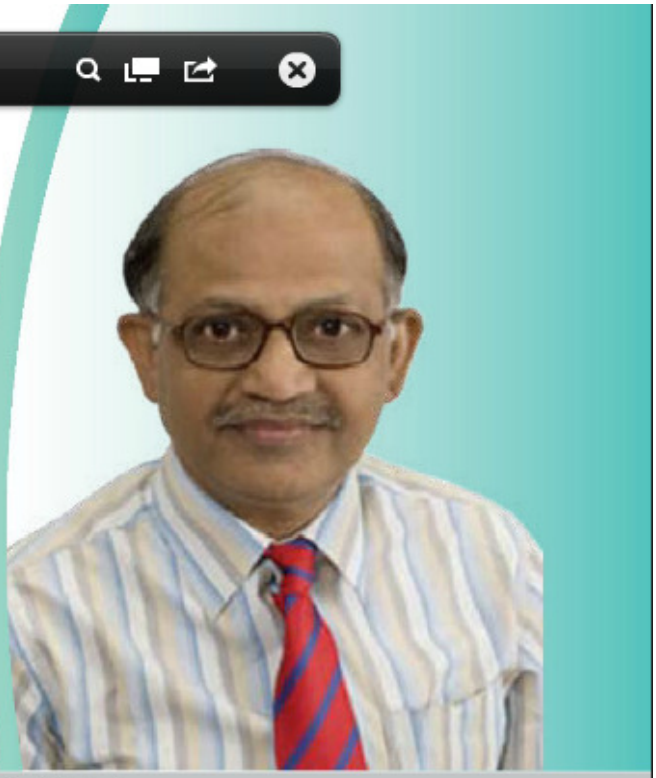
Innovative Carbon Research for Solar Energy Applications



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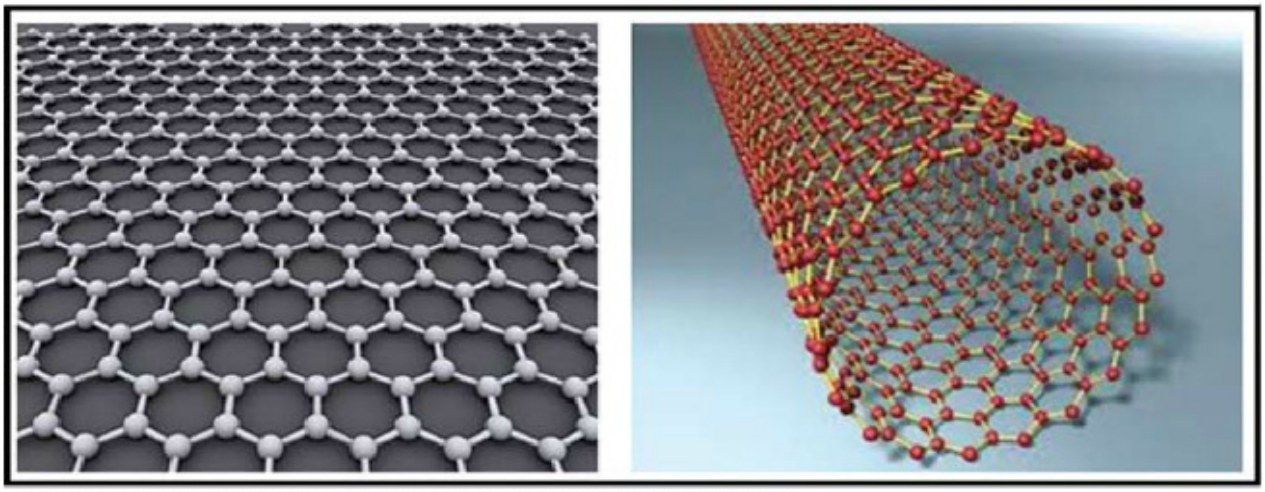
Several Solar Scientists are investigating how carbon can harness the sun's light. In order to replace the more expensive and toxic materials used in conventional photovoltaic technologies, a team at Gujarat Energy Research and Management Institute (GERMI), Gandhinagar in collaboration with researchers from Pandit Deendayal Petroleum University (PDPU), Gandhinagar and CSIR-Institute of Minerals and Materials Technology, Bhubaneswar has recently investigated on two important carbon nano-materials such as: graphene and carbon nanotubes and their polymer composites. They have demonstrated both theoretically and experimentally the use of these materials as transparent and current spreading electrode in thin film solar cells. The scientists published their findings in a special issue of Journal of Nanoscience and Nanotechnology [1, 2].

One of the material systems under investigation is graphene. This is a new form of carbon, which is a 2-dimensional planar sheet. It is very thin with a thickness of just one carbon atom, providing free-standing atomic crystals with extraordinary physical properties. For example: graphene is many times stronger than steel, a better conductor of heat and electricity than copper, and is almost transparent to light. Graphene therefore has many potential applications, from ultra-thin displays and touch screens, to transistors and solar panels.

The other material system under investigation by the team is carbon nanotube (CNT). This is another form of carbon, configurationally equivalent to two dimensional graphene sheet rolled into a tube. It has extraordinary electrical and mechanical properties suitable for device applications.

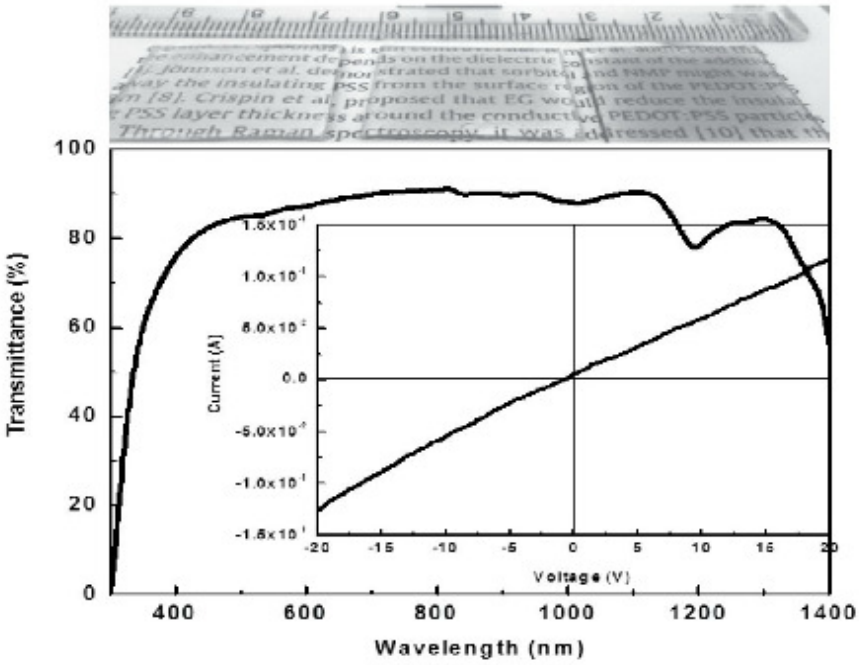
For many years, thin film solar cells are being pursued as viable alternatives to silicon solar cells. A critical aspect of these solar cells is the current conduction



Figures: (Left) Single-Layer Graphene and (Right) Single-Walled Carbon Nanotube

across the illuminated side of the device, namely transparent conducting film (TCF). This illuminated side (electrode) should be transparent with good conductance. The conventional TCF materials are ITO, FTO, ZnO, thin metal films, metal gratings, Ag nanowire networks etc. Among various TCFs, indium tin oxide (ITO) is the most widely used material. But it possesses some serious drawbacks relating to cost and material related properties. The high transparency accompanied with better conductivity favors graphene as a very suitable material for TCF in thin film solar cell applications.

In a recent work, we have fabricated bi-layer graphene (BLG) using micro-mechanical exfoliation of highly-ordered pyrolytic graphite [1]. This technique is very simple and cost effective, and relies on the mechanical peeling of graphene layers from graphite. The graphite generally consists of stacked layers of graphene. The structural, electrical and optical properties of BLG are systematically characterized. We have theoretically demonstrated its use as TCF in InGaN-based thin film solar cell. Consecutively modeling is carried out with TCAD-Silvaco 2D software and we have simulated the InGaN/ GaN p-i-n junction solar cell using the structural, electrical and optical properties of as-produced exfoliated bi-layer graphene as TCF. An efficiency of 15.24 % is found in the bi-layer graphene/ p-GaN/ n-InGaN/ n-GaN/ GaN/ Al203 system compared to 13.63 % for ITO/ p-GaN/ n-InGaN/ n-GaN/ GaN/ Al203 system. This

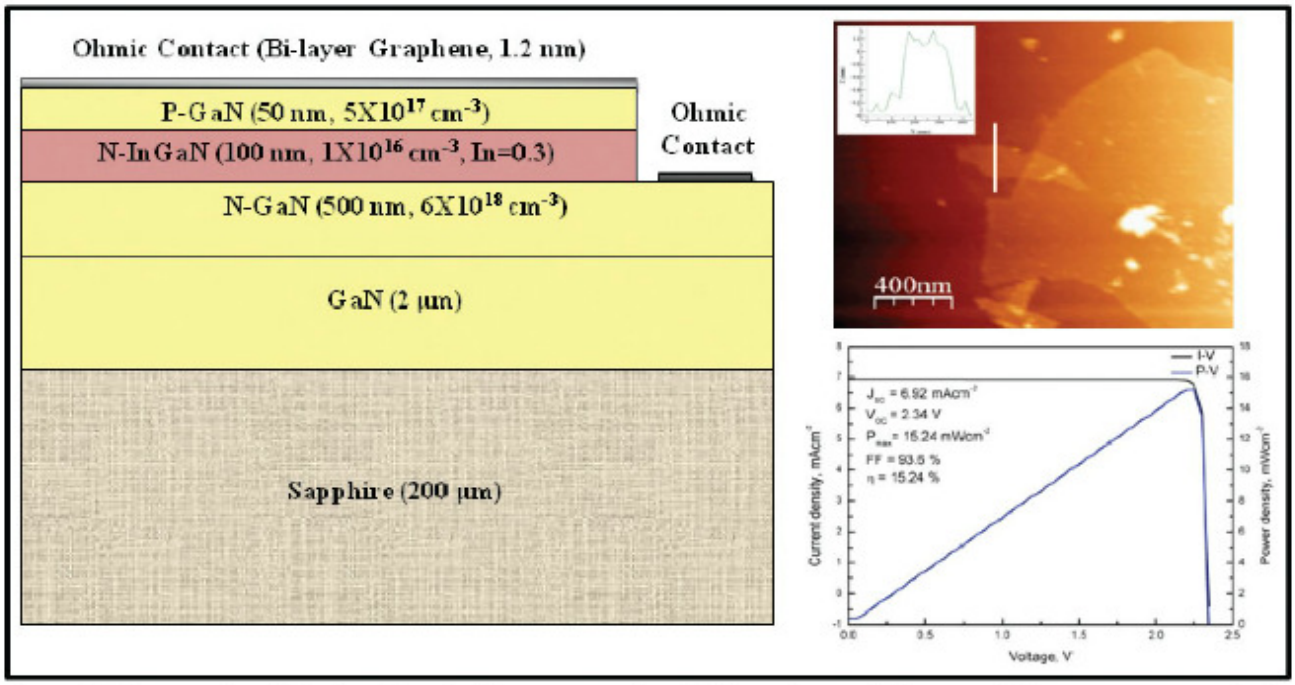


Figures: I-V characteristics of MWCNTs-polymer composite with ransmittance spectra and digital image of samples on the top.

study gives a good direction towards the use of carbon-based materials for solar cell applications.

In another work, multiwall CNTs (MWCNTs)-polymer composite TCF [2] was fabricated and its optical and electrical properties are characterized for possible replacement of ITO in thin film solar cells. The transparency of 85% at the wavelength of 550 nm with electrical conductivity of 10-4 S/cm has been achieved. This is a good signature of using the material as TCF. These properties can be improved further for betterment. The Current-Voltage (I-V) characteristics show linear behavior, thus confirming the Ohmic nature of nano-composites and metal contact. Moreover, this carbon-polymer composite is reported for the first time and has posseses unique potential for applications in optoelectronic devices.

The advantage of the above research works are in realization of carbon-based solar cells for manufacturing by the industry in the near future.



Figures: (Left) InGaN-based thin film solar cell with BLG as TCF. (Top Right) AFM image with line scan thickness measurement in the inset. (Top Bottom) J-V and P-V characteristics of the simulated InGaN-based thin film solar cell.