Electronic Supporting information

Polymer based Graphene/Zinc Oxide Nano Crystal (GZnNC): An Outstanding Thermoelectrical Energy Conversion Material

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S1: Table (iii): Thermoelectric properties of PVAc/GZnNC composite with concentrations

Sr. No	Composition	Electrical conductivity (σ) S/m (20ºC)	Seebeck coefficient (S), µV/k, (- ve)	Power Factor(PF) µW $m^{-1}K^{-2}$
1.	PVAc (80%)+GZnNC (20%)	0.0029	23.8	1.61×10^{-6}
2.	PVAc (60%)+ GZnNC (40%)	2.34	24.2	1.3×10^{-3}
3.	PVAc (40%)+GZnNC (60%)	82.5	26.3	5.7×10^{-3}
4.	PVAc (30%)+GZnNC (70%)	917.4	25.76	0.608
5.	PVAc (20%)+GZnNC (80%)	1478.2	23.7	0.831
6.	PVAc (10%)+GZnNC (90%)	2043.7	28.40	0.144
7.	PVAc (5%)+GZnNC (95%)	5078.2	32.6	5.39

S2: Table (iv) : Thermoelectric properties of PVAc/Graphene composite with concentrations

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Sr. No	Composition	Electrical conductivity (σ) S/m (20ºC)	Seebeck coefficient (S), µV/k (- ve)	Power Factor(PF) µW $m^{-1}K^{-2}$
1.	PVAc (80%) + Graphene(20%)	21.47	--	--
2.	PVAc (60%) + Graphene (40%)	186.48	--	--
3.	PVAc (40%) + Graphene (60%)	346.32	19.69	0.134
4.	PVAc (20%) + Graphene (80%)	484.84	17.64	0.154
5.	PVAc (10%) + Graphene (90%)	1333.33	21.44	0.612

6.	PVAc (5%) + Graphene (95%)	2898.55	20.73	1.245

S3: Table (v): Thermoelectric properties of PEDOT:PSS/GZnNC composite with concentrations

Sr. No	**Composition**	**Electrical conductivity (σ) S/m (20ºC)**	**Seebeck coefficient (*S*), μV/k (- ve)**	**Power Factor(PF)** $\mu W\ m^{-1}K^{-2}$
1.	PEDOT:PSS (60%) + GZnNC(40%)	32980.2	32.7	35.3
2.	PEDOT:PSS (50%) + GZnNC(50%)	34465.2	38.5	51.1
3.	PEDOT:PSS (40%) + GZnNC (60%)	22026.4	36.8	29.9
4.	PEDOT:PSS (30%) + GZnNC (70%)	24063.0	28.6	19.7
5.	PEDOT:PSS (20%) + GZnNC (80%)	15847.8	21.3	7.2
6.	PEDOT:PSS (10%) + GZnNC (90%)	2421.3	27.2	1.8
7.	PEDOT:PSS (5%) + GZnNC (95%)	4545.4	17.7	1.4

S4: Table (vi): Thermoelectric properties of PEDOT:PSS/GZnNC composite with concentrations.

Sr. No	**Composition**	**Electrical conductivity (σ) S/m (20ºC)**	**Seebeck coefficient (*S*), μV/k (- ve)**	**Power Factor(PF)** $\mu W\ m^{-1}K^{-2}$
1.	PEDOT:PSS (60%) + Graphene (40%)	76987	13.34	13.7
2.	PEDOT:PSS (50%) + Graphene (50%)	105067	12.2	15.6
3.	PEDOT:PSS (40%) + Graphene (60%)	133333	11.17	16.65
4.	PEDOT:PSS (30%) + Graphene (70%)	185125	9.75	17.6

5.	PEDOT:PSS (20%) + Graphene (80%)	242541	7.5	13.64
6.	PEDOT:PSS (10%) + Graphene (90%)	81726	8.2	5.4
7.	PEDOT:PSS (5%) + Graphene (95%)	172057	8.85	13.48

S5: Table (vii) : Thermoelectric properties of PEDOT:PSS/GZnNC composite with concentration

Sr. No	**Composition**	**Electrical conductivity (σ) S/m (20ºC)**	**Seebeck coefficient (*S*), μV/k**	**Power Factor(PF)** $\mu W\ m^{-1}K^{-2}$
CP-1	PVAc (20%)+GZnNC (80%)	1478.2	23.7	0.831
CP-2	PVAc (15%)+ PEDOT:PSS (5%) +GZnNC (80%)	202.02	25.58	0.132
CP-3	PVAc (10%)+ PEDOT:PSS (10%) +GZnNC (80%)	860.58	15.44	0.205
CP-4	PVAc (5%)+ PEDOT:PSS (15%) +GZnNC (80%)	274.72	20.35	0.113
CP-5	PEDOT:PSS (20%) + GZnNC (80%)	15847.8	21.3	7.2
CP-6	PEDOT:PSS sheet	27972	28	21.93

S6: Table (viii): Summary of thermoelectric properties of the best composite of inorganic and organic materials.

Thermoelectric materials	**σ, S/m**	***S*, μV/k**	**κ,** W/mK	**Calculated PF ($S^2\sigma$),** $\mu W\ m^{-1}K^{2}$
PANi + SWCNT composites with different SWCNT [1]	10-125 (RT)	11-40 (RT)	0.5-1 (RT)	0.5-5 (300K)
PANi+ unoxidized SWCNT [2]	5.30×10^{4}	33		0.6

Thermoelectric materials	**σ, S/m**	***S*, µV/k**	**κ,** W/mK	**Calculated** **PF (*$S^2\sigma$*),** µW $m^{-1}K^2$
PANi+ HCL+ MWCNT(40%) [3]	1.71×10^3	10	--	0.17
PANI+CNT (15.8%) [4]	6.1×10^3	29	0.4-0.5	PF=5
CNT+graphite+polylactic acid [5]	4.123×10^3	17	5.5	ZT=7.2×10^{-5} at RT
P3HT+MWCNT (30%) [6]	11	11.3 at 493K	--	--
P3HT+MWCNT (5%) [7]	1.31×10^{-1}	131	--	--
P3HT+SWCNT [8] (81%) P3HT+$FeCl_3$+ SWCNT (42-81%) P3HT+$FeCl_3$+ MWCNT (10-40%) P3HT+$FeCl_3$+ MWCNT (50%) [9]	1.8×10^4 1.1×10^5 8×10^3 1×10^3	32 29 29 12	0.13 -- -- 0.16	18 95 6 0.2
PEDOT:PSS+CNT(35%) [9]	4×10^4	--	0.2-0.4	ZT=0.02
PEDOT:PSS+ SWCNT(20-95%) [10]	6×10^4-3.6×10^5	15-28	0.56	42-95
Nafion +MWCNT (10-50%) [11]	0-8	20-26	--	0.5
Nafion +FWCNT (10 -50%) [5]	0-13	17-24	--	0-1
Nafion +SWCNT (10-50%) [5]	0-1	25-30	--	0.1-0.2
Graphene [12]	10^6	5000	--	ZT= 0.006 at 300K

PANi/Graphene composite [13] PANi Graphene **Pallet :** PANi :Graphene:: 4:1 to 1:1 **Film** PANi :Graphene:: 4:1 to 1:1	 10^3 2×10^4 1.4×10^3-5×10^3 20-700	 14 15 20-30 27-41	 -- -- -- --	 0.2 8 0.7-5.6 0.04-1.2
PANi + HCL +Graphene (50%) [14]	123	34	3.3	14
PANi+GNP (In situ polymerization with protonation ratio- 0.2) Neat PANi Neat GNP PANi/GNP (50mM, as made) PANi/GNP (50mM, reprotonated) [15]	 150 2×10^4 5900 1.74×10^4	 7 5 33 19	 0.6 74 13 15	ZT (300K)= 3.68×10^{-6} 3.04×10^{-6} 1.51×10^{-4} 1.26×10^{-4}
PANI + 30% Graphene (*In-situ* polymerization) [16]	5×10^3 at 323K	12	**--**	ZT= 1.95 $\times 10^{-3}$ at 453 K
PANI at 420K PANI + 5-30% Graphene [17]	500 700-4.0×10^3	13 28-32	-- --	0.1 0.4-2.6
PANI+$HClO_4$+Graphite (50 wt.%) [18]	1.2×10^4	19	1.2	1.2
PEDOT:PSS+GNP(2-3%) PEDOT:PSS + GN (1-4%) [19]	74-3170	44.75-165.8	0.14-0.30	
PEDOT:PSS/Graphene (1-5%) [20]	52800-63700	21.750-26.778	--	PF= 26.444-45.677

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