Electronic Supplementary Information (ESI-1)

Enhanced Thermoelectric Performance of Graphene based Nanocomposites Coated Self-Powered Wearable e-Textiles for Energy Harvesting from Human Body Heat

Nazakat Ali Khoso[1a], Xie Jiao[1b], Xue GuangYu[1c], Sun Tian[3c], JiaJun Wang[2*a,]

1 [a, b,c] College of Materials and Textiles, Zhejiang Sci- Tech, University, Zhejiang, Hangzhou, P.R China.
2[a] School of Art and Design at Zhejiang Sci-Tech University, Zhejiang Sci- Tech, University, Zhejiang, Hangzhou, P.R China.*

3[c] Shanghai Institute of Ceramics, Chinese Academy Sciences (CAS), Shanghai P.R China

[*]**Corresponding author:** wangjjhz@163.com

1. CHARACTERIZATIONS

Nicolet 5700 The elemental analysis of the graphene oxide, reduced graphene oxide, and PEDOT: PSS-rGO were analyzed using FTIR, Raman, XRD and XPS spectroscopy. A K-alpha mode on XPS (Thermofisher USA), X-ray diffraction (XRD), and (XPS) used to describe the rGO, GO, and PEDOT: PSS-rGO films and nano-composites.

1.1 FESEM

The Scanning electron microscopy (SEM) analysis of the sample was performed by using a Zeiss ultra-scanning electron microscope (SEM) for the surface of the treated and untreated fabrics. The electrical performance of the rGO and PEDOT PSS decorated cotton fabric was measured by using a four-point probe (SZT-2B) system (Suzhou Genisis Electronics Co.Ltd., China).

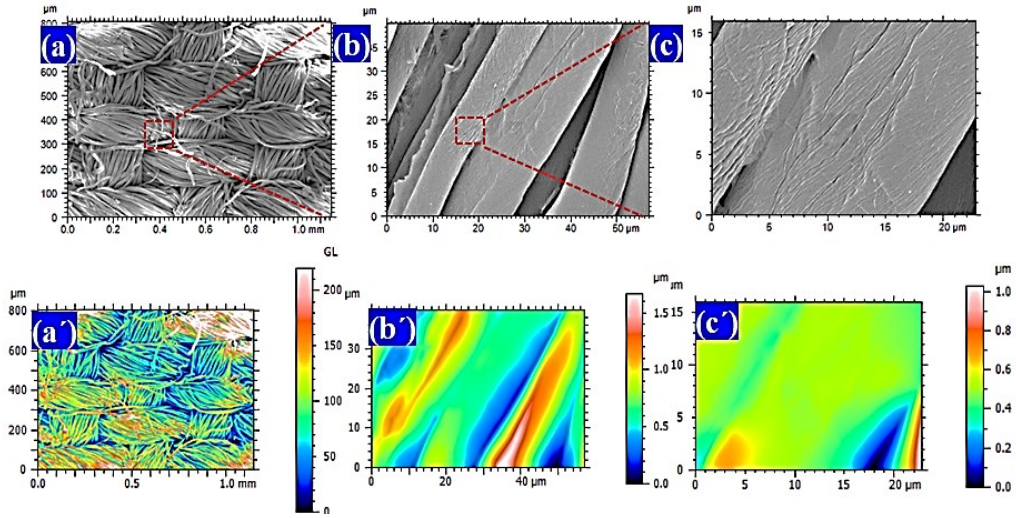

Fig. 1 (a), (b) and (c) FESEM micro graph of PEDOT: PSS-rGO coated cotton fabric at different magnifications, (a´), (b´) and (c´) IR colour rendering image of respective SEM images

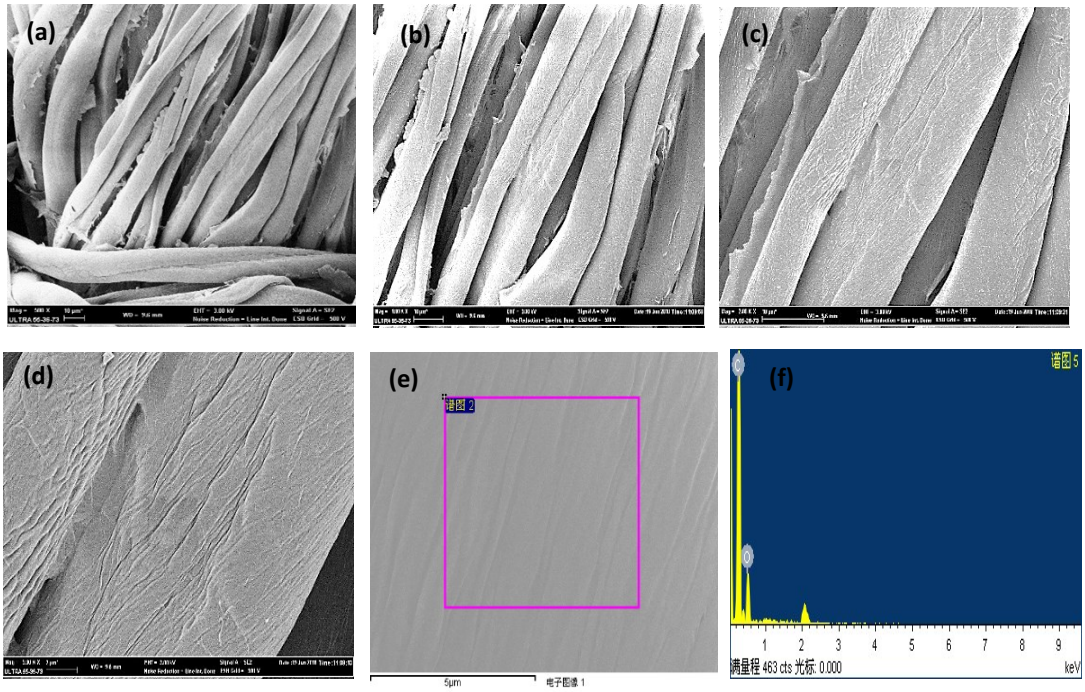

Fig. 2 (a), (b) and (c) FESEM micro graph of PEDOT: PSS-rGO coated cotton fabric at different magnifications, (d), (e) and (f) SEM with Elemental analysis using EDX respective SEM images

1.2 XRD & Rama Spectroscopy

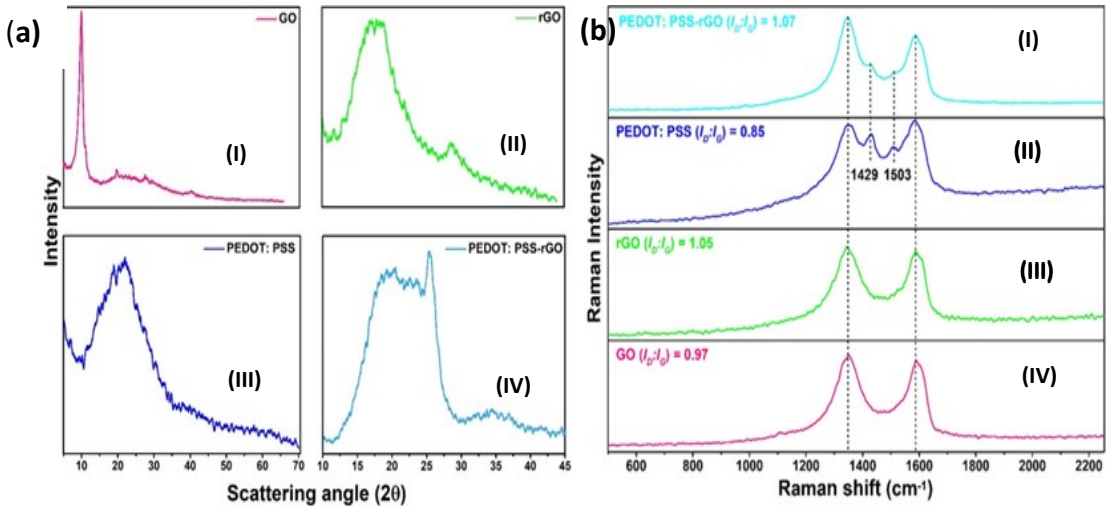

Figure. 3. a) XRD analysis of i) rGO/PEDOT: PSS ii) PEDOT: PSS, iii) rGO and iv) GO analysis of rGO/PEDOT: PSS & **Figure.2 b)** i) Raman analysis of Cotton fabric coated, ii) rGO/PEDOT: PSS iii) rGO, and c) GO and iv) Pristine Graphite

1.3 XPS Spectroscopy

A K-alpha mode XPS (Thermofisher USA), X-ray diffraction (XRD) were used to describe the rGO, GO, and PEDOT: PSS-rGO films and nano-composites. The NEXUS- XPS was recorded using an XPS spectrometer with a monochromatic Al K-α source of 1486.68 eV.

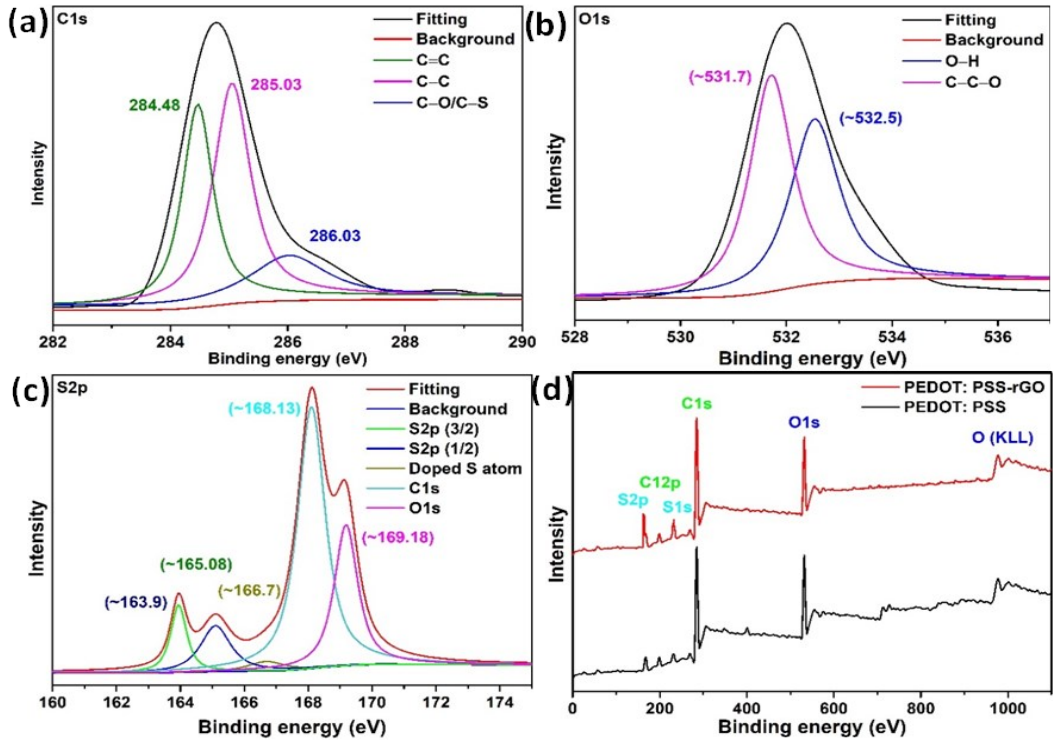

Figure. 4. a) XPS analysis of C (1s) and d) O (1s) spectrum b) Survey peaks

2. Measurements

2.1 Electrical Performance (Sheet Resistance)

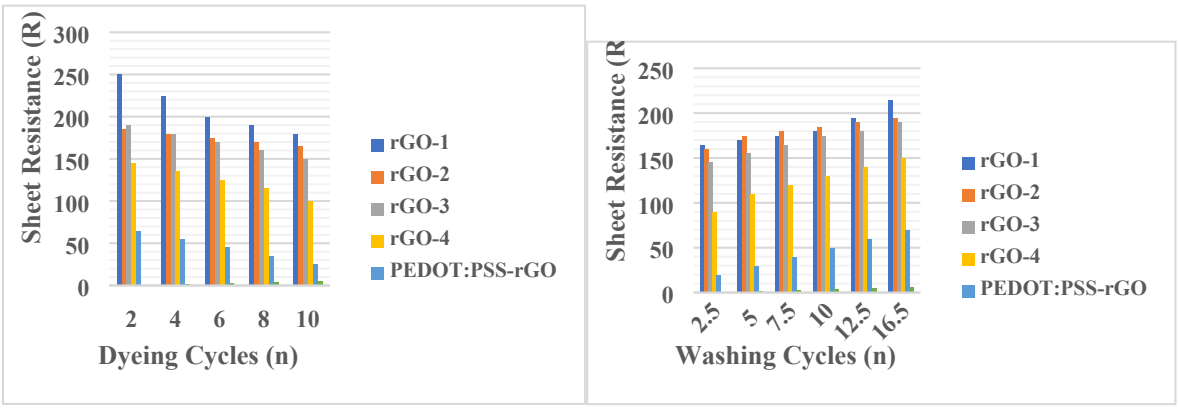

Fig. 5 change in sheet resistance with a) number of padding passes, b) number of washing cycles c) rGO content percent d) change in thermal conductivity with increasing the content percent of rGO

2.2 Thermoelectric Performance

2.2.1 Seebeck Coefficient and Power Factor

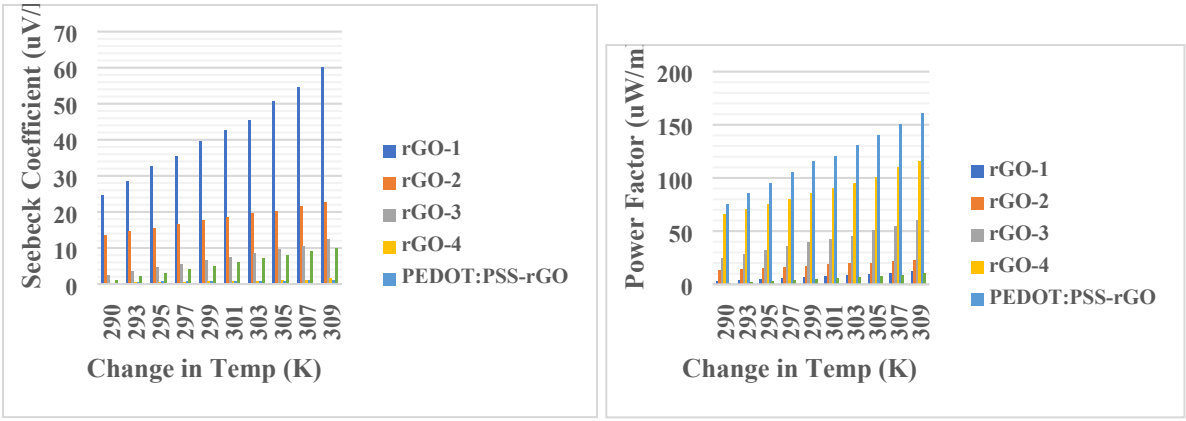

Fig. 6 The change in thermoelectric Seebeck effect due to change in concentration of rGO (W%) and power factor performance of TE device with change in concentration of rGO (W%) b) change in temperature (ΔT)/ °K

2.2.3 Output Power

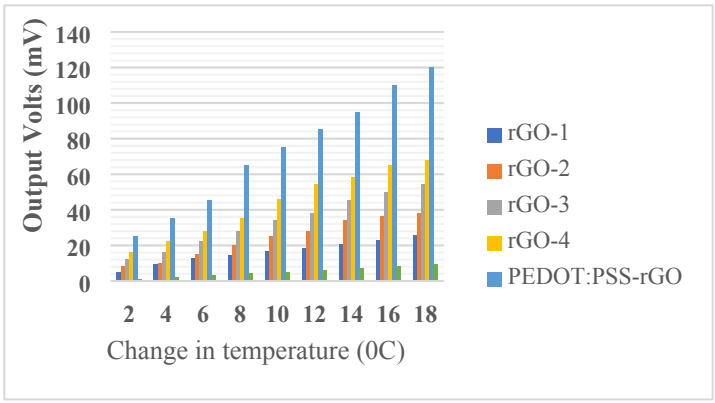

Fig. 7 Output Electric potential of (mV) with temperature gradient of (ΔT) 290-309K

2.2.4 Current Vs Voltage Relationship (I-V)

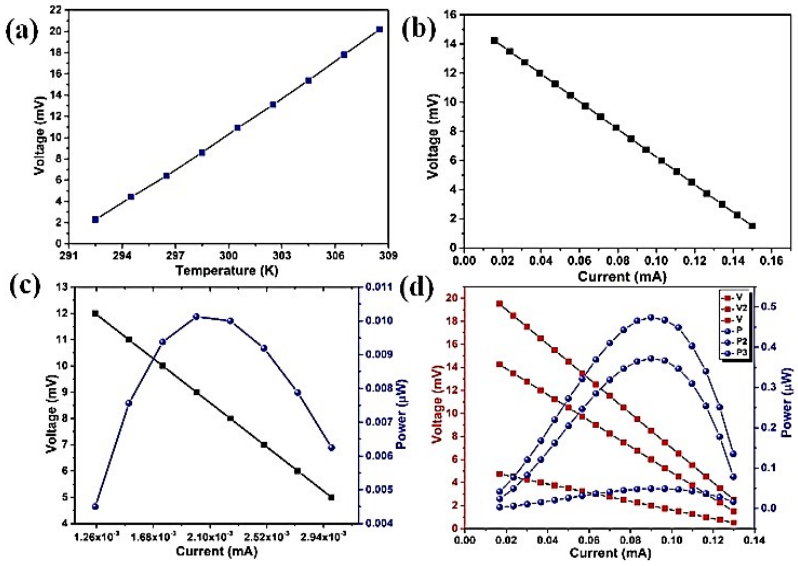

Fig. 8 a) Output Electric potential of (mV) with temperature gradient of (ΔT) 290-309K **b)** Current (I-V) relationship **c)** The current Vs Voltage (I-V) and **d)** Current Vs Power relationship between 4 leg and 6, 8 & 10-Leg TE device connected in a parallel arrangement

2.3 Textile Properties Performance

2.3.1 Water Contact Angle

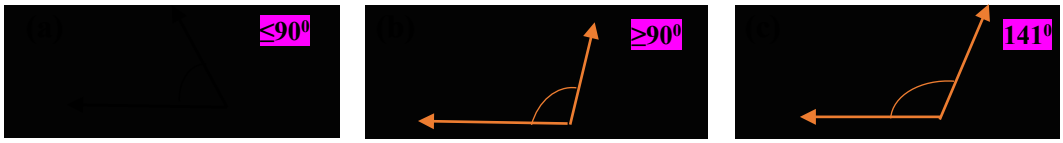

Fig.9 Effect of rGO Content percent on Water contact angle for GO, rGO and PEDOT:PSS-rGO coated cotton fabric

2.3.2 Wight pick up (%) and Particle Size

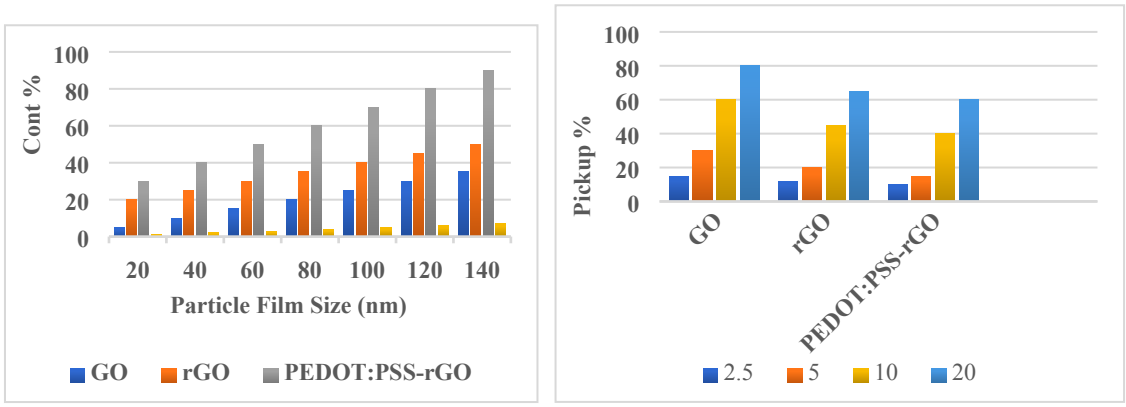

Fig.10 Effect of rGO Content percent on weight pick up% and particle size of GO, rGO and PEDOT:PSS-rGO coated cotton fabric

2.3.3 Water Contact Angle and Tensile Strength (mPa)

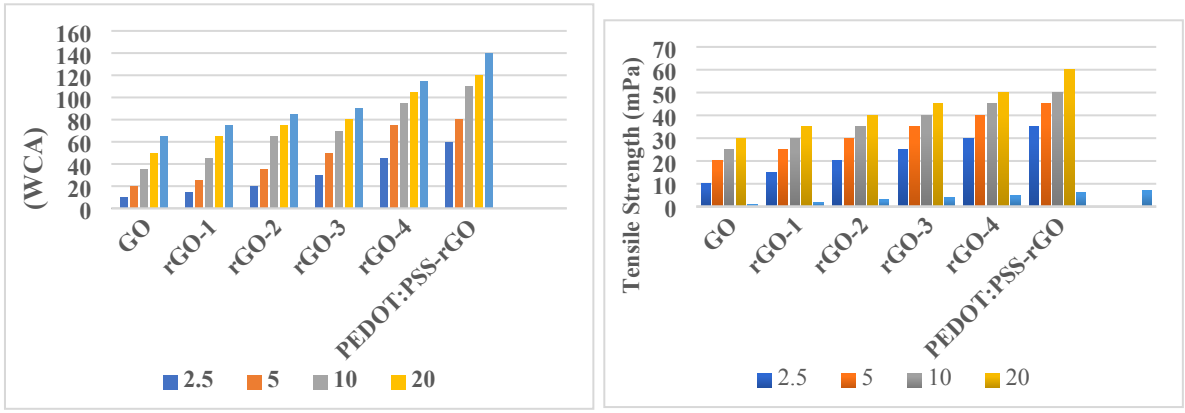

Fig.11 Effect of rGO Content percent on water contact angle and Tensile Strength of GO, rGO and PEDOT:PSS-rGO coated cotton fabric

3. Experimental Setup Design Model for Measurements

Thermal conductivity of the fabric using hotplate and Needle Probe based thermocouple

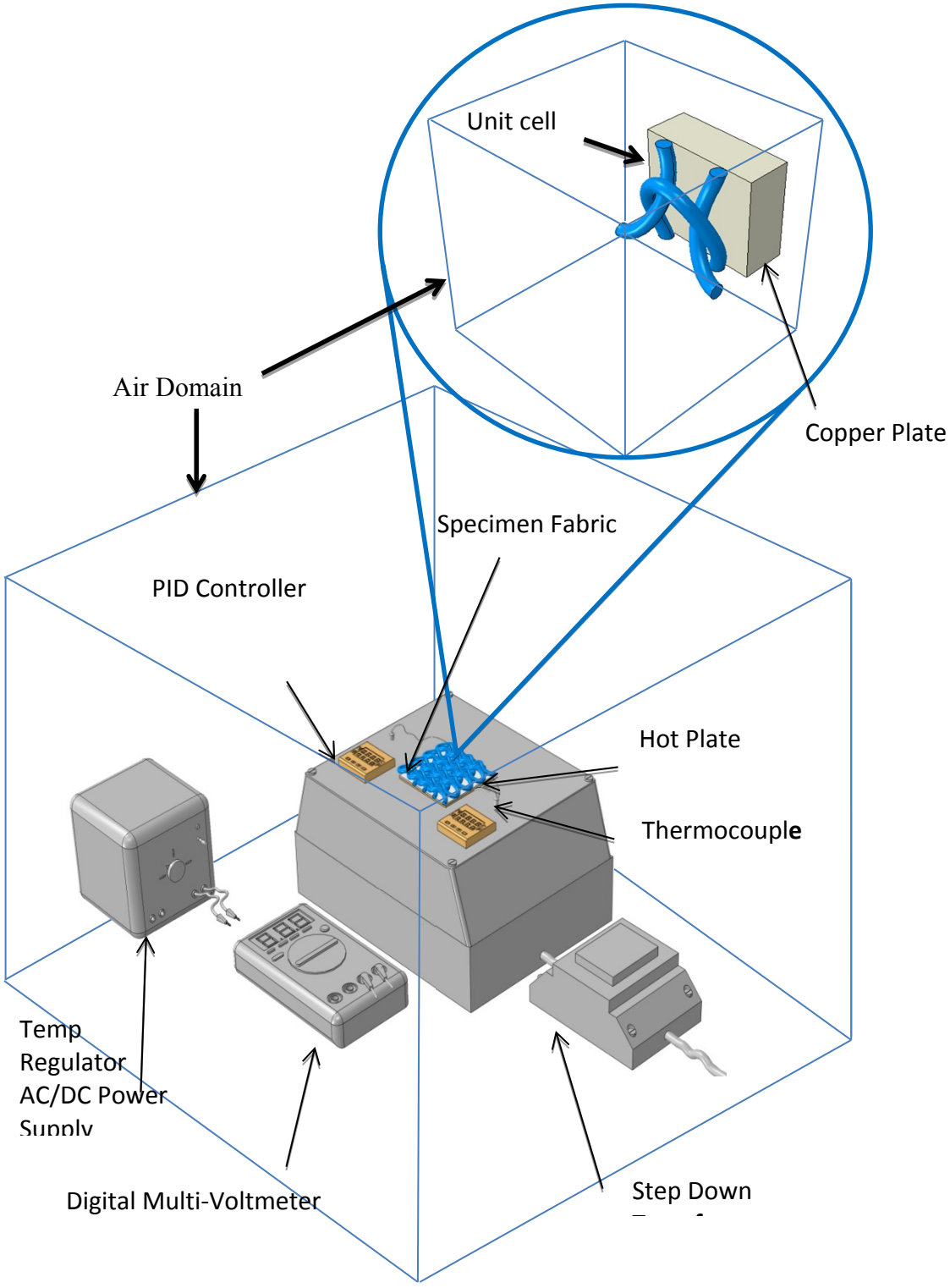

Fig.12 Measurement Setup for Thermoelectric performance measurement using hot plate, Seebeck setup **Source**. [Adopted from] Dammei Sun .et al. 2015

Electronic Supplementary Information (ESI-3)

4. Characterization

1.1 XPS Elemental Analysis

Table. 1 Carbon to oxygen (C/O) ratio of XPS analysis of textiles coated with rGO , compared with previously reported work

Sample	C (%)	O (%)	C/O	Ref.
Untreated	72.9	24.1	3.02	[82]
GO	73.7	22.4	3.29	[83]
rGO A.A	82.8	14.2	5.83	[84]
rGO $NaBH_4$	78.5	20.7	3.79	[85]
rGO H.H	83.6	13.3	6.26	[86]
rGO $Na_2S_2O_4$	85.5	14.0	6.15	[87]
rGO (A.A) 10% coated 1-3 Dips	83.3	16.5	4.86	This work
rGO (A.A) 10% coated 3-6 Dips	85.7	13.4	6.24	This work
rGO (A.A) 10% coated (7-10-Dips)	87.4	10.6	8.0	This work

5. Measurements

2.1 Sheet Resistance with Dyeing and Washing Cycles

Table.2 Sheet Resistance with dyeing Cycles with different weight percent of rGO

	GO	rGO-1	rGO-2	rGO-3	rGO-4	PEDOT:PSS-rGO
2	10	15	20	30	45	60
4	20	25	35	50	75	80
6	35	45	65	70	95	110
8	50	65	75	80	105	120
10	65	75	85	90	115	140

Table.3 Sheet Resistance with Washing Cycles with different weight percent of rGO

	GO	rGO-1	rGO-2	rGO-3	rGO-4	PEDOT:PSS-rGO
5	10	15	20	25	30	35
10	20	25	30	35	40	45
15	25	30	35	40	45	50
20	30	35	40	45	50	60

2.2 Thermoelectric Performance

Table. 4 Thermoelectric properties of Conductive polymer and reduced Graphene oxide nanocomposites coated textile device with different wt. % of rGO

rGO (w%)	rGO (KΩ/Sq.)	PEDOT: PSS (KΩ/Sq.)	PEDOT: PSS-rGO ((Ω/Sq.)	Seebeck (μV/K)	Power Factor ($\mu Wm^{-1}/K^{-2}$)
2.5	185	115±5	85±5	12.5	25
5.0	175	95±5	75±5	25.5	78
10.0	145	85±5	45±5	50.5	125
20.0	125	65±5	25±5	60.5	150

2.3 Seebeck Coefficient and Power Factor

Table. 5 Thermoelectric properties of Conductive polymer and reduced Graphene oxide nanocomposites coated textile device with different wt. % of rGO

Temp	rGO-1	rGO-2	rGO-3	rGO-4	PEDOT:PSS-rGO
2.5	165	160	145	90	20
5.5	170	175	155	110	30
7.5	175	180	165	120	40
10.5	180	185	175	130	50
12.5	195	190	180	140	60
16.5	215	195	190	150	70

Temp	rGO-1	rGO-2	rGO-3	rGO-4	PEDOT:PSS-rGO
2.5	250	200	190	145	65
5.5	238	185	180	135	55
7.5	232	180	170	125	45
10.5	226	175	160	115	35
12.5	215	170	150	100	25
14.5	205	160	145	90	15

2.3 Seebeck Coefficient and Output Power (mV)

Table. 6 Thermoelectric properties of Conductive polymer and reduced Graphene oxide nanocomposites coated textile device with different wt. % of rGO

Temp(K)	rGO-1	rGO-2	rGO-3	rGO-4	PEDOT:PSS-rGO
293	0.25	0.3	2.5	13.5	24.5
295	0.5	0.35	3.5	14.5	28.5
297	0.6	0.4	4.5	15.5	32.5
299	0.65	0.5	5.5	16.5	35.5
300	0.7	0.6	6.5	17.5	39.5
302	0.75	0.7	7.5	18.5	42.5
305	0.8	0.8	8.5	19.5	45.5

307	0.85	0.9	9.5	20.0	50.5
309	0.9	1.0	12.5	22.5	60.5

TEmp(^{0}C)	rGO-1	rGO-2	rGO-3	rGO-4	PEDOT:PSS-rGO
2.5	10.5	8.0	18	25	35
5.5	12.5	15	22	28	45
7.5	14.5	20	28	35	65
10.5	16.5	25	34	46	75
12.5	18.5	28	38	54	85
14.5	20.5	34	45	58	95
16.5	22.5	36	50	65	120