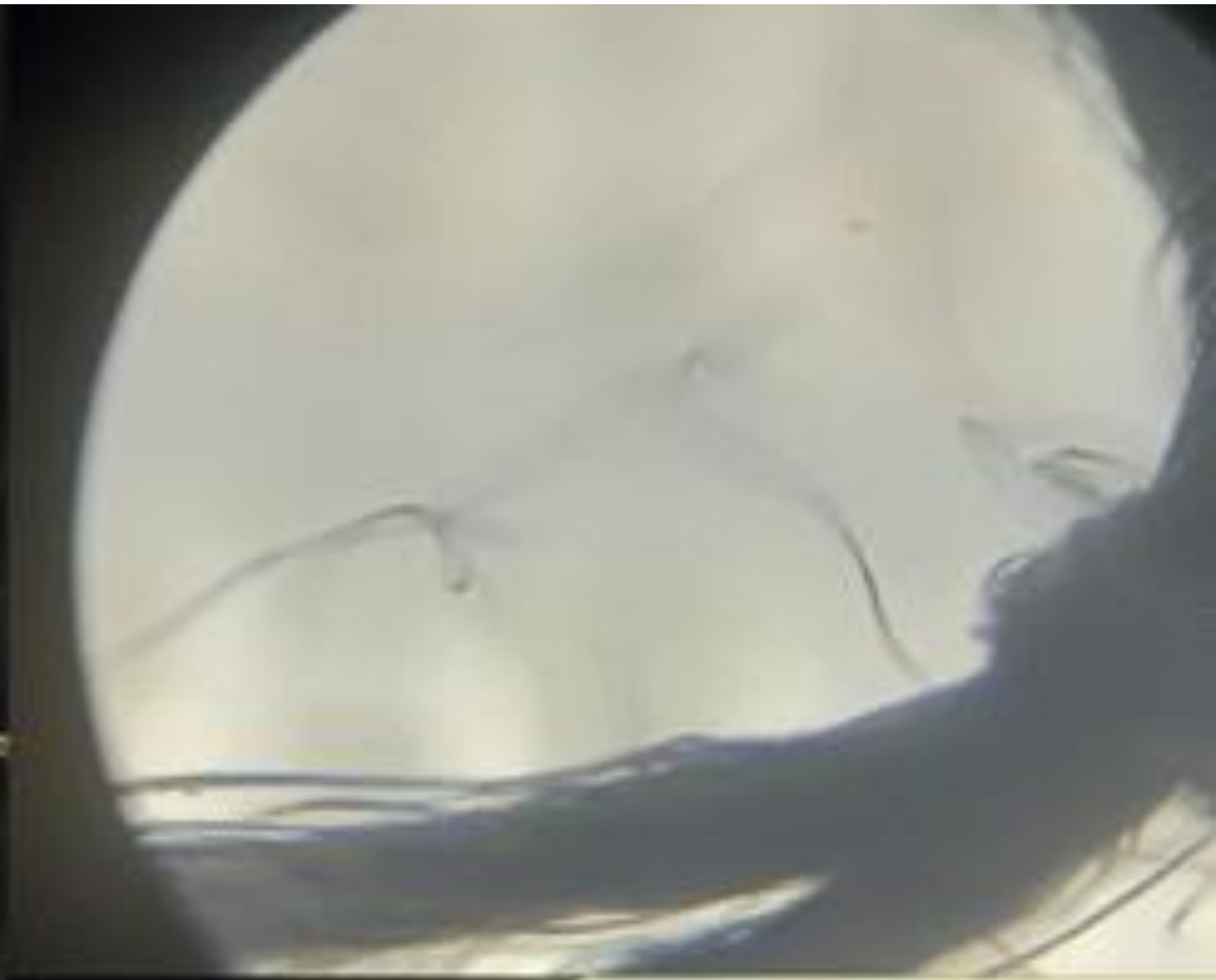
UNDERSTANDING THE CONDUCTING PROPERTIES OF YARN ALONG WITH IT'S APPLICATION



Links for documentation files

Google doc - https://docs.google.com/document/d/16mei-kUy_l-ponoLJgfMpnZRmnh4rIv7_t0WOB_1fvk/edit

Excel - https://docs.google.com/spreadsheets/d/132fGrDHev7mpNY4GyRv98tLuYg6zL9SAoV5Evk5WL0A/edit#gid=0

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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 or other fiber conductive fiberblended with core fiber. It must be ordinary conductive and must be machine sewable.

TYPES OF YARN USED

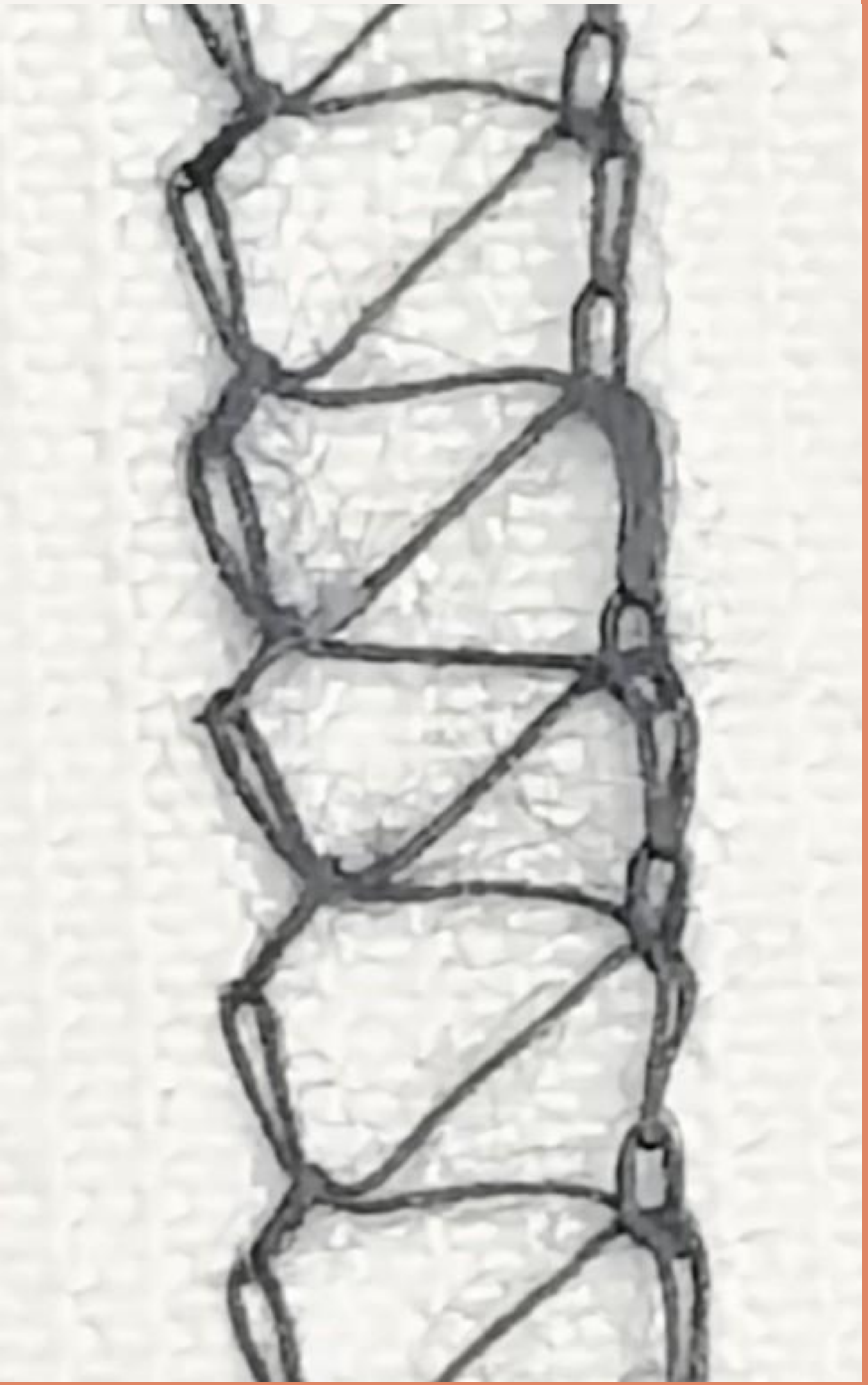
- **Blended Steel Yarn**

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
- DURABILI

ELECTRICAL

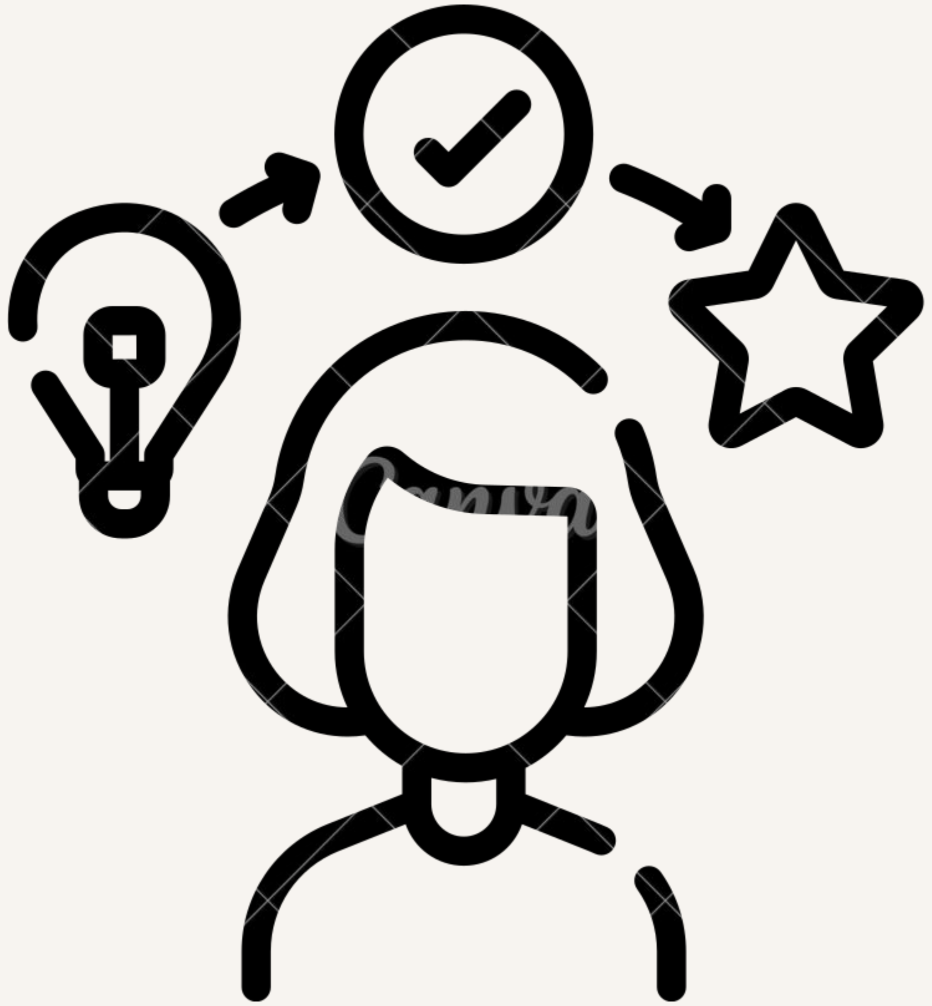
- RESISTANCE WITH VARIANCE IN LENGTH
- RESISTANCE WITH DIFFERENT NO. OF

MECHANICAL

- TENSILE STRENGTH
- THERMAL COEFFICIENT OF RESISTANCE

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

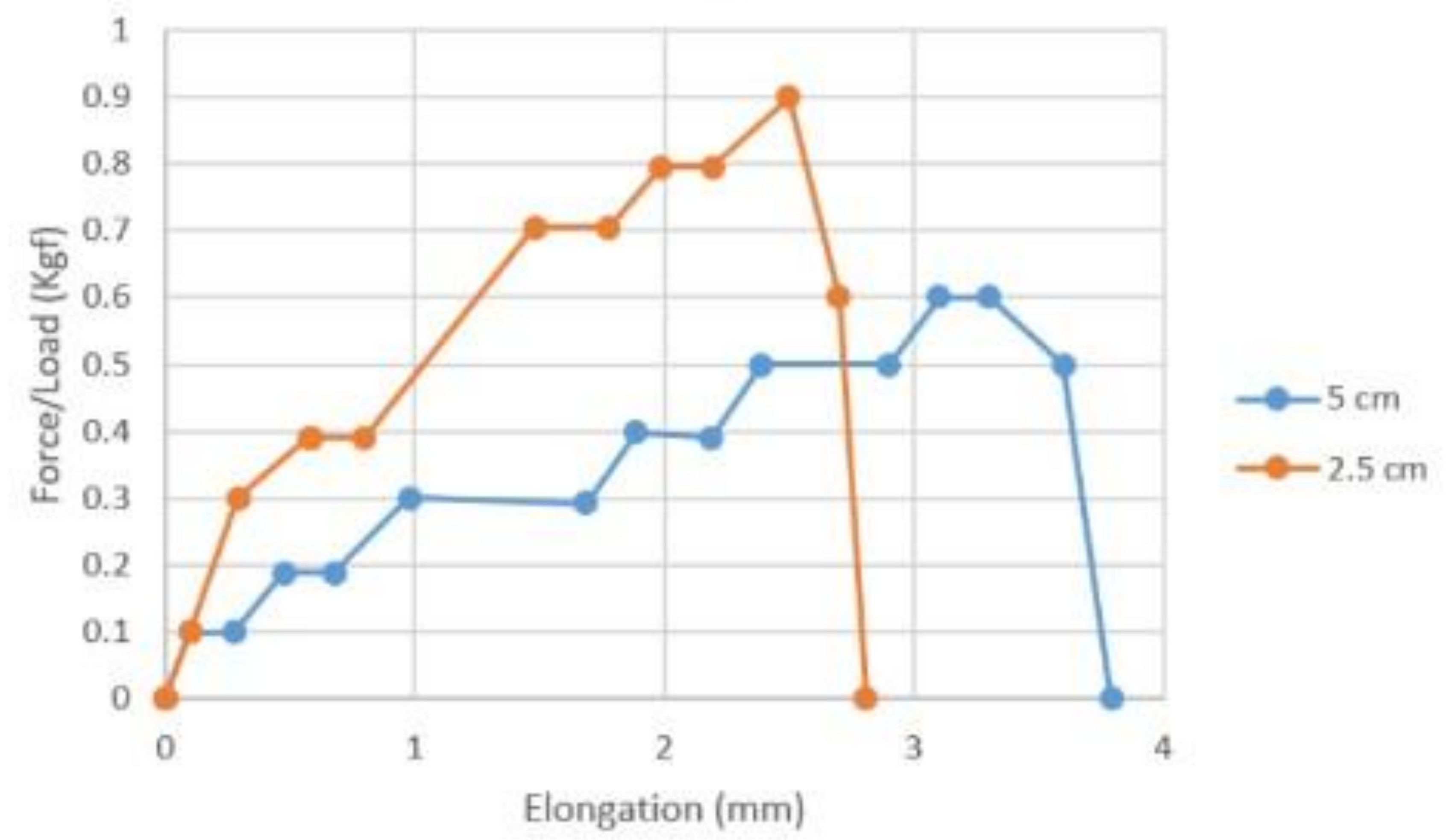


Fig.1 Plot of elongation vs load for the yarn type 1(orange curve) and type 2(blue curve)

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.

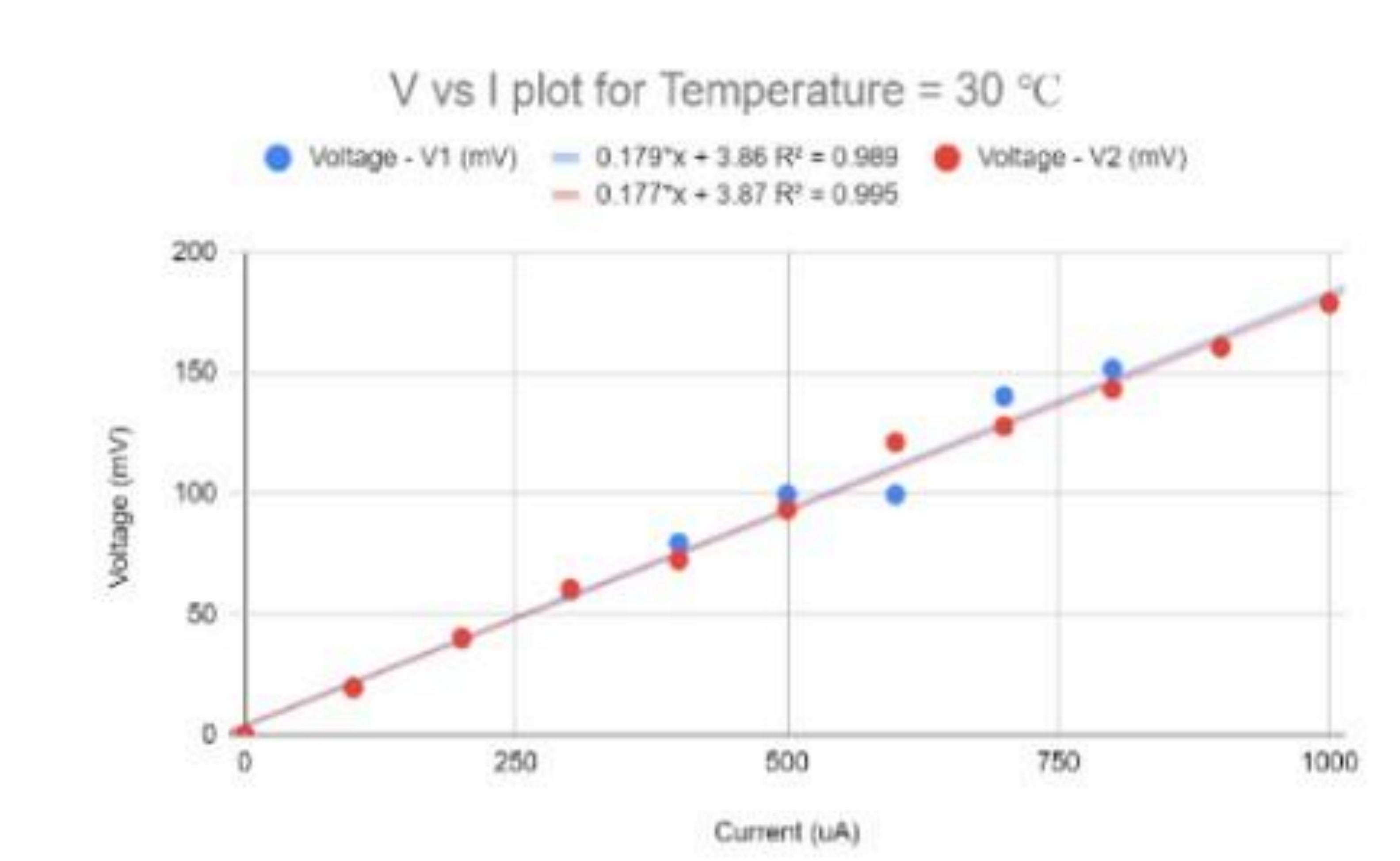
α = Temperature coefficient of resistance for conductor material.

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

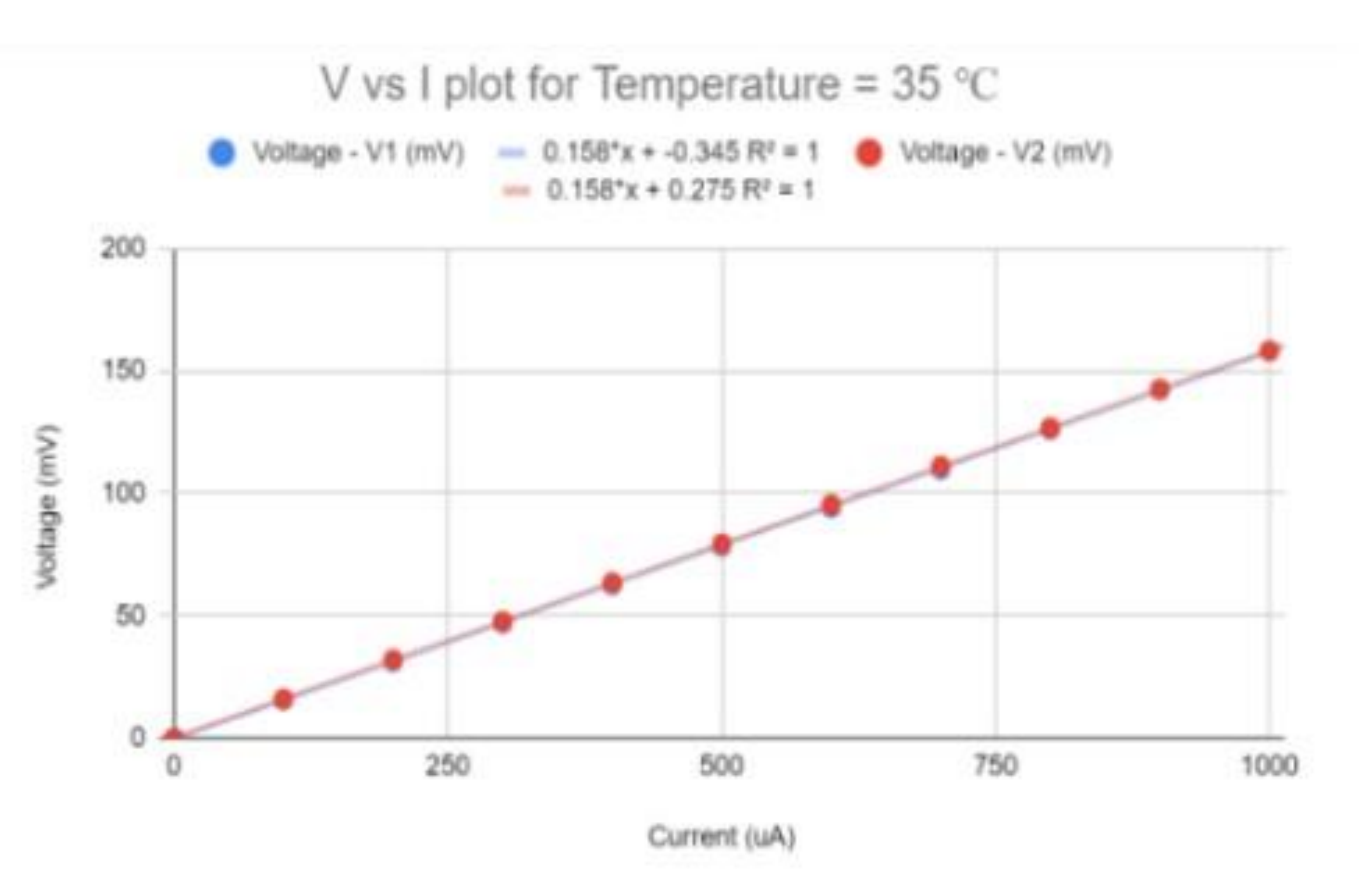
Temperature = 30 ℃				
Current (uA)	Voltage - V1 (mV)	Voltage - V2 (mV)	Average Voltage (mV)	Resistance (Ω)
0	0	0	0	
100	19.9	19.45	19.675	196.75
200	39.8	40.31	40.055	203.8
300	59.7	60.51	60.105	200.5
400	79.5	72.5	76	158.95
500	99.54	93.33	96.435	204.35
600	99.5	121.2	110.35	139.15
700	140.29	127.75	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

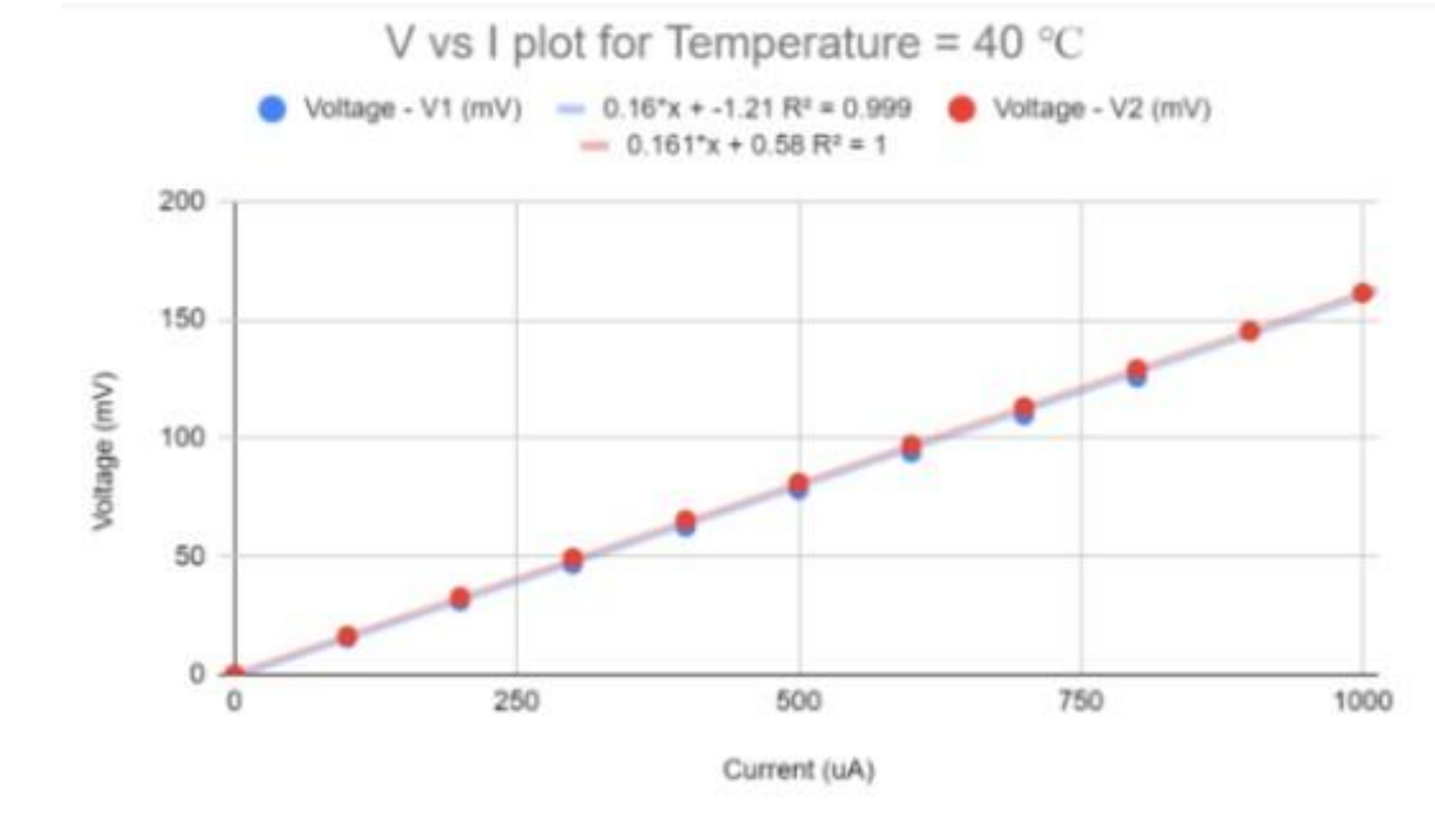
Resistance and voltage of the conducting yarn with different current passed at temperature 35 degree Celsius

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



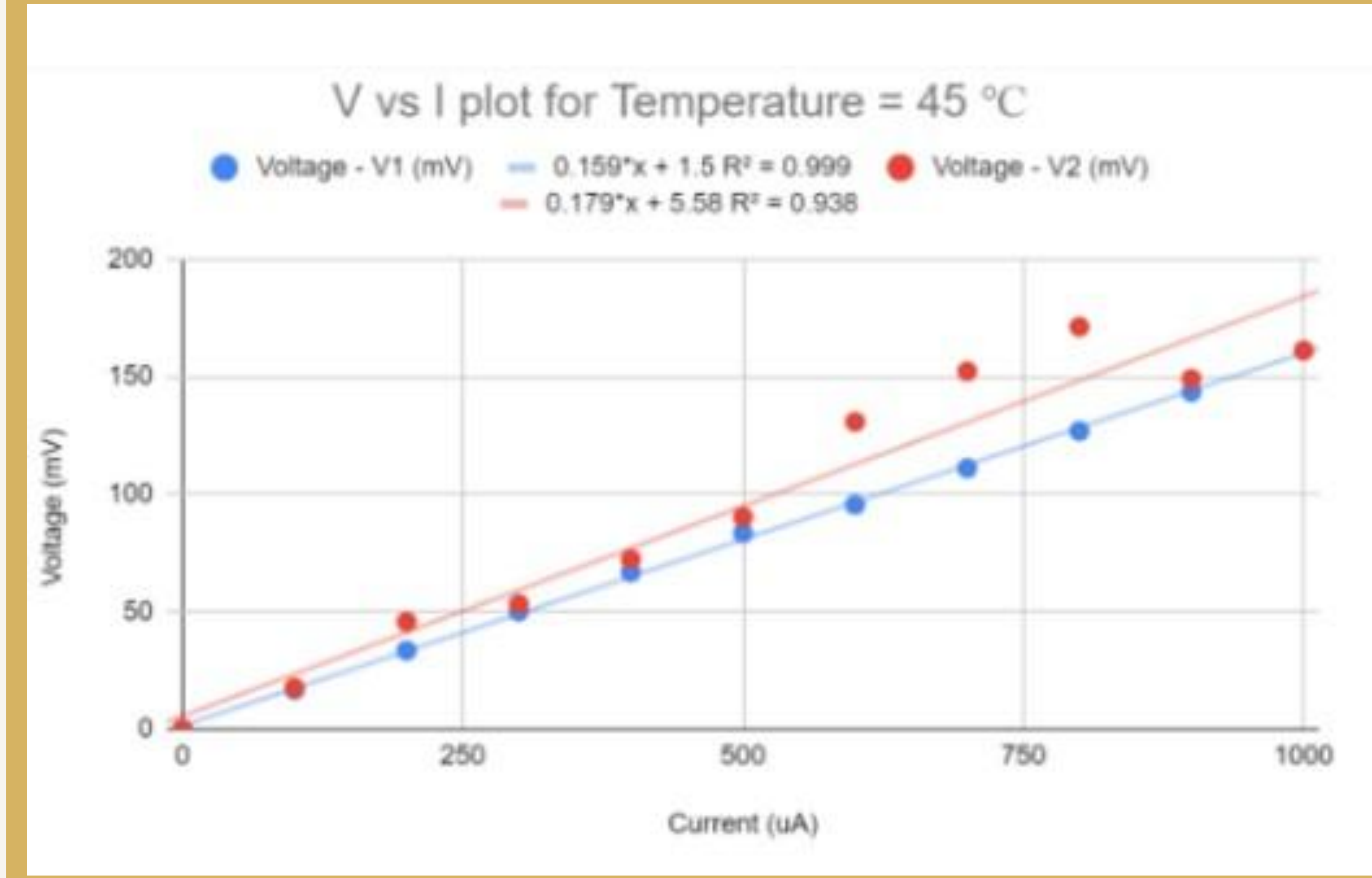
Resistance and voltage of the conducting yarn with different current passed at temperature 40 degree Celsius

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



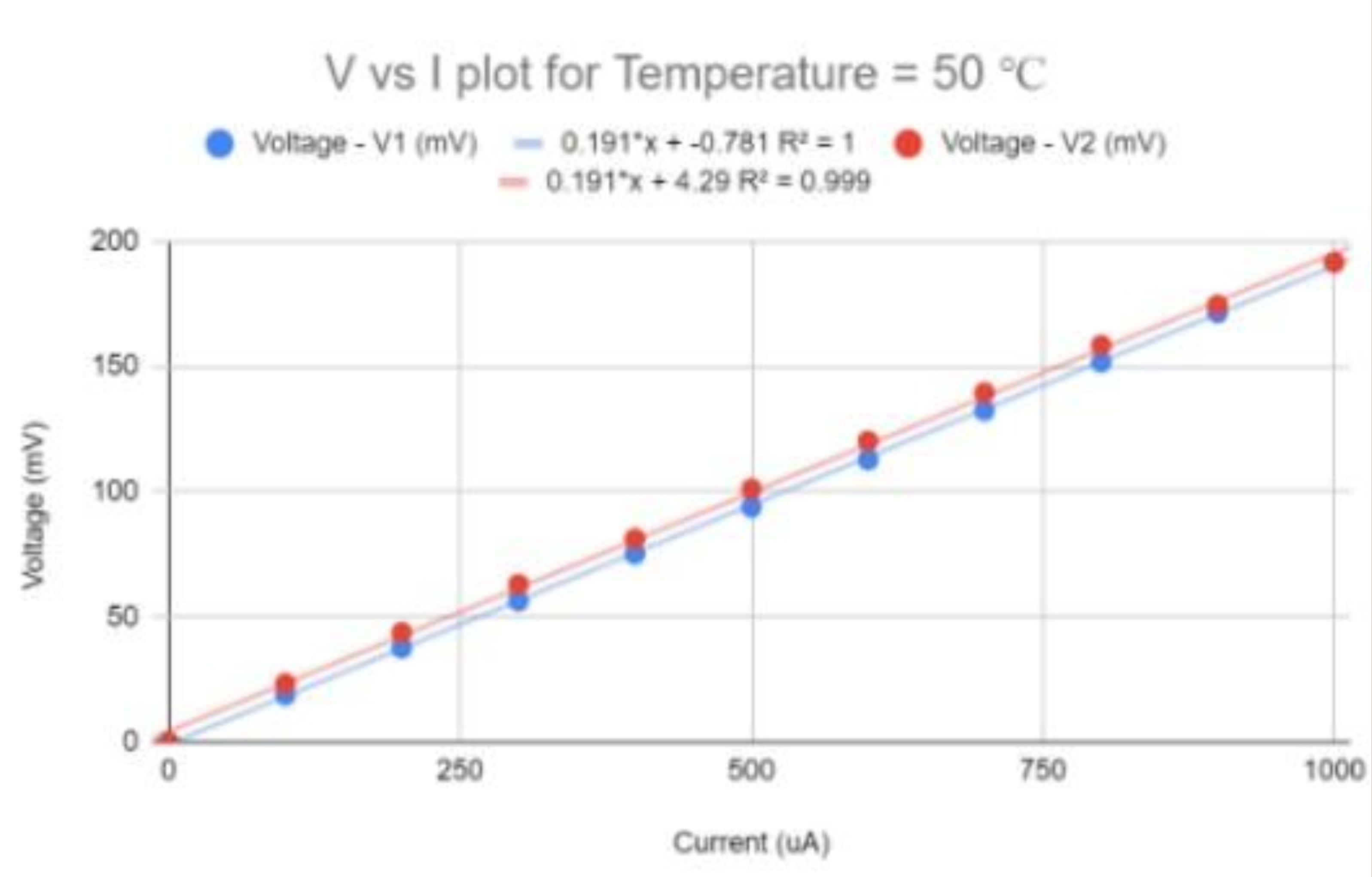
Resistance and voltage of the conducting yarn with different current passed at temperature 45 degree Celsius

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



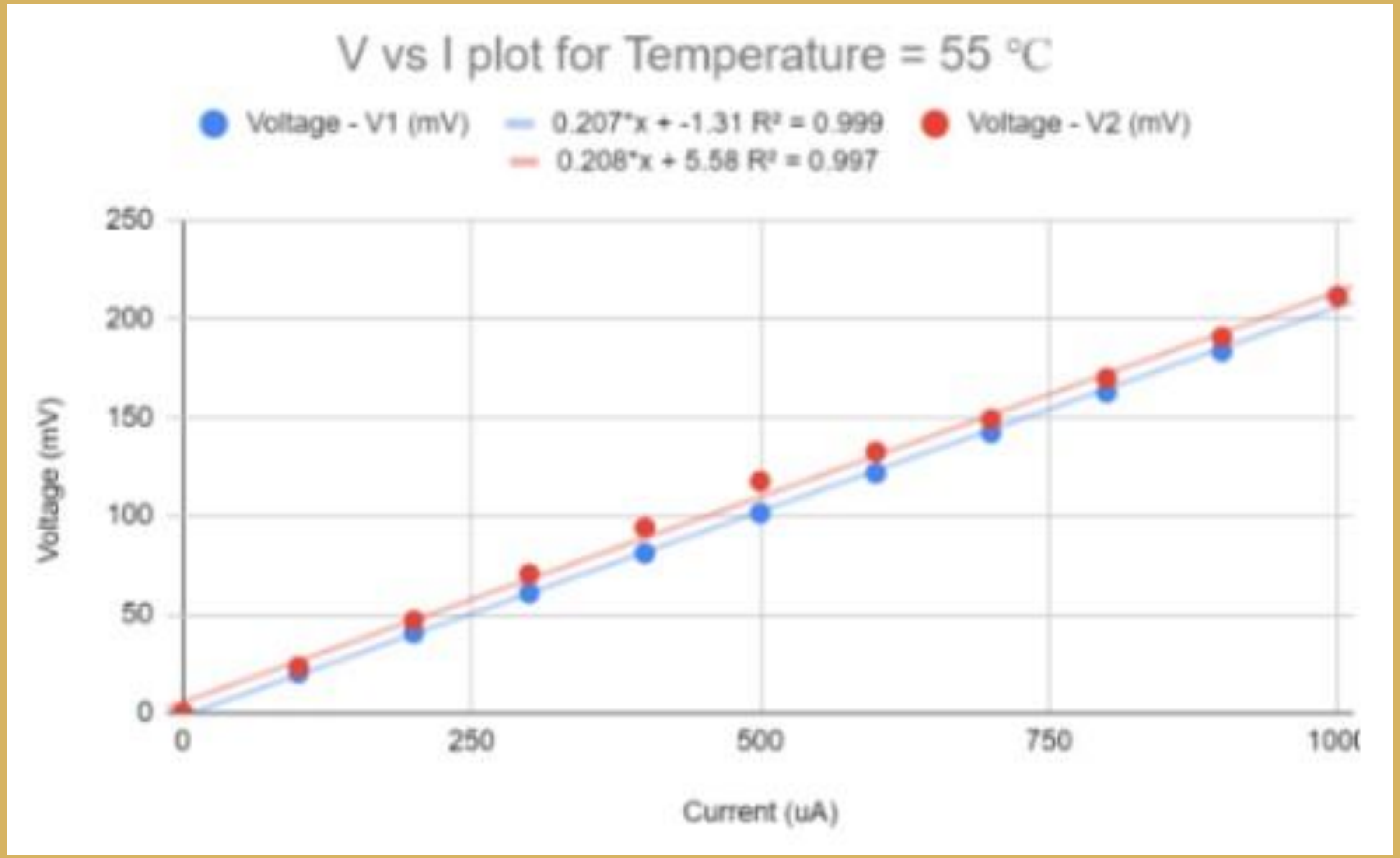
Resistance and voltage of the conducting yarn with different current passed at temperature 50 degree Celsius

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



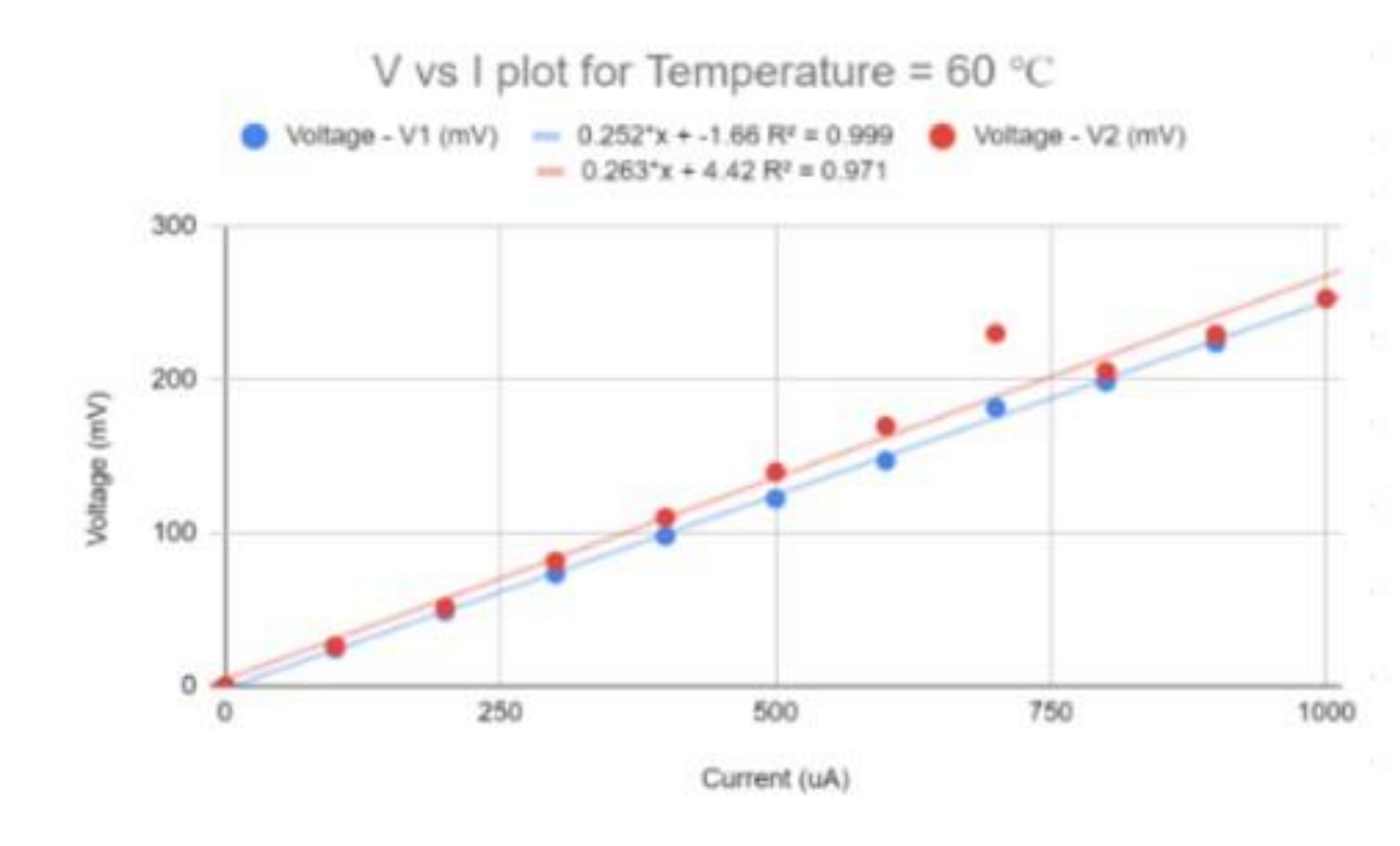
Resistance and voltage of the conducting yarn with different current passed at temperature 55 degree Celsius

Temperature = 55 ℃				
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(10⁴
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

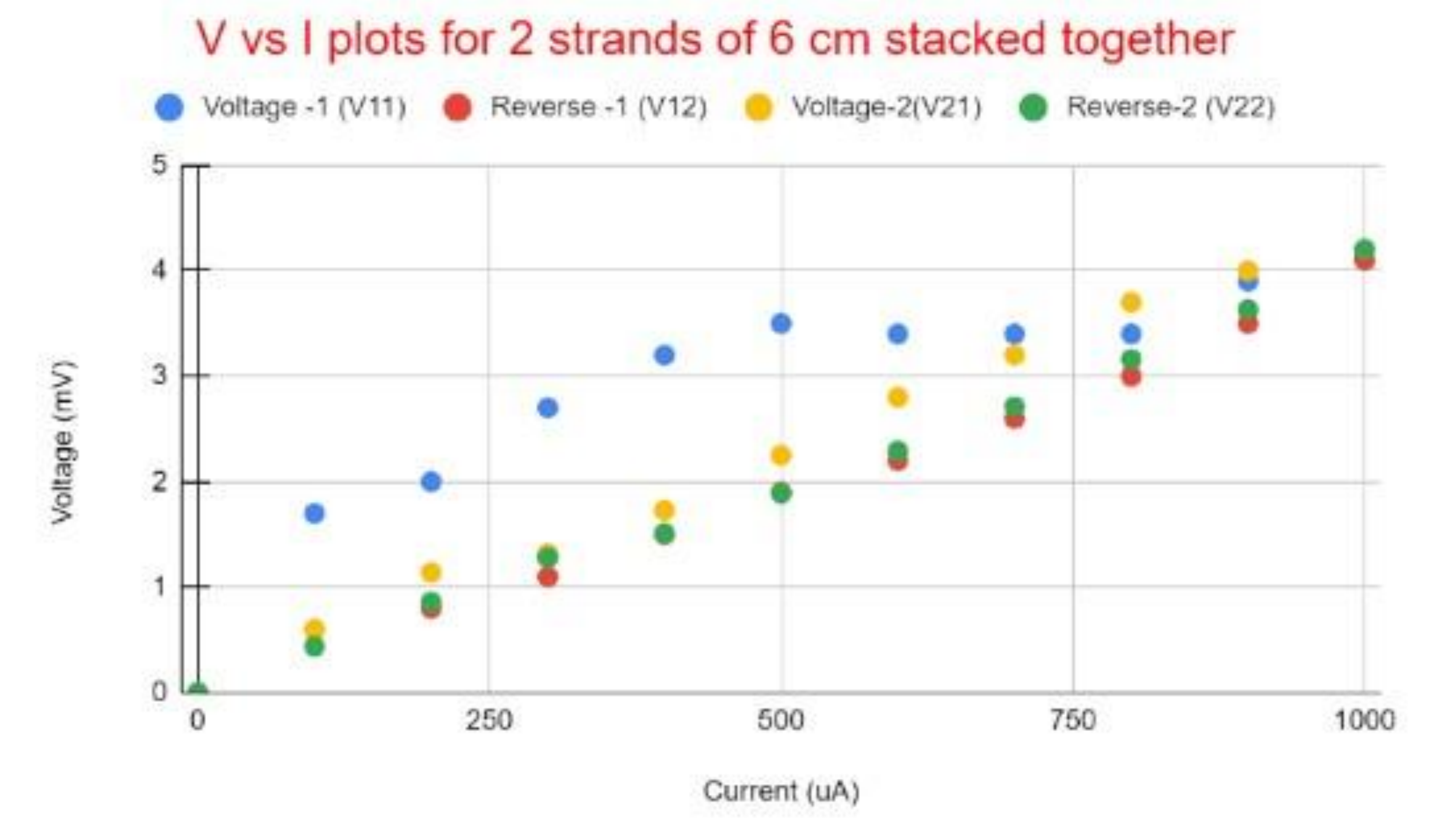


Fig.9Plotting the voltage-current graph of the results obtained from source meter

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

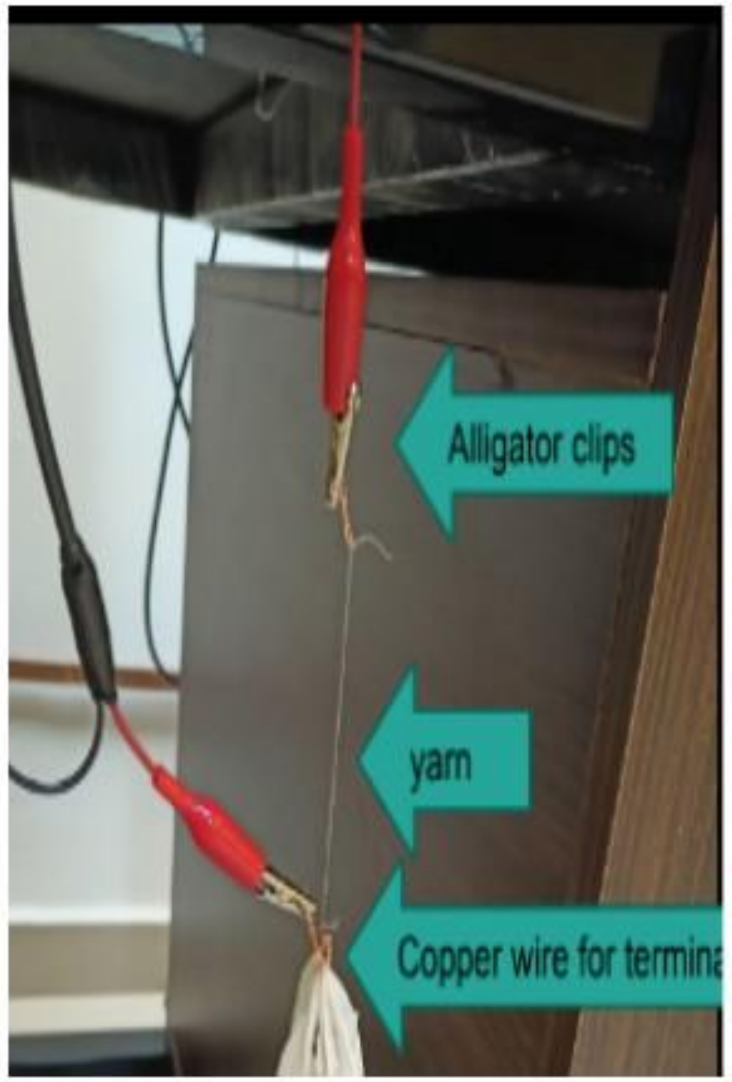
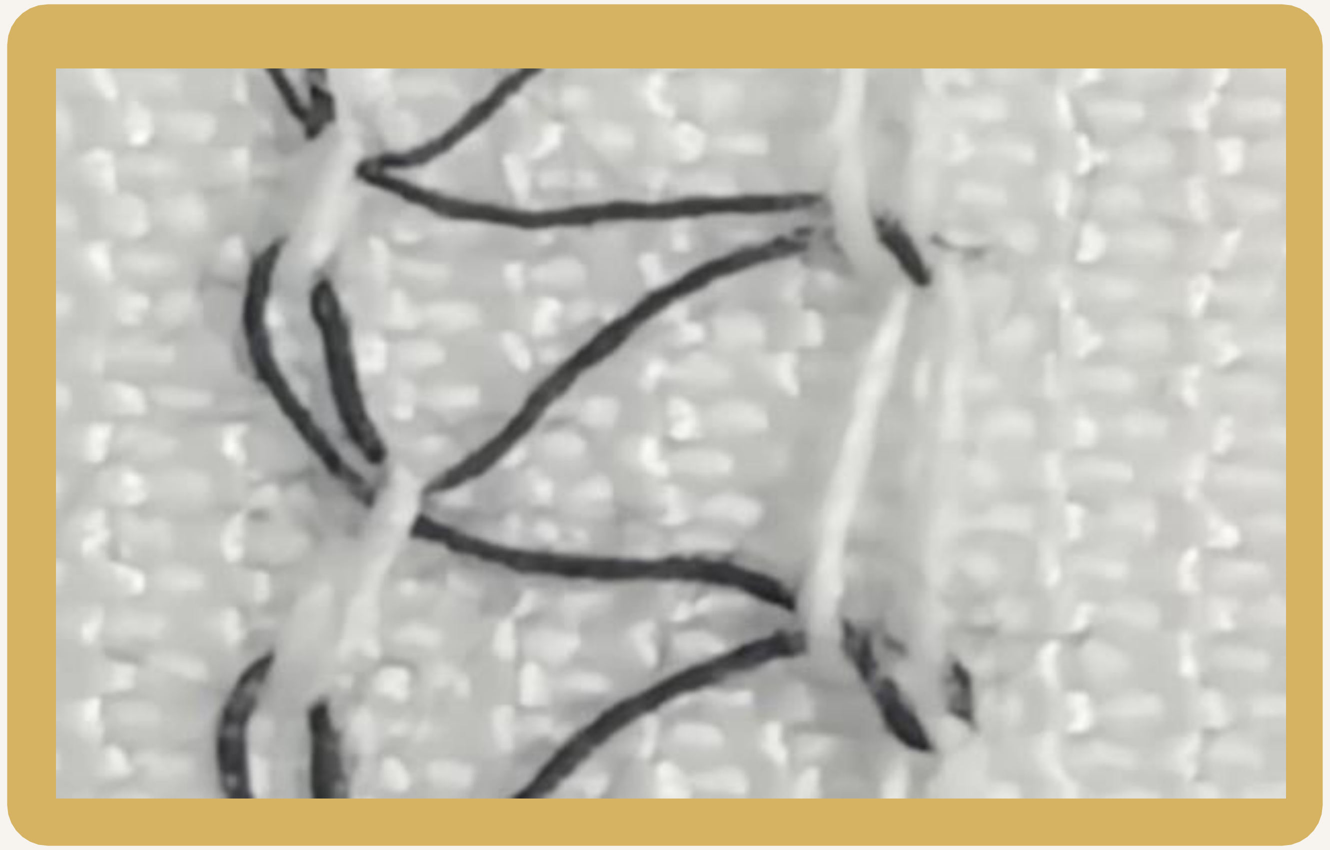


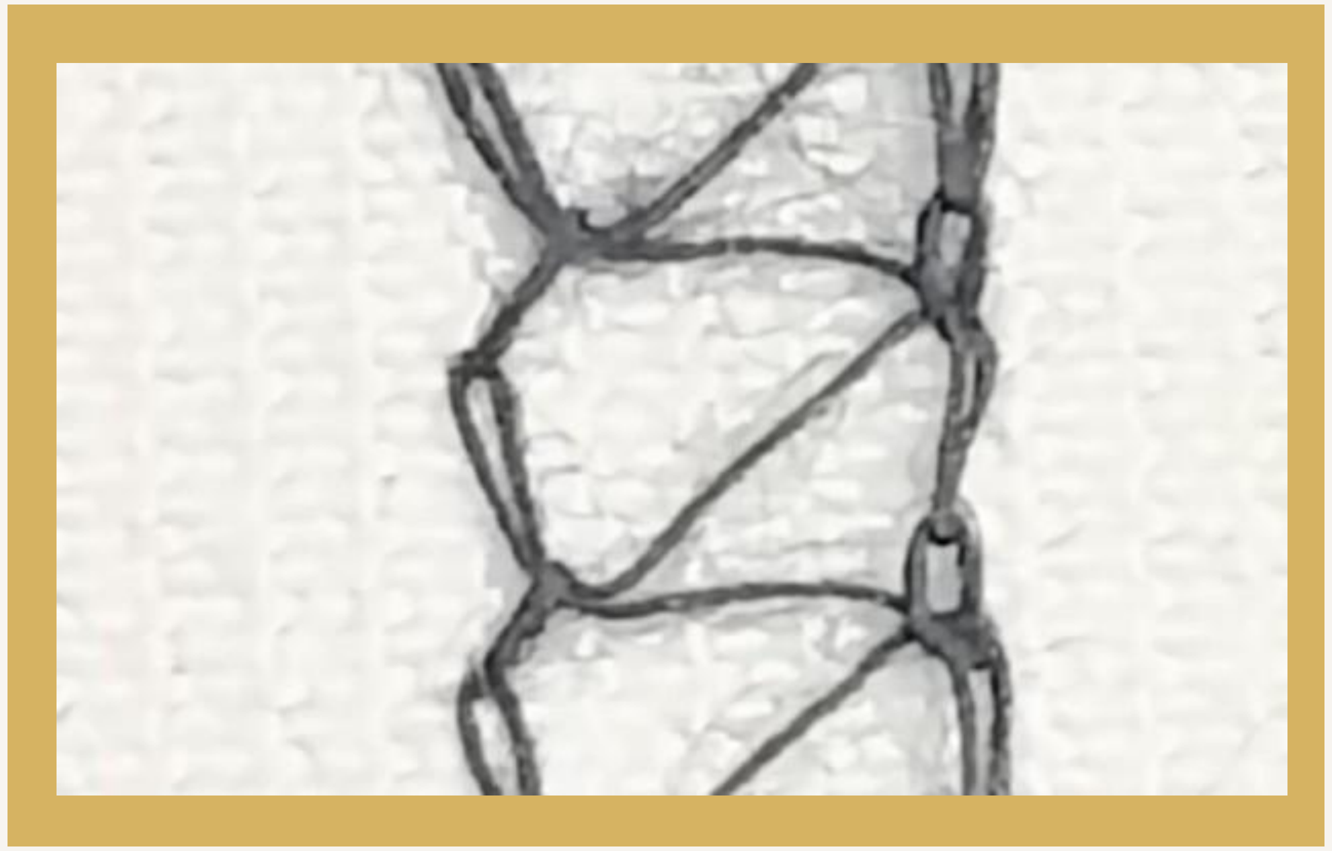
Fig.10 The setup for the experiment

Fig.11 Plot of resistance vs. weight

Weaving Patterns



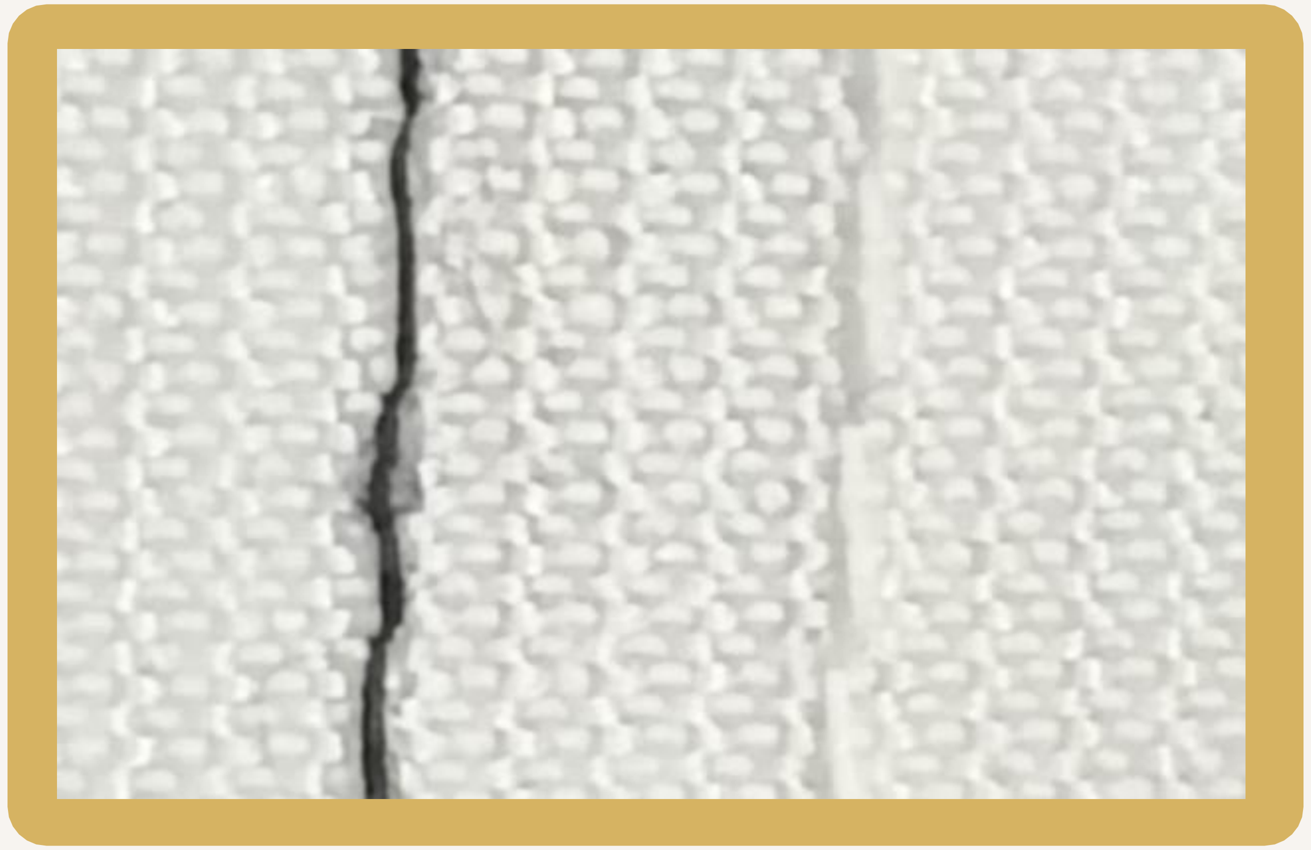
(A)



(B)

Weaving Patterns

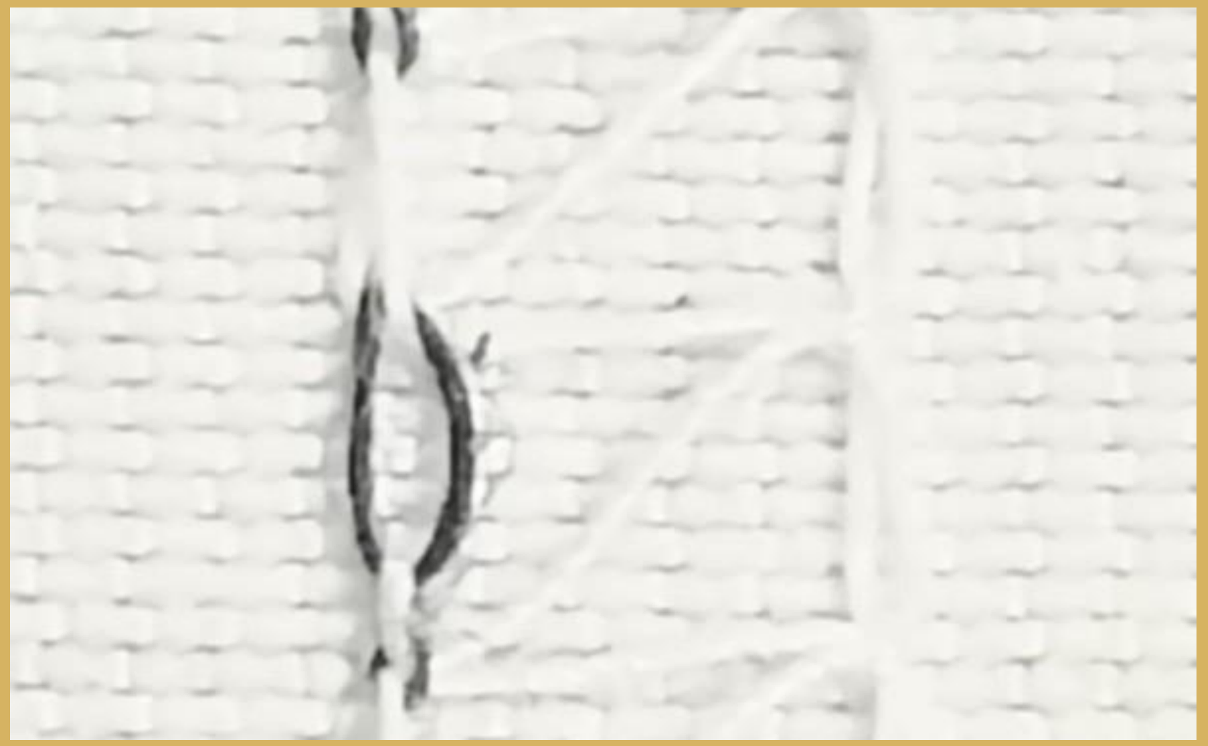
(C)



(D)

Weaving Patterns

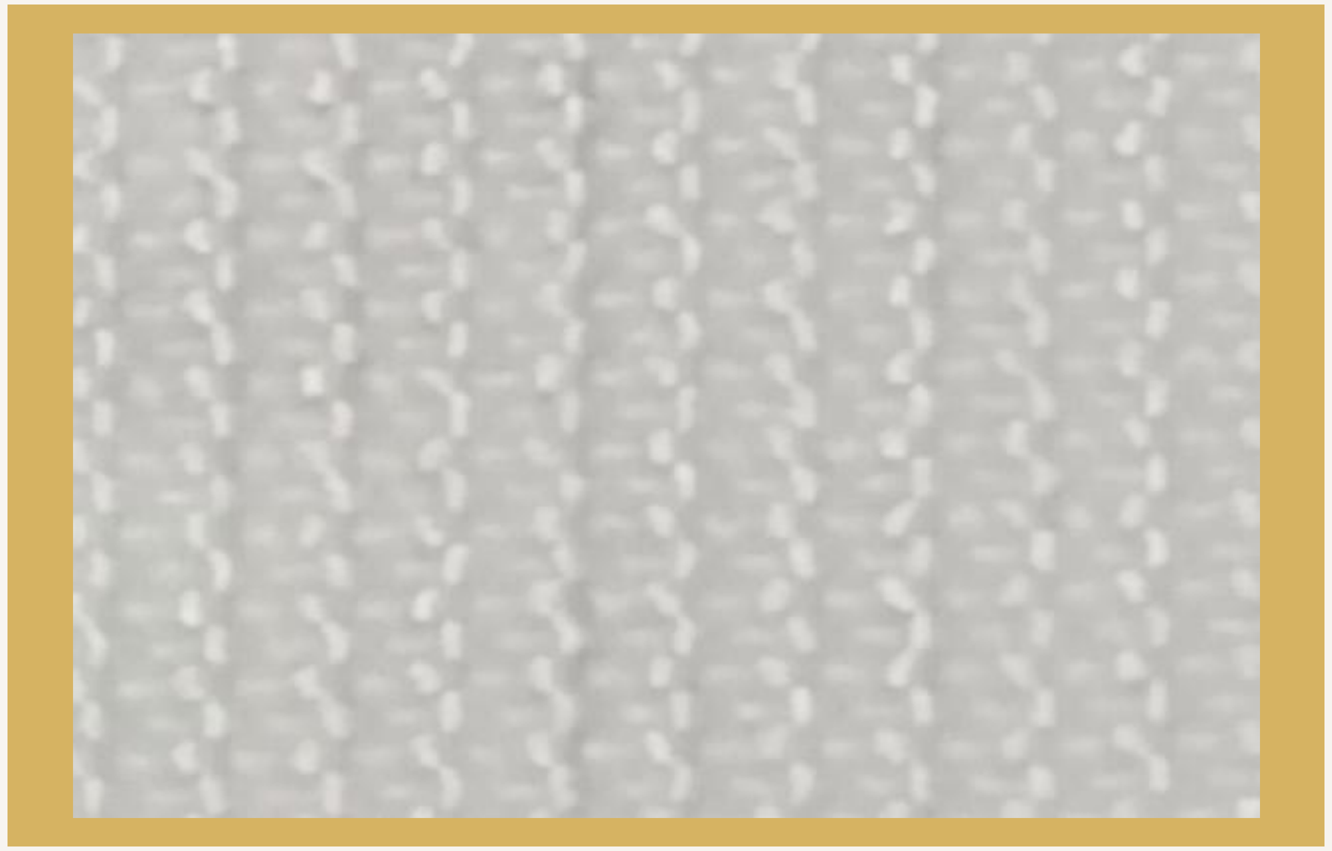
(E)



(F)

Weaving Patterns

(G
)



Elastic used for

Elastic used for F-G

Junctions and Knottings

- Using the Microscope at100x , we observed out the various knots and junction points to get an overview of knotting based study.

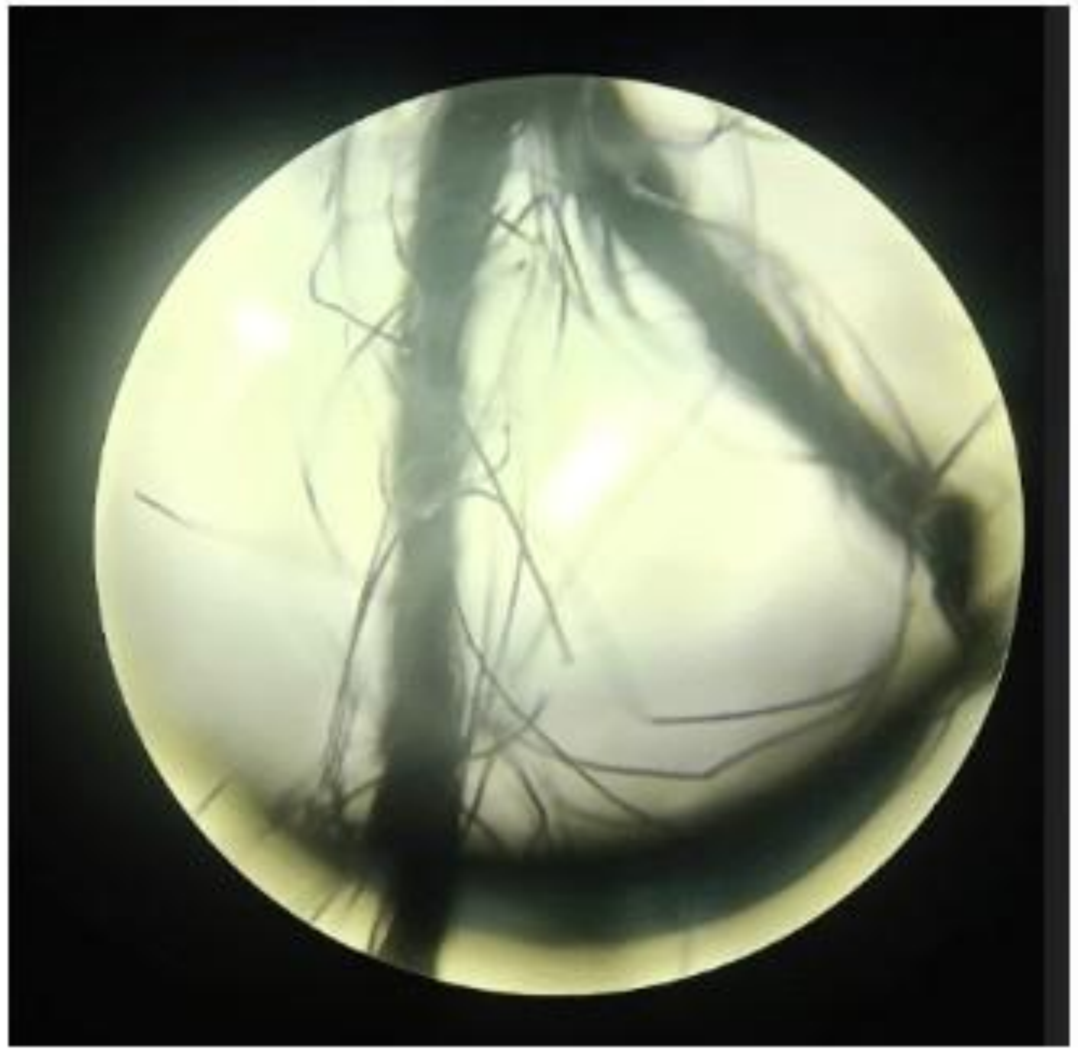


Fig.13 Weaving pattern

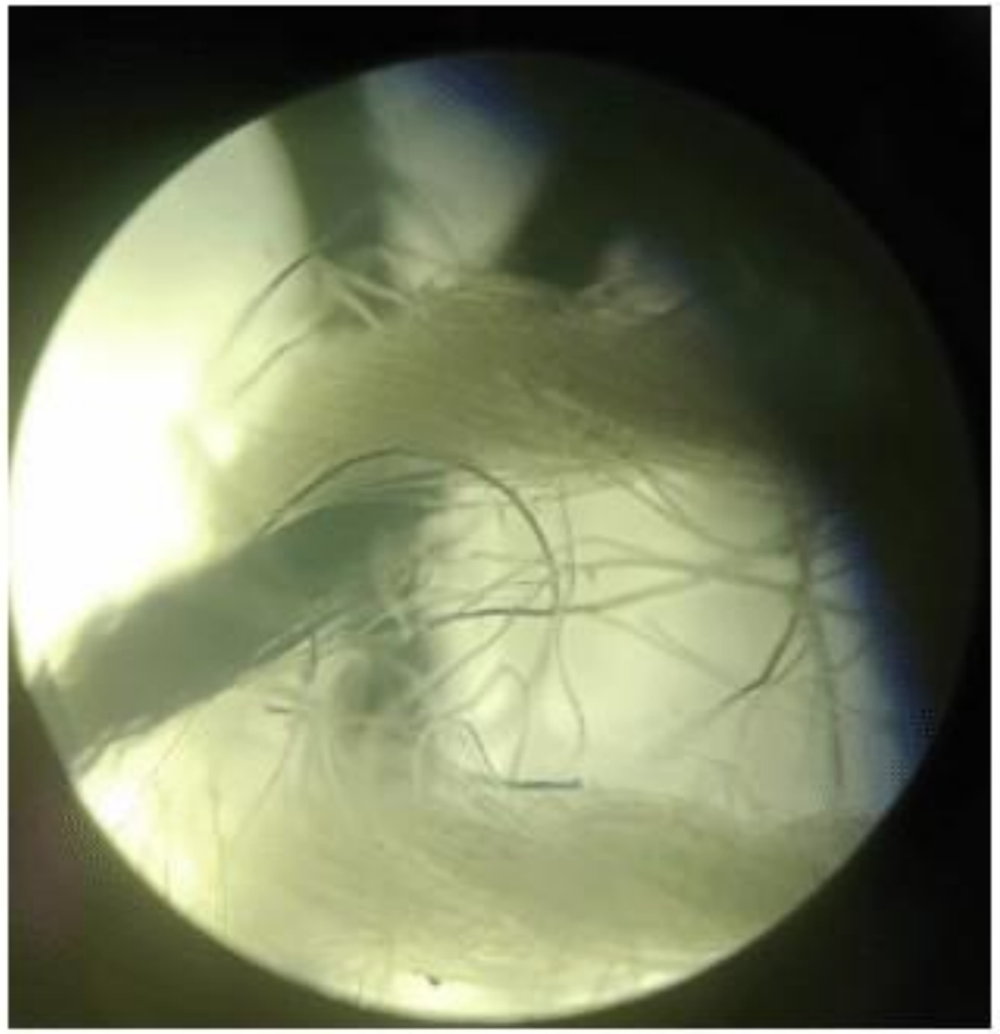


Fig. 14 Junction of conducting yarn and normal yarn under microscope

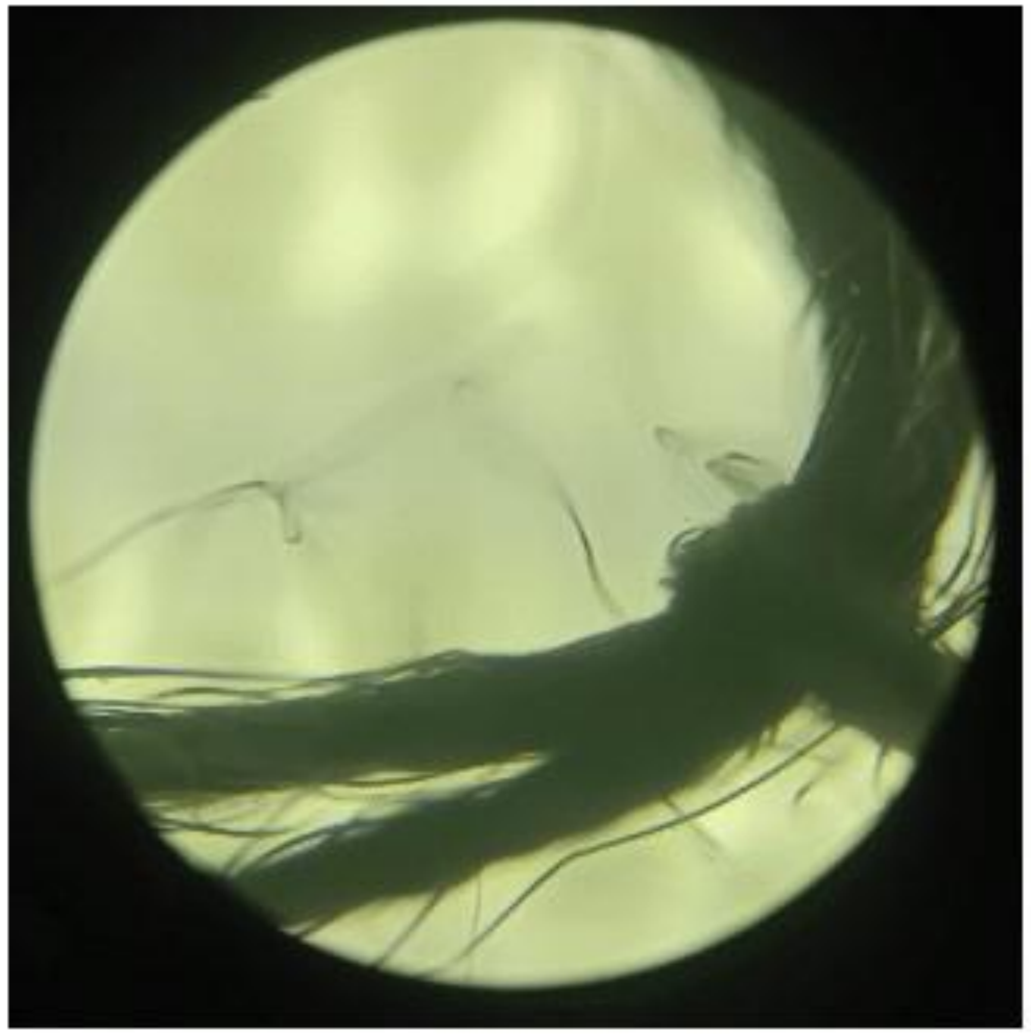


Fig.15 Knot between the yarn

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

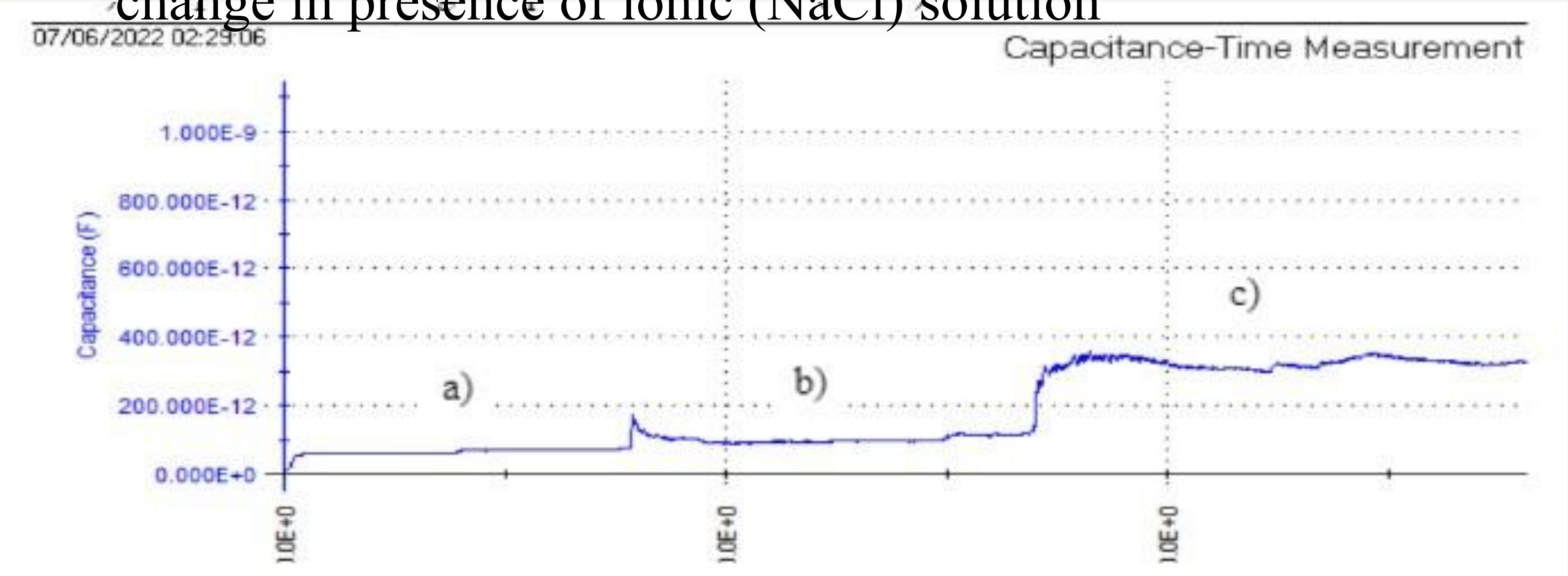
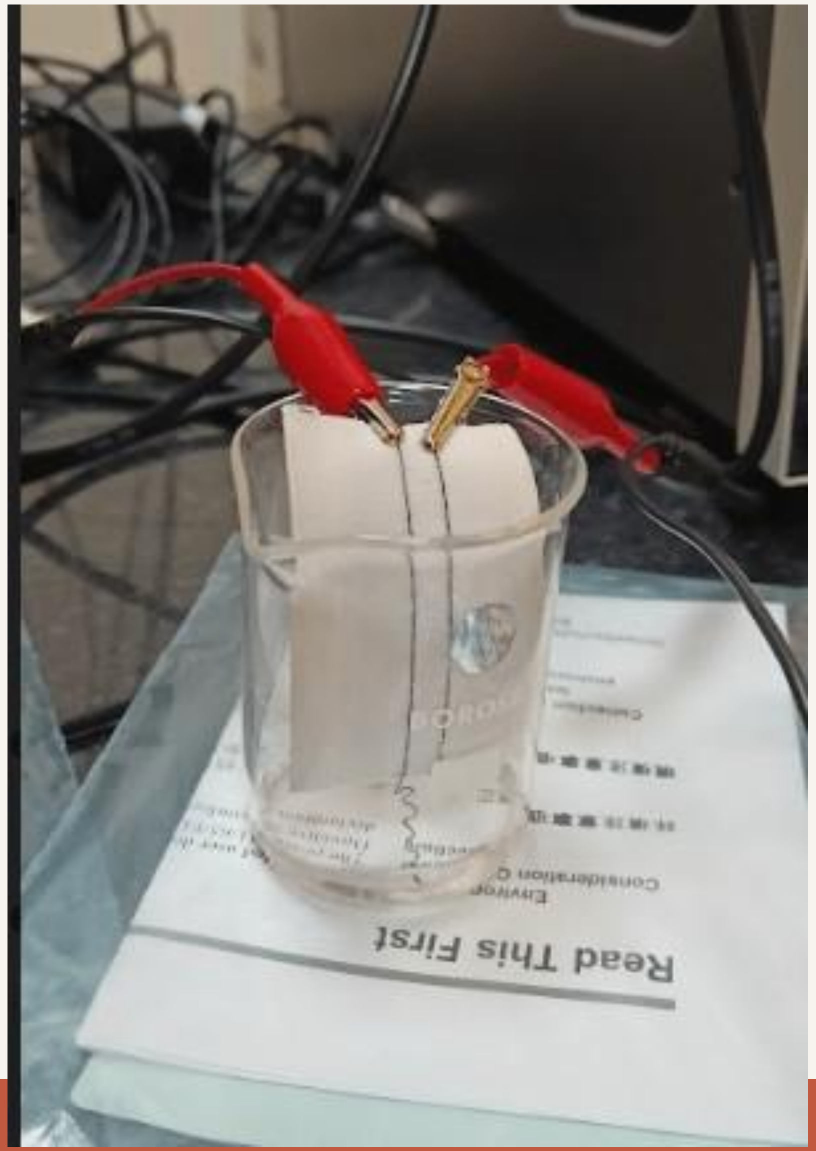


Fig.16 Plot of capacitance vs. time gradually as the dielectric is changed between two parallely weaved conducting yarns



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

Inthis 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

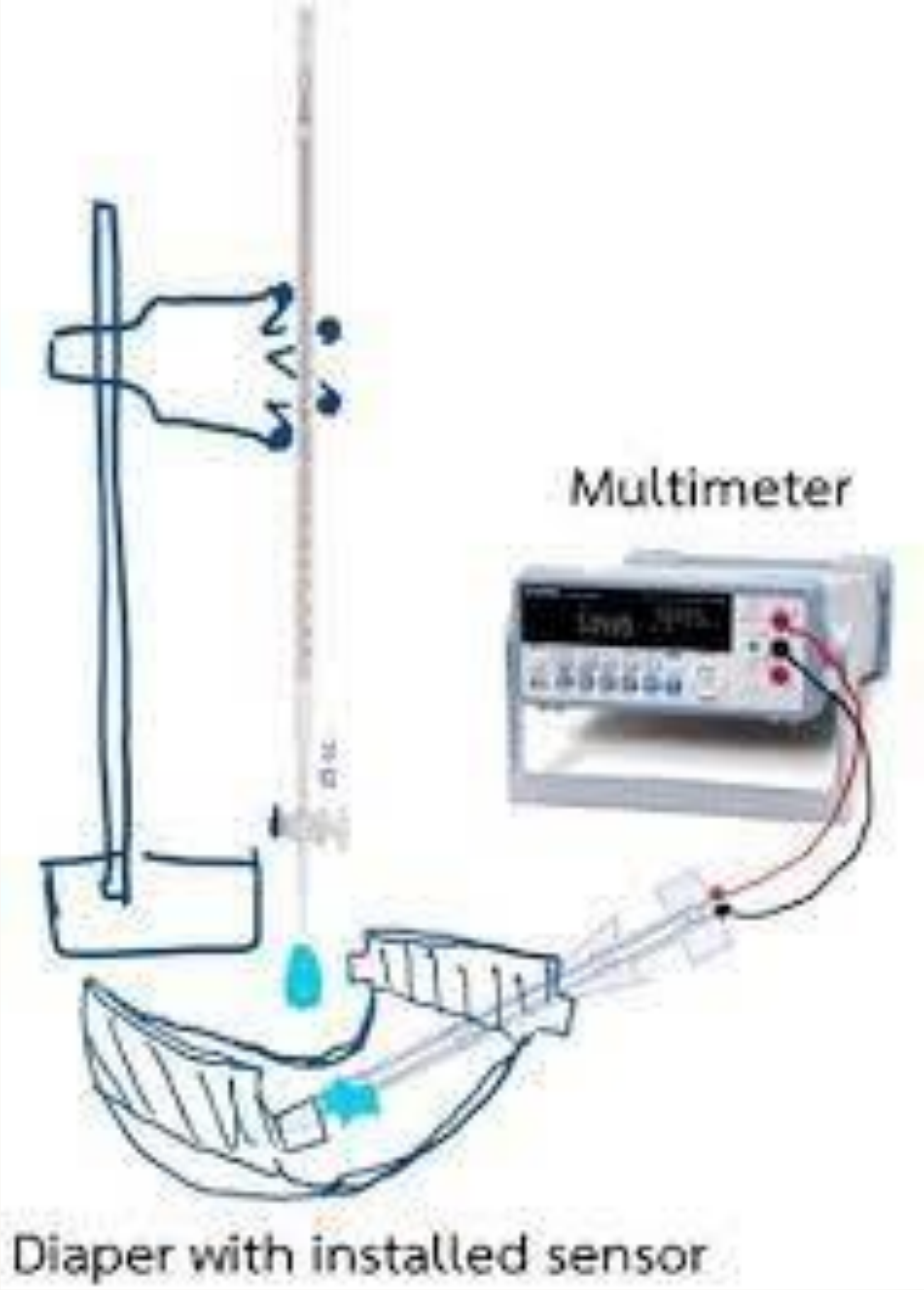
c) Large Bio-Potential Electrodes

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.



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