Applications of carbon nanotubes in different layers of P3HT:PCBM bulk heterojunction organic photovoltaic cells

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Introduction

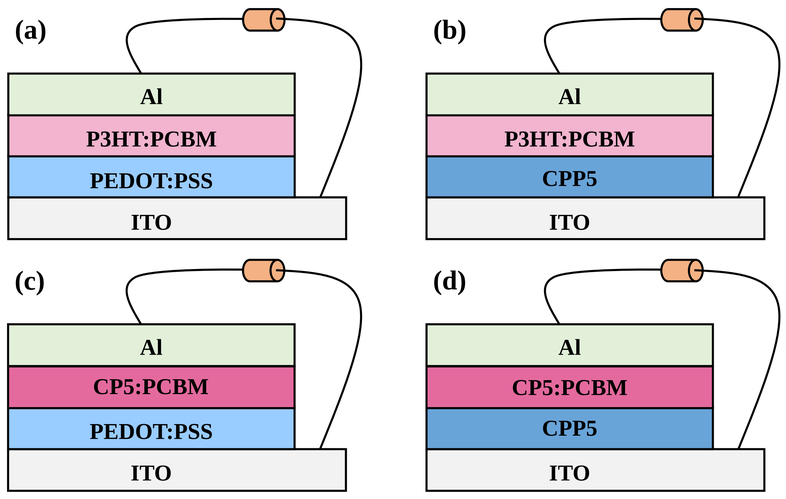
- Photovoltaic technology - The best solution to face the current global energy crisis.
- Organic photovoltaic cells (OPVCs):
  - Advantages of transparency, flexibility, easy processing on substrates with standard printing or coating techniques along with economic benefits.
  - Disadvantages of low power conversion efficiency (PCE) and less stability.
- Carbon nanotubes (CNTs) have extraordinary aspect ratio, high surface area, ballistic axial charge transport, low reflectance, mechanical stability, and electron accepting nature.
- Application of composites of CNTs & poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) as electrode material, and CNTs & Poly(3-hexylthiophene) (P3HT) in active layer for fabrication of OPVCs can enhance the device performance due to the collective advantages of individual materials.

$$PCE = (J_{sc}.V_{oc}.FF)/P_{in}$$

J_{sc} : Short-circuit current density
V_{oc} : Open-circuit voltage
FF : Fill factor
P_{in} : Input power density

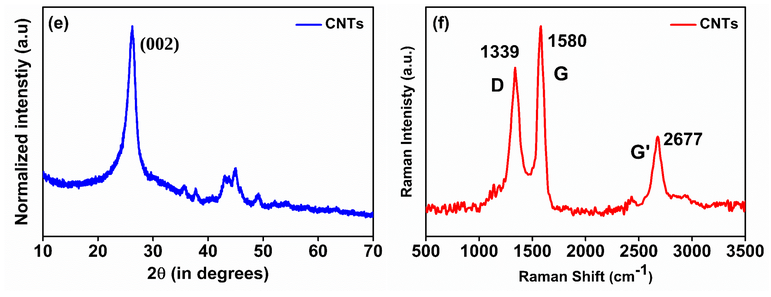
Experimental section

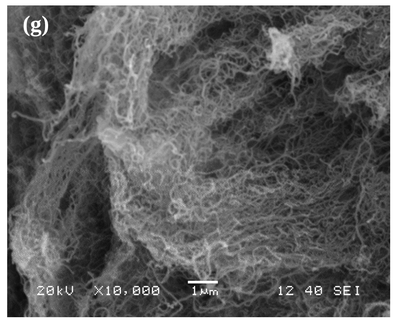
- Synthesis of CNTs by using Pyrolysis method
- Preparation of CNTs/PEDOT:PSS and CNTs/P3HT composites by solution method
- Fabrication of thin film OPVCs by spin coating



Designs of (a) Ref, (b) CPP, (c) CP, and (d) CPPCP OPVCs

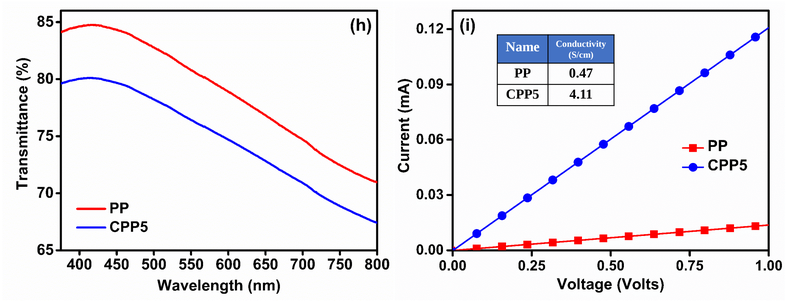
Results & Discussion



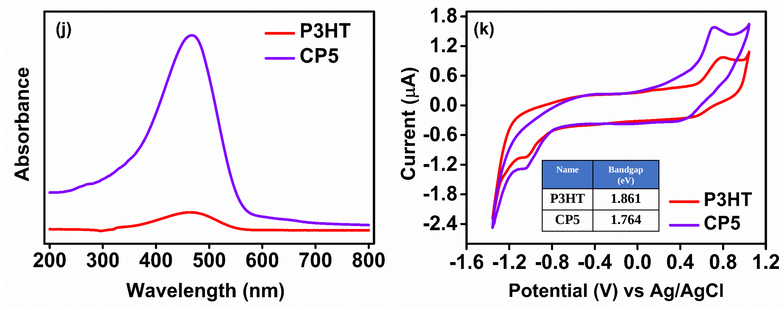


(e) XRD pattern, (f) Raman spectrum and (g) SEM image of CNTs

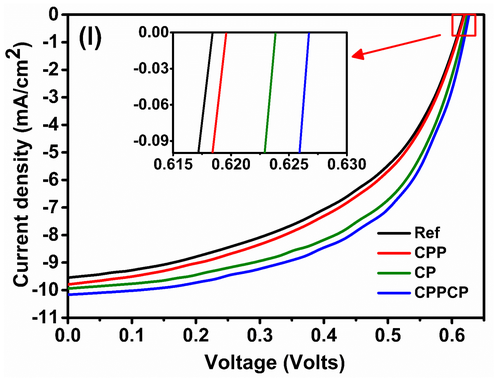
Results & Discussion



(h) Transmittance spectra and (i) I-V data of pristine PEDOT:PSS (PP) and the composite CPP5



(j) UV-Visible spectra and (k) CV data of pristine P3HT and the composite CP5



(l) J-V characteristics of all the OPVCs at room temperature

References

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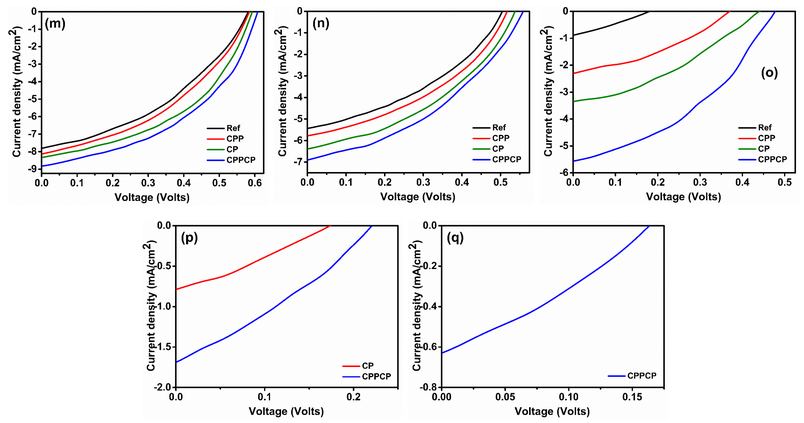
Results & Discussion



J-V data of OPVCs kept in open atmosphere after (m) 6 hours, (n) 12 hours, (o) 18 hours, (p) 24 hours, and (q) 30 hours of fabrication

Time since fabrication (hours)	OPVC name	Jsc (mA/cm2)	Voc (mV)	FF (%)	PCE (%)
0	Ref	9.55	618.25	48.76	2.88
	CPP	9.79	619.34	49.07	2.98
	CP	9.94	623.33	55.02	3.41
	CPPCP	10.16	625.96	55.93	3.56
6	Ref	7.82	581.5	40.44	1.84
	CPP	8.13	584.51	41.26	1.96
	CP	8.34	592.66	46.13	2.28
	CPPCP	8.83	607.98	45.19	2.43
12	Ref	5.43	504.12	39.15	1.07
	CPP	5.78	517.01	40.28	1.2
	CP	6.39	537.47	40.63	1.4
	CPPCP	6.9	558.62	39.77	1.53
18	Ref	0.89	180.31	28.81	0.05
	CPP	2.31	370.22	35.62	0.3
	CP	3.36	441.03	35.63	0.53
	CPPCP	5.56	477.15	38.77	1.03
24	Ref	--	--	--	--
	CPP	--	--	--	--
	CP	0.79	173.6	29.09	0.04
	CPPCP	1.69	220.24	30.22	0.11
30	Ref	--	--	--	--
	CPP	--	--	--	--
	CP	--	--	--	--
	CPPCP	0.63	163.41	30.87	0.03

Conclusions

- High quality CNTs have been successfully synthesized by simple pyrolysis to prepare CNTs/PEDOT:PSS and CNTs/P3HT composites.
- Incorporation of CNTs has resulted in improved physical properties of composites.
- OPVCs fabricated using the composites have demonstrated increment in the PCE as well as other electrical parameters due to the presence of CNTs.
- Periodic measurement of electrical output of the OPVCs kept in open atmosphere revealed extended lifetime of devices containing CNTs while the improvement in the device output has been maintained.
- The PCE and lifetime of the best performing device (CPPCP) have been enhanced by 24% and 67% respectively, compared to the reference OPVC.
- This research considerably encourages the applications of CNTs in OPVCs as well as in other organic optoelectronic devices.

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