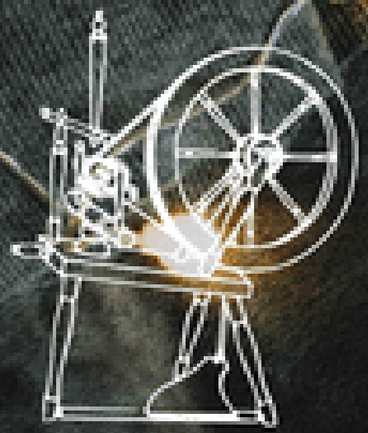
# UNDERSTANDING THE CONDUCTING PROPERTIES OF YARN ALONG WITH IT'S APPLICATION



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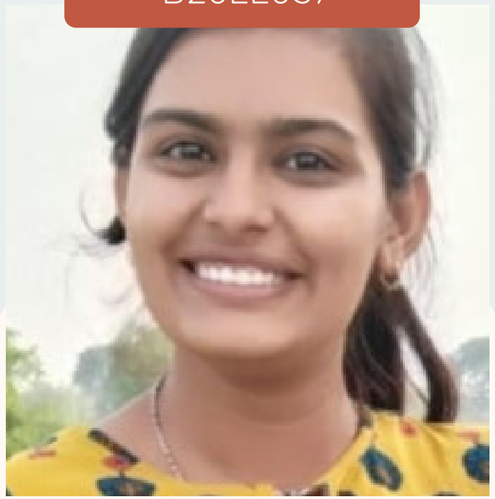

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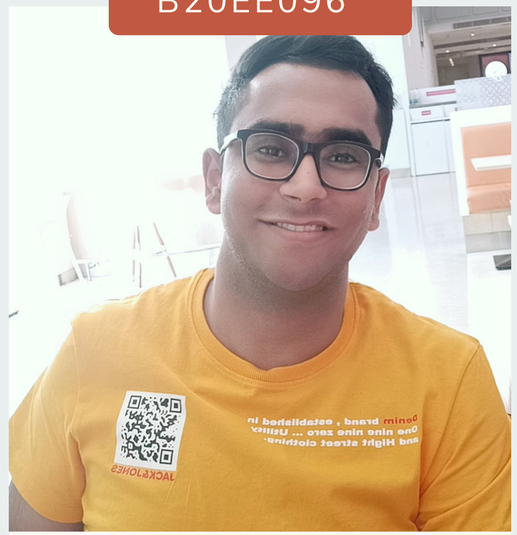


**MITARTH ARORA**

# CONTENT AHEAD

- Understanding the Properties of Conducting Yarns
- Experimental Data Collection and it's Analysis
- Exploration of such yarns for various applications

# INTRODUCTION

- The discipline of e-fabrics combines the power of electronics with the flexibility of textiles to create unique products. Power, networking, and communication are all enabled by the use of conductive yarns and fibers.

- The conductive qualities of the composite yarn depend on the kind of cover yarns chosen to wrap around the core. One or both of the cover yarns may be conductors. A stretchy conductive yarn should be resilient to repeated stretching and washing.

- We have done out a detailed study of yarns , it's various important properties and most importantly proceeded out towards it's real life applications.

# What are conducting yarns?

Conducting yarn is an organic conductive fiber made of stainless steel fiber or other conductive fiber blended with ordinary fiber. It must be conductive and must be machine sewable.

# TYPES OF YARN USED

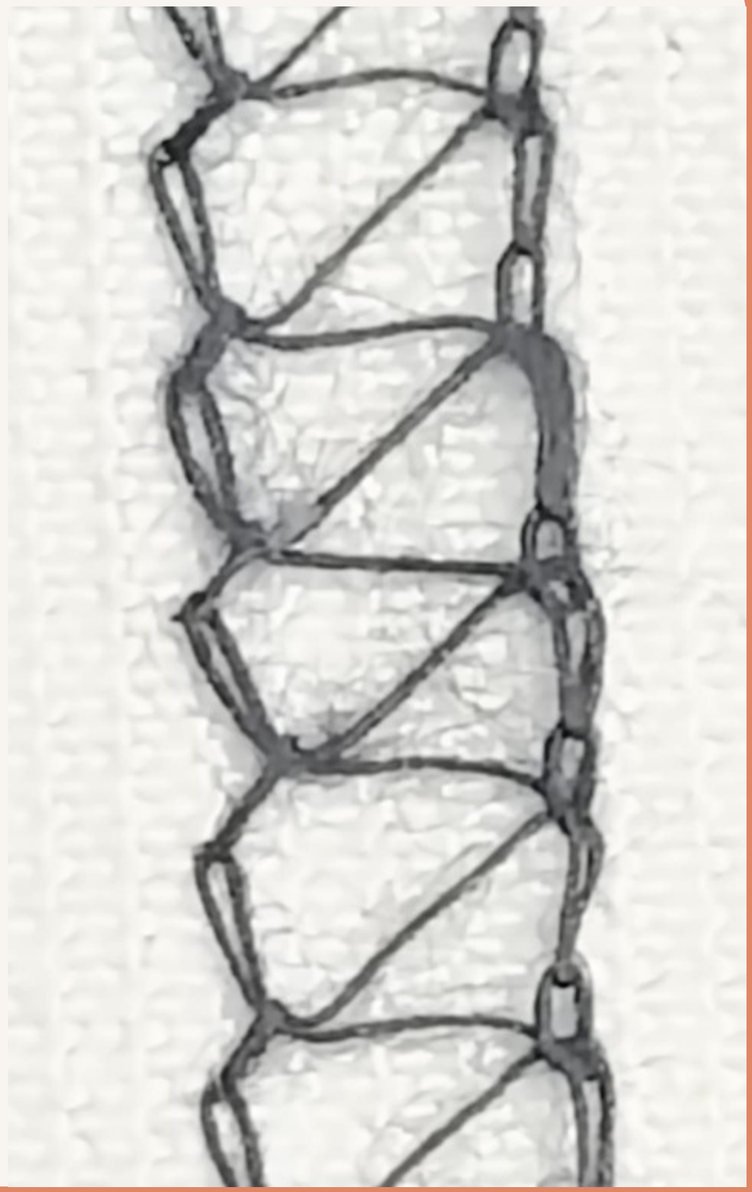
- **Blended Steel Yarn**

20% blended steel uniformly mixed up with 80% polyester

- **Tungsten Core Yarn**

13 um radius tungsten core with polyester(polyamide+p-Aramide) on outer layer

**Specifications -33 tex**



# Properties studied and results

## PHYSICAL

- LOW WEIGHT
- FLEXIBILITY
- STRENGTH
- DURABILITY

## ELECTRICAL

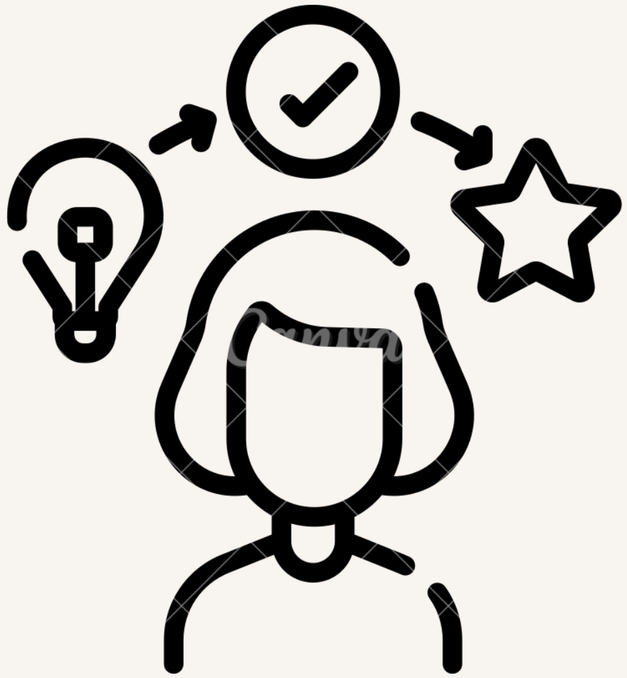
- RESISTANCE WITH VARIANCE IN LENGTH
- RESISTANCE WITH DIFFERENT NO. OF STRANDS
- CAPACITANCE

## MECHANICAL

- TENSILE STRENGTH
- THERMAL COEFFICIENT OF RESISTANCE
- BREAKING ELONGATION

# Experimental Data and Analysis

Following Experiments were being carried out in CASE and Basic Lab Building:



- UTM Based
- TCR Based
- Source Meter
- Probe Station
- Microscopy
- Knotting Patterns
- Weaving Patterns
- Dielectrics

# UTM (Universal Testing Machine)

- UTM was used to test the yarn breakdown point based on its mechanical properties, as well as its elongation was measured(shown in table below) and breakdown point helped us to understand the extent to which yarns can be stretched while stitching and weaving.

Table.1 a) Breakdown point of type 1 yarn (with outer polyester layer) b)Breakdown point of type 2 yarn(blended steel yarn)

a)

| Number of strands | 2 |
|---|---|
| Length | 2.5 cm |
| Elonagtion (mm) | Load(Kgf) |
| 0 | 0 |
| 0.1 | 0.1 |
| 0.291 | 0.3 |
| 0.575 | 0.39 |
| 0.591 | 0.39 |
| 0.798 | 0.39 |
| 1.48 | 0.705 |
| 1.779 | 0.705 |
| 1.986 | 0.795 |
| 2.194 | 0.795 |
| 2.5 | 0.9 |
| 2.7 | 0.6 |
| 2.807 | 0 |

b)

| Number of strands | 2 |
|---|---|
| Length | 5 cm |
| Elongation (mm) | Load(Kgf) |
| 0 | 0 |
| 0.1 | 0.1 |
| 0.277 | 0.1 |
| 0.476 | 0.188 |
| 0.675 | 0.188 |
| 0.978 | 0.3 |
| 1.687 | 0.293 |
| 1.886 | 0.398 |
| 2.189 | 0.39 |
| 2.39 | 0.5 |
| 2.9 | 0.5 |
| 3.1 | 0.6 |
| 3.3 | 0.6 |
| 3.6 | 0.5 |
| 3.79 | 0 |

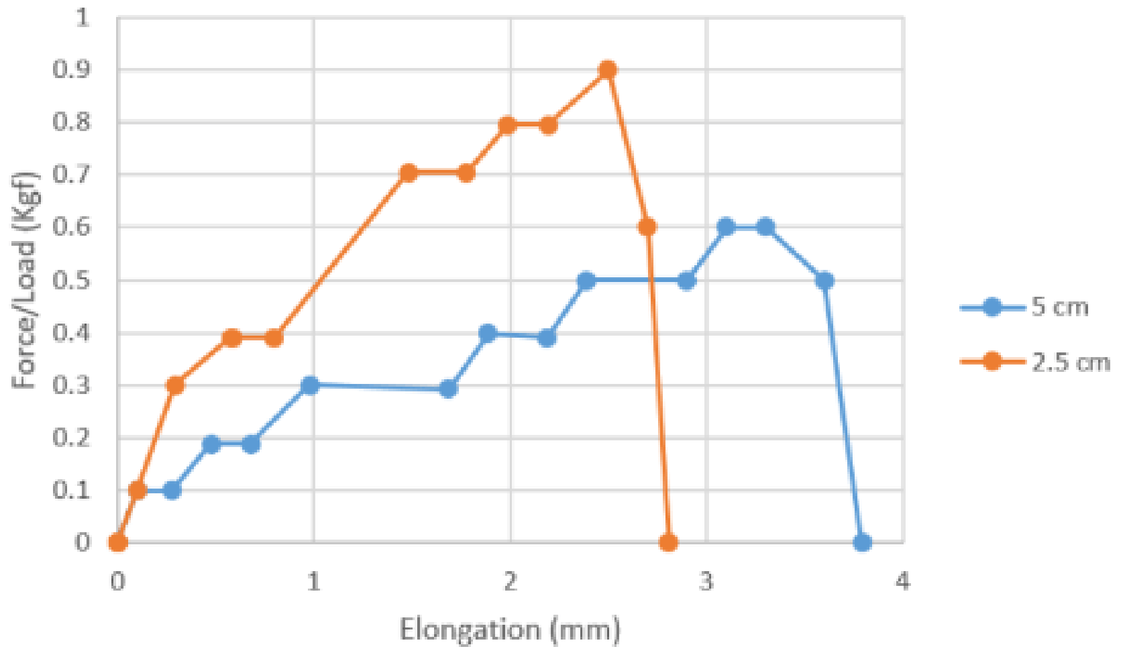



Fig.1 Plot of elongation vs load for the yarn type 1(orange curve) and type 2(blue curve)

# TCR (Temperature Coefficient of Resistance)

- TCR Machine was used in this experiment to get the Voltage-Current Graph at different temperatures for the blended steel yarn (type 2) to calculate the thermal coefficient of resistance as shown in data in the slides shown up next.

$$R = R_{ref}\,[1 + \alpha(T - T_{ref})]$$

*Where,*

$R$ = Conductor resistance at temperature "T"

$R_{ref}$ = Conductor resistance at reference temperature $T_{ref}$, usually 20°C, but sometimes 0°C.

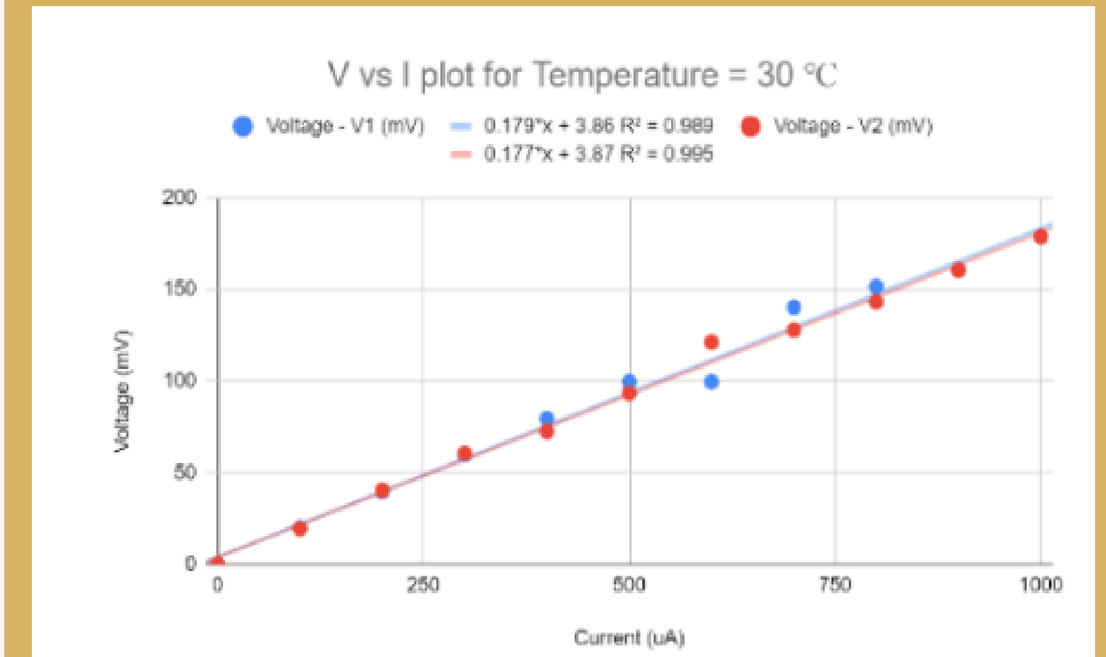
$\alpha$ = Temperature coefficient of resistance for conductor material.

$T$ = Conductor temperature in degrees Celcius.

$T_{ref}$ = Reference temperature that α is specified at for the conductor material

# Resistance and voltage of the conducting yarn with different current passed at temperature 30 degree Celsius

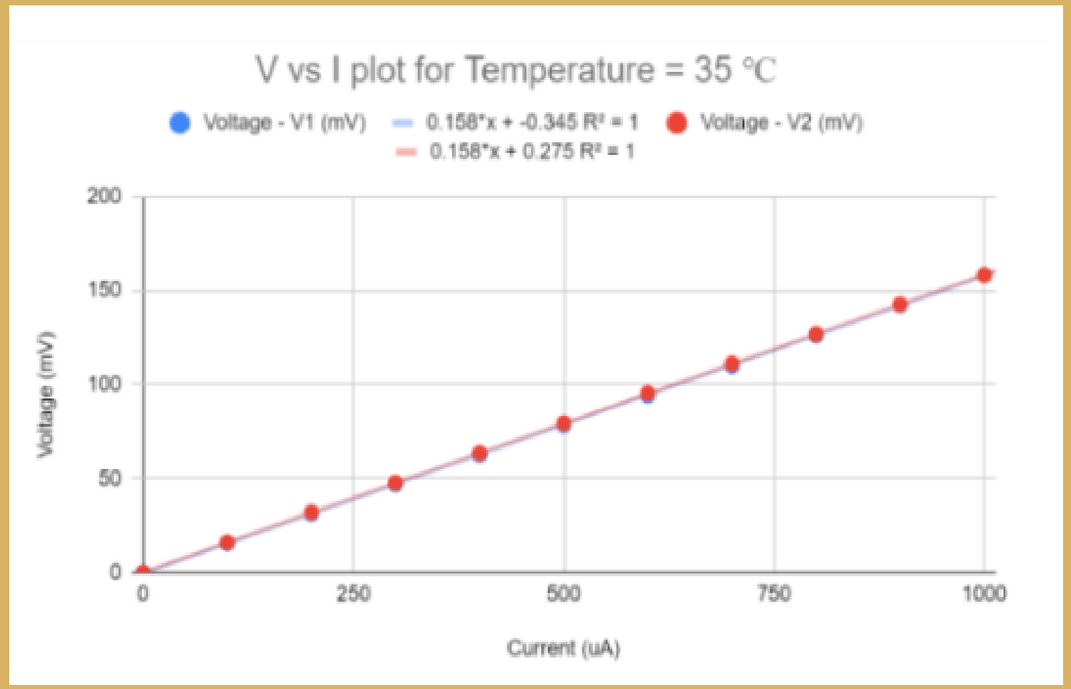
| Temperature = 30 ℃ | | | | |
|---|---|---|---|---|
| Current (uA) | Voltage - V1 (mV) | Voltage - V2 (mV) | Average Voltage (mV) | Resistance ( Ω ) |
| 0 | 0 | 0 | 0 | |
| 100 | 19.9 | 19.45 | 19.675 | 196.75 |
| 200 | 39.8 | 40.31 | 40.055 | 203.8 |
| 300 | 59.7 | 60.51 | 60.105 | 200.5 |
| 400 | 79.5 | 72.5 | 76 | 158.95 |
| 500 | 99.54 | 93.33 | 96.435 | 204.35 |
| 600 | 99.5 | 121.2 | 110.35 | 139.15 |
| 700 | 140.29 | 127.75 | 134.02 | 236.7 |
| 800 | 151.59 | 143.16 | 147.375 | 133.55 |
| 900 | 160.78 | 160.54 | 160.66 | 132.85 |
| 1000 | 178.77 | 178.77 | 178.77 | 181.1 |
| | | | | |
| | | | Average resitance = | 178.7700000000 |
| | | | Resistance from linear regression = | 178 |




Plotting the voltage-current graph and finding a linear relation using linear regression

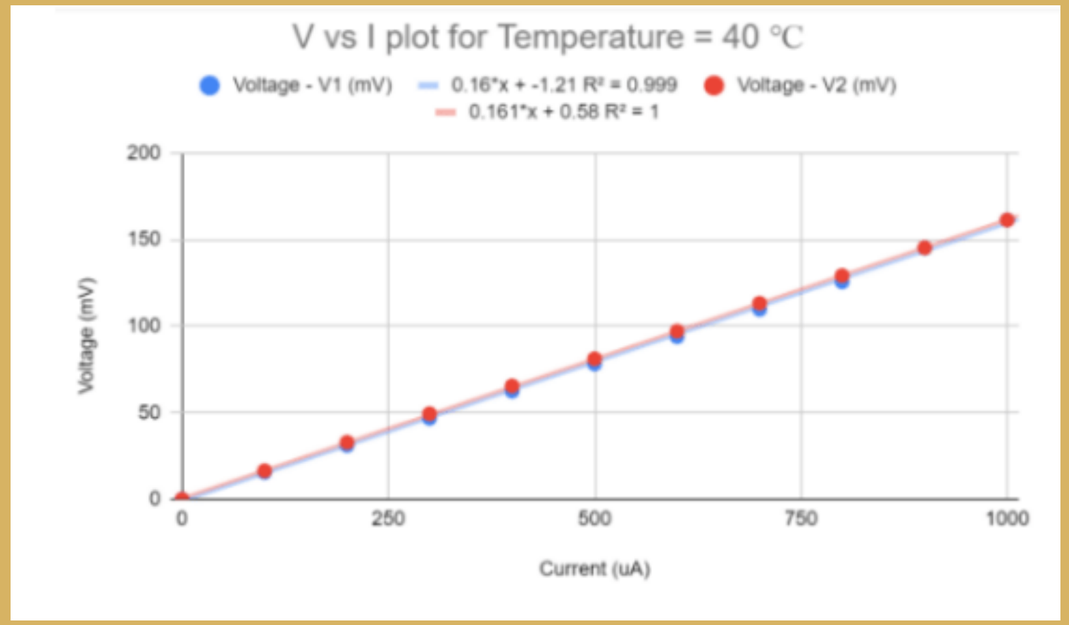
# Resistance and voltage of the conducting yarn with different current passed at temperature 35 degree Celsius

| Temperature = 35 °C | | | | |
|---|---|---|---|---|
| Current (uA) | Voltage - V1 (mV) | Voltage - V2 (mV) | Average Voltage (mV) | Resistance ( Ω ) |
| 0 | 0 | 0 | 0 | |
| 100 | 15.62 | 16 | 15.81 | 158.1 |
| 200 | 31.3 | 32.1 | 31.7 | 158.9 |
| 300 | 46.97 | 47.71 | 47.34 | 156.4 |
| 400 | 62.67 | 63.56 | 63.115 | 157.75 |
| 500 | 78.44 | 79.45 | 78.945 | 158.3 |
| 600 | 94.18 | 95.37 | 94.775 | 158.3 |
| 700 | 109.82 | 111.1 | 110.46 | 156.85 |
| 800 | 126.02 | 126.72 | 126.37 | 159.1 |
| 900 | 142.15 | 142.54 | 142.345 | 159.75 |
| 1000 | 158.15 | 158.15 | 158.15 | 158.05 |
| | | | | |
| | | | Average resitance = | 158.15 |
| | | | Resistance from linear regression = | 158 |



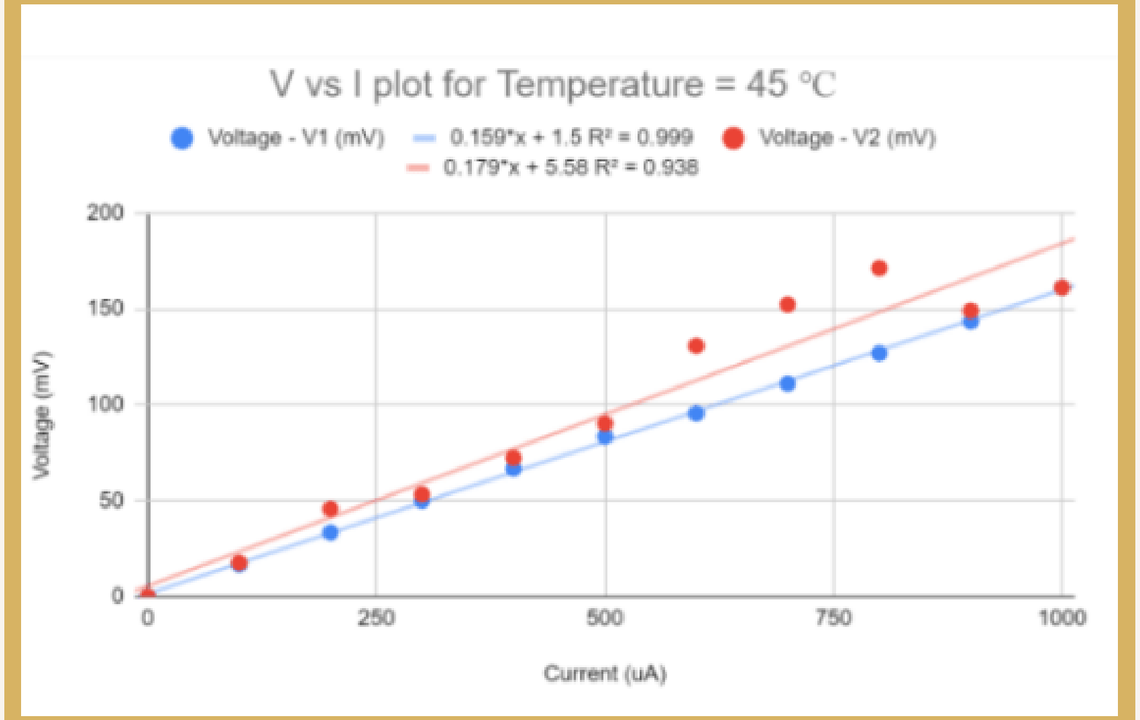
# Resistance and voltage of the conducting yarn with different current passed at temperature 40 degree Celsius

| Temperature = 40 °C | | | | |
|---|---|---|---|---|
| Current (uA) | Voltage - V1 (mV) | Voltage - V2 (mV) | Average Voltage (mV) | Resistance ( Ω ) |
| 0 | 0 | 0 | 0 | |
| 100 | 15.51 | 16.46 | 15.985 | 159.85 |
| 200 | 31.1 | 32.88 | 31.99 | 160.05 |
| 300 | 46.75 | 49.4 | 48.075 | 160.85 |
| 400 | 62.45 | 65.45 | 63.95 | 158.75 |
| 500 | 78.16 | 81.13 | 79.645 | 156.95 |
| 600 | 93.88 | 97.06 | 95.47 | 158.25 |
| 700 | 109.67 | 113.2 | 111.435 | 159.65 |
| 800 | 125.6 | 129.18 | 127.39 | 159.55 |
| 900 | 145.06 | 145.29 | 145.175 | 177.85 |
| 1000 | 161.3 | 161.3 | 161.3 | 161.25 |
| | | | | |
| | | | Average resitance = | 161.30 |
| | | | Resistance from linear regression = | 160.5 |



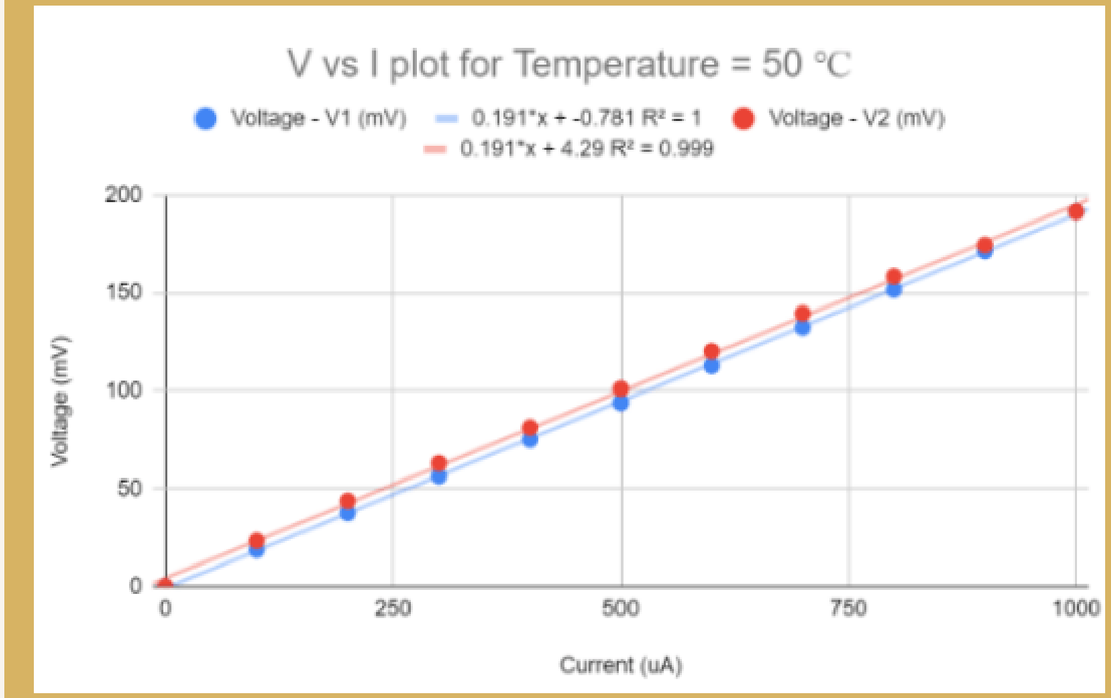
# Resistance and voltage of the conducting yarn with different current passed at temperature 45 degree Celsius

| Temperature = 45 °C | | | | |
|---|---|---|---|---|
| Current (uA) | Voltage - V1 (mV) | Voltage - V2 (mV) | Average Voltage (mV) | Resistance ( Ω ) |
| 0 | 0 | 0 | 0 | |
| 100 | 16.68 | 17.64 | 17.16 | 171.6 |
| 200 | 33.38 | 45.68 | 39.53 | 223.7 |
| 300 | 50.1 | 53.28 | 51.69 | 121.6 |
| 400 | 66.8 | 72.29 | 69.545 | 178.55 |
| 500 | 83.48 | 90.23 | 86.855 | 173.1 |
| 600 | 95.46 | 130.77 | 113.115 | 262.6 |
| 700 | 111.07 | 152.3 | 131.685 | 185.7 |
| 800 | 126.82 | 171.2 | 149.01 | 173.25 |
| 900 | 143.45 | 149.01 | 146.23 | 27.8 |
| 1000 | 161.14 | 161.14 | 161.14 | 149.1 |
| | | | | |
| | | | Average resitance = | 166.70 |
| | | | Resistance from linear regression = | 169 |



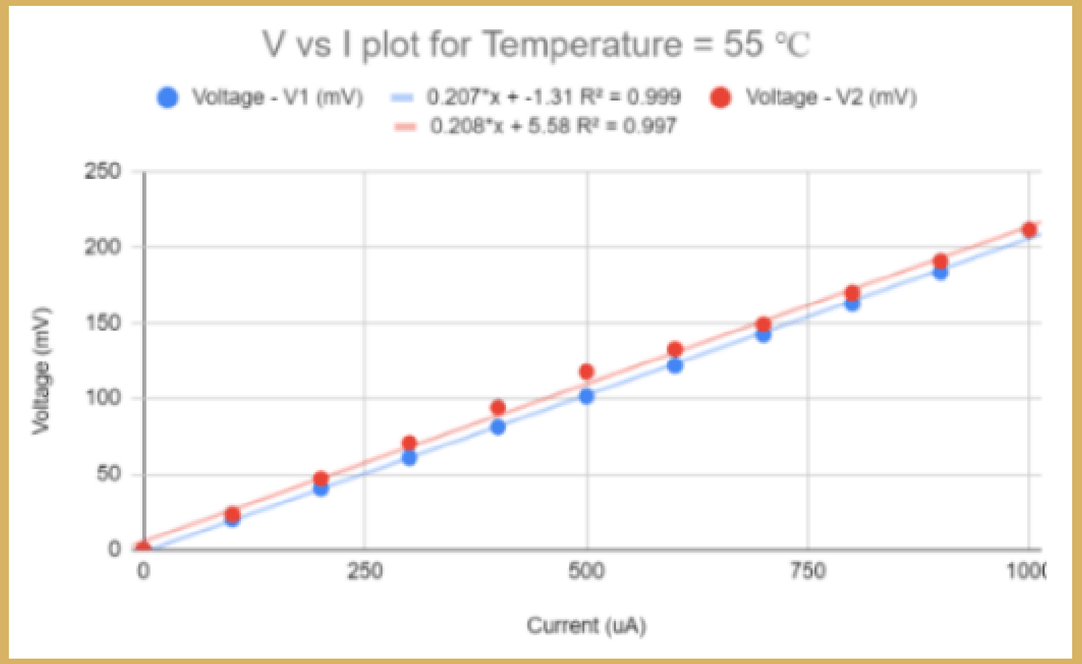
# Resistance and voltage of the conducting yarn with different current passed at temperature 50 degree Celsius

| Temperature = 50 °C | | | | |
|---|---|---|---|---|
| Current (uA) | Voltage - V1 (mV) | Voltage - V2 (mV) | Average Voltage (mV) | Resistance ( Ω ) |
| 0 | 0 | 0 | 0 | |
| 100 | 18.79 | 23.34 | 21.065 | 210.65 |
| 200 | 37.59 | 43.76 | 40.675 | 196.1 |
| 300 | 56.41 | 62.97 | 59.69 | 190.15 |
| 400 | 75.11 | 81.2 | 78.155 | 184.65 |
| 500 | 93.84 | 101 | 97.42 | 192.65 |
| 600 | 112.79 | 120.21 | 116.5 | 190.8 |
| 700 | 132.39 | 139.53 | 135.96 | 194.6 |
| 800 | 151.69 | 158.37 | 155.03 | 190.7 |
| 900 | 171.47 | 174.54 | 173.005 | 179.75 |
| 1000 | 191.56 | 191.56 | 191.56 | 185.55 |
| | | | | |
| | | | Average resitance = | 191.56 |
| | | | Resistance from linear regression = | 191 |



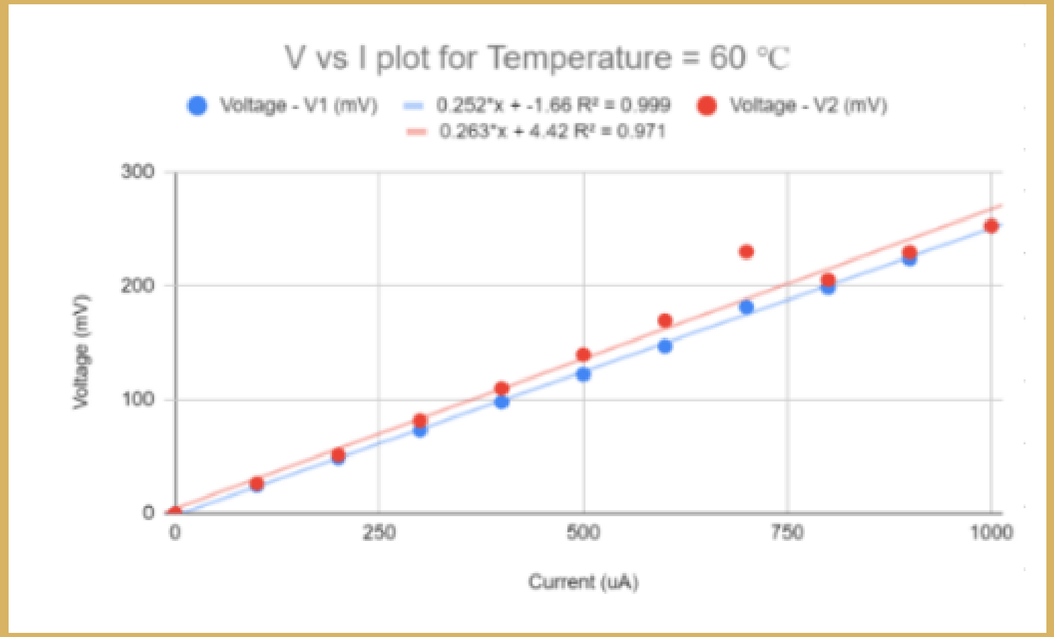
# Resistance and voltage of the conducting yarn with different current passed at temperature 55 degree Celsius

| Temperature = 55 °C | | | | |
|---|---|---|---|---|
| Current (uA) | Voltage - V1 (mV) | Voltage - V2 (mV) | Average Voltage (mV) | Resistance ( Ω ) |
| 0 | 0 | 0 | 0 | |
| 100 | 20.24 | 23.49 | 21.865 | 218.65 |
| 200 | 40.49 | 46.98 | 43.735 | 218.7 |
| 300 | 60.78 | 70.47 | 65.625 | 218.9 |
| 400 | 81.01 | 94 | 87.505 | 218.8 |
| 500 | 101.32 | 117.53 | 109.425 | 219.2 |
| 600 | 121.63 | 132.45 | 127.04 | 176.15 |
| 700 | 142.05 | 148.84 | 145.445 | 184.05 |
| 800 | 162.51 | 169.66 | 166.085 | 206.4 |
| 900 | 183.25 | 190.54 | 186.895 | 208.1 |
| 1000 | 211.37 | 211.27 | 211.32 | 244.25 |
| | | | | |
| | | | Average resitance = | 211.32 |
| | | | Resistance from linear regression = | 207.5 |



# Resistance and voltage of the conducting yarn with different current passed at temperature 60 degree Celsius

| Temperature = 60 °C | | | | |
|---|---|---|---|---|
| Current (uA) | Voltage - V1 (mV) | Voltage - V2 (mV) | Average Voltage (mV) | Resistance Ω ) |
| 0 | 0 | 0 | 0 | |
| 100 | 24.42 | 26.24 | 25.33 | 253.3 |
| 200 | 48.77 | 51.57 | 50.17 | 248.4 |
| 300 | 73.17 | 81.47 | 77.32 | 271.5 |
| 400 | 97.75 | 109.92 | 103.835 | 265.15 |
| 500 | 122.25 | 139.49 | 130.87 | 270.35 |
| 600 | 146.97 | 169.58 | 158.275 | 274.05 |
| 700 | 181.55 | 229.94 | 205.745 | 474.7 |
| 800 | 198.3 | 205.12 | 201.71 | 40.35 |
| 900 | 223.87 | 229.47 | 226.67 | 249.6 |
| 1000 | 252.72 | 252.72 | 252.72 | 260.5 |
| | | | | |
| | | | Average resitance = | 260.79 |
| | | | Resistance from linear regression = | 257.5 |



# Thermal coefficient of resistance for the different temperatures and the average TCR for the yarn

| T1(celsius) | T2(celsius) | R1(ohm) | R2(ohm) | TCR(ppm/celsius) X( 10 |
|---|---|---|---|---|
| 35 | 40 | 158 | 160.5 | 0.3 |
| 40 | 45 | 160.5 | 169 | 1.05 |
| 45 | 50 | 169 | 191 | 2.6 |
| 50 | 55 | 191 | 207.5 | 1.72 |
| 55 | 60 | 207.5 | 257.5 | 4.8 |
| 30 | 60 | 178 | 257.5 | 1.4 |
| | | | avg.TCR | 1.978333 |
| | | | | |

# Source Meter

- Using the Source Meter , we calculated out the values of change in Resistance vs Number of strands over a particular sweep voltage and current for the fixed particular lengths to get an overview of strand based study.

Table.10 Results obtained from testing on source meter

| Sl no | Current (uA) | Voltage -1 (V11) | Reverse -1 (V12) | Voltage-2(V21) | Reverse-2 (V22) | Resistance per unit length (Ohm / cm) from V21 | Resistance per unit length (Ohm / cm) from V22 | Mean |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | | | |
| 1 | 100 | 1.7 | 0.6 | 0.6 | 0.44 | 1000 | 733.3333333 | 866.6666667 |
| 2 | 200 | 2 | 0.8 | 1.14 | 0.86 | 900 | 700 | 800 |
| 3 | 300 | 2.7 | 1.1 | 1.32 | 1.28 | 300 | 700 | 500 |
| 4 | 400 | 3.2 | 1.5 | 1.73 | 1.51 | 683.3333333 | 383.3333333 | 533.3333333 |
| 5 | 500 | 3.5 | 1.9 | 2.25 | 1.89 | 866.6666667 | 633.3333333 | 750 |
| 6 | 600 | 3.4 | 2.2 | 2.8 | 2.29 | 916.6666667 | 666.6666667 | 791.6666667 |
| 7 | 700 | 3.4 | 2.6 | 3.2 | 2.71 | 666.6666667 | 700 | 683.3333333 |
| 8 | 800 | 3.4 | 3 | 3.7 | 3.16 | 833.3333333 | 750 | 791.6666667 |
| 9 | 900 | 3.9 | 3.5 | 4 | 3.63 | 500 | 783.3333333 | 641.6666667 |
| 10 | 1000 | 4.1 | 4.1 | 4.2 | 4.2 | 333.3333333 | 950 | 641.6666667 |

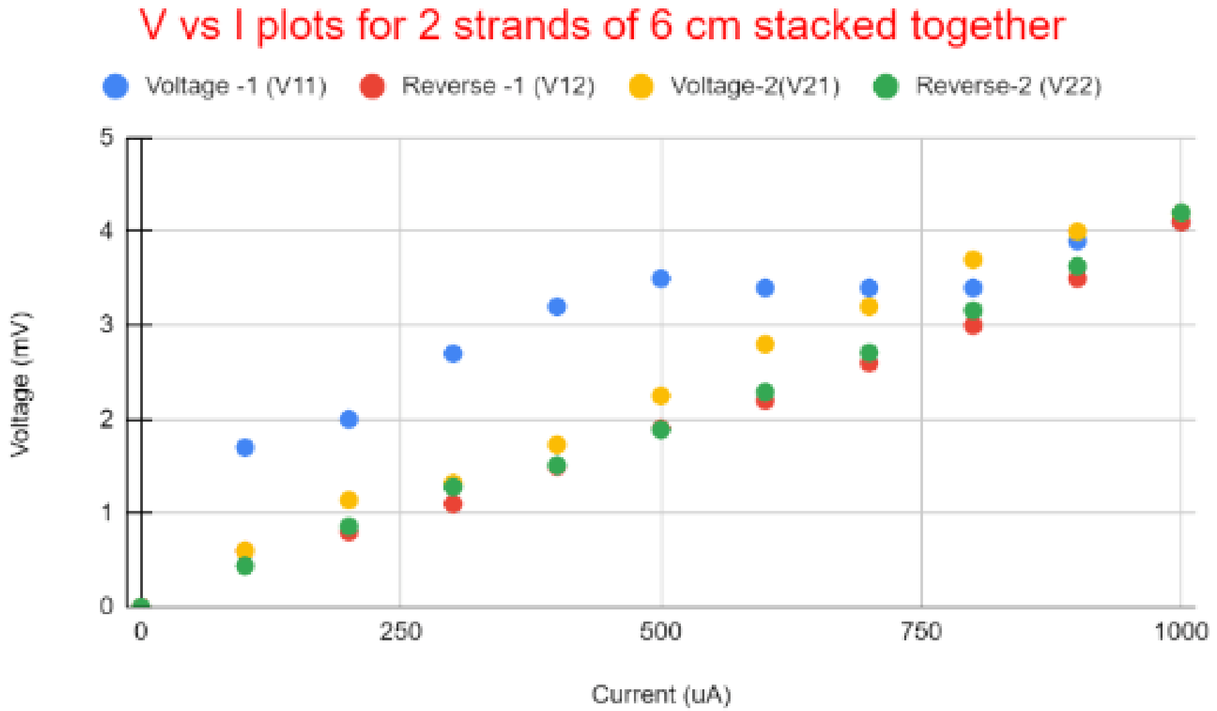



Fig.9Plotting the voltage-current graph of the results obtained from source meter

# Resistance vs weight-Probe Station

- We proceeded on the experimental set-up shown below using Probe Station to calculate the Resistance vs Weight to see how the increase of load is impacting our resistance of the conducting wire.

Table.11 Change in resistance with the weight applied

| weight | resistance(10^3 ohm) |
|---|---|
| 11 | 1030 |
| 22.9 | 736.25 |
| 34.8 | 705.64 |
| 46.7 | 439.29 |
| 58.6 | 405.4 |
| 70.5 | 368.43 |
| 82.4 | 349.73 |
| 94.3 | 343.84 |
| 106.2 | 367.78 |
| 118.1 | 353.21 |
| 130 | 394.65 |
| 141.9 | 405.1 |
| 153.8 | 412.08 |

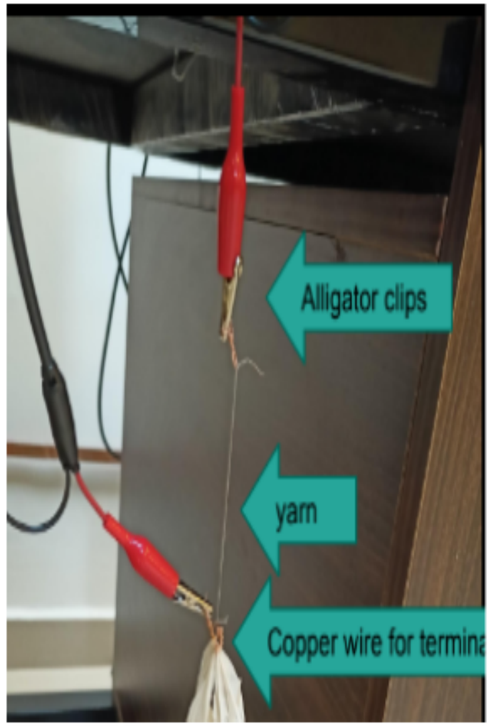



Fig.10 The setup for the experiment

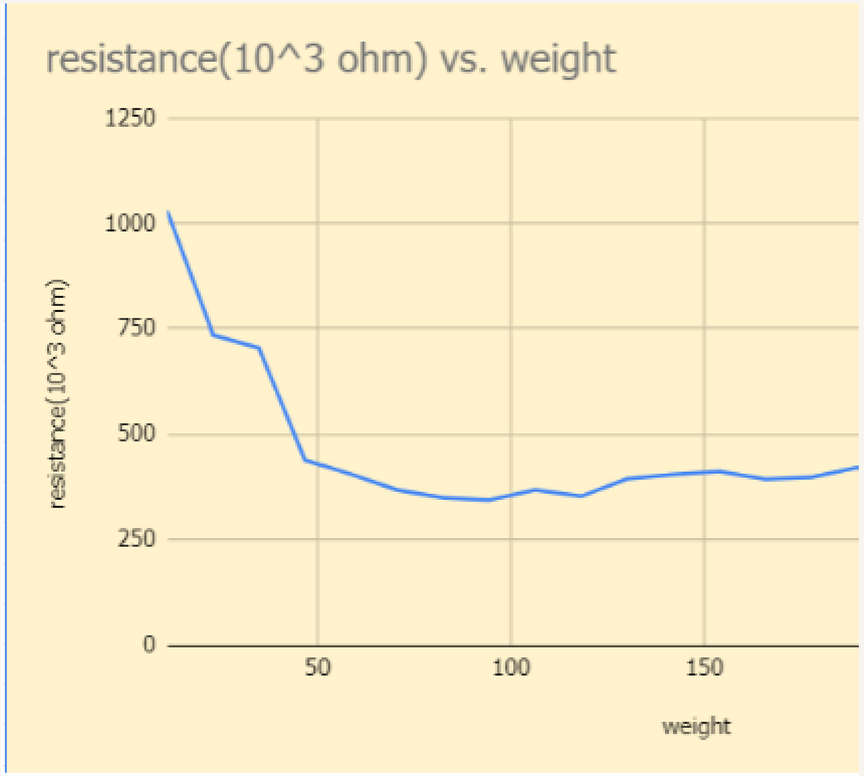
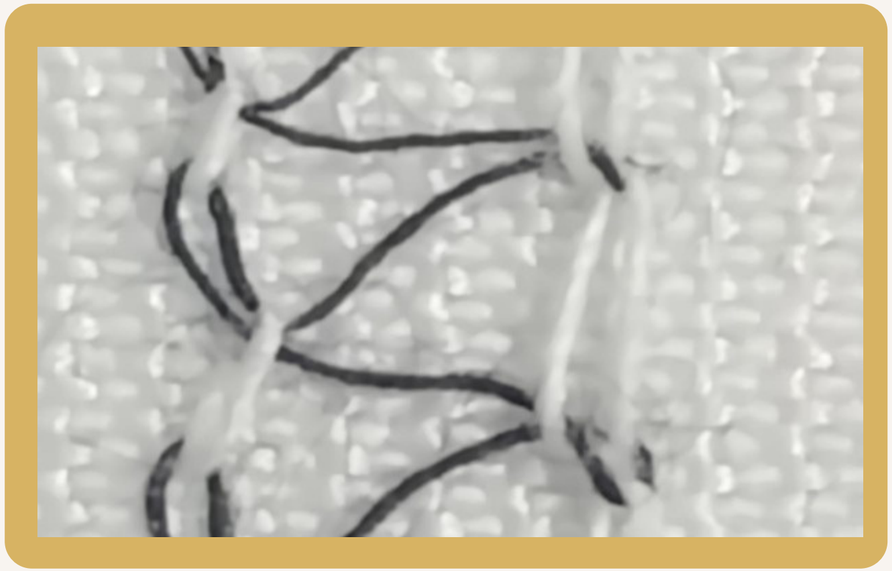
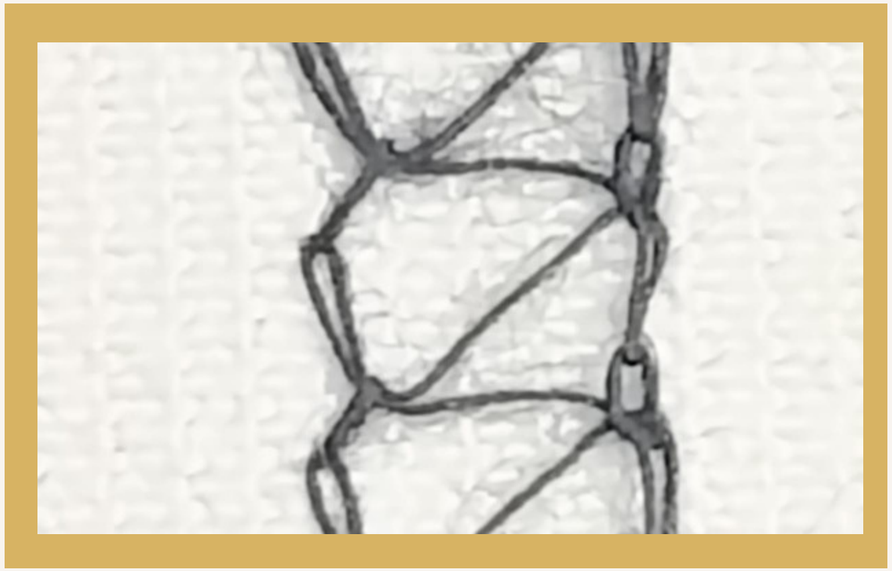



Fig.11 Plot of resistance vs. weight

# Weaving Patterns

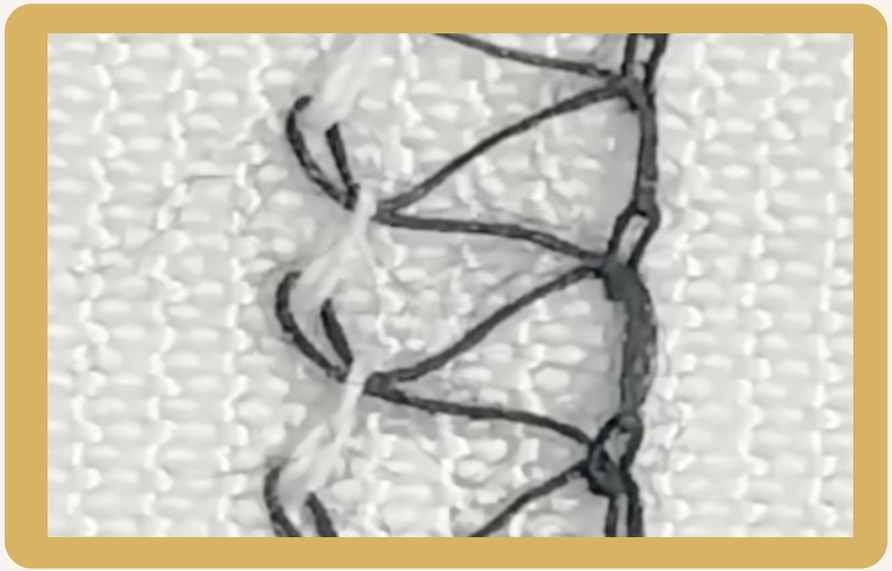


(A)

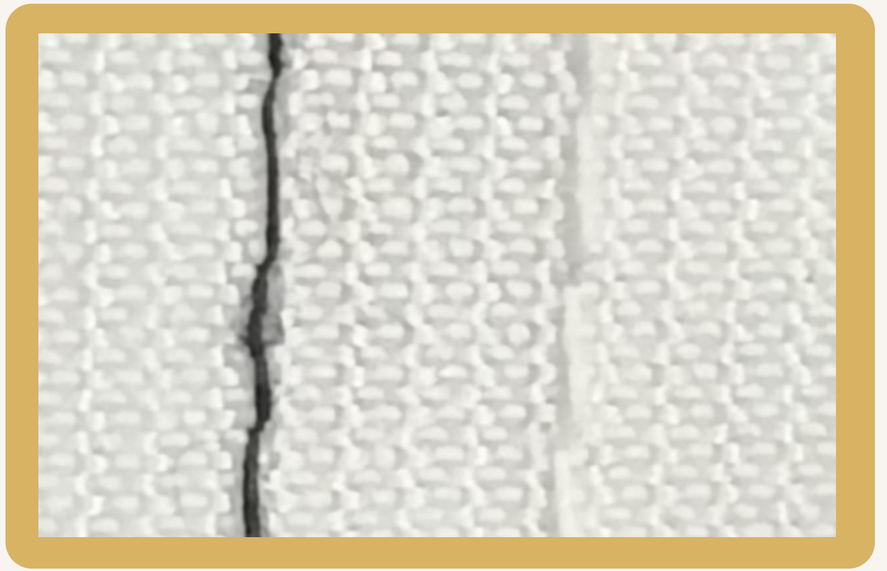


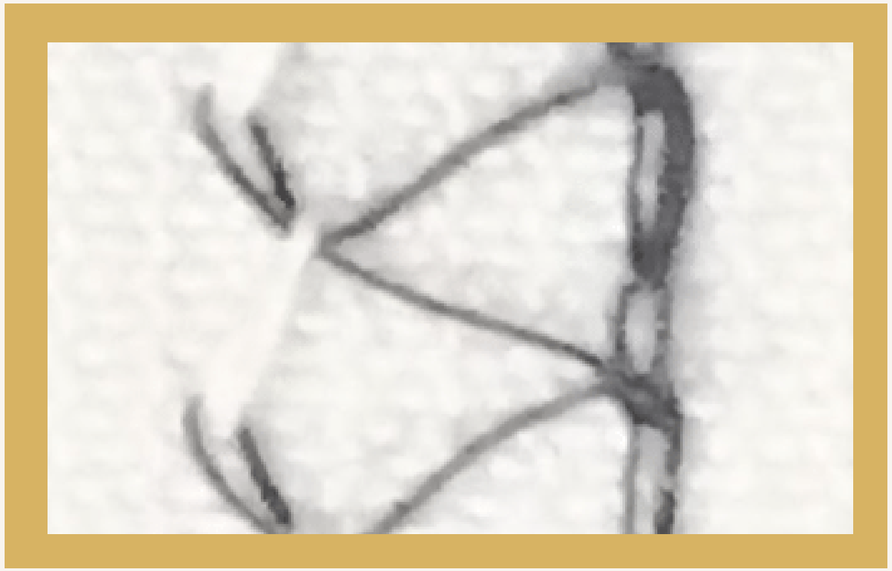
(B)

# Weaving Patterns



(C)





(D)

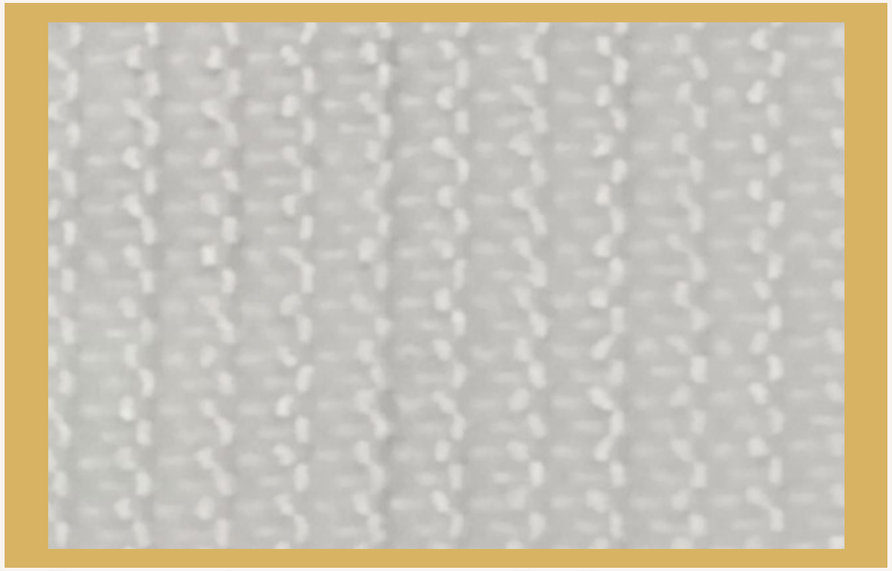
# Weaving Patterns

(E)

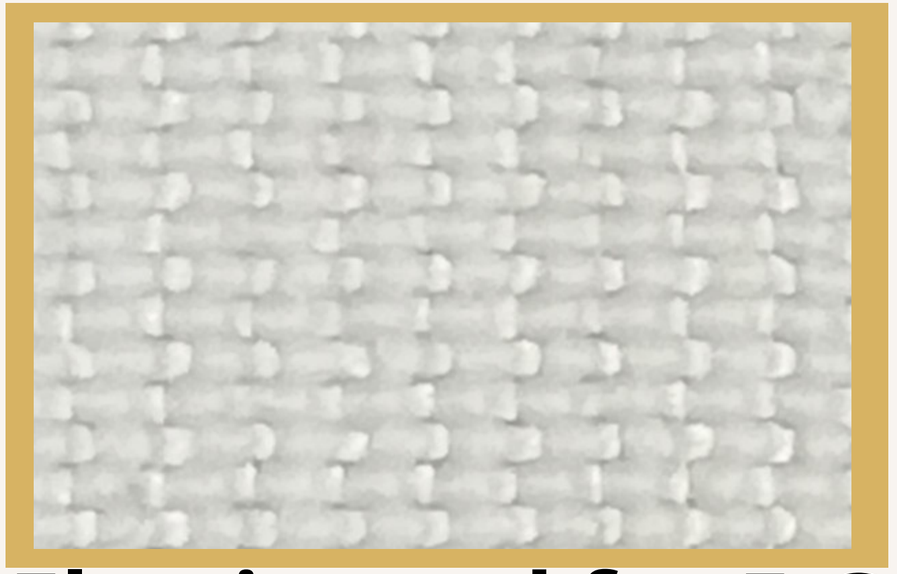
(F)

# Weaving Patterns

(G)



**Elastic used for A-E**



**Elastic used for F-G**

# Junctions and Knottings

- Using the Microscope at 100x , we observed out the various knots and junction points to get an overview of knotting based study.

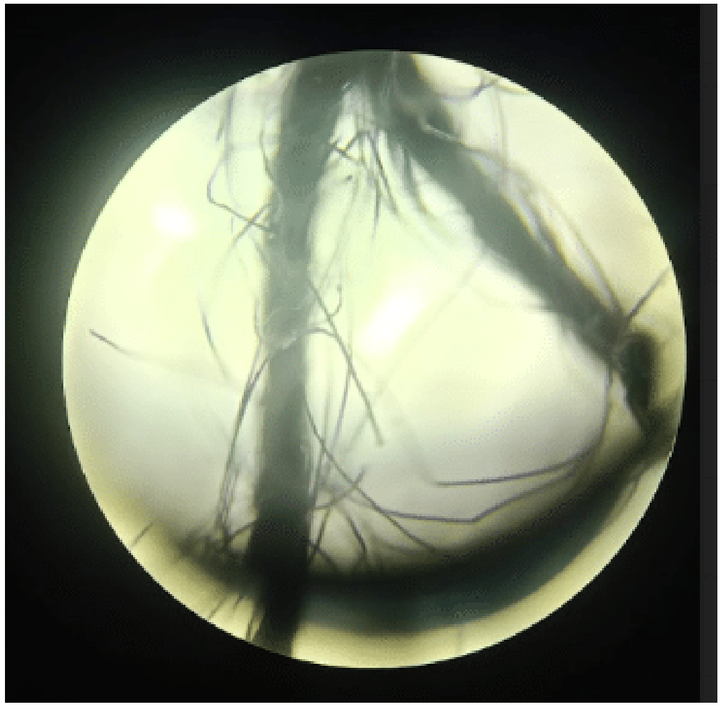


Fig.13 Weaving pattern

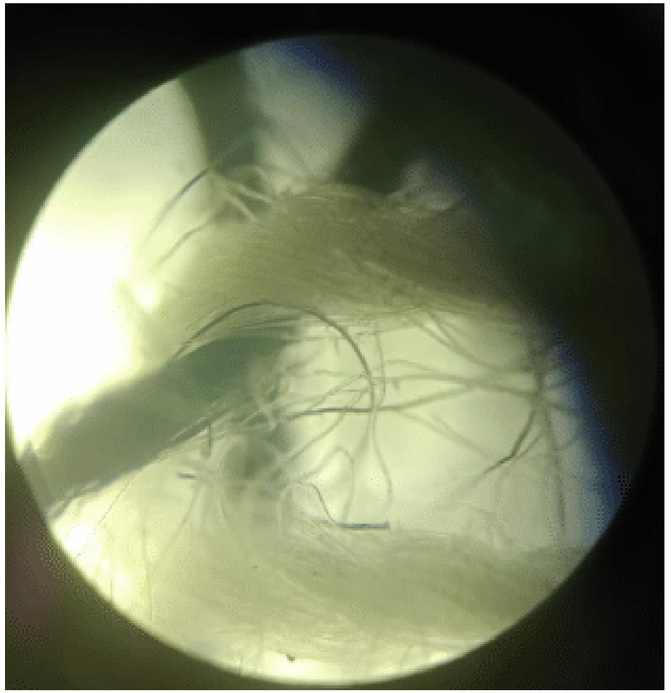


Fig. 14 Junction of conducting yarn and normal yarn under microscope

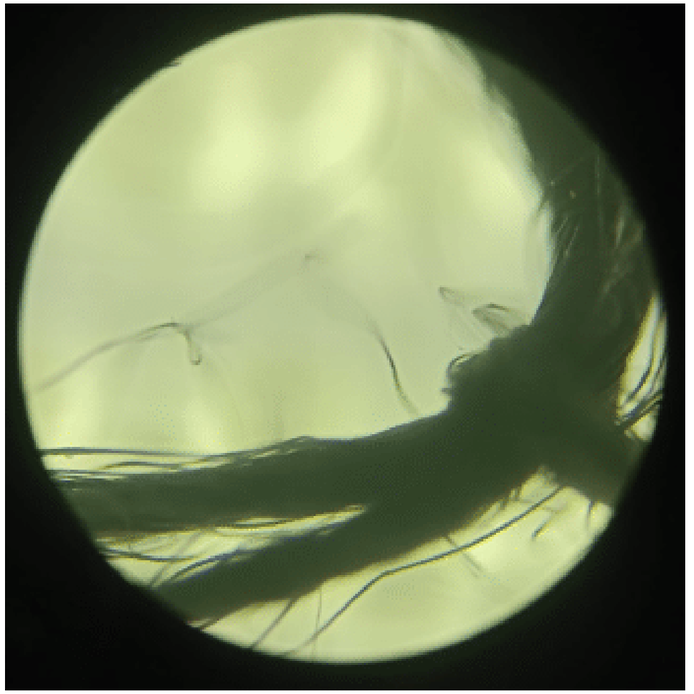


Fig.15 Knot between the yarn

# Capacitance using Dielectric as Ionic Solution

- We have studied the change in capacitance of the sample with two yarns weaved parallelly to each other on using dielectric as ionic solutions. The plot below shows the three cases:
  (a.) In presence of no dielectric
  (b.)Capacitance change in presence of deionized water
  (c.)Capacitance change in presence of ionic (NaCl) solution

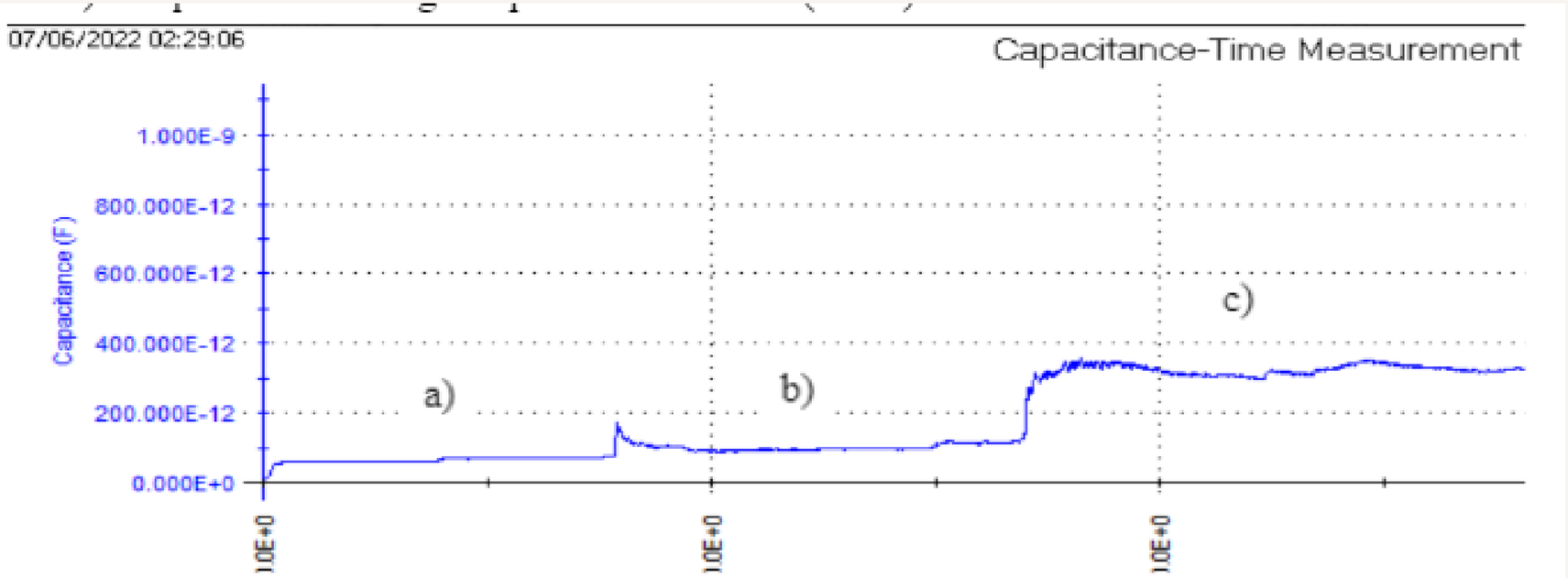
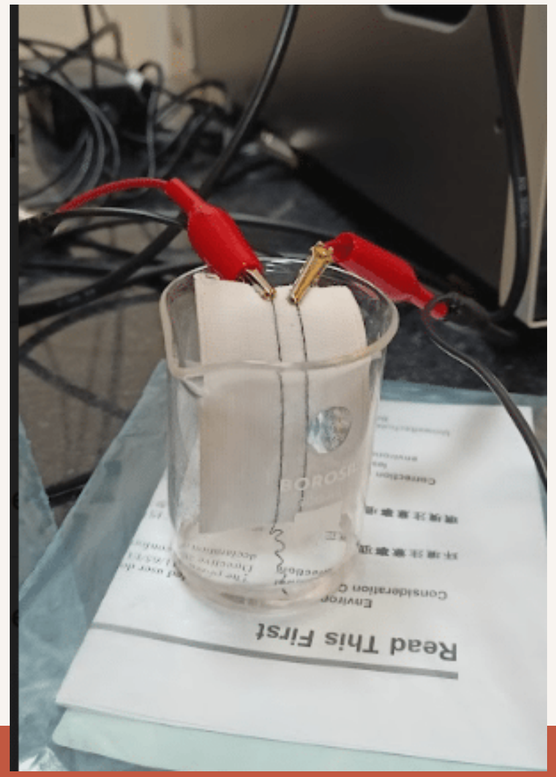


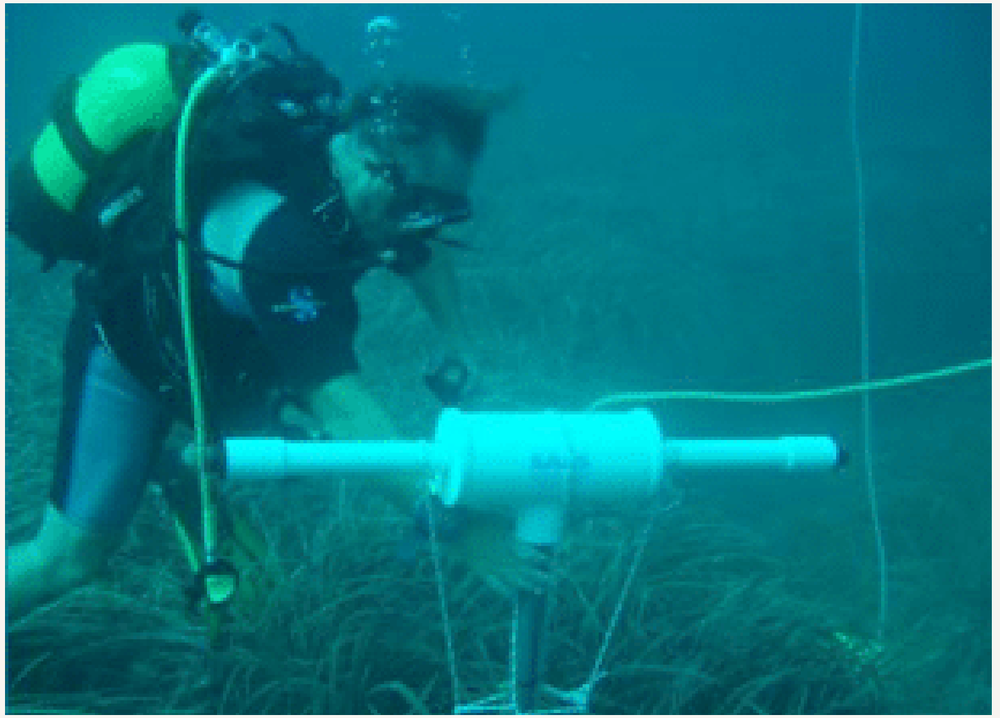

Fig.16 Plot of capacitance vs. time gradually as the dielectric is changed between two parallely weaved conducting yarns



# Application of Conducting Yarns

## a) Sensor in Underwater work station

Sudden peak and change in capacitance of the two parallelly weaved conducting yarn in presence of ions can be utilized to make sensors which can be used in underwater workstations.



# Application of Conducting Yarns

## b) Heat sensor in wearable textiles

In this a simple adjustable regulator circuit to detect resistance change with temperature can be designed in order to use it a sensor for humans.

# Application of Conducting Yarns

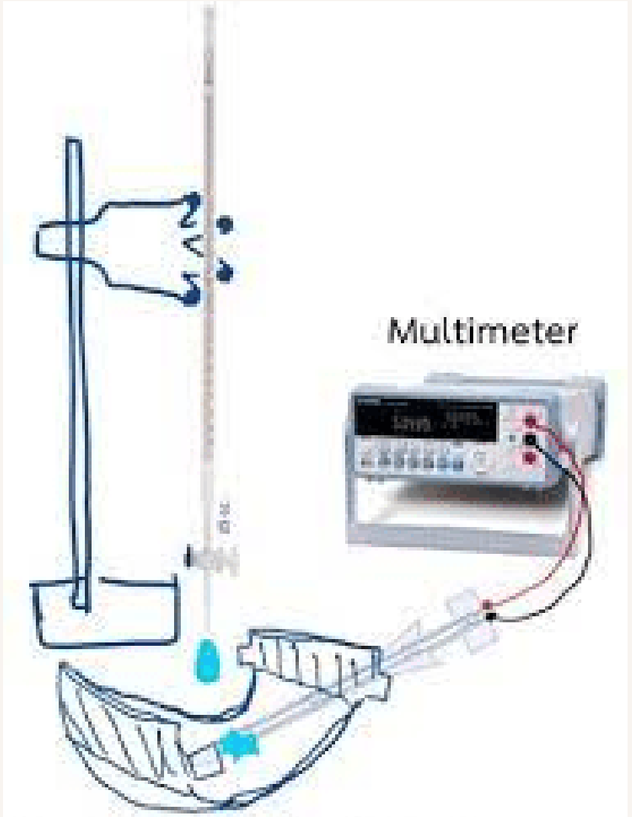
## c) Large Bio-Potential Electrodes

These material can act out as Biopotential electrodes which will act as an interface between the biological tissue and the electronic measuring circuit, performing the transduction of ion current into electronic current.

# Application of Conducting Yarns

## d) Sensor based Diapers

Conducting Yarns can be used for the application in the Med Tech industry where the patients are in the high need of getting sensor based Diapers so as to prevent bed sores and other serious medical issues.



Diaper with installed sensor

# Application of Conducting Yarns

## e) Heart Attack Sensing Technology

Conducting yarns can be used as sensors to detect if a person is sweating profusely in case when one gets a heart attack.

**Rest list of applications is inexhaustible in nature**


Thank
You