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# Capacitance Sensors on Carbon Fibers Paper (CS-CFP)

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**Abstract:- In this article mainly focus on paper based sensors, a paper be made carbon fibers and wood fiber, is electric conduction. So it can make capacitance sensor on carbon fibers paper. This article has analyzed the character of capacitance on carbon fibers paper and with experimental measurements. Results show that capacitance sensors on carbon fibers paper is effective new material used making sensors.**

***Keywords:-*** *Carbon fibers paper, capacitance sensors.*

## I. INTRODUCTION

Paper is a thin material produced by pressing together moist fibres of cellulose pulp derived from wood, rags or grasses, and drying them into flexible sheets.[1] It is a versatile material with many uses, including writing, printing, packaging, cleaning, and a number of industrial and construction processes. No manufactured product plays a more significant role in every area of human activity than paper and paper products. Its importance in everyday life is obvious from its use in recording, storage and dissemination of information.

In the broadest definition, a sensor is a device, module, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor. A sensor is always used with other electronics, whether as simple as a light or as complex as a computer. [2]

Sensors are used in everyday objects such as touch-sensitive elevator buttons (tactile sensor) and lamps which dim or brighten by touching the base, besides innumerable applications of which most people are never aware. With advances in micromachinery and easy-to-use microcontroller platforms, the uses of sensors have expanded beyond the traditional fields of temperature, pressure or flow measurement.[3]

Paper-based sensors are a new alternative technology for fabricating simple, low-cost, portable and disposable analytical devices for many application areas including clinical diagnosis, food quality control and environmental monitoring.[4]The unique properties of paper which allow passive liquid transport and compatibility with chemicals are the main advantages of using paper as a sensing platform. Depending on the main goal to be achieved in paper-based sensors, the fabrication methods and the analysis techniques can be tuned to fulfill the needs of the end-user.

In 1956, the first paper device for the semi-quantitative detection of glucose in urine was demonstrated .[5] Due to the development of paper-based microfluidics in the past few years, paper has become a promising platform for lab-on-a-chip devices in which large-scale and complicated laboratory tests could be performed.[5]

In electrical engineering, capacitive sensing is a technology, based on capacitive coupling, that can detect and measure anything that is conductive or has a dielectric different from air.[6] Many studies from academia and industry have been made in the past decade, over the years, scientists and experts have developed a wide range of technologies.[6] The capacitive sensors are used in a variety of industrial and automotive application. A capacitive sensor converts a change in position, or properties of dielectric material into an electrical signal.[7]

This paper is wand to invent a new material used as capacitance sensors and develop a technology of capacitance sensors on carbon fibers paper, a briefly review of recent advances in paper-based sensors and capacitance sensors, making fourth forms carbon fibers paper, through experiment analyzed the characters of carbon fibers paper used as capacitance sensors, coming true capacitance on carbon fibers paper.

## II. MATERIALS AND METHODS

- *Detecting instrument*
- *DDS signal source*

Wave form: Sine, square wave (duty ratio adjustable), triangular wave, saw tooth wave
Frequency range: 1Hz ~ 20MHz (sine wave), 1Hz ~ 2MHz (others)

- *Power*

Model: HW—120100B1W
Input: AC 100—240, 50/60 Hz, 0.5A
Output: DC 12.0 V, 1.0 A

- *USB TESTER*

Model: GXD-2803
Voltage: DC4-30 V
Current: 0-5.1 A
Support: QC 2.0 & QC3.0

- *Digital Multi-meter*

Model: TASI TA8301
Measuring range:
DC: 200mV----1000V, 20μA----10A
AC: 2V----750V, 20μA----10A
Resistive: 200Ω----20MΩ
Capacitance: 20mF----hFE

- *PC-Oscilloscope*

Model: INSTRUSTAR USD205X
Bandwidth: 60 Mhz
Real Time: 5.8 ns
Attenuation Ratio: 1X & 10X
Input Resistance: 10 MΩ
Input Capacitance: 1X: 70 pF----120Pf

*The main materials*

Block Resistance (BR) is an important characterization of two-dimensional conductive materials, to make capacitance sensors with carbon fiber paper, have made four Block Resistance forms of carbon fibers paper.(Fig. 1) In the study select sized 180x180mm, and given two signal $F_1$ = 100kHz, $F_2$ = 300kHz. The Data of tested those paper as capacitance sensor, shown in the table 1.

| No. | $R_X=R_Y$ (Ω) | BR (Ω/cm$^2$) | F1 100kHz | | F2 300kHz | |
|---|---|---|---|---|---|---|
| | | | C (nf) | AC (V) | C (nf) | AC (V) |
| CFP-1 | 1290 | 3.9<br>81 | 1.051 | 0.292 | 1.081 | 0.143 |
| CFP-2 | 1070 | 3.3<br>02 | 0.410 | 0.095 | 1.194 | 0.075 |
| CFP-3 | 60.6 | 0.1<br>87 | 0.492 | 0.083 | 1.516 | 0.118 |
| CFP-4 | 9510 | 29.<br>35 | 1.233 | 1.468 | 1.519 | 0.086 |

Table 1. Compare to different Block Resistance on Carbon Fiber Papers

Fig 1:- Carbon Fiber Paper

## III. ANALYTICAL MODEL

- *Resistance Touch Panel*

The Resistance Touch Panel is made up two carbon fiber paper, as X-X and Y-Y touch films, and both between in the papers is an isolated layer. It is connected as below the Fig. 2

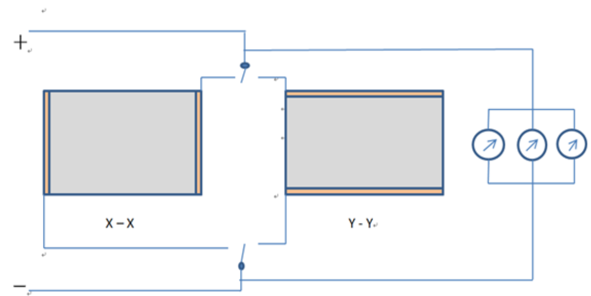
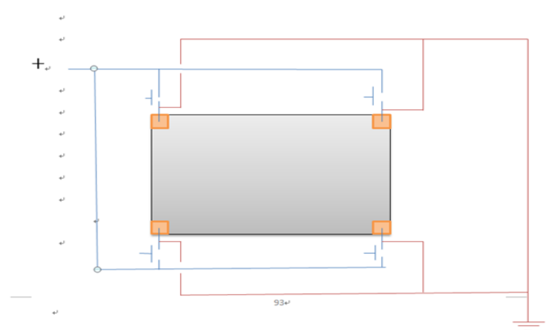



Fig 2:- The Carbon Fiber Paper Resistance Touch Panel is connected

- *Capacitance Touch Panel*

The Capacitance Touch Panel is made in only one carbon fiber paper. It is connect as below Fig. 3




X - X

Fig 3:- The Capacitance Touch Panel is made in only one carbon fiber paper.

- *Vibration Capacitance Sensor*

The Vibration Carbon fiber paper Capacitance Sensor is made up two carbon fiber paper, as vibration films, and both between in the papers is an isolated layer. It is connected as below the Fig. 4

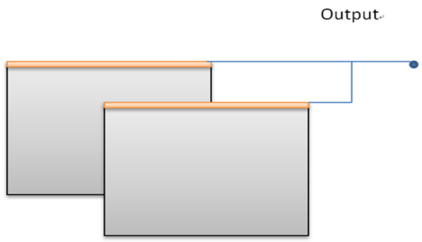



Fig 4:- The Vibration Carbon fiber paper Capacitance Sensor construct

## IV. PRINCIPLE OF CAPACITANCE SENSOR

The simplest form of a capacitor consists of two conductors, e.g. two metal plates, separated by an insulator. The following formula shows the parameters which influence capacitance:

$$C = \varepsilon^* (A/d) \qquad (1)$$

Where $\varepsilon = \varepsilon_0 * \varepsilon_r$
C is the capacitance
A is the area of the plates
d is the distance between the plates

## V. EQUIVALENT CIRCUIT SIMULATION

Multisim is industry-standard SPICE simulation and circuit design software for analog, digital, and power electronics in education and research. In this study use Multisim 13.0 as equivalent circuit simulation. All the forms of capacitance sensors on carbon fibers paper can be seen as two changeable capacitance like Fig. 5.

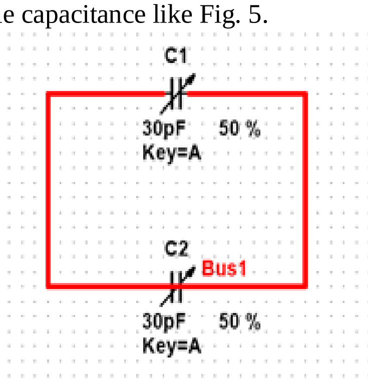



Fig 5:- As two changeable capacitance

1. Equivalent circuit simulation on Four points of Capacitance Touch Sensor

Select to one paper is capacitance to give it a 100kHz signal C = 1.627nF, $l_{x-x} = l_{Y-Y}$ = 140mm. capacitance changing with be touched see the Table 2. Simulation on fore points capacitance touch sensor see Fig. 6.

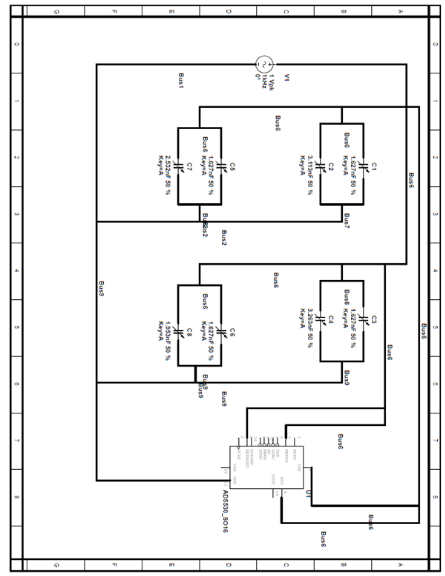


Fig 6:- Simulation on Four points of Capacitance Touch SENSOR

| Capacitance | Touch Points | | | |
|---|---|---|---|---|
| | Point1 | Point1 | Point1 | Point1 |
| Touch Capacitance (nF) | 4.15 | 4.74 | 4.89 | 3.58 |
| Capacitance be Changed (nF) | 2.532 | 3.113 | 3.263 | 1.953 |

Table 2. Capacitance changing with be touched

2. Equivalent circuit simulation on Approximate switch

Select to one paper is capacitance to give it F > 300kHz signal, C = 2.38nF, lx – x = lY – Y = 140mm. capacitance changing with asymptotic capacitance be changed see the Table 3. Simulation on Approximate switch see Fig. 7

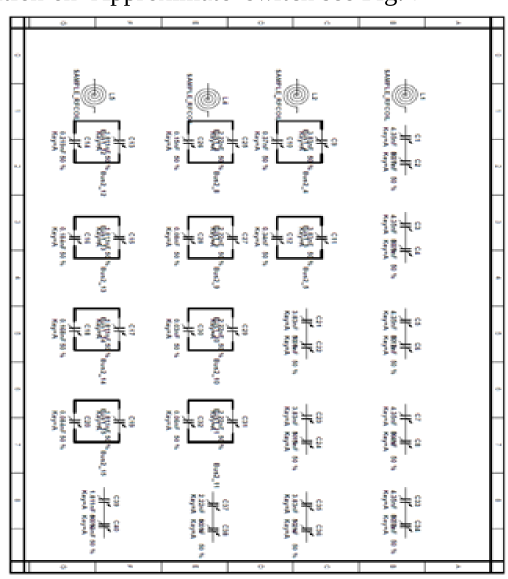


Fig 7:- Simulation on Approximate switch

| Frequency (MHz) | Initial Capacitance (nF) | Distances (mm) | | | | |
|---|---|---|---|---|---|---|
| | | 50 | 100 | 150 | 200 | 250 |
| 300 (kHz) | 1.740 | 2.42 | 2.37 | 2.33 | 2.23 | 1.882 |
| | C Changed (nF) | 0.68 | 0.63 | 0.59 | 0.49 | 0.142 |
| 1.00 | 1.811 | 2.03 | 1.995 | 1.979 | 1.895 | 1.778 |
| | C Changed (nF) | 0.219 | 0.184 | 0.168 | 0.084 | -0.033 |
| 5,00 | 2.22 | 2.37 | 2.30 | 2.28 | 2.28 | 2.19 |
| | C Changed (nF) | 0.15 | 0.08 | 0.03 | 0.06 | -0.03 |
| 10.00 | 2.31 | 2.52 | 2.49 | 2.45 | 2.33 | 2.29 |
| | C Changed (nF) | 0.21 | 0.18 | 0.14 | 0.02 | -0.02 |
| 15.00 | 3.83 | 4.20 | 4.17 | 2.75 | 2.68 | 2.63 |
| | C Changed (nF) | 0.37 | 0.34 | -1.08 | -1/15 | -1.2 |
| 20.00 | 4.35 | 4.28 | 4.26 | 4.23 | 3.95 | 3.83 |
| | C Changed (nF) | -0.07 | -0.09 | -0.12 | -0.4 | -0.52 |

Table 3. Capacitance changing with asymptotic capacitance be changed

3. Equivalent circuit simulation on the filling levels sensor

The data of the filling levels sensor see table 4 and Simulation on the filling level sensor see the Fig. 8

| Water Level(mm) | Capacitance (nF) | Added Capacitance(nF) |
|---|---|---|
| 10 | 0.032 | 0.032 |
| 20 | 0.034 | 0.002 |
| 30 | 0.054 | 0.020 |
| 40 | 0.095 | 0.041 |
| 50 | 0.138 | 0.043 |
| 60 | 0.176 | 0.038 |
| 70 | 0.255 | 0.020 |
| 80 | 0.256 | 0.021 |
| 90 | 0.276 | 0.030 |
| 100 | 0.315 | 0.039 |

Table 4. Water level vs capacitance

Experimental Results

## VI. EXPERIMENT RESULTS

*1. Touch Sensors*

The Resistance Touch Sensor is made up two carbon fiber paper, as X-X and Y-Y touch films, and both between in the papers is an isolated layer. The Capacitance Touch Sensor is made in only one carbon fiber paper. The detection index test with AC and DC 12V. The Resistance and Capacitance touch panel selects a computer keyboard A ---- Z 26 points. (Fig.8 ) and table 5, table 6.

Fig 8:- The Capacitance Touch Panel As Computer Keyboard

| Test Points | Touch Voltage (V) | | | |
|---|---|---|---|---|
| | $V_{Point1}$ – GND | $V_{Point2}$ – GND | $V_{Point3}$– GND | $V_{Point4}$ – GND |
| A | 7.61 | 7.84 | 8.82 | 7.76 |
| B | 7.55 | 7/96 | 9.80 | 8.63 |
| C | 7.86 | 7.66 | 8.45 | 8.65 |
| D | 7.05 | 7.23 | 8.79 | 8.17 |
| E | 7.48 | 7.38 | 7.90 | 7.37 |
| F | 7.60 | 7.30 | 8.75 | 8.86 |
| G | 7.36 | 7.05 | 8.52 | 7.54 |
| H | 7.34 | 7.17 | 8.89 | 7.99 |
| I | 7.50 | 7.69 | 7.87 | 7.11 |
| J | 7.74 | 7.30 | 8.75 | 7.61 |
| K | 7.50 | 7.35 | 9.06 | 7.57 |
| L | 7.57 | 7.50 | 9.63 | 7.27 |
| M | 8.09 | 7.59 | 8.95 | 7.82 |
| N | 8.45 | 7.89 | 9.58 | 7.53 |
| O | 8.51 | 7.14 | 8.68 | 8.07 |

| | | | | |
|---|---|---|---|---|
| P | 7.53 | 7.21 | 9.49 | 7.36 |
| Q | 7.65 | 7.19 | 8.10 | 6.89 |
| R | 7.49 | 6.89 | 9.18 | 7.41 |
| S | 7.82 | 7.00 | 8.38 | 6.93 |
| T | 7.28 | 7.32 | 9.54 | 7.16 |
| U | 7.41 | 7.24 | 8.50 | 7.25 |
| V | 7.46 | 7.67 | 8.31 | 6.79 |
| W | 7.31 | 7.04 | 8.12 | 7.09 |
| X | 7.54 | 7.36 | 8.88 | 7.68 |
| Y | 7.43 | 6.84 | 8.82 | 7.46 |
| Z | 7.64 | 7.32 | 9.92 | 6.70 |

- Non-Touch Resistance $R_{X-X}$ = 823 Ω $R_{Y-Y}$ = 5160 Ω
- Non-Touch Voltage $V_{Spoint1-GND}$ = 8.82 V, $V_{Spoint2-GND}$ = 11.56 V, $V_{Spoint3-GND}$ = 12.25 V, $V_{Spoint4-GND}$ = 9.62 V.
- Non-Touch Current $I_{spoint1-GND}$ = 0.07 mA, $I_{spoint12-GND}$ = 0.02 mA, $I_{spoint13-GND}$ =0.06 mA, $I_{spoint4-GND}$ = 0.05 mA.

Table 5. Detection index of The Resistance Touch Panel as DC

| Test Points | Touch Resistance (Ω) | | Touch Voltage (V) | | Touch Current (mA) | |
|---|---|---|---|---|---|---|
| | $R_{X-X}$ | $R_{Y-Y}$ | $V_{X-X}$ | $V_{Y-Y}$ | $I_{X-X}$ | $I_{Y-Y}$ |
| A | 500 | 470 | 1.10 | 0.89 | 2.17 | 2.96 |
| B | 470 | 600 | 0.80 | 1.70 | 2.10 | 2.71 |
| C | 560 | 530 | 1.15 | 1.85 | 1.39 | 2.60 |
| D | 480 | 460 | 1.06 | 1.37 | 1.76 | 2.41 |
| E | 540 | 470 | 0.92 | 1.00 | 2.12 | 2.52 |
| F | 450 | 440 | 1.16 | 1.50 | 1.43 | 2.43 |
| G | 590 | 560 | 0.83 | 1.87 | 1.76 | 2.75 |
| H | 500 | 520 | 1.17 | 1.41 | 1.13 | 2.43 |
| I | 680 | 680 | 1.21 | 1.83 | 1.59 | 2.72 |
| J | 950 | 1008 | 1.02 | 1.97 | 1.20 | 2,07 |
| K | 500 | 470 | 1.15 | 1.96 | 1.21 | 5.52 |
| L | 480 | 500 | 1.14 | 2.40 | 1.85 | 3.83 |
| M | 420 | 430 | 1.03 | 1.60 | 1.46 | 3.93 |
| N | 460 | 460 | 1.08 | 1.25 | 1.72 | 3.45 |
| O | 550 | 560 | 1.33 | 2.01 | 2.32 | 2.82 |
| P | 420 | 530 | 1.30 | 2.07 | 1.27 | 2.97 |
| Q | 530 | 610 | 1.12 | 1.13 | 2.30 | 2.80 |
| R | 580 | 600 | 1.24 | 1.61 | 1.91 | 2.30 |
| S | 520 | 520 | 1.10 | 1.13 | 1.26 | 2.72 |
| T | 480 | 500 | 1.32 | 1.37 | 1.73 | 2.90 |
| U | 750 | 720 | 1.27 | 1.96 | 1.39 | 1.70 |
| V | 510 | 560 | 0.98 | 1.29 | 1.39 | 1.70 |
| W | 480 | 520 | 1.32 | 1.25 | 2.11 | 2.06 |
| X | 460 | 500 | 0.93 | 1.56 | 1.27 | 2.52 |
| Y | 900 | 720 | 1.12 | 1.89 | 1.23 | 1.96 |
| Z | 490 | 480 | 0.96 | 0.96 | 1.89 | 2.96 |

- Non-Touch Resistance $R_{X-X}$ = 360 Ω $R_{Y-Y}$ = 160 Ω
- Non-Touch Voltage $V_{X-X}$ = 4.03 V $V_{Y-Y}$ = 2.68 V
- Non-Touch Current $I_{X-X}$ = 16.068 mA $I_{Y-Y}$ = 20.5 mA

Table 6. Detection index of The Capacitance Touch Panel as AC

2. *CS - CFP and Data analysis*

- A Floodometer be made two carbon fiber paper, it is a changeable capacitor, when added some water the capacitance changing with water level changed. The data of with changing water level. Water level vs capacitance is linear relation between, see Fig 9

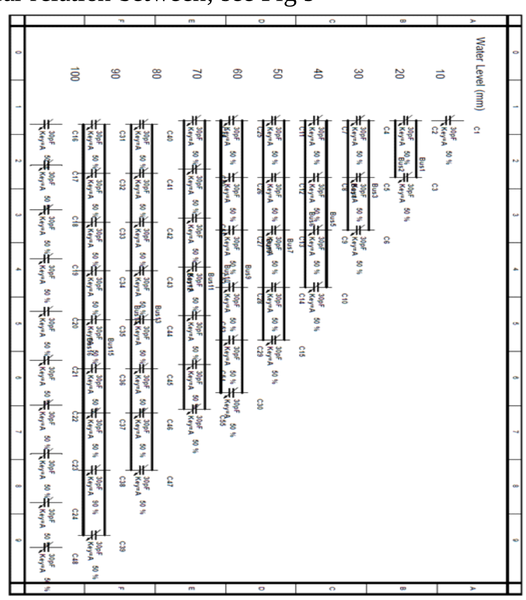



Fig 9:- Simulation on The filling levels sensor

- A Gravimeter be made two carbon fiber paper, between in the two papers with an elastic layer, it is a changeable capacitor,(Fig. 68) when added some things on the

Gravimeter, the capacitance changing with some things changed, the data of with changing some things. Table 7.

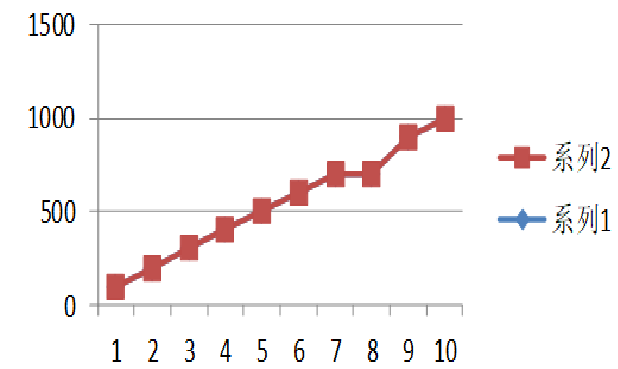



Fig 10:- Water level vs capacitance

The data get from table 4

| Weight (kg) | Capacitance (nF) |
|---|---|
| 1.5 | 0.010 |
| 3.0 | 0.013 |
| 4.5 | 0.016 |
| 6.0 | 0.031 |
| 7.5 | 0.037 |

Table 7. Weight vs capacitance

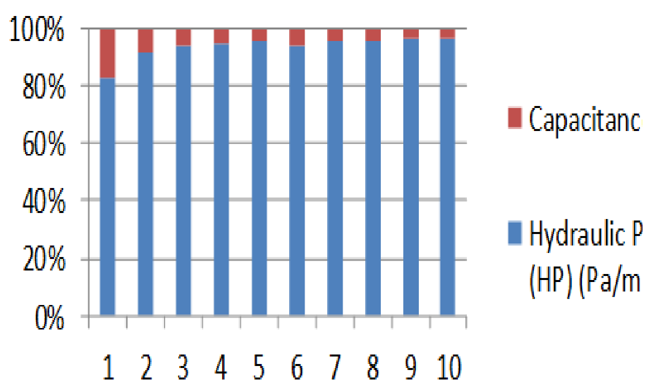



Fig 11:- Hydraulic Pressure Vs Capacitance

From Fig. 11 can see the Water Level vs Capacitance being linear relation.

- A Pressure measuring set be made two carbon fiber paper and between in two paper has a hole paper, it is a changeable capacitor, when added some water the capacitance changing with Hydraulic pressure changed. The data of with changing water Level vs Hydraulic pressure vs Capacitance see table 7 and Fig. 10, Fig 11, Fig 12.

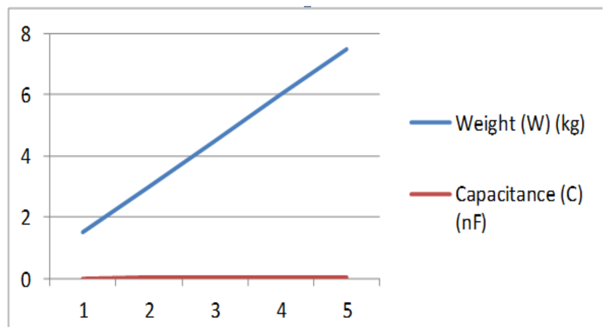



Fig 12:- WEIGHT VS CAPACITANCE

| Depth of water (mm) | Hydrualic ressure (Pa/mm$^{2)}$) | Capacitance (nF) |
|---|---|---|
| 10 | 0.98 | 0.200 |
| 20 | 1.96 | 0.180 |
| 30 | 2.94 | 0.195 |
| 40 | 3.92 | 0.215 |
| 50 | 4.90 | 0.231 |
| 60 | 5.88 | 0.292 |
| 70 | 6.86 | 0.315 |
| 80 | 7.63 | 0.356 |
| 90 | 8.82 | 0. 366 |
| 100 | 9.80 | 0.376 |

Table 8. depth of water vs Hydraulic pressure vs capacitance

- $HP = 9.8*10^{-3}*WL$ Pa/mm$^2$

From Fig. 11 can see the hydraulic pressure and capacitance being linear relation.

$k = (8.82 – 6.86) / (0.356 – 0.312) = 47.80487805$ (2)

So,

$HP = k * C = 47.80487805 * C$ (3)

Like Fig. 13.

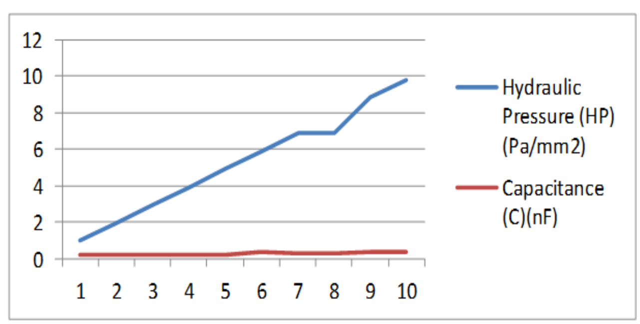



Fig 13:- Hydraulic Pressure Vs Capacitance

## VII. DISCUSSION

Although paper-based sensors are very promising, they still suffer from certain limitations such as accuracy and sensitivity.

As carbon fiber papers are used making touch sensors, the carbon fiber paper need improved characteristics, such as light transmittance, touch resistance, temperature resistance and water resistance.

It can use Carbon fiber- Kevlar fiber paper technology, Carbon fiber Silicone oil paper technology, Carbon fiber parchment paper technology and Non-woven fabrics technology.

## VIII. CONCLUSIONS

The newest researches are.

- *American is building new sensors based on paper:*

Touch paper was developed by researchers at Carnegie Mellon University, and the video demo was released, detailing how the paper works. (Fig. 15) The paper tracks writing notes and automatically converts them into digital signals. The system includes conductive film and a carbon - carrying coating for paper. The end result is a paper that detects touch through fingers and writing tools, which can change the process of digitizing handwritten content and look like ordinary paper. [12]

- *Britain is building new sensors based on graphene:*

Recently, at the university of Exeter in England engineers have developed a new production method, directly on the copper substrate build complete equipment series, which used in the commercial production of graphene, after that, a complete and fully functioning device can be transferred to choose a good substrate. This will greatly promote the development of the graphene market, open the great potential of graphene application, graphene-driven industrial revolution may become a reality. [13]

- *Flexible wearable electronic sensors:*

So researchers have devoted themselves to developing new materials, new technologies and new sensors .Realize sensor integration and intelligence; Realize the miniaturization of hardware system and components of sensor technology. Sensors that intersect with other disciplines. At the same time, it is hoped that the sensor can be transparent, flexible, extended, freely bent or even folded, portable and wearable. Along with the development of flexible matrix materials, flexible sensors that meet the above trend characteristics emerge on this basis.[14]

These researches, as two dimensional conductive materials, are gaps:

- The first research's system includes conductive film and a carbon - carrying coating for paper. The carbon - carrying coating made with printing technology by Carbon fiber conductive ink. The problem is electrical instability.
- The traditional method of making sensors from graphene is time-consuming, complex and expensive, involving many technological steps, including graphene growth, membrane transfer, lithography and metal contact deposition.
- The third method of making sensor used Textile technology or graphene technology, or print technology, the questions of the third method is as same as the first and the second.

Especially, those methods are difficult to achieve big area sensor, but the carbon fibers paper achieve this very easy. Such as 10000m$^2$ or than larger. This technology can solve sensor used smart city, example a sensor on carbon fibers paper is buried road, what a road smart.

## IX. ACKNOWLEDGMENTS

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Conflicts of Interest: "The authors declare no conflict of interest."

## REFERENCES

[1]. Ajit K Ghosh, 'Fundamentals of Paper Drying – Theory and Application from Industrial Perspective', Principal, AKG Process Consulting, 33 McFarlane Court, Highett, Australia.

[2]. Sensor, From Wikipedia, the free encyclopedia, https://en.wikipedia.org/wiki/Sensor.

[3]. Bennett, S. (1993). A History of Control Engineering 1930–1955. London: Peter Peregrinus Ltd. on behalf of the Institution of Electrical Engineers. ISBN 0-86341-280-7<The source states "controls" rather than "sensors", so its applicability is assumed. Many Nonits are derived from the basic measurements to which it refers, such as a liquid's level measured by a differential pressure sensor.>

[4]. Devi D. Liana 1,2, Burkhard Raguse 1, J. Justin Gooding 2 and Edith Chow 1 'Recent Advances in Paper-Based Sensors' Sensors 2012, 12, 11505-11526; doi:10.3390/s120911505.

[5]. Comer, J. Semiquantitative specific test paper for glucose in urine. Anal. Chem. 1956, 28, 1748–1750.

[6]. 'Capacitive sensing', From Wikipedia, https://en.wikipedia.org/wiki/Capacitive_sensing.

[7]. Zhibin Han, Yishou Wang * and Xinlin Qing, 'Characteristics Study of In-Situ Capacitive Sensor for Monitoring Lubrication Oil Debris', Received: 25

October 2017; Accepted: 5 December 2017; Published: 8 December 2017.
[8]. Brajesh Kumar , G Rajita, Nirupama Mandal, 'A Review on Capacitive-Type Sensor for Measurement of Height of Liquid Level', Volume: 47 issue: 7, page(s): 219-224 Article first published online: September 5, 2014; Issue published: September 1, 2014.
[9]. http://digi.tech.qq.com/a/20180428/017099.htm.
[10]. 'Britain is building new sensors based on graphene' http://www.szcwtech.com/new/hy/244.html.
[11]. 'Three key parts of flexible wearable electronic sensor are briefly discussed', http://www.elecfans.com/article/88/142/2018/20180506673024.html.
[12]. http://digi.tech.qq.com/a/20180428/017099.htm.
[13]. 'Britain is building new sensors based on graphene', http://www.szcwtech.com/new/hy/244.html.
[14]. 'Three key parts of flexible wearable electronic sensor are briefly discussed', http://www.elecfans.com/article/88/142/2018/20180506673024.html.