Abstract
To overcome drawbacks of inorganic photovoltaics, organic photovoltaics (OPVs) have been introduced as a viable alternative energy source with cost effective, lightweight and flexible nature instead of silicon-based solar cells. However, low power conversion efficiency (PCE), which is a product of ill-defined oriented spatial arrangements leading to higher PCE.

Background & Motivation
Silicon-based solar cell as first generation of photovoltaics (PVs) with high cost of fabrication and installation, inflexibility, heavy weight, and environment unfriendliness pointed out the necessity of low-cost and solution-processable organic photovoltaic (OPV) rather than efficient but toxic inorganic semiconductors such as Ge, GaAs, CdTe, and CdS. Organic solar cell with advantages such as tunable electron properties of conjugated polymers through chemical synthesis, mechanical flexibility, disposability, cost effectiveness, light weight, solution processibility, and high throughput manufacturing, started a new era for designing a large scale production method which do not require high temperature and pressure nor vacuum condition.

Innovation
By employing supramolecular nanoscale self-assembly which is a potent method to impose well-defined ordering to organic materials, building blocks will form a highly oriented spatial arrangements leading to higher PCE. Rosette nanotube (RNT) with advantages such as kinetic stability, process-ability, high aspect ratio, and chemical tunability offers a dramatic PCE enhancement. By functionalizing guanine*cytosine (G*C) motifs which are base components of RNT, with photoactive porphyrin molecule, photoactive rosette nanotubes have been synthesized which introduce order to morphology leading to better electron transfer and resulting in higher efficiency.

Characterization
Optical energy levels of the three RNTs which are functionalized with different porphyrin groups have been measured by ultraviolet photo spectroscopy and absorption on set of a thin film. The results showed these RNTs can be used In OPVs structure as electron donor material to form a donor-acceptor (D-A) pair in the photoactive layer of the solar cell. One dimensional structure of RNT also enhance the electrical conductivity. Thin films of three RNTs and three unassembled motifs have been fabricated. Based on the resistivity and thickness of the thin films, we calculated the conductivity of the films and realized that in comparison to the non-assembled controls, the thin films of RNTs showed several orders of magnitude higher conductivity.

To investigate the efficiency of photo-induced electron transfer between the RNTs and PCBM, which is well-known electron acceptor, spin casted films of three RNTs have been fabricated to compare it to spectra of RNTs without acceptor. The photoluminescence (PL) spectra of these spin-cast thin films have been collected on quartz substrate. The PL spectra of the RNTs have strong and broad emission bands in the Vis-NIR region in both thin films and solutions. In the blend films, the emissions were quenched in all the cases.

These porphyrin-functionalized RNTs may contribute to the repertoire of electron donor materials in solution-processed OPVs. Structure of organic solar cell based on RNT electron donor is shown below. Determining true efficiency of these cells are still on progress and will be reported elsewhere.

Results
Scanning electron microscopy images below confirmed formation of tubular structure at nanoscale. Figure below shows functionalized G*C motifs before and after self assembly.

Conclusion
Bio-inspired one-dimensional porphyrin arrays were obtained from the hierarchical self-assembly of DNA base analogs of guanine and cytosine through hydrogen bonding and n–n stacking. Three different porphyrin-functionalized rosette nanotubes (RNTs) with lengths ranging from a few hundred nanometers to several micrometers were obtained. Narrow band gap, energy level alignment and conductivity enhancement indicate the high potential of these photo-active structures in the design of efficient organic photovoltaics (OPVs). This work introduces a new strategy to build one-dimensional structures with higher charge carrier mobility that displays unique optoelectronic properties to contribute to the repertoire of electron-donor materials in solution-processed OPVs.

References

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