet can also be measured. At the same time this series of instruments can measure and calculate the surface / interfacial tension, CMC, the shape of the droplet size, surface free energy. The instrument cost is about US $6,704-8,380 in the market price.

Description on SI-CAM2000D

Standard components

1, USB digital CCD camera	1 pcs
2, continuous variable power optical system	1 unit
3, manually controlled knob injection system	1unit
4, manual CCD tilt platform	1 pcs
5, image analysis measurement system software	1 set
6, Instructions and Operation Manual electronic edition	1 set
7.50 l micro-injector	1pcs
8,100 l micro-injector	1 pcs
9, disposable injector	

1. Parameters	**2. Sample stage control**
1, the contact angle measuring range: 0 to 180 degrees 2, the contact angle measurement Resolution: 0.01 degrees 3, the surface tension measurement ranges (the hanging drop method): 0 ~ 2000mN / m (mN / m)	a) Move back and forth manually, stroke 50mm, 0.1mm accuracy b) Move around manually, stroke 50mm, 0.1mm accuracy c) Moving up and down manually, stroke 25mm, 0.1mm accuracy d) Levelling feet to adjust the horizontal platform level e) Sample table size 70mm × 100mm, without temperature control system

3,The injector control a) Manually moving the upper and lower part: the rack stroke 25mm, 0.1mm accuracy b) Manual knob controlled injection system	**4, CCD optical system** a) Optical zoom 0.7-4.5 × continuous zoom (zoom only parameters, as well as built-in amplification rear mirror) magnification: 50-318piexl / mm b) Speed CCD line parameters USB2.0 standard industrial CCD25 700 frames / sec (optional higher-speed CCD)
5, Backlight control a) Tuneable monochromatic light source LED cold light source b) The front and rear lens adjustment manual stroke 10mm, 0.1mm accuracy c) Up and down to adjust the lens manually, stroke 10mm, 0.1mm accuracy d) A plan to adjust the lens manually tilt platform	6, The software part a) half-angle protractor measurement method, half-width hypsometry, automatic measurements, five-point fitting b) Dynamic measurement automatically Trigger video .Video Speed: 25 frames / sec. c) Storing interval 1-3600 seconds optional d) Dynamic contact angle advancing angle and receding angle, for measuring the roll angle should be optional 360-degree rotating platform e) Comparing the left and right angle calculated and averaged around corner f) The amount of the droplet control software control, accuracy of 0.1 microliters (with optional automatic precision injection device) g) The surface free energy Owens two-liquid method (otherwise optional) h) curved convex surface correction

Diagram	Brand	Model	Measuring method	Price
	Rame hart	200	Automated Dispensing System and Manual Tilting Base	Not mention
	Drop Shape Analyzer	DSA100	WH method, Tangent , method, Circle fitting	$8,000.00 USD
	SI-CAM	200D	circle fitting , ellipse fitting , curve ruler (tangent fitting), Spline curve-fitting	US $6,704-8,380

Figure 2.11: Comparison between the products

All of those three sample equipment tools in the market is definitely good and accurate in measuring the contact angle, but the problem is the price is higher at least 6000 USD – 8000USD for one set. Then the idea of developing own measurement tools for contact angle is decides because the mechanism of the measurement is the same ways. As the result is acceptable then the method is approved to measure the contact angle

CHAPTER 3

METHODOLOGY

3.1 Overview

This chapter explain the methodology used in the project to achieve the objective. The idea is start by designing the test rig with the suitable dimension. The step of design and process of the preparation of rig including the fabrication of the product. After the rig was ready the sample preparation for testing was prepared for the experiment. The testing was conduct on the sample to investigate the contact angle of the droplet on the different sample. The preliminary result was then was analysed to get the contact angle of the droplet will present to show the expected result for the experiment.

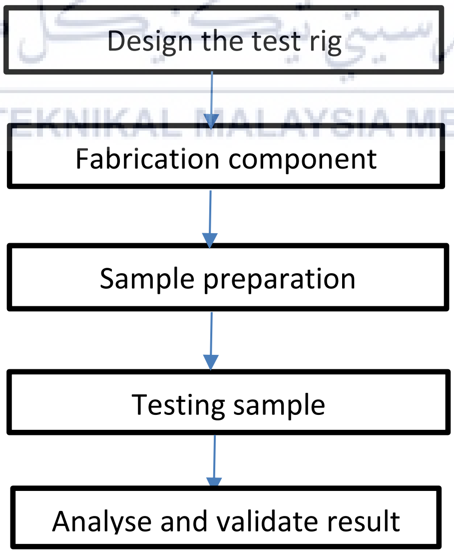


Figure 3.1: Flow diagram of methodology

3.2 Design and Fabrication of Test Rig

The design of the test rig was done using sketching and CATIA program in order to get the measurement. The dimension of the base is 68cm x 50cm x 4.5cm ($l \times w \times t$) using a plywood as a raw material. The base need to be larger space because need to place the liquid dispenser, digital microscope, stage cube and the entire component for the product. The component that needed in the measurement tools of contact angle is shown in Figure 3.3 below.

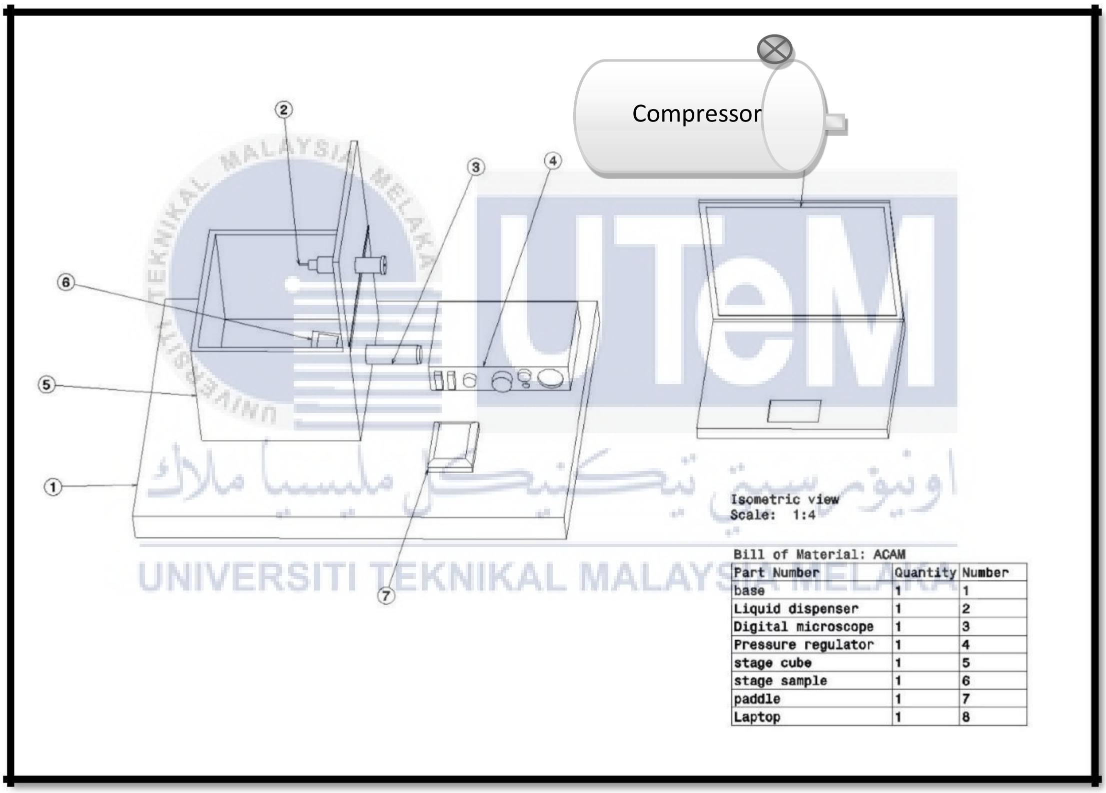


Figure 3.2: Schematic diagram for measurement tools

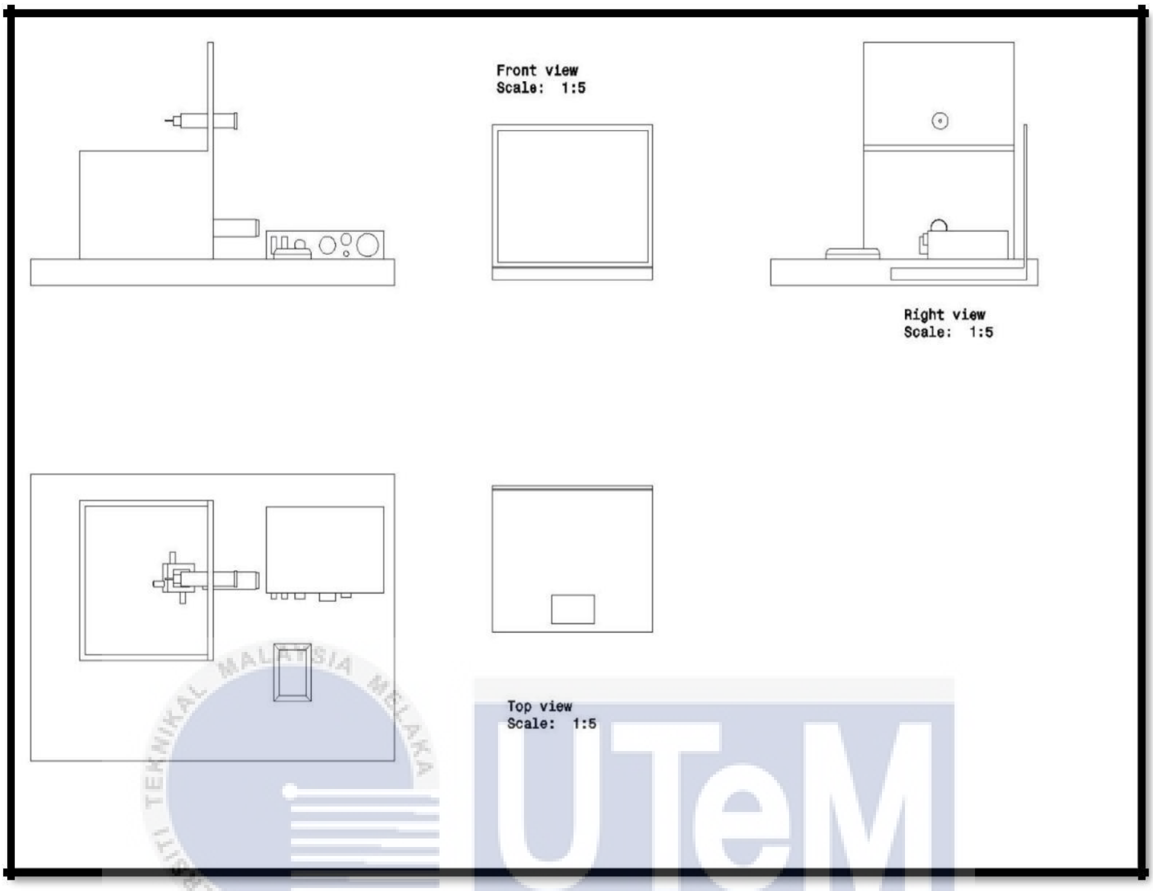


Figure 3.3: View from different angle

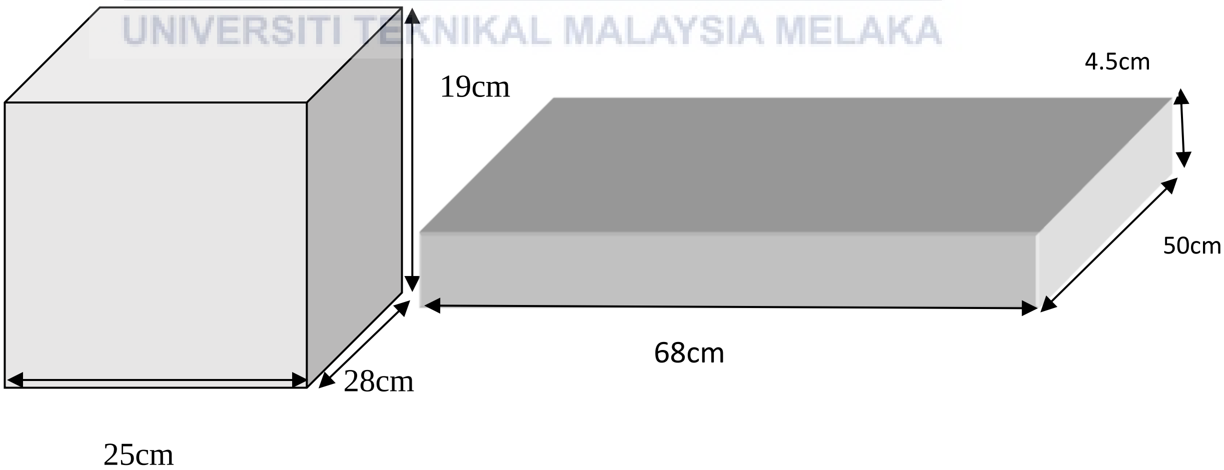


Figure 3.4: Dimension of stage cube and base

3.2.1 List of Components

Name	Picture	Descriptions
1. Sample Stage		• The stage have three moveable axis which is x, y and z axis that can be adjustable in order to move the specimen to the right spot before the contact angle image was captured.
2. Compressor		• The air pressure is produced from the compressor to move up the droplet in the syringe.
3. Pressure Regulator		• The air pressure from the compressor is control by regulator to get the accurate pressure for the droplet to fall on the stage.
4. LED		• LED give the lighting for the capturing image of contact angle

5. Digital Microscope		• The image of the contact angle was captured with the microscope which have high accuracy and zoom in magnification that can focus on the sample
6. Liquid Dispenser		• The distilled water is place in the syringe before falling on the sample specimen on the stage by the press button of the paddle.

Figure 3.5: List of component uses in test rig

There was a few step to maintenance the pressure regulator.

1. Make sure certain air supply is clean and dry

2. Make sure certain AC outlet is grounded and proper voltage rating

3. Avoid turning barrels upside down or laying barrel so that material may run through airline to internal component

4. Do not left the pressure regulator exposed to excessive moisture or solvent situation.

3.2.2 Fabrication

Fabrication process in which the entire component was assembling to build the measurement tools to test the functionality of the product. As the base for the product, the plywood with 68cm x 50cm x 4.5cm (l ×w ×t). The process of following step was include in the report.

3.2.2.1 Material description

The material used to design and fabrication of test rig in this project were plywood, screw, glue, aluminium and regulator. The material that had chosen is suitable for the test rig according to the purposed of objectives which to develop the measuring tools for contact angle for teaching and learning purpose. The test rig was made up DIY to save cost and can be design by own idea if there was a correction in the fabrication process. Furthermore this tool can be commercialized because it can be used for industry to measure the contact angle before making some part of the product.

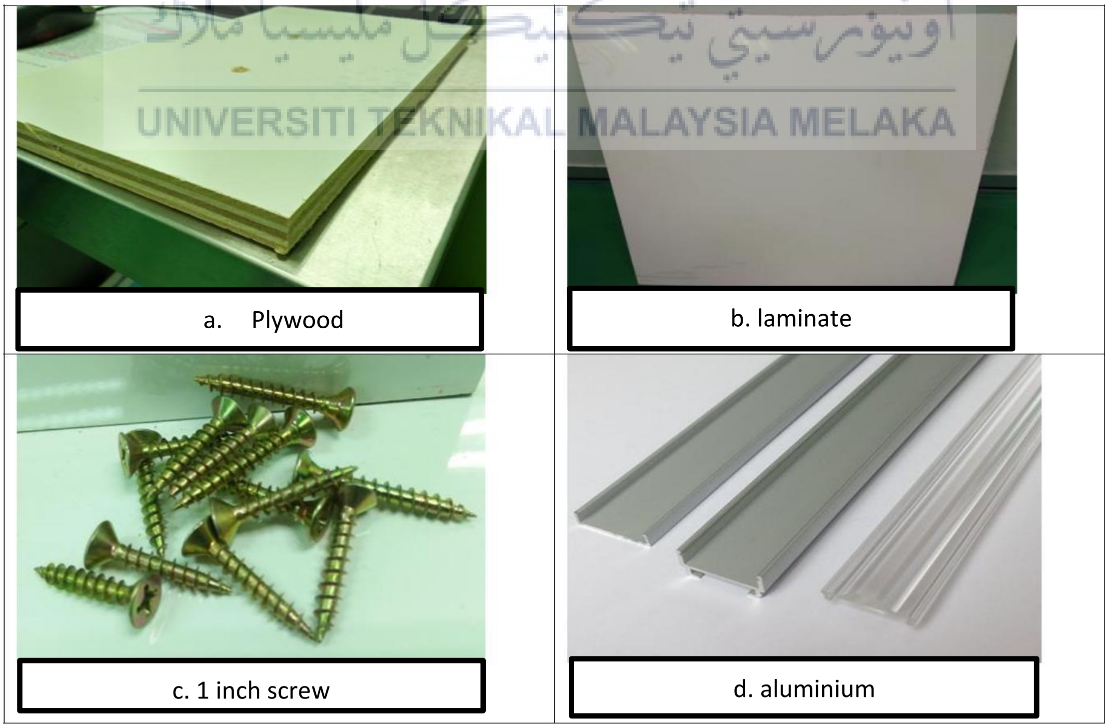


Figure 3.6: List of materials

3.2.2.2 Development Process

Figure 3.7: Cutting and Grinding

1. Cutting, grinding and combine the plywood to make a cube as the room for the sample stage. Then the surface of the plywood was grinded using a grinder to smooth the surface.

Figure 3.8: Making a hole for LED

2. The hole for LED size was made by using a jigsaw to make sure the size accurate and can place the LED well. Then after the hole is made the sand paper to clean up the surface.

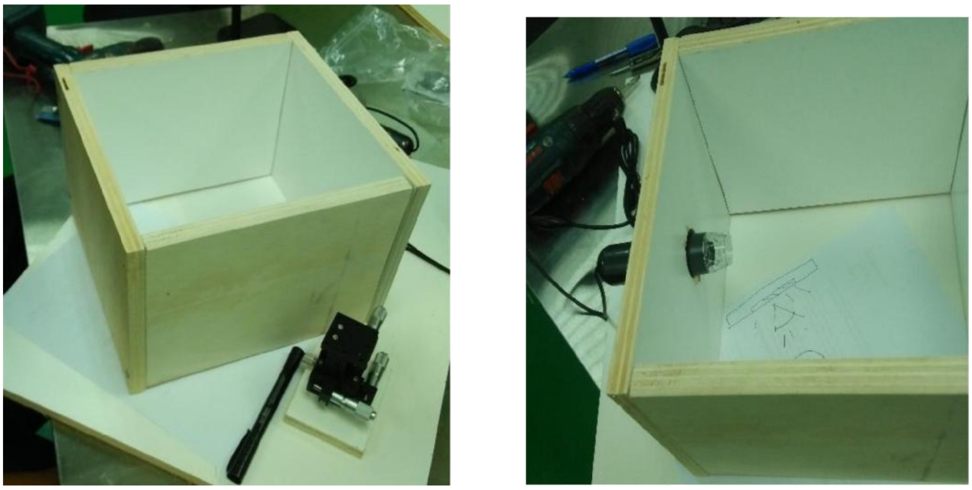


Figure 3.9: Assembly the component

3. The component was assemble by a screw at the junction part to make a cube with a dimension 25cm x 28 cm x 19 cm (l ×w ×h). A hole with diameter 3cm was made for the placement of the digital microscope.

Figure 3.10: Full assemble of the product

4. The product of measuring tools equipment after the assembly is now can be test to get the result of contact angle. The lighting of LED need to cover up because it cannot receive direct light that will make the image on screen will blur.

Figure 3.11: Fully assemble of measurement tools

The stage cube with dimension 25cm x 28 cm x 19 cm (l ×w ×h) was design to place the sample stage (inside the stage cube) and the LED inside the box to avoid outside factor that may affect the result. The digital microscope was directly connected to the PC that will receive the image of the droplet on the stage rig. The angle for the droplet was observed then measured using Image J Software to get the measurement of the angle before concluded that the type hydrophobicity of the sample. To get the high efficiency of the measurement, the test needs to do a various time and get the average value.

3.3 Testing Experiment on Sample

The experiment to measure the contact angle was set up accordingly to the objectives and follow the right method from past study. Before conducting experiment the sample need to be prepared.

3.3.1 Sample Preparation

For the testing of measurement the sample that used was lotus leaf and silica carbide with different grip (180,360 and 2000). Those sample then was cut and place on the aluminium plate with dimension 2cm x 2.5cm x 0.1cm ($l \times w \times t$). The purpose of placing sample on the plate is to make sure all the sample in same size while experiment was running.

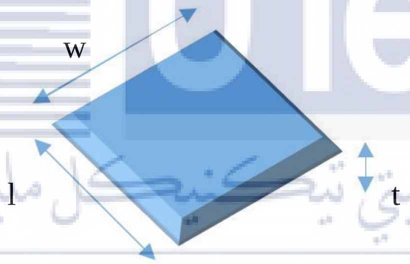
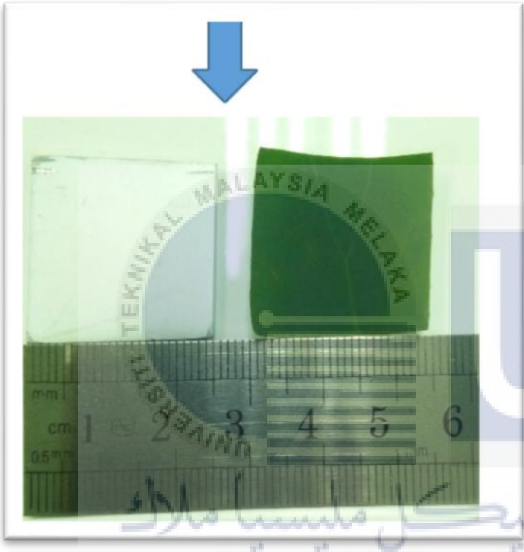


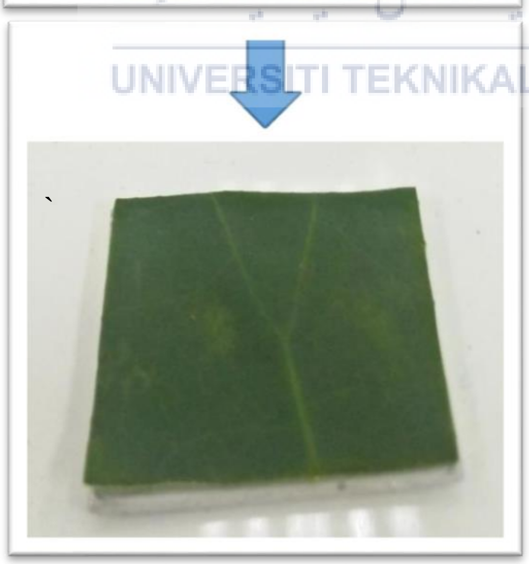
Figure 3.12: Dimension plate for sample

a) Lotus Leaf

1. The fresh sample of lotus leaf



2. The leaf was cut into same size of the plate

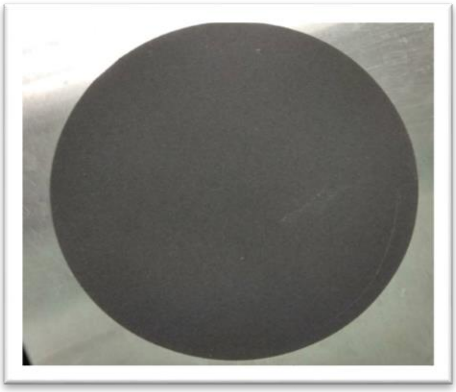


3. Then the leaf now attach to the plate using double sided tape to make sure the leaf not moving during experiment

Figure 3.13: Preparation sample

b) Silica Carbide (180 gsm)

The silica carbide 180 grit



Then it was cut into the specific size with the sample plate

The sample is ready to be test with measurement tools to get the contact angle

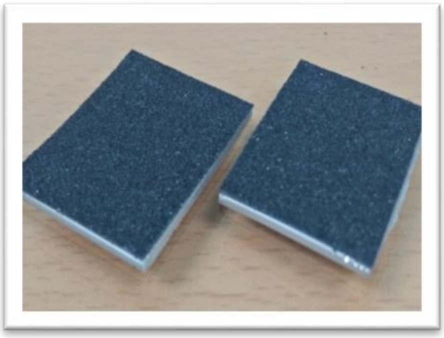


Figure 3.14: Preparation sample

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Overview

This chapter present the result and the discussion of the whole progress that have be done for the developing process of contact angle measuring tools for hydrophobicity properties. After some experimental data have done, the result show some good progress and performance for the hydrophobicity properties.

4.2 Measurement of Sample

4.2.1 Lotus Leaf

Angle measurement using Image J software to measure the contact angle of the droplet. The use of Image J software is to make sure that the angle of the droplet is measured approximately to classify the hydrophobicity properties. Each sample was measured for 30 times to get the average result.

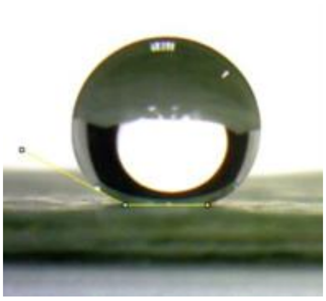


Figure 4.1: Droplet image on lotus leaf

The result shows that the contact angle of the droplet on the specimen which is lotus leaf is higher than 150°. This proved that the surface specimen is reach superhydrophobic condition which is good water repellency. As the result give the good result in measurement of contact angle, then the objective was achieve in developing the contact angle measurement tools. After conducting testing on sample (lotus leaf), the average measurement contact angle was 152.02° and the standard deviation was 1.24 which is full fill the properties of superhydrophobic term.

4.2.1.1 Analysis on lotus sample

a. One Sample T Test

One-Sample T

Descriptive Statistics

N	Mean	StDev	SE Mean	95% Lower Bound for μ
30	152.020	1.240	0.226	151.635

μ: mean of Sample

Test

Null hypothesis H_0: $\mu = 150$
Alternative hypothesis H_1: $\mu > 150$

T-Value	P-Value
8.92	0.000

Figure 4.2: One Sample T Test result of Lotus leaf

As for the test, the hypothesis is stated that H null is equal to 150 and H1 is greater than 150. The measurement tools that have been develop can measure the value of means which is 152.02 which is greater than H null. The significant level, α of this test is 0.05 and since the P-value (0.000 = 0.001) lower than α, the null hypothesis (H0) is rejected. The value of mean got from the experiment is higher than the H null which mean the result is correct and accepted.

b. Normality Test

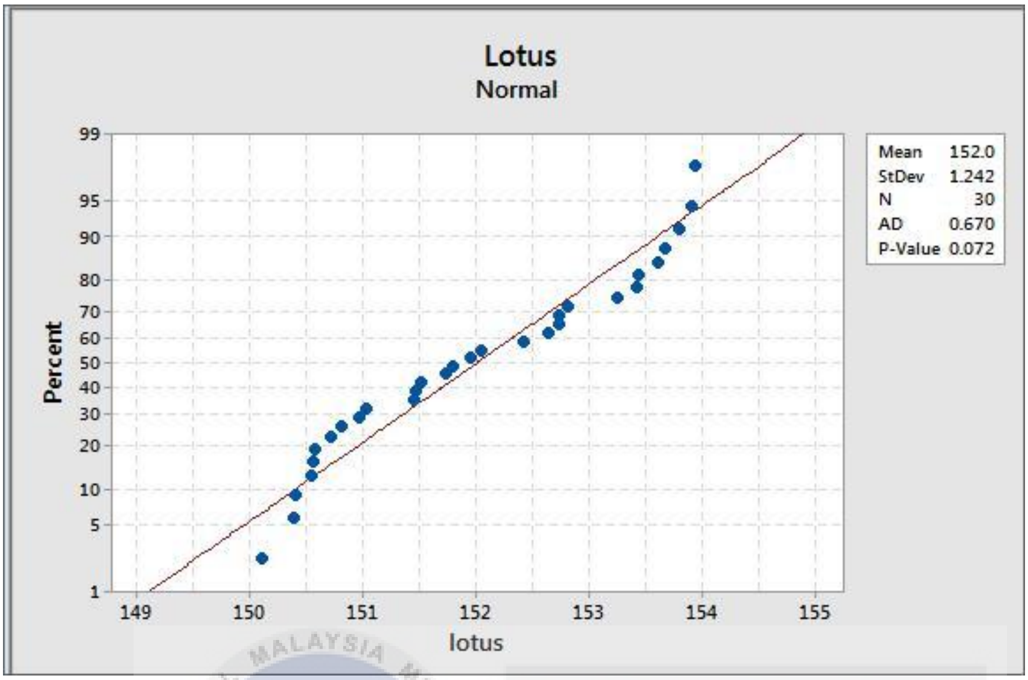


Figure 4.3: Normality Test result of Lotus leaf

To run the test, the hypothesis is stated as below:

a. H_o Data are from a normally distributed population

b. H1: Data are not from a normally distributed population

By having 95% of confidence interval, the significant level, α become 0.05. Since the P-value obtain from normality test is 0.072, it is greater than α. Thus, the null hypothesis (H0) is accepted which cause the data classified as normally distribution.

4.2.2 Silica Carbide 180 grit sample

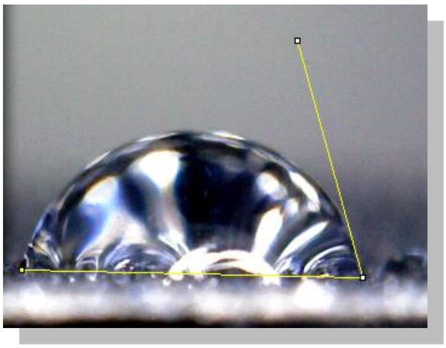


Figure 4.4: Droplet image on silica carbide

As the result of the measurement show the contact angle on silica carbide is below than 90˚, therefore it is hydrophilic properties which are not good water repellence. The surface of the sample is not good in repelling water; the water molecules will trap and slowly diffuse into the product. The average contact angle result that gets from the experiment is 72.60˚ and the standard deviation is 1.03.

4.2.2.1 Analysis on Silica Carbide sample

a. One Sample T Test

One-Sample T

Descriptive Statistics

N	Mean	StDev	SE Mean	95% Upper Bound for μ
30	72.600	1.030	0.188	72.920

μ: mean of Sample

Test

Null hypothesis $H_0: \mu = 90$
Alternative hypothesis $H_1: \mu < 90$

T-Value	P-Value
-92.53	0.000

Figure 4.5: One Sample T Test of Silica Carbide

The significant level, α of this test is 0.05 since the confident interval is 95%. The P value is 0.000 is equal to 0.001 that means the null hypothesis is rejected. The result show that the angle of sample is less than 90 by the H null which means the surface is high wetting ability and not good water repellence. As the means value is 72.6 than the H1 is accepted.

b. Normality Test

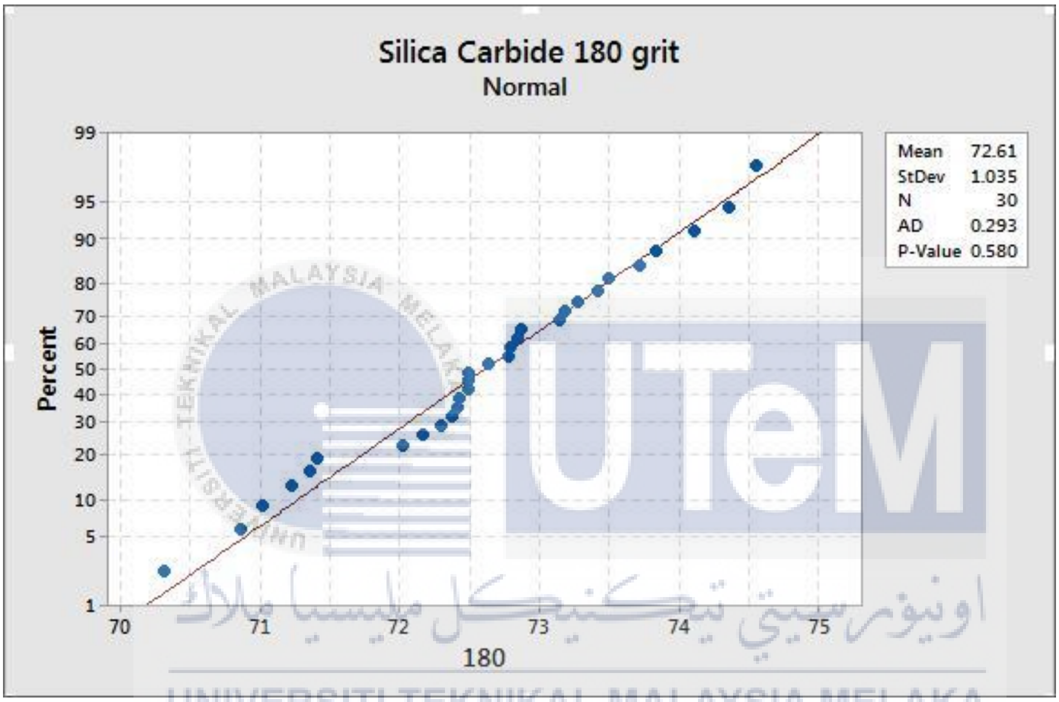


Figure 4.6: Normality Test result on Silica carbide

To run the test, the hypothesis is stated as below:

a. H_o Data are from a normally distributed population

b. H1: Data are not from a normally distributed population

By having 95% of confidence interval, the significant level, α become 0.05. Since the P-value obtain from normality test is 0.58, it is greater than α. Thus, the null hypothesis (H0) is accepted which cause the data classified as normally distribution. The testing on measurement tools give the accurate result after comparing with the past study about the hydrophobicity.

CHAPTER 5

CONCLUSION

5.1 Conclusion

In the conclusion, there are two main objectives that need to be considering throughout the research. The first objective is to develop an innovative and portable contact angle measurement equipment tools for hydrophobicity analysis with low-cost manufacturing process and easy to handle. Since the objective is to make the portable measurement tools, the criteria that must be full fill such as light weight, low cost of development, easy to maintenance and size reduction in order to get the experiment on. The second is to verify and validate the measurement data accuracy of the contact angle using Minitab Software to make sure the data that get from the experiment is correct and tally with the past study with high technology tools.

As a summary that can be conclude in the previous chapter, the literature study of contact angle and hydrophobicity properties has been presented in the report for review. The hydrophobicity is one of the important thing in designing the new product especially in electronic manufacturing. The term hydrophobicity plays important role to make sure the product can repel water and safe to use to achieve a superhydrophobic coating. The hydrophobic is usually used to define the contact of a solid surface with any liquid. In order to define the hydrophobicity properties, the contact angle need to measure first.

The experiment also has been conduct to obtain the value of contact angle of a sample which is lotus leaf. The lotus leaf was chosen as a sample because it have a high water repellency and suitable for hydrophobicity analysis. The method used to measure the contact angle is following the international standard by referring the past study and the advance measurement tools in market. Even though the equipment that has been used in the project is low cost and by fabricating by hand made, the result of the measurement of contact angle show a good result that prove the superhydrophobicity of lotus leaf surface.

As the result give the good result in measurement of contact angle, then the objective was achieve in developing the contact angle measurement tools. After conducting testing on sample (lotus leaf), the measurement contact angle was 152.02° which is full fill the properties of superhydrophobic term.

5.2 Recommendation

To improve the performance of test rig, there are some recommendations which is to develop the automatic measurement of angle software that can reduce the error in the measurement since ImageJ software need us to manually measure the angle by plotting the line to the tangential of the droplet. If the software can be developing, it will be must easier to calculate the contact angle and less error will be solved.

Also the storage of the supply pressure is need to be improved. As the project need the compressor to supply the pressure to the pressure regulator, it such a burden to carry the compressor since the tools is portable that can be move everywhere. So if the compressor can be replace by the small pressure tank that can be easily bring out with the product is such a good improvement.

The 3-axis stage also can be improve by design with automatic controller to adjust the place of the droplet on the sample stage. This can easily for the user to find the best position of the droplet image before capture the image and the calculation.

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APPENDIXS

Silica carbide 180 grit measurement of contact angle

	RIGHT	LEFT	AVERAGE	SUM AVERAGE
1	74.546	74.421	74.4835	74.34717
	74.089	73.091	73.59	
	73.978	75.958	74.968	
2	75.818	73.802	74.81	73.8325
	74.602	72.649	73.6255	
	72.742	73.382	73.062	
3	73.202	72.238	72.72	72.3755
	72.185	72.692	72.4385	
	71.118	72.818	71.968	
4	75.482	74.931	75.2065	73.4965
	74.651	71.631	73.141	
	73.195	71.089	72.142	
5	71.711	71.482	71.5965	72.161
	70.709	73.714	72.2115	
	70.362	74.988	72.675	
6	74.059	72.418	73.2385	74.55267
	73.423	75.737	74.58	
	76.03	75.649	75.8395	
7	75.949	73.35	74.6495	72.77567
	74.768	70.672	72.72	
	72.692	69.223	70.9575	

8	73.856	73.023	73.4395	73.17733
	72.991	73.467	73.229	
	73.279	72.448	72.8635	
9	72.974	73.767	73.3705	73.40717
	73.179	73.316	73.2475	
	74.692	72.515	73.6035	
10	72.957	71.453	72.205	72.48417
	73.324	71.565	72.4445	
	72.499	73.107	72.803	
11	73.519	69.75	71.6345	71.01417
	72.506	71.852	72.179	
	69.828	68.63	69.229	
12	72.756	71.726	72.241	72.867
	72.271	74.603	73.437	
	73.603	72.243	72.923	
13	68.746	72.533	70.6395	71.409
	69.088	74.626	71.857	
	70.145	73.316	71.7305	
14	69.202	70.553	69.8775	70.30567
	70.11	73.168	71.639	
	68.727	70.074	69.4005	
15	73.07	70.309	71.6895	72.014
	73.871	73.788	73.8295	
	70.204	70.842	70.523	
16	73.823	70.188	72.0055	72.2895

	73.122	72.946	73.034	
	72.209	71.449	71.829	
17	71.478	73.523	72.5005	72.83767
	72.361	74.778	73.5695	
	74.736	70.15	72.443	
18	75.789	74.624	75.2065	73.71383
	74.685	71.713	73.199	
	74.326	71.146	72.736	
19	70.487	72.585	71.536	71.2165
	70.476	69.685	70.0805	
	72.872	71.194	72.033	
20	73.762	71.988	72.875	70.8595
	70.54	68.943	69.7415	
	70.31	69.614	69.962	
21	73.808	74.109	73.9585	73.14317
	71.994	73.485	72.7395	
	71.986	73.477	72.7315	
22	72.756	70.991	71.8735	71.35367
	73.847	69.254	71.5505	
	70.254	71.02	70.637	
23	72.088	70.786	71.437	72.40383
	73.108	72.161	72.6345	
	73.373	72.907	73.14	
24	74.981	74.934	74.9575	74.10117
	73.462	73.427	73.4445	

	73.349	74.454	73.9015	
25	72.094	72.596	72.345	72.63567
	72.112	72.486	72.299	
	74.181	72.345	73.263	
26	73.753	72.341	73.047	72.78417
	73.154	73.353	73.2535	
	71.909	72.195	72.052	
27	71.963	72.479	72.221	72.48867
	71.187	74.661	72.924	
	71.001	73.641	72.321	
28	72.251	71.212	71.7315	72.42667
	71.634	73.994	72.814	
	73.053	72.416	72.7345	
29	74.854	72.521	73.6875	73.26733
	73.622	73.343	73.4825	
	72.515	72.749	72.632	
30	72.432	73.065	72.7485	72.49067
	72.214	72.866	72.54	
	71.242	73.125	72.1835	
	AVERAGE			72.60772
	STANDARD DEVIATION			1.03529

Lotus leaf measurement of contact angle

	RIGHT	LEFT	AVERAGE	SUM AVERAGE
1	150.986	150.011	150.4985	150.9758
	151.324	152.461	151.8925	
	150.473	150.6	150.5365	
2	149.982	151.03	150.506	150.1872
	149.982	150.759	150.3705	
	150.48	148.89	149.685	
3	150.041	151.87	150.9555	151.4572
	151.557	152.257	151.907	
	151.754	151.264	151.509	
4	153.695	151.074	152.3845	151.796
	151.587	152.301	151.944	
	151.526	150.593	151.0595	
5	154.867	152.199	153.533	153.9398
	154.38	154.509	154.4445	
	154.587	153.097	153.842	
6	155.468	154.273	154.8705	153.9
	154.329	153.644	153.9865	
	153.435	152.251	152.843	
7	153.705	153.159	153.432	153.6637
	153.053	154.506	153.7795	
	153.053	154.506	153.7795	
8	152.426	152.354	152.39	152.6378

	153.818	152.008	152.913	
	152.959	152.262	152.6105	
9	151.128	152.278	151.703	151.8028
	151.817	150.974	151.3955	
	152.959	151.661	152.31	
10	153.869	152.032	152.9505	152.7348
	153.295	152.7	152.9975	
	152.475	152.038	152.2565	
11	153.722	153.094	153.408	153.6093
	153.918	154.212	154.065	
	153.612	153.098	153.355	
12	153.533	152.167	152.85	152.7302
	152.652	153.386	153.019	
	153.359	151.284	152.3215	
13	153.425	153.708	153.5665	153.7983
	154.096	153.632	153.864	
	154.464	153.465	153.9645	
14	153.784	152.949	153.3665	153.4117
	152.518	153.657	153.0875	
	153.664	153.898	153.781	
15	154.564	152.625	153.5945	152.8178
	152.626	152.16	152.393	
	152.216	152.716	152.466	
16	150.873	150.782	150.8275	150.5832
	150.41	150.513	150.4615	

	151.318	149.603	150.4605	
17	153.611	152.204	152.9075	152.4678
	152.793	152.333	152.563	
	152.193	151.673	151.933	
18	153.156	152.526	152.841	151.9565
	150.889	150.945	150.917	
	152.193	152.03	152.1115	
19	149.589	149.349	149.469	150.3913
	150.302	150.978	150.64	
	151.675	150.455	151.065	
20	150.69	150,923	75536.85	25279.08
	150.461	150.832	150.6465	
	150.255	149.253	149.754	
21	150.422	150.586	150.504	150.8083
	152.512	150.654	151.583	
	151.354	149.322	150.338	
22	151.212	151.304	151.258	151.0398
	150.383	152.103	151.243	
	150.461	150.776	150.6185	
23	150.472	151.968	151.22	150.7248
	150.357	150.356	150.3565	
	150.199	150.997	150.598	
24	150.66	150.915	150.7875	151.4718
	150.124	150.309	150.2165	
	153.594	153.229	153.4115	

25	152.205	154.622	153.4135	153.2547
	152.173	153.13	152.6515	
	152.83	154.568	153.699	
26	150.524	153.932	152.228	153.4377
	154.602	154.049	154.3255	
	154.231	153.288	153.7595	
27	153.185	151.63	152.4075	152.049
	153.063	151.37	152.2165	
	152.648	150.398	151.523	
28	149.801	150.295	150.048	150.5493
	152.324	150.26	151.292	
	150.361	150.255	150.308	
29	150.73	149.407	150.0685	150.5647
	151.266	149.894	150.58	
	150.311	151.78	151.0455	
30	151.798	152.626	152.212	151.7333
	152.493	151.592	152.0425	
	151.079	150.812	150.9455	
	AVERAGE			152.017
	STANDARD DEVIATION			1.242