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Investigation for the electrical conductivity, Rheology, and surface characteristics for the Flexographic inks

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Abstract— **in this research an investigation for the electrical conductivity, Rheology, and surface characteristics for the flexographic inks. four different types of inks were analysed which are GNP-R1, GNP-NH3, FLG-R1,andFLG-NH3. The results of viscometry testing shows high viscosity for FLG ink comparing with the GNP, where the FLG ink is too thick comparing with GNP, however the handle screen printing the FLG cannot be obtained according to the thicken of the FLG . The wall slip testing was investigated for FLg, where Wall slip occurs by the depletion of dispersed at the surfaces of the solid ,this phenomenon leads to create frictionless layer at the solid wall. The results of surface characteristics shows the thickness and roughness of the surface which was compared , and finally the electrical conductivity was measured using two method , two points probe and four points probes , where the results of four points probe which is more accurate show the maximum difference in electrical resistivity between R1 and NH4 is less than 10%.**

Keywords—FLG,GNP, Rheology, Wall slip, electrical conductivity.

I. INTRODUCTION

A. Backgound

A broad range of printing techniques have been implemented to different products fabrication. These technologies include; offset printing, flexo-printing, gravure printing, inkjet printing and screen printing. Based on the nature of the product to be printed, one must take an appropriate selection regarding the type of substrate, ink, the structure of the designed device, pattern geometry, and cost of production as well as product quality. The most significant printing parameters that are usually considered when selecting the printing technology include [1];

- Printing accuracy and resolution,
- Uniformity, composition of designing ink and the drying process,
- Wetting control and interface formation,
- The inks compatibility with printing components like inkjet heads, doctor blades, masks and rollers which have a considerable influence on both of quality and yield in mass production;
- The throughput and cost considerations.

In this project, the main focus will be on the flexographic printing process. Among the invented conventional printing techniques, the flexography technology is considered as the newest one. It was known as Aniline printing. It's very similar to letterpress since it prints from a relief image. This process is favorable since it produces images with high quality and this because it utilizes ink metering systems in addition to printing plates rather than the system of cast metal image carriers. In addition to its fast production, the Flexography is appropriate for the halftones production. One of the key features of this process is that it's very sensitive to the print mix viscosity which influences the ding speed, solvent retention and coating weight [2]. This means that incompatible qualities of prints and pigment can be resulted if the viscosity is changed throughout printing [3]. From this, the vision of utilizing Graphene Nano Platelets (GNPs) ink in the Flexography printing will be analyzed in this study. It's a carbon-based inks which delivers the feature of conductive coating.

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According to [4], recently, Graphene has gained a high interest because of its promising electrical, mechanical and thermal properties. Graphene Nano-Platelets comprises between 5-100 graphene layers and may deliver a cost-effective substitute to single layer graphene. They have a thickness of 50nm and a length of 5um which gives a high aspect ratio that provides the platelets with an extremely high specific surface area. When this area is coupled with carbon's, the relative inert nature provides the platelets with a high propensity to agglomerate because of the van der Waals loads. This may results to doublets or higher multiplets formation. From this, the possibility to disperse these materials is of great significance in case of utilizing them in mass manufacture process like printing. FLG (Few layer grapheme) is an expensive material comparing with GNP it has high electrical conductivity and can be used to improve the electrical characteristics of the ink as in this project, this type of material can be composed using different methods such as chemical vapor deposition . [24]

B. Improving the electrical conductivity of inks

The effect of adding Graphite to improve the properties of the ink was investigated by different researchers such as ; **Phillips et al.** [17] studied the effect of variable carbon to graphite ratio of carbon graphite on its conductive properties when used as printing ink. They observed that the conductivity of carbon graphite ink can be can be optimized according to the desired application, performance and print quality. This can be done by altering the ratio of the components with respect to each other of the ink, namely: carbon black, graphite and polymer. Apart from the quantitative variations of the components of the ink, the qualitative analysis of the components should also be taken into account while optimizing the ink. This is because properties of the components are related to the quality of the material also. Same material when comes from variable sources, has variable characteristics in terms of particle size, nature of interactions and electrochemical behavior. The materials used in their experiment were: Graphite (Timrex SFG15, Imerys Graphite and Carbon—typical D90 17.9 lm according to manufacturer) and carbon black (Conductex SC Ultra, Birla Carbon— with mean particle size 20 nm). There prepared total 10 batch of the carbon graphite ink with keeping the graphite to carbon black ratio variable. The graphite to carbon black ratios used for the experiment were: 0.5:1, 1, 1.8:1, 2.6:1 and 3.2:1. Each ratio was prepared using higher carbon concentration of 29.4% with resin being 70.6% and a lower carbon concentration of 21.7% with resin being 78.3%, by mass. A polymer, VINNOL, was also used in the preparation of the ink in form of vinyl resin base made prior to the addition of carbon black and graphite.

The parameters that were measured and analyzed were: Ink viscosity, ink film thickness & surface form and electrical properties (in terms of shear resistance & resistance of printed lines). It was observed that the maximum conductivity was achieved with batch that has higher carbon concentration of 29.4 % by mass and graphite to carbon black ratio of 2.6:1. Whereas in case of lower carbon concentration batch of 21.7%, the batch with graphite to carbon black ratio of 1.8:1 showed enhanced conductivity. The shear resistance observed during the experiment was in the range of 38.7–252.2 X/h with a corresponding resistivity being in the range of 0.029–0.127 X cm. Phillips et al. [20] felt that conductivity of the ink can be further optimized by increasing the carbon content in the compound but it will have some detrimental effects. Increasing the carbon content will also increase the ink adhesion and decreasing the durability. This will also complicate the process.

Park et al. [18] studied the effects of changing the respective ratio of conductive filler and resin in the preparation of conductive ink. They prepared samples in the shape of rectangle, keeping the formulation of the ink and dimensions variable. The samples were tested and analysed for surface resistivity, ageing resistance and surface temperature. The findings of their experiment can be applied to heating production development of different powers. Graphite (30 μm) and carbon black (30) were used as the conductive fillers. Modified epoxy resin was used as the blinder. KRTTS and Triethylenetetramine (chemically pure) were used as coupling and curing

It was found that the surface resistivity is reduced when conductor filler is increased from 20% to 30%. And when the concentration of conductor filler is increased from 30% to 60%, increase in the resistivity tends to slow down. The reason for this slowing down is, the conductive filler exceeds its threshold level of percolation and hence it does now enhance the resistivity any further. Power density is also dependent

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on dimensions (length:width) of the sample and proportion of the conductive filler in the samples.

To study the ageing resistance phenomena, formula D & E (with 200x4 mm^2 sample) were exposed to 400h electricity. The test shows that the formula D was quite stable as the resistance increase (from 28.7Ω to 28.8Ω) was negligible in its case, when charged from 0 to 300h. On other hand, when formula E was charged from 0 to 300h, the resistance increased from 18.6Ω to 19.8Ω, exhibiting the ageing phenomenon. The reason is that formula E has high concentration of conductive filler as compared to resin. Surface heating temperature is also a function of the conductive filler concentration in the conductive ink and the dimensions of the sample. It was found to increase with increase in conductive filler proportion. Also higher ratio of length to width results in higher surface heating temperature. Park et al. [20] derived a formula for optimizing the conductive ink suitable for heating, which is:

m(resin) : m(graphite) : m(carbon black) :: 4 : 3 : 1

For sample with dimensions 50:1, the power density was estimated to be 232W/m2 and surface heating temperature to be 43°C with keeping the alternating current to be 220 A. On other hand, for the sample 20:1, the power density was 356W/m^2 and the temperature was 55°C, keeping other conditions same [18].

Philip et al. [19] studied the relationship between characteristics of conducting carbon graphite printable ink and properties of solvent. The characteristics of carbon graphite ink that were focused on the study were mainly drying characteristics, consistency of the process and electrical conductivity. Screen printed carbon pastes were used for the experiment. The materials used for the experiment were made up of identical proportion of graphite to carbon black proportion, same binder (nitrocellulose) and same proportion of solvent. This way four materials were prepared keeping everything same, except the solvent. It has been found that boiling point of a solvent is one of the significant factors for drying characteristics. Hence, boiling point was the chief deciding factor for selecting the solvent for the study. The four materials with solvents had the boiling points in the range of 166°C to 219°C. The composition of the material for the experiment was: Carbon/graphite – 31%, Solvent – 60% and Binder – 9%. The printing film used for the experiment was of thickness in the range of 6 m to 161 m. Once all the four materials were spread across the films, the films were exposed to industrial dryer multiple times. The dyer was operated at a temperature of 155°C. The thickness of the films and the resistance were measured after the successive exposure of the films to the dryer. It was found that the thick films had the resistance of 14X/sq whereas the thin films had resistance of 46X/sq. in terms of residence time, the thick films attain the stability in terms of resistivity in around 12.5 minutes. On other hand, it took 2.5 minutes only for thin films to become stable. Hence, the study postulates that in order to increase the sheet resistance, depositing multiple thin films together is a better approach than using a singly thick film [19].

The experiment shows that in order to study effect of drying on conductivity, the resistivity of each material residence time should be studied. The temperature should be kept 130°C or above for the study. Resistivity has a direct relation with residence time. The relationship is well evident in case of thick films as compare to thin films, where the reduction is negligible. It was also found that the solvents with lower boiling points have faster rate of drying. This leads to contraction of film at increased rate creating extreme tension between the upper layers of the film. During the experiment, no correlation could be made between volatility of the material and process variation [19]. This area could be further researched using highly volatile solvent.

Jewell et al. [20] studied the relationship between material solvent, process consistency and printed film conductivity. The study is similar to study conducted by Philip et al. [20] and is an extension of the same. In their study, they proposed that the productivity of the printing process can be enhanced by decreasing the boiling point of the solvent material, without having any detrimental effect on the process consistency. It also minimizes the sheet resistance and improves the conductivity. They found that the reason behind these effects is higher inter particle contact. They performed simulations for testing the performance of material and drying process. The findings concludes that while manufacturing of printing films, multilayer printing is a more suitable and advantageous method. These findings of the experiment are not only applicable to bulk manufacturing for carbon sensor electrodes only, but appropriate for any field that deals with conductive carbon as a component. Few of examples of such field are: photovoltaic devices and electrical circuits.

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Secor et al. [22] studied a new material for graphene for its application in electronic printing industry. They mentions that advancements in the field of carbon nano-materials have showed that graphene can be successfully applied in the printing field as a conductive ink. For their experiment, they used nitrocellulose as a stabilizer and processed graphene with it. This mixture was formulated to prepare printing ink. The films are coated with graphene/nitrocellulose material is mechanically flexible and has high electrical conductivity of around 40000 S/m. they also performed various test on the graphene/nitrocellulose ink for environmental stability and confirmed the stability. They proposed that graphene ink is efficient in performance and has huge potential as a conductive ink for printed and flexible electronics.

Király and Ronkay [23] performed investigation on the hybrid effect in a polypropylene matrix posed between graphite and carbon black. The main parameters to be tested were the electrical conductivity, mechanical properties, and processability. The purpose was to develop conductive polymers to replace metals in suitable applications with enhanced performance owing to the former's reduced density and better corrosive resistance. The matrix material in their experimental analysis was 'Tipplen H949' polypropylene with 45g/10minute melt flow rate (MFR). Crystalline natural graphite was used in powdered form with 6 m^2/g specific surface and 20 µm average particle diameter. Three different types of carbon black was used in the investigation. Carbon black and graphite were not simply used as fillers, but hybrid systems of carbon black (5-10% weight) and graphite (40-70% weight) were used for producing the improved bipolar plates made of polypropylene composites. The bipolar plates are essential components fuel cells. To ensure increased conductivity, the crystallinity and particle shape of graphite content were focused on, and in terms of origin – natural graphite was preferred over its synthetic counterpart for higher conductive performance. Other factors affecting conductive performance of graphite (and thereby the PP composite product) include granular size and specific surface area. The density of graphite used in the composite was 2.12 g/cm^3 for PP matrix of density 0.89 g/cm^3, while the carbon black density ranged from 1.77 – 1.88 g/cm^3. The test methods used in this study included three point bending test done on a Zwick Z020 universal tester. The specific combination of carbon black and graphite when dispersed into the PP matrix was found to show synergic effect in that the electrical conductivity was boosted and decreased the polymer's flowability so as to allow hot pressing for processing of the resulting bipolar plate product. This therefore allowed optimized performance of the constituting fuel cell.

C) Rotogravure printing process

This process is defined as a high volume printing process which is commonly utilized for high quality publication prints and packaging creation such as flexible packaging like food where print quality is very significant. In the field of Publication products, this involves quality colour magazines. The first utilization of the Rotogravure printing in engraved copper plates was in the 15th century. The recently applied rotogravure process utilizes either laser or electromechanically engraved cylinders for the purpose of holding the image. These cylinders are known with their extremely hard wearing which allow it to be utilized for long runs of printing at an extremely high speed with few image quality degradation [6].

Throughout running the Rotogravure printing process; the image is created on a cylinder through a series of cells by which the ink is carried. The ink is moved through a bath and passed to the substrate. In this component of the process, the gravure image carrier cylinder rotates where its rotation resulted to inks filling in small cells located in the gravure cylinder surface. The excess ink is then metered by the doctor blade. After that, the cylinder cells are caused to be in contact with the substrate at an impression nip contact in which the ink is passed from the cells toward the substrate. To maintain a successful passage of ink to the substrate, an Electro static assist (ESA) is used. Finally, an inter station driers are used to dry the ink is prior to passing to the subsequent colour [5,6].

C. Rotogravure printing variables

Different variables effect on the Rotogravure printing quality, Where these variables are related to rotogravure process as presented in following subsections :

1) The rotogravure cylinder

The cylinder of this process is a composite component which is made from several layers. It comprises a base in which the printed material is coated to permit the

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engraving of image. At the end stage, it's plated for surface hardening and for prolonging the cylinder life. The cylinder is typically mounted on a steel cylinder which is electroplated with copper. A balance should be made for the steel cylinder in order to maintain that it will not vibrate when running the pressing at a high speed. If a vibration is occurred, then it leads to errors in printing, raised the wear in the cylinder and doctor blade in addition to press damage. This component should not be deflected throughout the printing cycle[7].

2) Doctor blade

The second variable is called the doctor blade. The operation of this variable is very serious for the print quality. It is targeted to do two key functions which are ink metering in the cells and inks removing from the non-image locations to avoid defects through printing like scumming. In this variable, the following parameters should be considered [8];

- The angle measured between the cylinder and the doctor blade. This angle is required to insure the accurate conditions of ink transferring at the blade tip. A bout 60 degrees angle should be obtained between the doctor blade and the tangent line to the surface of the cylinder at the contact point.
- The distance measured between the impression point and the doctor blade;
- The blade tip profile.

This variable can affect the printing process in term of deflection and lifting of the doctor blade throughout high speed printing. This can be avoided through reinforcing the doctor blade with a backing blade.

3) Ink

The printing ink is the very important component in the printing system. Gravure needs a low viscosity ink which means that this ink used a high percent solvent of 90%. In most cases, the used inks have Newtonian nature and utilize water as organic solvents. At a high speed printing, a very volatile solvents is often used which in turn decreased the required time for ink drying between printing units [8-10]

4) Electrostatic assist (ESA)

A serious difficulty that faced the rotogravure printing is the possibility to missing dots during ink transferring from the cells. For this purpose, the Electrostatic assist is used, which provides the ink with an electrical charge which aids the processes on ink transferring in an accurate way. This process utilized in broad applications such as in papers [11][12].

5) Press design

Most of the gravure presses are utilized for web based substrates printing, packaging, publication and niche applications as well as in carton printing. Figure 3 illustrates its application in packaging. In publication printing, the utilized press is very large and has a web width of 3.5 metres. This width is two times more than the packaging width which is 1 metre [10].

Figure 3: Rotogravure press for a packaging application [13].

D. Screen printing

Screen printing is anther printing method where the ink is printed to the substrate using a mesh this mesh, the ink is distributed over the image using a squeezer, it's worth to mention this process can be obtained manually or using screen printing machine. Different researchers used screen printing to prepare ink and test it using thermal conductivity such as [17] , in that research it was inferred that thicker printed films can be obtained by increasing the thread diameter along with an increase in screen emulsion. These films will be having lower value of resistance due to lower conductivity [17]. But for doing so, different conductive materials would be needed as filler material. Moreover, decreasing the amount of carbon will result more viscous ink. This will eventually degrade the print quality. In case, graphite only or carbon black only ink is prepared, there will be different set of issues arising. Graphite based ink would be a highly resistive ink, but it would complicate the printing process. Carbon black based ink will have higher value of rest viscosity, lower

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value of high shear viscosity and increased shear thinning. They observed that there is a relationship between the thicknesses of the ink film with the viscosity at low shear rates. And due to this association, highly viscous ink results in thicker printed ink films. They also found that ink with low viscosity value gives more consistent lines and easy to slump. Low carbon content has direct relationship with thickness of the ink film with reduced drying in. This will enhance the making of fine features and print runs but will compromise in low conductivity. Also **Philip et al.** [21] present an extension of their earlier work on printing process in this paper. This is an experimental study of process of manufacturing of resistive heated panels for elevated flooring. The method used in this process for depositing the heating element is through screen printing and hence has application of conductive printing ink (i.e. carbon-graphite paste). The study proposes optimization method for analysis of material formulations for a production line of 300 tiles. For this purpose, the material was selected on the basis of its rheological properties and drying behaviour. The sheet resistance of the material was 35Ω/sq on printing through a polyester size of 77-48. It was found that higher film thickness with rough screen type was not suitable for this process. This was mainly due to increased chances of occurrence of deformations in the film structure and also the time required for drying is generally more for these type of screens. A process drift was observed during the manufacturing process resulting from the solvent absorption. The study proposed that the findings of this work can be applied to numerous fields where screen printing is used as a method of material deposition. Few of such applications can be in sensors, circuit boards and third generation photovoltaic cells.

E. original project plan/intention

According to the defined issues above, the main aim of this study was to planed initaily to improve the electrical conductivity flexographic ink using GNP during the progress of this project it was found FLG (few layer graphene) is capable to efficiently incorporate with the flexographic printing process. Throughout working on this aim, the following points summarize the key objectives that was suggested to be accomplished;

- Applying testing methods to multiple carbon-resin ratio mixes;
- Analysing the printing rheology process;
-Evaluating the printing quality;
-Applying the process of four-point probe to measure the conductivity;
-Utilizing a white light interferometer in order to test the layer thickness

II. METHODOLOGY

The experimental methodology can be explain as shown in the following diagram.

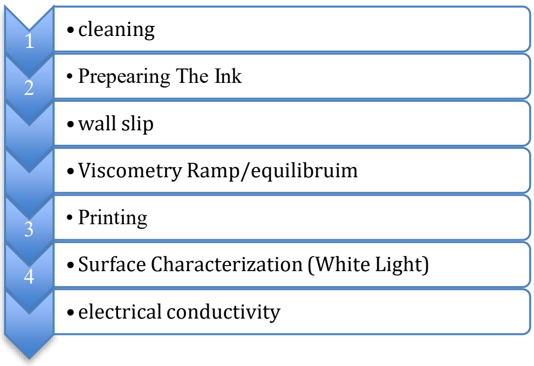

Figure 4: the methodology of experimental testing

The used plates should be cleaned firstly , where this cleaning should be obtained to avoid any impurities in macro or micro scale because the used material with very small particles size (nano scale) so any impurities on the plate surfaces effect on the structure . The inks comprise of 3 components:

1. Plasma fictionalised material (GNP or FLG), where the NH3/R1 refer to fictionalisation types from the plasma process.

2. TPu polymer

3. Solvent Using marlven kinexus device

In this research GNP ink was created using chemical risen will be used such as diacetone alcohol and Poly(vinyl chloride-co-vinyl acetate-co-vinylalcohol) , the GNP powder was added slowly with hand mixing to avoid air bubbles and the solid disperse. Then the will be mixed for a specific time and speed. The weather conditions including the humidity and the air temperature effect on the ink making processes , where the non-uniform distribution for the temperature over the plate and the humidity effect on the ink formation so plates were heated to get uniform temperature

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distribution over the plate and to remove the humidity from the surface , however to reduce the solvent from it the fluid was trimmed with ensuring it applied on the right position of the plate . the heating temperature of the plate was taken as 25 ℃ .

As previously mentioned, there are several printing processes that are suitable to be applied in this project but only two of them are discussed in this section which are the Rotogravure printing and screen printing. The manually screen printing process required special skills to get high quality image , where the movement of squeezer should be considered to be in one direction where the reverse direction printing will effect on the quality of the printing and surface properties .

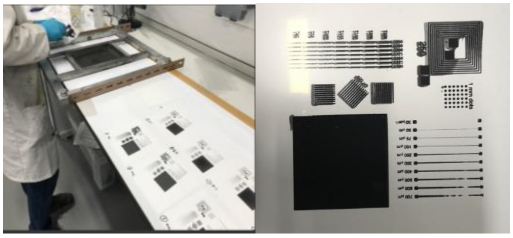

Figure 5: the screen printing process

The FLG NH3 and R-1 were not printed because they can be printed using hand screening and required a specific machine of screen printing according its behaviour of the particles and plasma, in other word this type of ink is too thick.

The rheology process of the fourth inks was obtained by testing was obtained to measure the shear rate , shear stress and viscosity the testing gap was taken as 0.4, 0.5 and 0.6 mm as shown in results section.

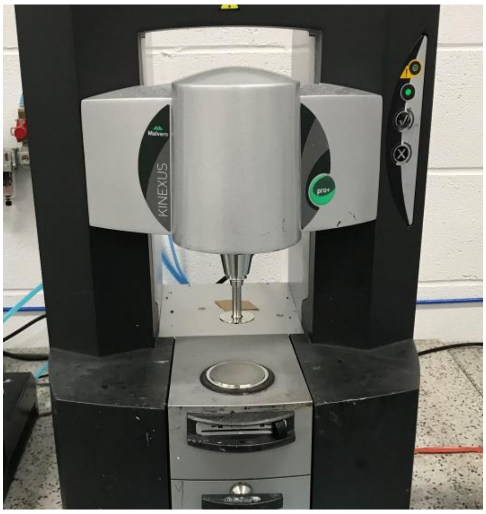

Figure 6: marlven kinexus

The ink over the plate can be implemented using different conditions such as naturally, using parallel plate or using rough plate, where in this case for parallel thickness, the glue /risen was implemented over think which caused wall slip . Wall slip occurs by the depletion of dispersed at the surfaces of the solid ,this phenomenon leads to create frictionless layer at the solid wall. However this phenomenon effect on the measurement of viscosity of the fluid . the rough plate was used to solve the problem of wall slip by increasing the friction between the surface and fluid.

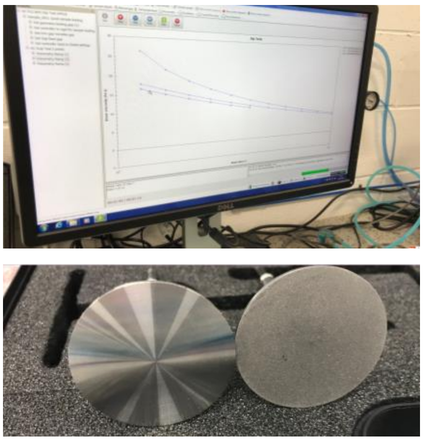

Figure 7: rough and smooth plate of marlven kinexus

The Surface Characterization (White Light) was investigated to check the roughness of the surface where

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the light was applied to the surface of the reflection of the light generates an image for the material, where the thickness of the material can be measured by fixing the light above the printing edge and then measuring the differential height of the print. The results of this test are shown in the next section (results section).

The electrical conductivity was measured using two methods; a) two points method and four points method. Regarding the two points probe method, the electrical conductivity was measured using two lines 600µm and 700 µm . The four point's probes method is more accurate to measure the electrical conductivity but its complex because it depends on area but the two points probe method depends on the length , however different records were measured and the average value was estimated using these two tests for the printed sheets .

III. RESULTS

This section shows the results of experimental work , where Figure below shows the shear stress vs, the shear rate as produced by Ramp viscometry testing where the shear stress reduces with increasing the shear rate , the Viscosity can be measured by finding the ratio between the shear stress to shear rate as shown in the following equation.

$$\tau = \mu \frac{du}{dy}$$

Whereμ: the viscosity

$\frac{du}{dy}$: shear rate

τ : Shear stress

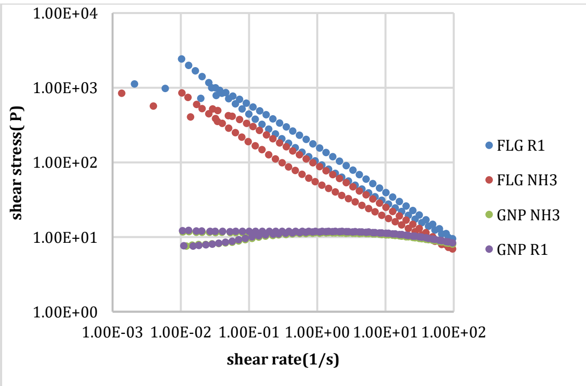

Figure 8: shear stress vs. shear rate

The average value of viscosity for the different inks is shown in the following figure where the FLG ink has the highest viscosity comparing with the GNP , its worth to mention that the; FLG (few –layer Graphene) is new material was used instead of GNP this material is more thinner than the GNP in other hand, the FLG is more expensive than the GNP . The FLG contains malty layers comparing with GNP where the GNP contains 6-10 layers and where FLG contains 8-16 layers

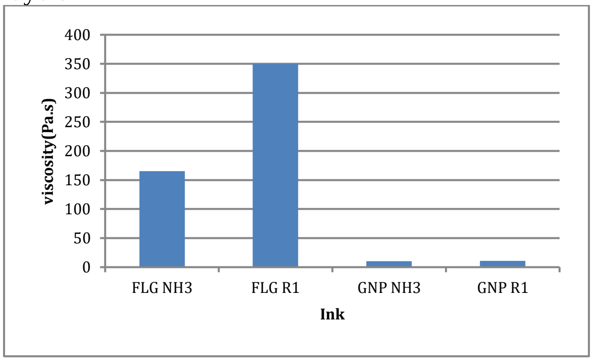

Figure 9: the average viscosity vs. .ink type.

The equilibrium viscosity was tested for the different types of inks where the following figure shows the results

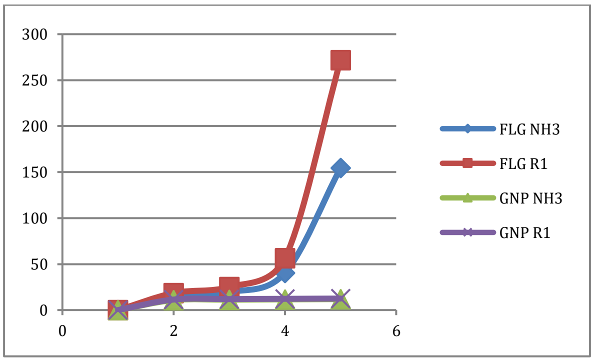

Figure 10 shear stress vs. shear rate at equilibrium testing

Wall Slip testing results are shown in the following figures for shear viscosity vs. the shear rate, where the shear stress is reduced by increasing the shear rate, where the slope of this curve presents the dynamic viscosity of FLG however it noted clearly the

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difference between the FLG-R1and FLG-NH3 is insignificant .

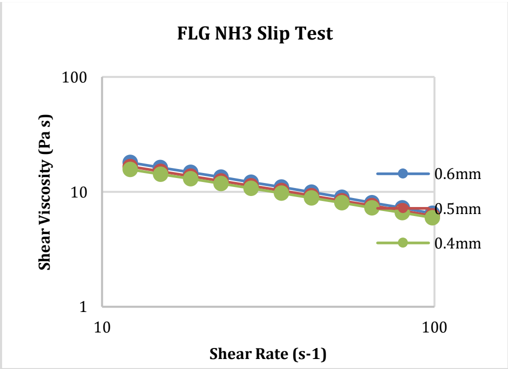

Figure 11: the wall s lip test for FLG-NH3

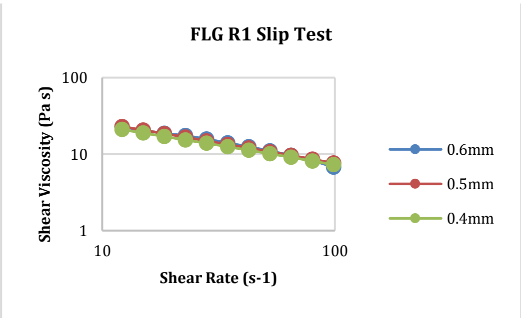

Figure 12: the wall slip test for FLG-R1

The samples were printed on different sheets for NH3 and R1 to be tested figure below shows a sample sheet of printing using handle screen printing. In the testing process three sheets were considered which are sheet 4, 5, and 6. Its worth to mention the flexographic printing was not used in this project because the GNP ink has low viscosity which leads to depletion of dispersed at the substrate surfaces due to the wall slip.

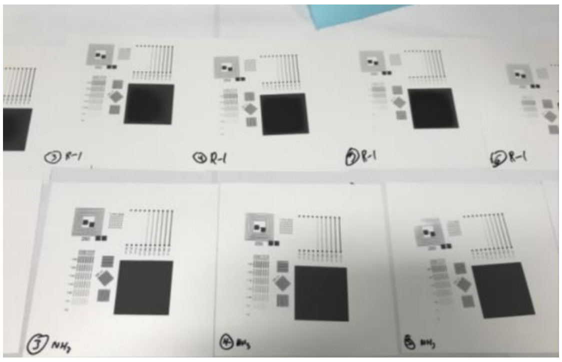

Figure 13: sample of sheet printing using screen printing

The surface roughness and ink thickness was investegated for six samples in three sheets where figure below shows a sample of the obtained graph from this testing.

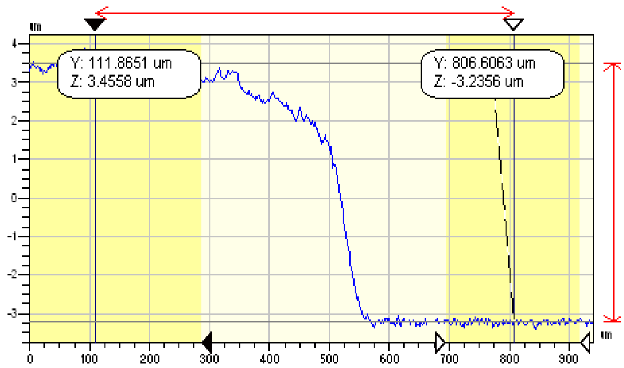

Figure 14: investigation surface characteristics using NH3-4

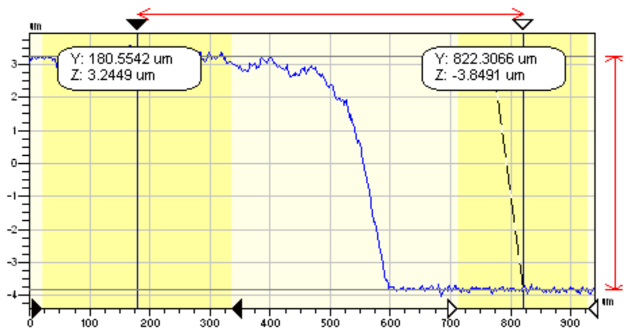

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Figure 15: investigation surface characteristics using NH3-4

The results of surface roughness are shown in the following figure for the different sheets and inks , it was noted clearly the highest roughness was measured for R1 ink in sheet six , where the difference in roughness depends on different factors such as the speed of ink squeezing and the pressure which is applied in printing process .

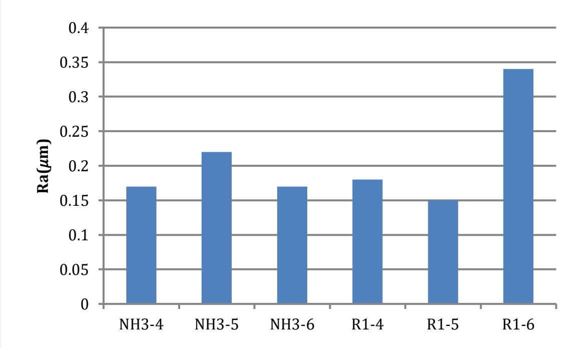

Figure 16: The roughness of surface using different types of ink

The thickness of ink for different samples is shown in figure 17 , where the results shows the thickness of ink layer in range of 6 to 7 (μm). The maximum thickness was recorded for NH3 in sheet 5.

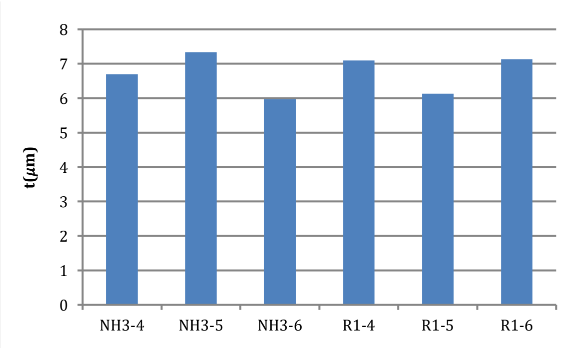

Figure 17: The thickness of ink for different samples.

Figure 18 shows the electrical resistivity using four point probes method, where three records were measured per sheet the average value was plotted. However the minimum resistivity was presented for NH3-4 which means this sheet has the heist electrical conductivity and NH3-6 has the minimum conductivity. Comparing NH3-4 with R1-4 it can be noted clearly the difference in values is less than 5%, comparing NH3-5 with R1-5 the difference is less than 3%, and finally the difference between NH3-4 with R1-4 is less than 8%. The difference in records between the different sheets can be explained according to the draying level of the sheet, the applied pressure, ink film thickness, where the high pressure reduce less ink thickness the comparison between the different samples is shown in figure 19.

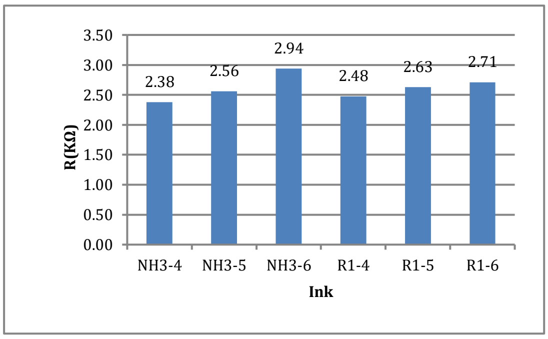

Figure 18: The electrical resistance of different samples using four points probes method.

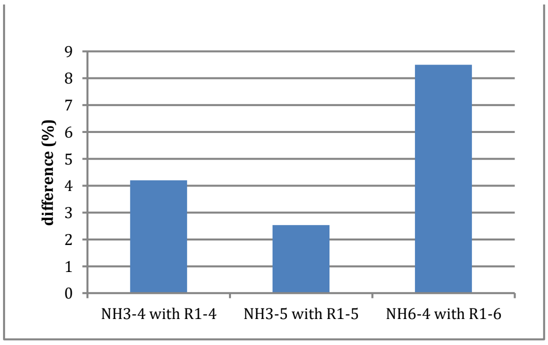

Figure 19: The comparison of different samples using four points probes method.

The results two points probes method for electrical resistance are shown in the following figure at 700 μm and 600 μm for R1 samples the electrical resistance in range of 1-1.2 KΩ.

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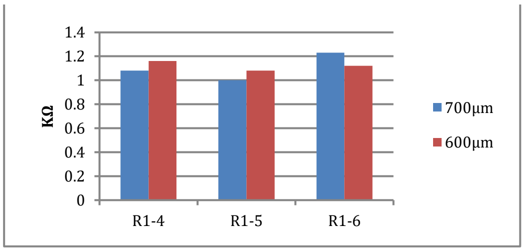

Figure 20: The electrical resistance of different samples using two points probes method (R1).

Figure 21 shows the comparison between the different NH3 samples using two points probes method, where the variation in results is high . the maximum electrical resistance about 1.6 KΩ for NH3in sheet six for 700 μm.

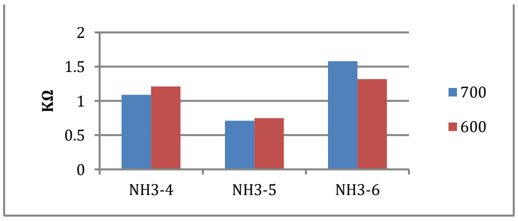

Figure 21: The electrical resistance of different samples using two points probes method (NH3).

Figure 22shows the difference between the different records for R1 and NH3 , where the maximum difference at sheet 5 , with percentage about 44%.

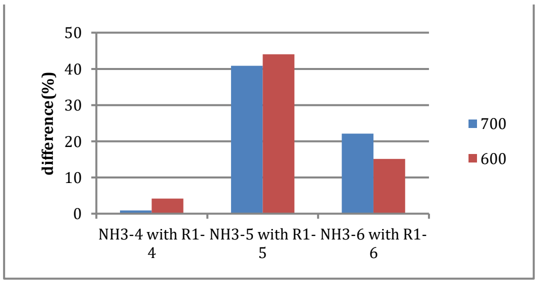

Figure 22: The comparison of different samples using two points probes method.

CONCLUSION

The most significant printing parameters that are usually considered when selecting the printing technology are; Printing accuracy and resolution Uniformity, composition of designing ink and the drying process;Wetting control and interface formation; The inks compatibility with printing components like inkjet head and The through put and cost consideration. The effect of adding Graphite to improve the properties of the ink was investigated by different researchers. Screen printing is anther printing method where the ink is printed to the substrate using a mesh this mesh, the ink is distributed over the image using a squeezer, it's worth to mention this process can be obtained manually or using screen printing machine. Rotogravure

is defined as a high volume printing process which is commonly utilized for high quality publication prints and packaging creation such as flexible packaging like food where print quality is very significant. According to the defined issues above, the main aim of this study was to planed initially to improve the electrical conductivity flexographic ink using GNP during the progress of this project it was found FLG (few layer graphene) is capable to efficiently incorporate with the flexographic printing process. In this research GNP ink was created using chemical risen will be used such as diacetone alcohol and Poly(vinyl chloride-co-vinyl acetate-co-vinylalcohol) . the FLG ink has the highest viscosity comparing with the GNP , its worth to mention that the; FLGis more thinner than the GNP where the glue /risen was implemented over thickness which caused wall slip .Wall slip occurs by the depletion of dispersed at the surfaces f the solid ,this phenomenon The electrical conductivity was measured using two methods; a) two points method and four points method. Regarding the two points probe method, The samples were printed on different sheets for NH3 and R1 to be tested. The results of surface roughness noted clearly the highest roughness was measured for R1 ink in sheet six.The maximum thickness was recorded for NH3 in sheet

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