Study of Organic Polymer Solar Cells incorporating Carbon Nanotube

Ang Yun Jia*, Hwa Chong Institution
Dr Wendy Yung, Assistant Research Scientist, Singapore Institute of Manufacturing Industry (SIMTech)

HWA CHONG INSTITUTION

Introduction & Rationale

Carbon nanotubes have demonstrated excellent photovoltaic properties. Hence, current efforts for incorporating CNTs has achieved vast potential. The basis of the study is creating aligned, vertically-structured nanotubes for ordered bulk heterojunction polymer solar cell. In the study, we have varied the post-fabrication thermal annealing time for comparisons. We report that the incorporation of carbon nanotubes have resulted in increased carrier mobility by ballistic conductivity and regulation of heat control enhances device performances.

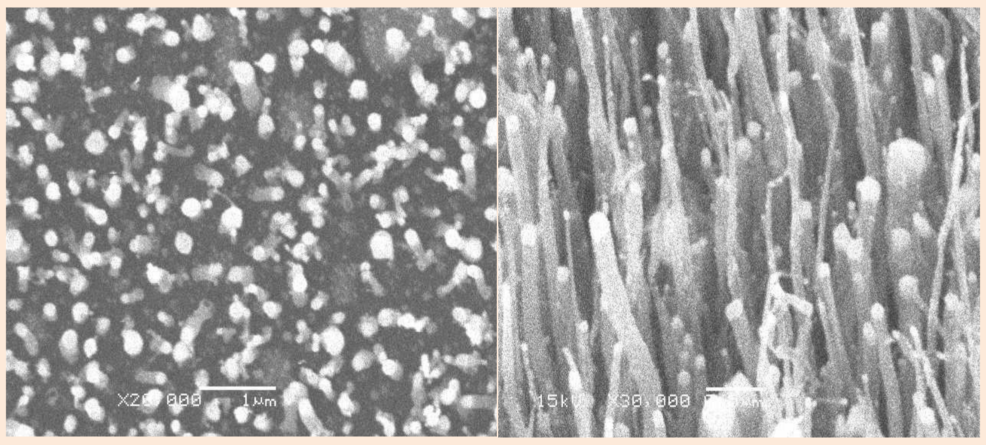
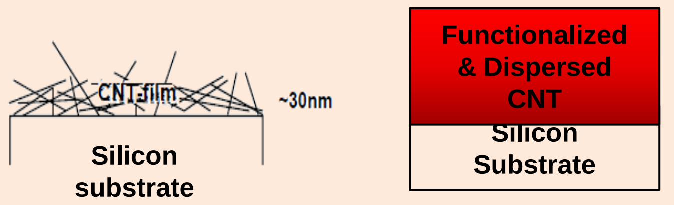


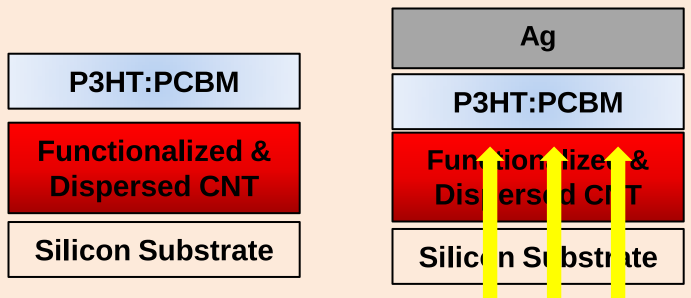
Figure 3a (above). SEM images showing increased specific surface area for absorption, with greater presence of voids for polymer infiltration between CNTs.
Figure 3b (below) Schematic layout of fabricated organic polymer (PCBM-P3HT) solar cell incorporating carbon nanotubes and silver metal as electrodes. All devices have a photoactive area of 0.3cm X 0.3cm and polymer loading concentration of 1% wt.

Methodology

Step 1: Growing, functionalizing and dispersing of CNTs



Step 2: Spin-coat P3HT-PCBM and applying silver contact



Results and Discussions

Scanning Electron Microscope (SEM) observations

Most nanorods were aligned in the electron transport direction. A thin polymer film indicated by darker regions (figure 3a) demonstrates homogenous mixture of P3HT-PCBM forming an interpenetrating composite in between carbon nanotubes.

Atomic Force Microscope (AFM) observations

- Without annealing, surface is even and polymer layer is unevenly distributed.
- Annealing after 10 and 20 mins indicated rougher surface

Annealing decreases the charge-transport distance and reduces recombination of excitons. Rougher surfaces indicates self-organization of polymer blend, implying an ordered structure. The rougher the polymer layer, the greater the annealing time required.

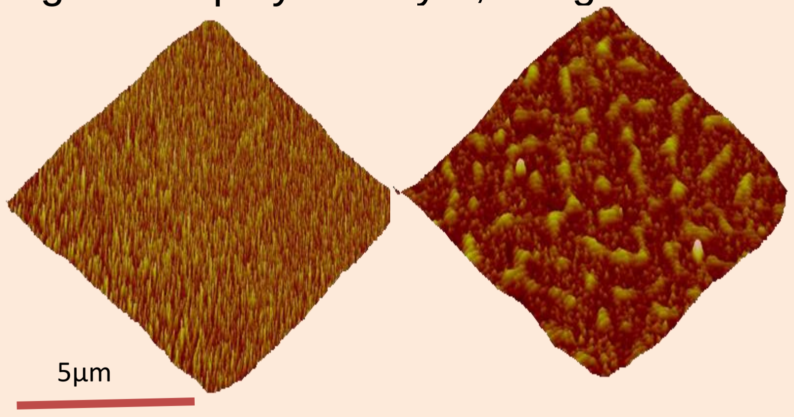


Figure 4. AFM images of polymer surface morphology before (left) and after (right) thermal annealing

Current and Resistance Measurements

Results demonstrate that cell efficiency increases with annealing time. The best results were obtained after thermal annealing at 110°C for 10 mins on a hot plate (device 3)

Measurements indicate that after thermal annealing:

- P3HT showed greater self-assembled and greater contact with CNTs
- Improved charge carrier mobilities along the long axis of fibrils along π–π stacking
- Formation of an interpenetrating polymer phase segregation crucial for greater efficiency

Figure 5 shows the I-V curve of the devices at different annealing time. Diode effect is greater in device 2 and 3 compared to 1, as can be seen by the improved current density.

Device No.	Annealing Time(mins)	Current Density (Isc)/ A	Resistance (Ω)
1	Unannealed; Dry in open petri dish	0.0128928	90.3
2	5 mins; 110°C	0.0502968	65.4
3	10 mins; 110°C	0.0648782	71.8
4	20 mins; 110°C	0.0464211	78.2

Table 1. Performance of fabricated P3HT/PCBM solar cell at different annealing conditions

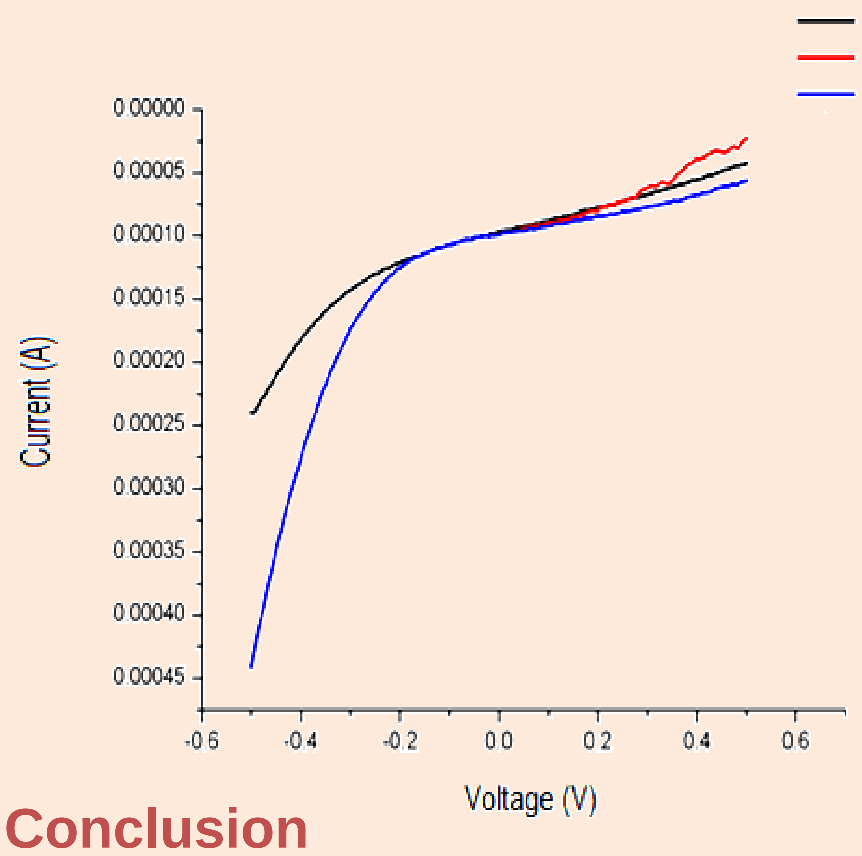
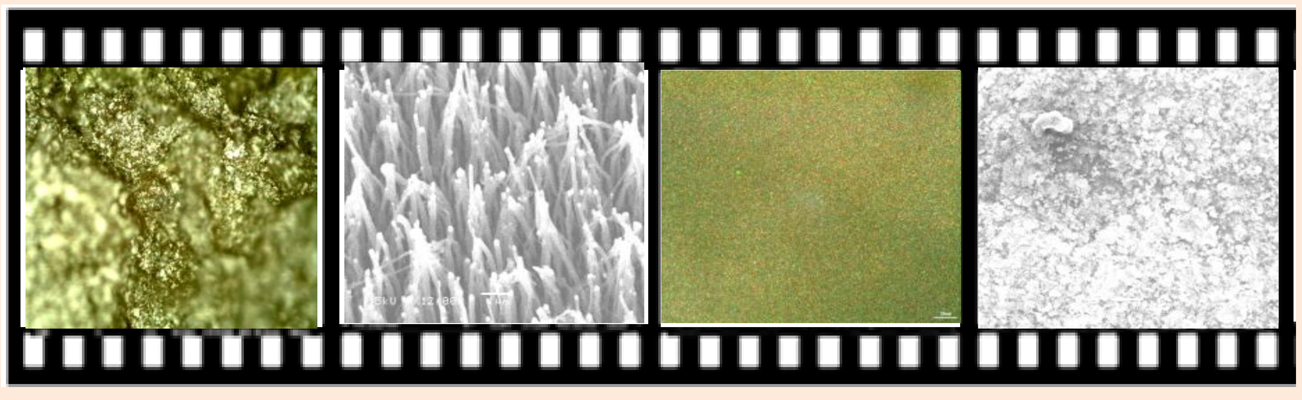


Figure 5. I–V characteristic curves of devices measured under illumination . The conditions are respectively: Device 2 (5 mins), Device 3 (10 mins) and Device 1 (unannealed).

Conclusion

In conclusion, promising results suggest that the MWCNTs would be a suitable alternative to conventional ITO contact due to the interpenetrating donor-acceptor network with the photoactive composite. Annealing at high temperatures improves the cathode contact, resulting in smoother surfaces and greater penetration.



References & Acknowledgements

- Mrs Tan Ai Chin, teacher-mentor for her constant guidance
- Mr Yap Ching Chong, for his detailed supervision
- NTU EEE Nanolabs for their gracious loan of equipments

All images and pictures were taken by the author.