IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Effect of Partial Slip and Radiation on MHD Nanofluid over an Exponentially Stretching Sheet Embedded in Double Stratified Medium

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Abstract: In this paper, we presented MHD boundary layer nanofluid flow and heat transfer towards an exponentially stretching sheet embedded in double stratified medium. Using similarity transformation technique, the governing system of partial differential equations is transformed into a system of ordinary differential equations and are solved numerically by using the well-known implicit finite difference scheme known as the Keller Box method. The velocity, temperature and nanoparticle volume fraction profiles are expressed graphically for different flow pertinent parameters, namely the Magnetic parameter (M), Radiation parameter (R), Thermal stratification parameter (St), Solutal stratification parameter (Sd), Suction parameter (S), Prandtl number(Pr), Eckert number(Ec), Lewis number(Le), Thermophoresis parameter (Nt), Brownian parameter (Nb). Moreover comparative study between the previously results and the present study is made and they show good agreement.

Index Terms - **Nanofluid, MHD, Slip effect, Stratified medium.**

I. Introduction

The study of Magnetohydrodynamics (MHD) plays an important role in agriculture, engineering and petroleum industries. MHD has won practical applications, for instance, it may be used to deal with problems such as cooling of nuclear reactors by liquid sodium and induction flow water which depends on the potential differencing the fluid direction perpendicular to the motion goes to the magnetic field. A nanofluid is a fluid containing nano meter-sized particles, called nanoparticles. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. The nanoparticles used in nanofluid are typically made of metals, oxides, carbides, or carbon nanotubes. Common base fluids include water, ethylene glycol and oil. Nanofluids have novel properties that make them potentially useful in many applications in heat transfer, including microelectronics, fuel cells, pharmaceutical processes, and hybrid-powered engines, engine cooling/vehicle thermal management, domestic refrigerator, chiller, heat exchanger, in grinding, machining and in boiler flue gas temperature reduction. They exhibit enhanced thermal conductivity and the convective heat transfer coefficient compared to the base fluid. The term Nanofluid was first introduced by Choi [1]. Nanofluids are the suspensions of various nano particles in the base fluids which in turn evolved as a challenge for the scientist in thermal sciences [2]. They find wide range of applications in heat transfer and a deep research is under progress at various research institutions to enhance the heat transfer mechanism. The nanofluid synthesized by using chemical solutions have high conductivity enhancement and excellent stability as compared with other methods. T. Hayat et al.[3]solved with the use of convergent series by the Homotopy analysis method the MHD effects on a thermo-Solutal stratified nanofluid flow on an exponentially radiating stretching sheet. P. Loganthan and C.Vimala[4] was studied MHD flow of nanofluid over an exponentially stretching sheet embedded in a stratified medium with suction and radiation effects by using shooting technique. Nanofluids has many applications are primarily used as coolant in heat transfer equipment such as heat exchangers, electronic cooling system(such as flat plate) and radiators.the concept of Brownian motion and thermophoresis for horizontal stretching surface. Currently, an extensive literature can be found for both Newtonian and non-Newtonian fluid with various physical models in the presence of nanoparticle.

The boundary layer flow on a continuous stretching sheet has attracted considerable attention during the last few decades due to its numerous applications in engineering and industrial manufacturing processes such as metal spinning, hot rolling and polymer extrusion. Both the kinematics of stretching and the simultaneous heating or cooling during such processes has a decisive influence on the quality of the final products. Crane[5] investigated a flow past a stretching sheet whose velocity is proportional to the distance from the slit. This occurs in the drawing of plastic film. Magyari and Keller[6] extended the work of Crane by assuming stretching sheet need not be linear but it can be is of exponential and they solved this situation by using the both analytical and numerical methods. Radiation and mass transfer Radiation effects on MHD boundary Layer flow due to an exponentially Stretching Sheet with Heat Source studied by G Vijaya Lakshmi et.al[7].

The effect of stratification is an important aspect in heat and mass transfer.. Thermal stratification may arise when there is a continuous discharge of the thermal boundary layer into the medium, for example, the thermal stratification of lakes refers to a change in the temperature at different depths in the lake, and is due to the change in water's density with temperature. This phenomenon occurs due to a change in temperature or concentration, or variations in both, or due to the presence of fluids with different densities. M Swathi[8] investigated on MHD flow of a viscous fluid induced by an exponentially stretching sheet in a thermally stratified medium and the numerical solutions are obtained by using shooting method.

Later this work was extended by G Vijaya Lakshmi et.al[9] by investigating the effects of Joule heating and viscous dissipation on MHD boundary layer flow of an exponentially stretching sheet embedded in thermally stratified medium and the results are obtained by using implicit finite difference method. Rizw an Ul Haqet al[10] studied mixed convection flow of thermally stratified MHD nanofluid over an exponentially stretching surface with viscous dissipation effect by using Finite difference method.The flow direction is towards the sheet, and then it is a stagnation flow phenomenon. In fluid dynamics, Stagnation points exist at the surface of objects in the flow field, where the fluid is brought to rest by the object.Hiemenz[11] was first studied about stagnation point flow. Ibrahim et al[12] studied MHD Stagnation Point Flow and Heat Transfer due to Nanofluid Towards a Stretching Sheet and numerically solved using fourth order Runge–Kutta method along with shooting technique. G Vijaya Lakshmi, L Anand Babu ,K Srinivasa Rao[13] investigated the chemical reaction effect on Heat and mass transfer in MHD stagnation point nanofluid flow over stretching sheet in porous medium with and prescribed surface heat flux by sing finite difference method.

The no-slip condition for viscous fluids assumes that at a solid boundary, the fluid will have zero velocity relative to the boundary interface. But in the existence of slip-flow, the flow velocity at the solid wall is non-zero. The fluids that exhibit the boundary slip have important technological applications such as in the polishing of the artificial heart valves and internal cavities. Partial slips occur for fluid with particulate such as emulsion suspensions, foams and polymer solutions. Swathi M[14]investigated the slip effects on an MHD boundary layer flow past an exponentially stretching sheet with suction/blowing and thermal radiation solved by shooting method. MHD boundary layer flow and heat transfer of a nanofluid past a permeable stretching sheet with velocity, thermal and Solutal slip boundary conditions was investigated by Wubshet Ibrahim and Bandari Shankar[15] numerically solved using fourth order Runge–Kutta method along with shooting technique. Effects of slip and heat generation/absorption on MHD stagnation flow of nanofluid past a stretching/shrinking surface with convective boundary conditions studied by Samir Kumar Nandy and Tapas Ray Mahapatra B[16] .MHD partial slip flow of Ag-water nanofluid over a stretching sheet was studied by Preeti Agarwala R Khare[17].Effects of MHD on Boundary Layer Flow in Porous Medium due to Exponentially Shrinking Sheet with Slip conditions explained by Shalini Jain and Rakesh Choudhary[18].

The objective of this present work is to extend the flow and heat transfer analysis in boundary layer over an exponentially stretching sheet embedded in a stratified medium. The present study is to extend the work of Khan and Pop[19] for the effect of partial slip on MHD stagnation flow of Nanofluid over an exponentially stretching sheet embedded in temperature and concentration stratified medium. Using suitable similarity transformations, a third order ordinary differential equation corresponding to the momentum equation and a second order differential equation corresponding to the heat equation and diffusion equations are derived. Numerical calculations up to desired level of accuracy were carried out for different values of dimensionless parameters of the problem under consideration for the purpose of illustrating the results graphically. The analysis of the results obtained shows that the flow field is influenced appreciably by the stratification parameter, stagnation point and slip conditions. Estimation of heat transfer coefficient which is very important from the industrial application point of view is also presented in this analysis. It is hoped that the results obtained will not only provide useful information for applications, but also serve as a complement to the previous studies. Stagnation-Point Flow by an Exponentially Stretching Sheet in the Presence of Viscous Dissipation and Thermal Radiation studied by Z. Iqbal et .al[20].Mixed convection flow of thermally stratified MHD nanofluid over exponentially stretching sheet using finite difference method was explained by Prabhakar et al [21].MHD effects on a Thermo-Solutal Stratified Nanofluid Flow on an exponentially radiating stretching sheet was explained by T. Hayat et.al [22]

2. FLOW ANALYSIS AND MATHEMATICAL FORMULATION:

Consider the steady nanofluid flow of an incompressible viscous electrically conducting fluid over an exponentially stretching sheet coinciding with the plane $y = 0$. The flow is confined to y> 0. Two equal and opposite forces are applied along the x-axis, so that the wall is stretched keeping the origin fixed. A variable magnetic field $B(x) = B_0 e^{\frac{x}{2L}}$ is applied normal to the sheet and B_0 is a constant. Buoyancy forces are also considered for thermal and concentration to deal double stratified phenomena. The sheet is of temperature $T_w(x)$ and is embedded in a thermally stratified medium of variable ambient temperature $T_\infty(x)$ where $T_w(x)>T_\infty(x)$. It is assumed that $T_w(x) = T_0 + ae^{\frac{x}{2L}}, C_w(x) = C_0 + be^{\frac{x}{2L}}, T_\infty(x) = T_0 + ce^{\frac{x}{2L}}$ and $C_\infty(x) = C_0 + de^{\frac{x}{2L}}$, where a, b, c and d are constants respectively $(a \geq 0, b \geq 0, c \geq 0 and \ d \geq 0)$.

The continuity, momentum, energy and concentration equations of governing such type of flow are written as

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \quad (1)$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \vartheta\frac{\partial^2 u}{\partial y^2} - \frac{\sigma B^2(x)}{\rho_f} \quad (2)$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \frac{k}{\rho c_p}\frac{\partial^2 T}{\partial y^2} - \frac{1}{\rho c_p}\frac{\partial q_r}{\partial y} + \frac{(\rho c_p)_p}{(\rho c_p)_f}\left[D_B\frac{\partial C}{\partial y}\frac{\partial T}{\partial y} + \frac{D_T}{T_\infty}\left(\frac{\partial T}{\partial y}\right)^2\right] + \frac{\mu}{\rho c_p}\left(\frac{\partial u}{\partial y}\right)^2 \quad (3)$$

$$u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = D_B\frac{\partial^2 C}{\partial y^2} + \frac{D_T}{T_\infty}\frac{\partial^2 T}{\partial y^2} \quad (4)$$

Where velocity components are given by u and v in x and y directions. Kinematic viscosity is given by V, electric conductivity is σ, magnetic induction is by B, fluid density is ρ, temperature of the fluid is T, thermal conductivity of the fluid is k, specific heat at constant pressure is C_p, coefficient of fluid viscosity is μ, radiative heat flux is q_r.

The boundary conditions of the problem is given by

$$u = U_w = u_0 e^{\frac{x}{2L}} + \alpha_0\frac{\partial u}{\partial y}, v = -V(x), T = T_w(x) = T_0 + ae^{\frac{x}{2L}}, C = C_w(x) - C_0 + be^{\frac{x}{2L}} \text{at } y = 0 \quad (5)$$

$$u \rightarrow U_e = U_\infty e^{\frac{x}{2L}} 0, \rightarrow T_\infty(x) = T_0 + ce^{\frac{x}{2L}}, C \rightarrow C_\infty(x) = C_0 + de^{\frac{x}{2L}} \text{as } y \rightarrow \infty \quad (6)$$

here, stretching velocity is $U(x) = U_0 e^{\frac{x}{2L}}$, reference velocity U_0, velocity of suction is V(x) > 0 and velocity of blowing V(x) < 0, a special type of velocity at the wall is considered as $V(x) = V_0 e^{\frac{x}{2L}}$ and the initial strength of suction is V_0.

Introducing the suitable transformations as

$$\eta = \left(\frac{U_0}{2\nu L}\right)^{\frac{1}{2}} e^{\frac{x}{2L}} y, u = U_0 e^{\frac{x}{L}} f'(\eta),$$

$$v = -\left(\frac{\nu U_0}{2L}\right)^{\frac{1}{2}} e^{\frac{x}{2L}}(f(\eta) + \eta f'(\eta)), \frac{T - T_\infty}{T_w - T_0} = \theta(\eta), \quad \frac{C - C_\infty}{C_w - C_0} = \varphi(\eta) \quad (7)$$

Substituting the Eq. (7) in Equations (2) - (5) the governing equations are transformed to

$$f''' + ff'' - 2f'^2 - 2Mf' = 0 \quad (8)$$

$$(1+4/3R)\theta'' + Prf\theta' - Prf'\theta - \Pr St\, f' + \Pr Nb\,\theta'\varphi' + PrNt\,\theta'^2 + \Pr Ec((f'')^2 = 0 \quad (9)$$

$$\varphi'' + Le(Prf\varphi' - Prf'\varphi - \Pr Sd\, f') + \frac{Nt}{Nb}\theta'' = 0 \quad (10)$$

and the boundary conditions take the following form:

$$f = S, f' = 1 + \lambda f'', \theta = 1 - St, \varphi = 1 - Sd \text{ at } \eta = 0$$

$$f' \to 0, \theta = \varphi = 0 \text{ at } \eta \to \infty \tag{11}$$

Where the prime denotes differentiation with respect to η, M = $\sqrt{\frac{2\,\sigma B_0{}^2 L}{\rho U_0}}$ is the magnetic parameter, Ec = $\frac{U_0{}^2}{(T_w - T_0)C_p}$ is the Eckert Number, S = $\frac{V_0}{\sqrt{\frac{U_0 \nu}{2L}}}$>0 (or < 0) is the suction (or blowing) parameter, Prandtl number is Pr = $\frac{\mu C_p}{k}$, thermal stratification parameter is $St = \frac{c}{a}$, concentration stratification parameter is $Sd = d/b$, Stably stratified environment is for Sm>0 and if Sm= 0 corresponds to an unstratified environment, $Le = \frac{\nu}{D_B}$ is the Lewis number, the Brownian motion parameter is Nb = $D_B \tau \frac{(C_w - C_\infty)}{\nu}$, the thermophoresis parameter is $Nt = \frac{D_T}{T_\infty} \tau \frac{(T_w - T_\infty)}{\nu}$, $\tau = \frac{(\rho c_p)_p}{(\rho c_p)_f}$, $\lambda = L\sqrt{\frac{U_0}{2L}}$

Table I. Comparison of the values of $-\theta'(0)$ for different values of physical parameters Pr and M when Nb=Nt=St=Sd=Ec=0

M	Pr	Magyari and Keller[6]	Bidin , Nazar[23]	Ishak[19]	Present Study
0	1	0.954782	0.9548	0.9548	0.9546
0	2		1.4714		1.4714
0	3	1.869075	1.8691	1.8691	0.8687
0	5	2.500135		2.5001	2.4997
0	10	3.660379		3.6604	3.6604
1	1			0.8611	0.7911

Table II. Computation of values for various parameters where the fixed values Pr=0.7, Le=M=S=R=0.5

St	Sd	Nt	Nb	Ec	S	λ	$-\theta'(0)$	$-\varphi'(0)$
0.3	0.3	0.3	0.3	0.1	0.3	0.3	0.6185	0.9873
0.5	0.3	0.3	0.3	0.1	0.3	0.3	0.5456	0.9561
0.7	0.3	0.3	0.3	0.1	0.3	0.3	0.4619	0.9437
0.7	0.5	0.3	0.3	0.	0.3	0.3	0.4472	0.7636
0.7	0.7	0.3	0.3	0.1	0.3	0.3	0.4339	0.7198
0.7	0.7	0.5	0.3	0.1	0.1	0.1	0.4368	0.5896
0.7	0.7	0.7	0.7	0.1	0.1	0.1	0.4394	0.3384
0.7	0.7	0.7	0.3	0.2	0.1	0.1	0.4182	0.6119
0.7	0.7	0.7	0.5	0.3	0.1	0.2	0.3548	0.8003
0.7	0.7	0.7	0.3	0.3	0.1	0.3	0.2634	0.6384
0.7	0.7	0.7	0.3	0.3	0.2	0.1	0.2993	0.7119
0.7	0.7	0.7	0.5	0.3	0.3	0.1	0.3548	0.8003

3. NUMERICAL METHOD:

The nonlinear ordinary differential Equations (8)-(10) together with boundary conditions (11) are solved numerically by Keller box method as mentioned by Cebeci and Bradshaw.[24]

According to Vajravelu et al,[25] to obtain the numerical solutions, the following steps are considered in this method.

- Reduce the ordinary differential equations to a system of first order equations.
- Write the difference equations for ordinary differential equations using central differences.
- Linearize the algebraic equations by Newton's method, and write them in matrix vector form.
- Solve the linear system by the block tri-diagonal elimination technique.

4 .RESULTS AND DISCUSSION:

From the Figures 2 (a), 2(b) and 2(c) we observed that the effect of magnetic parameter (M) on the velocity profile and is reduced with the increasing value of M due to Lorentz force. But in the case of the temperature and concentration profiles, as increases magnetic field increases the temperature and concentration profiles.

In Figure 3, the relationship between Kinematic energy (K.E) and enthalpy is nothing but Eckert number Ec and it is clear that as increasing the values of Ec in turn increases temperature profile.

From Figure 4, the Prandtl number (Pr) which is the ratio of the momentum diffusivity and the thermal diffusivity of base fluid. For the increasing values of Pr the temperature profile and thermal boundary layer thickness will decreases quickly and there will be higher heat transfer effects. Thus the base fluid plays an important role in the heat transfer of the nanofluid.

Figure 5(a) and 5(b) denotes the effect of Brownian motion parameter (Nb) on temperature profile and concentration profile. Brownian motion depends on the size of nanoparticle. As Brownian motion parameter (Nb) increases the temperate profile increases and it is clear that the increasing value of Nb decreases the nanoparticle volume fraction in turn it also decreases the nanoparticle volume boundary layer thickness.

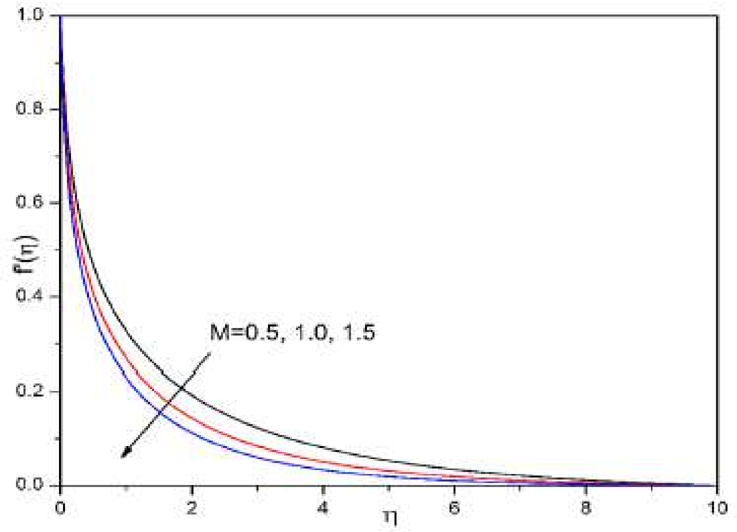

Fig 2(a) Effect of magnetic parameter (M) on velocity proifle

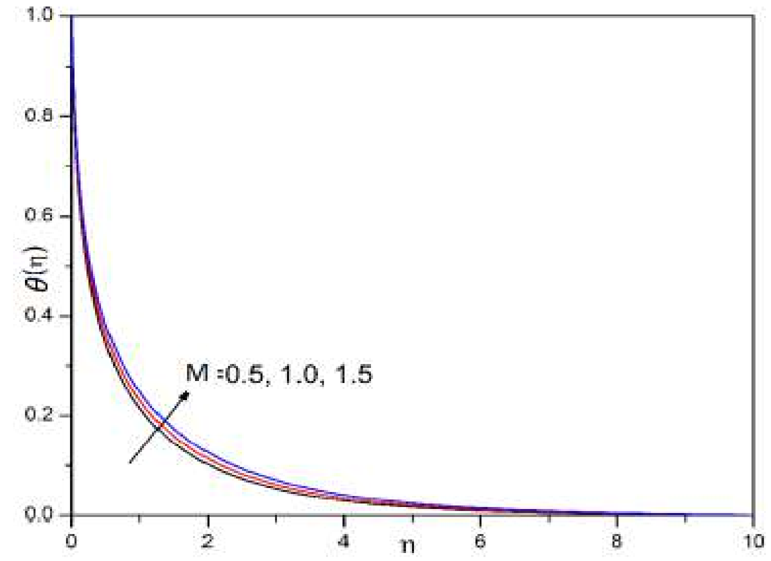

Fig 2 (b) Effect of magnetic parameter (M) on tempuratre proifle.

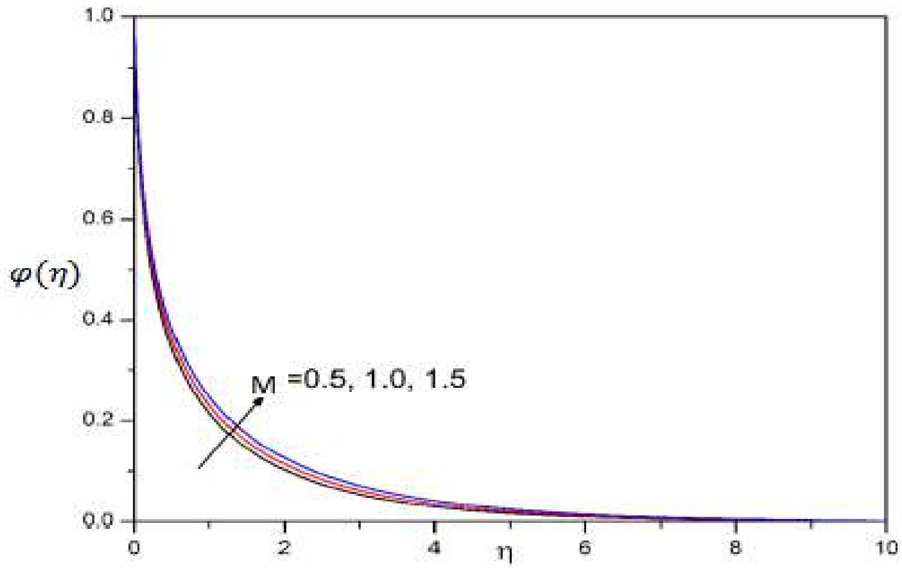

Fig 2(c) Effect of magnetic parameter (M) on concentartion proifle.

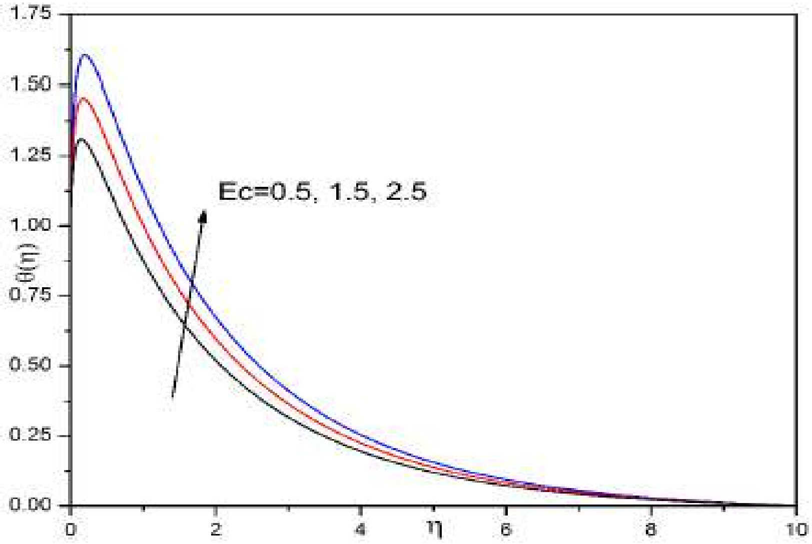

Fig. 3.Effect of Eckect parameter (Ec) on tempuratatare proifle

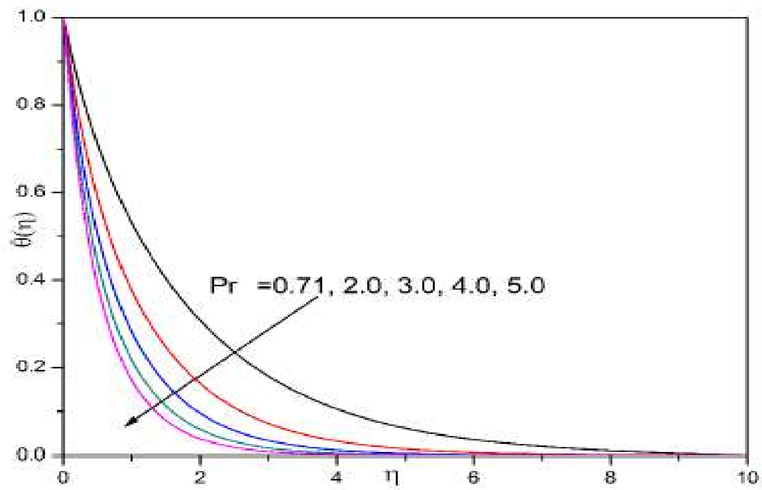

Fig .4.Effect of Prandtl number (Pr) on tempurature proifle

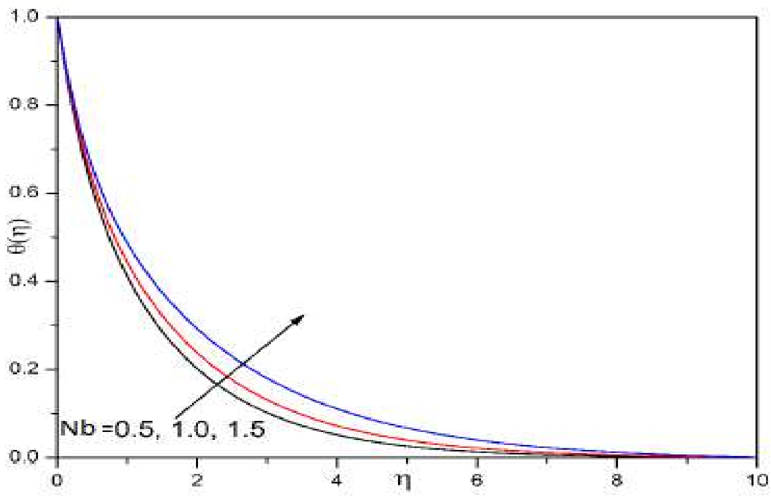

Fig.5**.** (a) Effect of Brownian motion parameter (Nb) on temperature proifle.

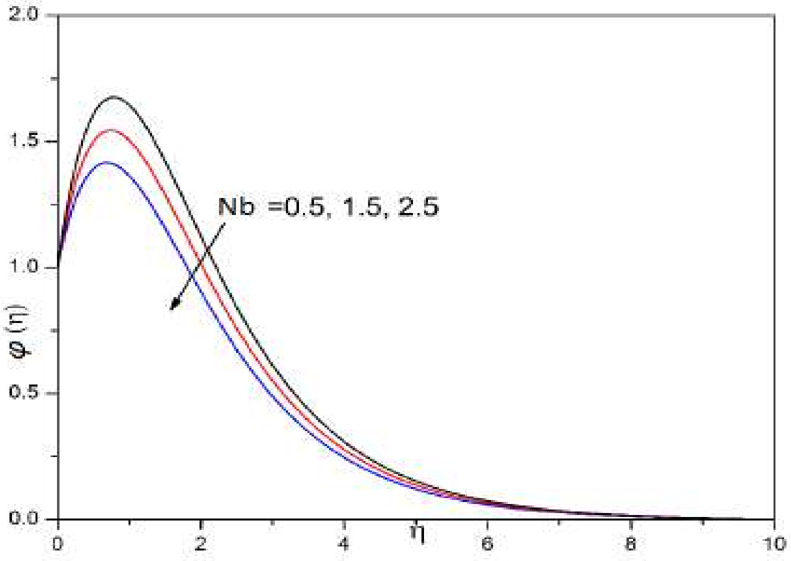

Fig 5 (b) Effect of Brownian motion parameter (Nb) on concentration proifle.

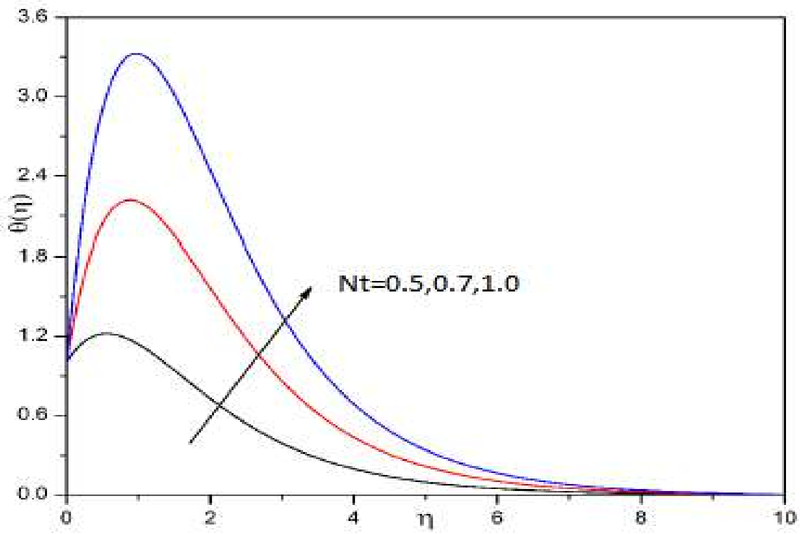

Fig.6. Effect of Themophoresis parameter (Nt) on temperature profile.

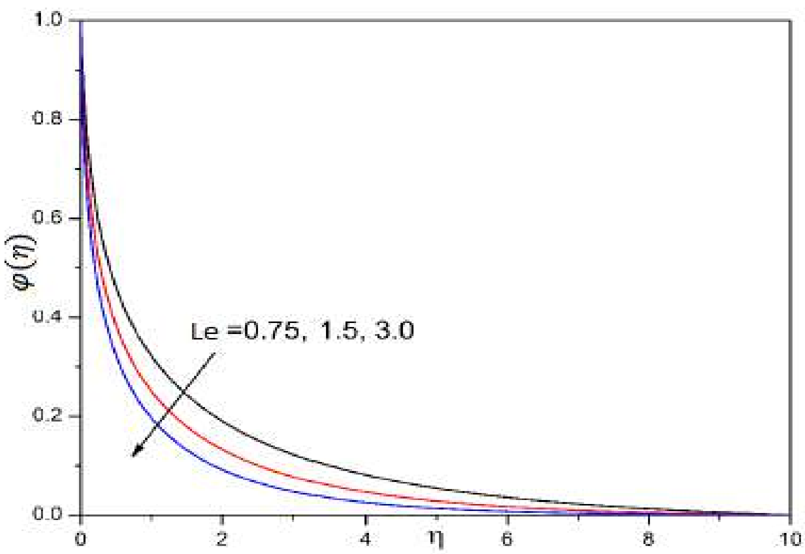

Fig.7. Effect of Lewise (Le) on concentration proifle.

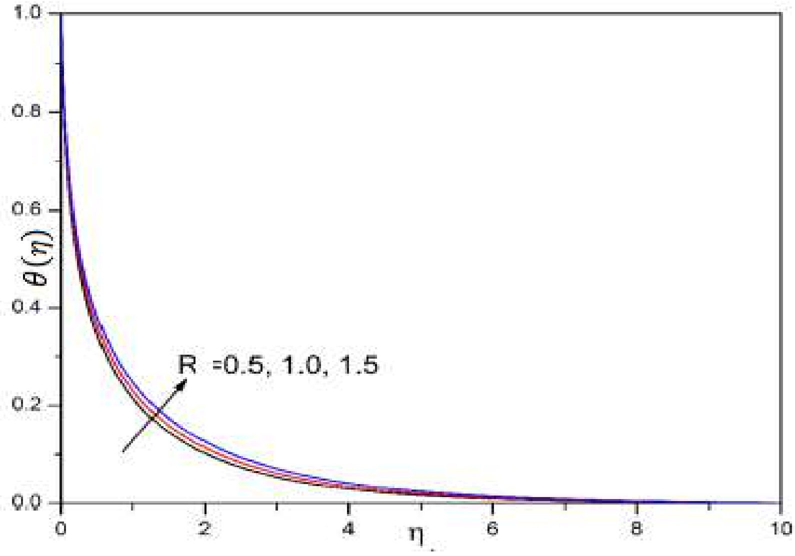

Fig.8 Effect of Radiation parameter (R) on tempurature proifle

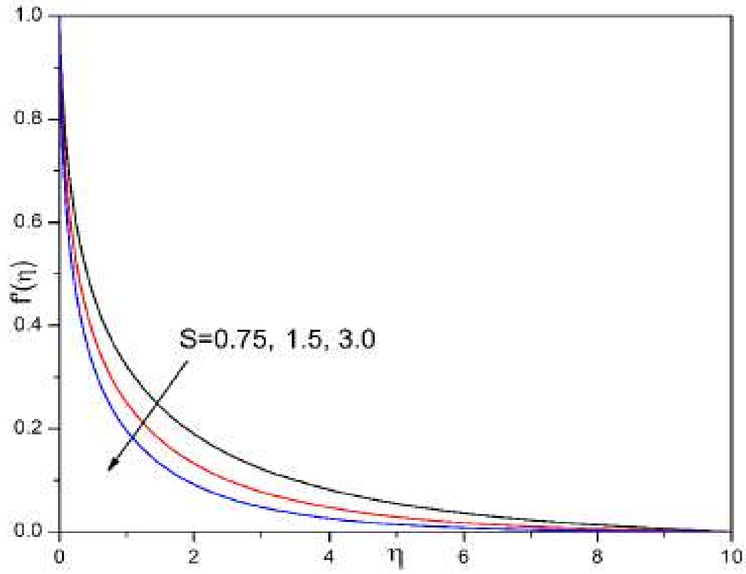

Fig.9(a) Effect of Suction parameter (S) on velocity proifle.

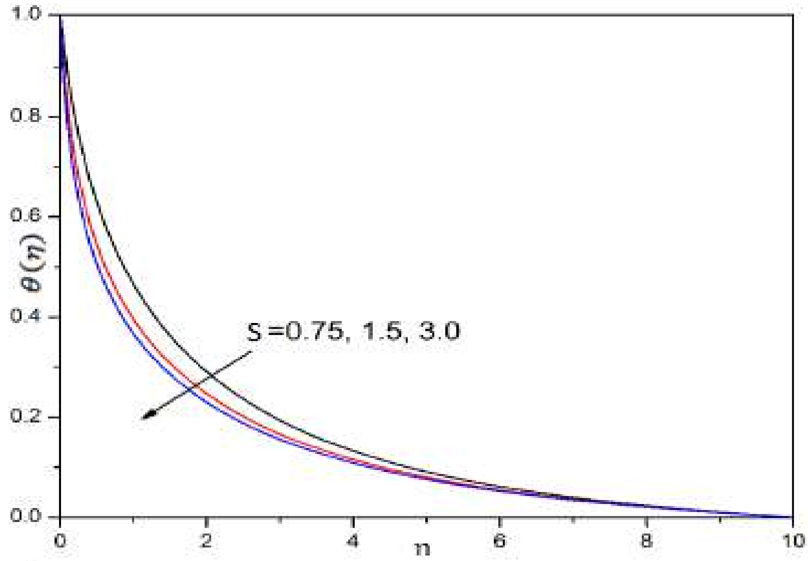

Fig 9(b) Effect of Suction parameter (S) on temperature proifle.

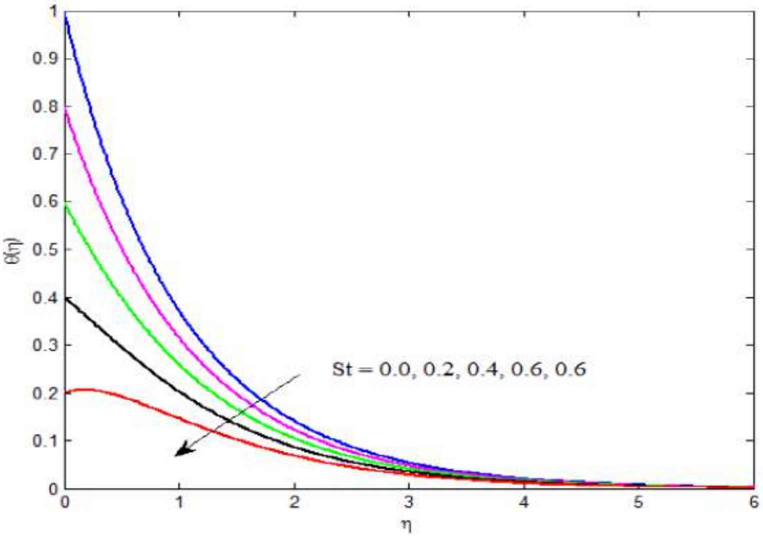

Fig 10 Effect of theramal startification parameter (St) on tempurature profile

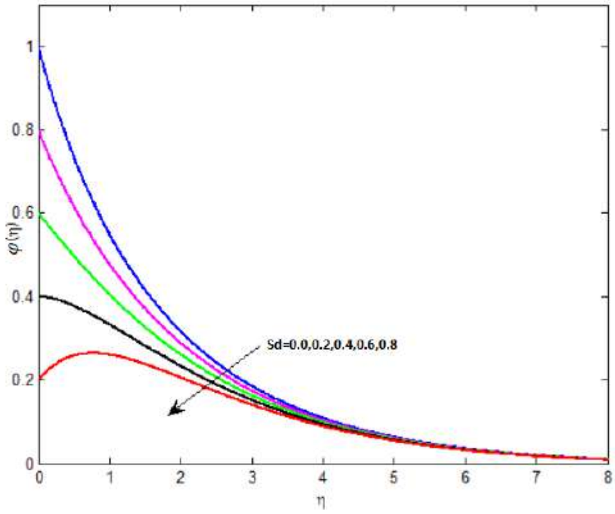

Fig.11 Effect of Solutal startification parameter (Sd) concentration profile.

The effect of thermophoresis parameter (Nt) was studied on the temperature parameter $\theta(\eta)$ and is shown in Figure 6. Increasing the value of thermophoresis parameter increases the temperature distribution. From Figure 7 it is clear that with the increase in the value of Lewis number Le decreases concentration profile and the thickness of the nanoparticle volume boundary layer. Figure 8 describes the Radiation effect (R) on temperature profile as radiation parameter increases the temperature profile increases.

As shown in the Figures 9(a) & 9(b) as velocity and temperature profile increases the influence of wall transpiration (i.e. suction / injection) parameter (S) decreases.

In Figure 10 and 11 the thermal stratification and Solutal stratified parameter have opposite effects on Nusselt and Sherwood number. As Thermal stratified number St increases the Nusselt number behaviour decreases where as Solutal stratified parameter Sd increases the Sherwood number behaviour decreases.

Table II illustrates the variations of Nusselt number$-\theta'(0)$and Sherwood number $-\varphi'(0)$

With variable values of St, Sd, Nt, Nb, Ec, S, λ. From the table it is clear that increases in the values of the partial slip parameter reduces the Nusselt number. We can conclude that Sherwood number is reduced with increasing the values of Le, Nb and R

5. CONCLUSIONS:

The following conclusions are drawn.

- As increasing magnetic parameter M, velocity profile decreases but in the case of temperate and concentration profile it increases.
- Slip parameter of velocity increases which in turn enhances the velocity profile and reduces the concentration profile.
- As increasing the thermal and concentration stratification parameters there is reduction in the temperature and concentration profile too.

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Optimal Dye Sensitized Solar Cell and Photocapacitor Performance with Efficient Electrocatalytic SWCNH Assisted Carbon Electrode

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Cite This: *ACS Appl. Energy Mater.* 2021, 4, 11225−11233 Read Online

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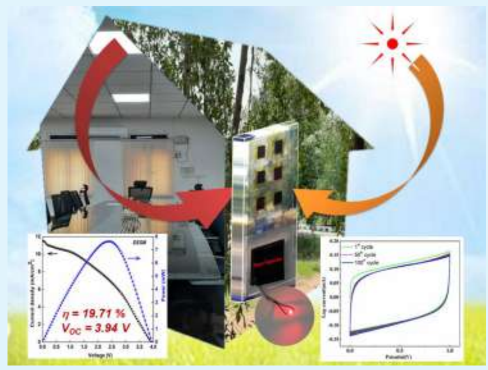
ABSTRACT: The present work demonstrates the high photovoltaic power conversion efficiency (PCE) of 11.12% using single wall carbon nanohorn assisted carbon counter electrode based dye sensitized solar cells (DSSCs), which demonstrates a superior PCE compared to that of platinum (9.41%). This superior performance was a motivation to fabricate a dye sensitized solar module (DSSM) consisting of six series connected DSSCs arranged in a bifacial manner toward the application of building integrated photovoltaics. The DSSM demonstrated a remarkable, champion PCE of 19.71%. This high PCE, driven to fabricate an integrated device (photocapacitor), consists of a DSSM and a supercapacitor (SC). Upon two-sided illumination, the DSSM generated electrical power, and the same power is used for charging the supercapacitor. A working light emitting diode is demonstrated with discharge of the SC. The detailed fabrication strategies and results are discussed.



KEYWORDS: *cost-effective carbon electrode, screen print, platinum-free, single wall carbon nanohorns, spray coat, dye sensitized solar cell, bifacial, DSSM, supercapacitor, photocapacitor*

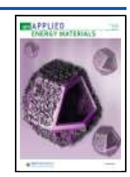
1. INTRODUCTION

The global energy requirement is crucial, and it can potentially be addressed through a clean energy conversion photovoltaic technology. Cost-effective, third-generation solar photovoltaics have become significant, so attention has been paid due to its easier fabrication process, environmental friendliness, and good energy conversion efficiency. The dye sensitized solar cell (DSSC) is identified as an affordable photovoltaic technology and has attracted more attention for its capability to deliver low-cost power generation.[1−3] DSSC consists of a photoelectrode (PE) of dye anchored TiO_2 nanoparticles, an electrolyte comprising redox couples (generally, I^-/I_3^-), and a counter electrode (CE). Counter electrodes play a critical role in achieving high power conversion efficiency (PCE). Developing a potential CE is essential, as CE catalysts have high conductivity, have good catalytic activity, are more stable, etc. Generally, a very thin platinum (Pt) layer will be deposited onto a conductive fluorine doped tin oxide (FTO) coated glass substrate which is used as the counter electrode, due to its extreme catalytic performance for tri-iodide reduction and good electrical conductivity.[4,5] Due to its higher cost, rare availability leads to minimal large-scale production for power production. To overcome this, efforts have been made by researchers for the development of cost-effective catalysts, include carbonaceous materials, nitride, sulfides, etc., as promising catalysts materials.[6−13] The present research focuses on a Pt-free, cost-effective CE as an alternative to the "champion" CE. The present study aims to develop an effective, potential CE through an easy preparation processes.

Numerous carbon-oriented materials like active carbon,[14] carbon powder,[15,16] carbon spheres,[17,18] and fullerenes[19] have been used as CEs which have shown remarkable progress. The performance of DSSCs fabricated with carbon-oriented CEs are lower compared to Pt based CEs. Improved electrocatalytic active sites through deposition of another material over CE catalysts could result in higher performance.[20] The single wall carbon nanohorn (SWCNH) based CE assisted DSSC exhibited a good PCE.[21−25]

The development of bifacial DSSM provides a potential candidate for building integrated photovoltaics (BIPVs).[26−29] The bifacial BIPV structure enables light energy from direct sunlight (coming from outside) and diffused light (indoor light) to be converted into electric power. DSSCs are recognized as the best choice for indoor light conversion (~ 200−1000 lx radiance).[30−34] The DSSC is an ideal substituent for charging in tiny electronic gadgets under indoor light conditions. The DSSC combined with a battery or supercapacitor acts as a self-powered system, demonstrating its

Received: July 15, 2021
Accepted: September 20, 2021
Published: September 30, 2021



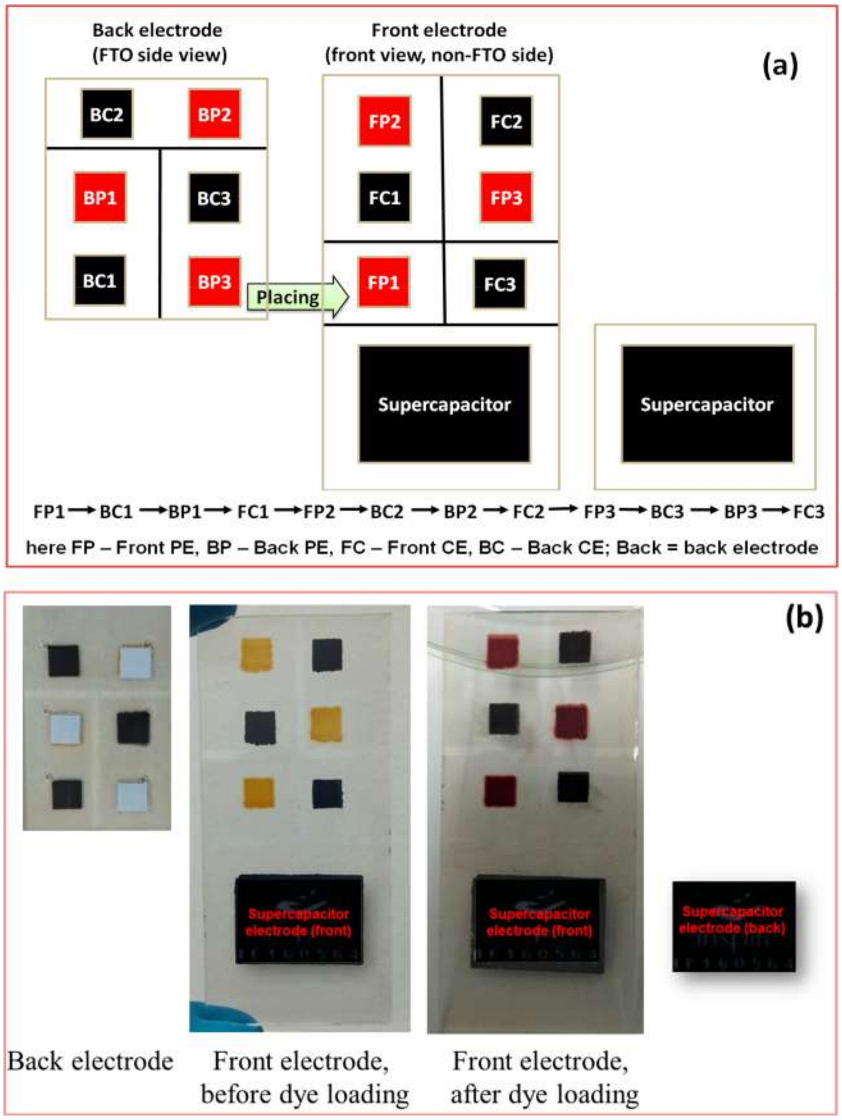


Figure 1. (a) Back and front DSSM glass after proper removal of the FTO layer (black line); and (b) resultant electrodes after material coatings.

advancement.[35] Many approaches are being attempted to improve the performance of self-powered systems.[36,37]

Photocapacitors are emerging as promising, self-sufficient energy devices consisting of solar cells and supercapacitors. Over the past few years, researchers are focusing on the development of high-performance photocapacitors with higher energy density and good specific capacitance. The photocapacitor is capable of converting the electromagnetic radiation from the sun into electricity and storing the converted power. Most commonly, reported studies reveal a single solar cell charging a supercapacitor (SC). This limits the final voltage of the storage section such that it is not sufficient to drive most applications, like low-power electronics. To address this concern, here we proposed a device that consists of a bifacial DSSM (constituted series of six DSSCs) as a light harvester and an ionic liquid based supercapacitor as a storage unit. The two efficient SWCNH/carbon assisted identical electrodes are used for SC fabrication and are filled with an ionic $EMIBF_4$ electrolyte. Upon two-sided illumination of the bifacial DSSM, the delivered voltage is used for charging the supercapacitor.

Here, SWCNH supported carbon is used as the CE for the DSSC as well as for SC electrodes. The DSSM delivered a V_{oc} of 3.94 V with an overall efficiency of 19.71%. The enhanced performance is reflected from its higher conductivity, excellent electrochemical properties, and the high current density of SWCNH/carbon CEs.

2. EXPERIMENTAL SECTION

Photoelectrode Preparation. Photoelectrodes were prepared by the procedure discussed here. First, FTO (fluorine doped tin oxide) (Greatcell Solar, TEC7, 7 Ω/square) conducting glass substrates were carefully washed with detergent liquid and eroded in sequence with deionized water, absolute ethanol, acetone, and finally 2-propanol for 10 min each to eliminate organic contaminants if any. A compact film of titanium dioxide solution (Solaronix, T-L/SC) was layered over a cleaned FTO glass substrate, which was then heated to 70 °C for 30 min. A 13−15 μm TiO_2 film is realized by screen printing 18 NR-T transparent titanium dioxide paste (18-NR, Greatcell Solar) and sintering to 500 °C (30 min). The treatment of a compact layer like that described above is again repeated. Then, the substrates were cooled to 100 °C and immersed in a solution of N719 dye (0.3 mM in absolute ethanol) in dark conditions for 16 h. Finally, electrodes were washed gently with ethanol to remove any unanchored molecules of N719 dye.

Counter Electrode Preparation, Test Cell (DSSC) Assembly. The carbon based counter electrodes were prepared via screen print

https://doi.org/10.1021/acsaem.1c02087
ACS Appl. Energy Mater. 2021, 4, 11225−11233

by use of a commercial carbon paste (Solaronix) and sintered to 500 °C. A solution containing 5 mg of SWCNH dispersed in 2-propanol was spray coated over a carbon coated FTO glass substrate at 100 °C to get SWCNH/carbon counter electrodes. For comparison, platinum based CEs were prepared (spin coating of a Pt solution at 2000 rpm, sintered to 500 °C).

The closed type individual test cell (DSSC) was fabricated by a sandwich of photoelectrodes and counter electrodes, with thermal adhesive film (Solaronix, 25 μm, polymer melt film) placed in between, pressed gently on a hot plate while heating at 110 °C. Altered HI-30 electrolyte was injected via the technique of back vacuum, and holes at CEs were closed through the polymer melt film and cover glass.

Dye Sensitized Solar Module (DSSM) Fabrication and Integration with Supercapacitor. *Front Electrode Preparation.* Glass substrates (FTO conducting) of 8.5 × 4 cm^2 size were taken and etched properly using zinc dust and HCl to disconnect electrically from one to another part as shown in Figure 1a (black lines indicate the FTO removed part). Initially, glass substrates were cleaned in ethanol and acetone in an ultrasonicator for 10 min. A 5 μm thick carbon film was deposited to act as CE (FC1, FC2, FC3, and supercapacitor part, one electrode) using a screen print technique and heated to 100 °C. Over FC1, FC2, and FC3, SWCNHs solution (in 2-propanol) was spray coated and heated to 100 °C. As the other parts on the front electrode are treated, TiO_2 paste was then deposited (FP1, FP2, FP3) by using a screen print technique, along with sintering to 500 °C for 30 min to remove binders and solvents to electrically interconnect well with the respective nanoparticles. Then, the electrode was soaked for 16 h in 0.3 mM N719 dye in ethanol solution. While soaking, the carbon part (FC1, FC2, FC3 and supercapacitor part) is sealed with Kapton tape and Surlyn to avoid damage of carbon.

Back Electrode Preparation. FTO glass substrates of 5 × 3.5 cm^2 size were used, to have additional space for the electrode contact for measurements and etched properly to disconnect electrically from one to another part as shown in Figure 1a (black lines specify the FTO removed part). Six inlet holes of approximately 0.5 mm diameter were drilled (shown in Figure 1b) for electrolyte filling. FTO glass substrates were cleaned, and carbon films were deposited for CE parts (BC1, BC2, BC3) using screen printing and heated to 100 °C. Over BC1, BC2, and BC3, SWCNH solution was sprayed and heated to 100 °C. As the other parts on the back electrode, TiO_2 paste was then deposited (BP1, BP2, BP3) by using a screen printer and then sintered to 500 °C for 30 min. Before dye soaking, the carbon part (BC1, BC2, BC3) was sealed with Kapton tape and Surlyn to avoid damage of the carbon. Then, the electrode was soaked for 16 h in 0.3 mM N719 dye in ethanol solution, and the resulting electrode is shown in Figure 1b as after dye loading.

Assembling of DSSM. These front and back electrodes were sealed by placing a thermal adhesive film (Solaronix, polymer melt film) with a gentle hot press up to 110 °C. An acetonitrile (AcN) based redox coupled altered electrolyte (altered HI-30) was injected using a back vacuum filling technique via 6 holes followed by its perfect seal.

Integrated Device. Another FTO glass substrate of size 3.5 × 4 cm^2 was cleaned thoroughly, and the carbon paste was screen printed (deposition area 2 × 3 cm^2) and heated to 100 °C. Then, the SWCNH solution was sprayed and sintered at 500 °C; this acted as a second electrode for the supercapacitor. A separator consisting of a Surlyn sheet was placed between the two supercapacitor electrodes, and a liquid electrolyte of $EMIBF_4$ was filled and gently sealed. Figure 2 presents the resultant photocapacitor (integrated the dye sensitized solar cell with the supercapacitor).

3. CHARACTERIZATION AND MEASUREMENTS

Microstructural studies of carbon, SWCNH, and SWCNH decorated carbon bilayer films and cross sections are examined by SEM (scanning electron microscopy, JEOL, JSM-IT500) and also by EDAX through APEX. X-ray diffraction studies were recorded by a Rigaku Miniflex diffractometer in between 0° and 80° of 2θ value. Electrocatalytic activity was observed through cyclic voltammetry (CV) with an electrochemical workstation CompactSTAT.h IVIUM technology with three-electrode configurations. Ag/Ag^+ was used as the reference electrode, by use of acetonitrile solution containing 0.5 mM I_2, 0.1 M $LiClO_4$, and 5 mM LiI, at a scan rate of 50 mV s^{-1}. Photocurrent density (J)−voltage (V) characterization of the developed test devices was examined with a solar simulator (PEC-L01, Peccell Inc.) containing a spectral filter (AM 1.5) and source meter (2401N Keithley). The light intensity of the solar simulator is adjusted to 100 mW/cm^2. The Tafel polarization plots and EIS (electrochemical impedance spectroscopy) were carried out for symmetrical dummy test cells (CompactSTAT.h workstation), with 10 mV of amplitude between frequencies of 1 Hz and 1 MHz.

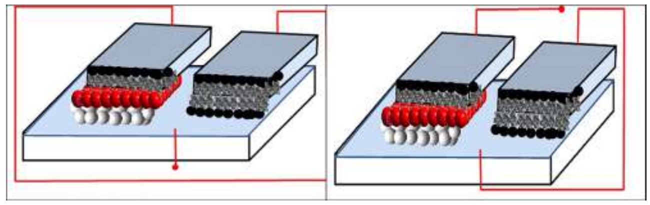


Figure 2. Photo supercapacitor connections under illumination and in the dark.

4. RESULTS AND DISCUSSION

The microstructural studies of carbon, SWCNH, and SWCNH decorated carbon based electrodes are examined by SEM studies, and the resulting images are presented as Figure 3. The pristine carbon had flakes of smooth and thin layer structures shown in Figure 3a. Figure 3b represents a SWCNH/carbon based electrode having an interconnected nature. Carbon flakes covering the SWCNH layer are observed for the SWCNH coated carbon electrode, shown in Figure 3b. Figure 3c presents the SWCNH coated electrode, consisting of agglomerated SWCNHs. Figure 3d represents the cross-sectional view of SWCNH over carbon coated electrodes. The carbon film thickness of 12 μm is present, over which a

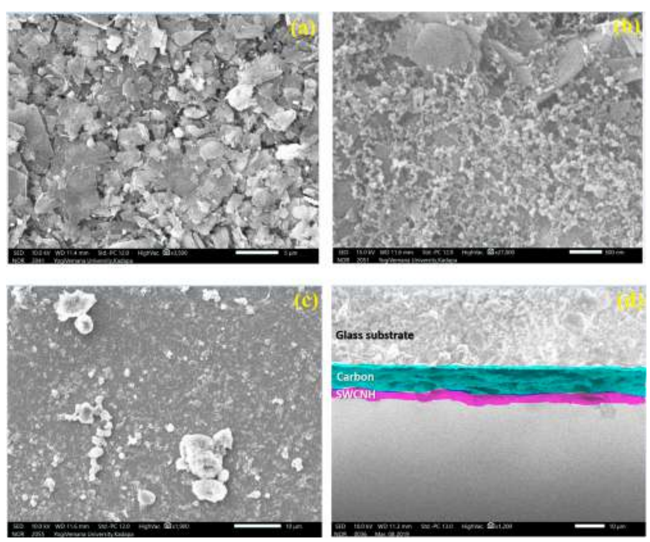


Figure 3. SEM images of (a) carbon, (b) SWCNH/carbon, (c) SWCNH, and (d) cross-sectional view of SWCNH/carbon.

https://doi.org/10.1021/acsaem.1c02087
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thin SWCNH layer is observed. The EDAX spectra are represented in Supporting Information Figure S1. The X-ray diffraction (XRD) studies are performed and presented as Figure S2 of Supporting Information.

The performance of the electrocatalytic activity of the developed counter electrodes is monitored in an I^-/I_3^- redox based solution by use of cyclic voltammetry (CV) studies having a three-electrode configuration. The platinum (Pt) wire acts as the counter electrode, and the Ag/Ag^+ acts as the reference electrode in acetonitrile based solution consisting of 10 mM LiI, 0.1 M $LiClO_4$, and 1 mM I_2.

The prepared working electrodes (carbon, SWCNH, SWCNH/carbon, and Pt solution coated FTO glass substrates) are inserted into the solution, and ultrapure N_2 (nitrogen) gas is purged well before the start of the scans for better performance. The witnessed results are presented in Figure 4, in which the two pairs of prominent of peaks are

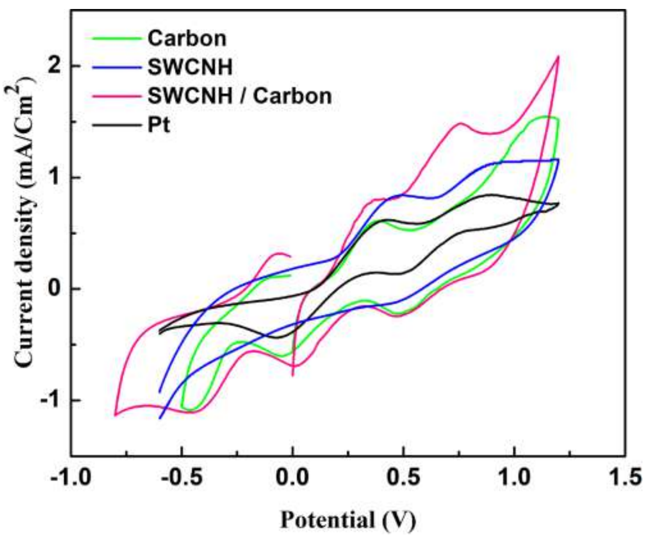

Figure 4. *C*−*V* curves of carbon, SWCNH, SWCNH/carbon, and Pt electrodes.

clearly observed. The two pairs of redox peaks, anodic peaks and cathodic peaks, are observed for carbon, SWCNH/carbon, Pt, and SWCNH. The cathodic peak reflects the reduction of tri-iodide, and anodic peaks reflect the oxidation of iodide and tri-iodide. SWCNH/carbon presented oxidation and reduction peaks similar to those for Pt. This specifies that the SWCNH/carbon electrode displays improved catalytic activity compared with that of Pt. The redox reaction that occurs at the CE of DSSC in the cyclic voltammogram is owed to the reduction of iodine molecules. The SWCNH/carbon electrode presented both higher oxidation and reduction current density in a comparison with those of Pt, predicting a wild rate of triiodide reduction.[38] For the carbon working electrode, there is another pair of peaks found; this is associated with oxidation and reduction of carbon itself.[39]

The Tafel slope is an intrinsic characteristic of electrocatalyst materials that is determined by the rate-limiting step.[40] Figure 5 represents Tafel polarization curves with logarithmic current density (log mA) as a voltage function for oxidation and reduction reactions of carbon, SWCNH/carbon, SWCNH, and Pt electrodes. Tafel polarization was accomplished with symmetric dummy test cells (two similar counter electrodes sandwiched, with filled electrolyte into the cell to become

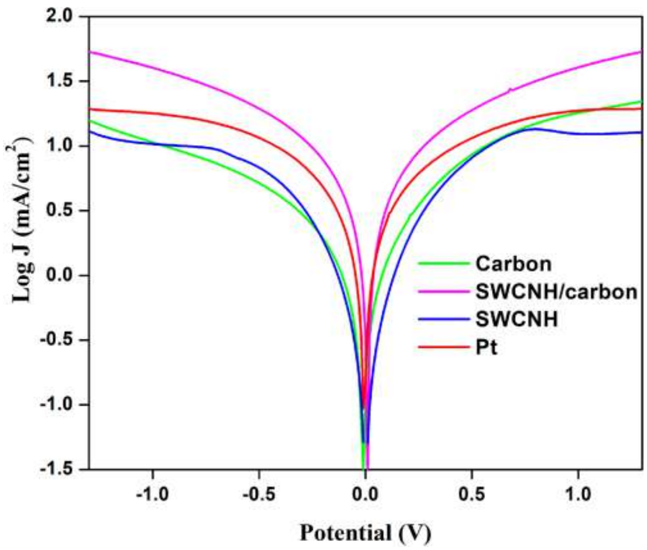

Figure 5. Tafel polarization curves of carbon, SWCNH, SWCNH/carbon, and Pt CEs.

symmetric dummy test cells). From Figure 5, the SWCNH/carbon electrode performed a larger exchange current density (J_O) than the carbon, SWCNH, which implies a higher electrocatalytic activity and reduced charge-transfer resistance at the electrode−electrolyte interface. Tafel curve branches of anodic and cathodic nature for the SWCNH/carbon electrode presented a greater slope representing a higher exchange current density.

Figure 6 depicts photo current density−voltage (*J*−*V*) curves; its resultant photovoltaic parameter values with

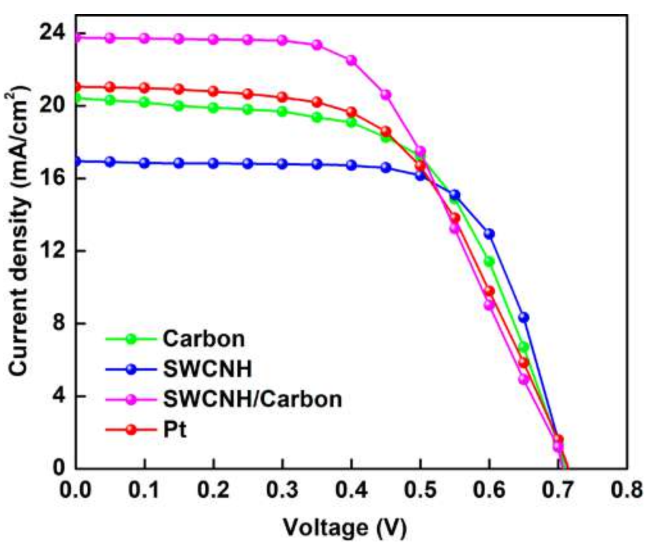

Figure 6. *I*−*V* curves of carbon, SWCNH/carbon, SWCNH, and Pt CE based DSSCs.

acetonitrile based electrolyte are given in Table 1. The photovoltaic performance with N719 dye based DSSC accumulated with prepared electrodes and derived performance of photovoltaic parameters, like short-circuit current density, efficiency, fill factor, open-circuit voltage, is tabulated in Table 1. DSSC with carbon CE shows J_{sc} = 20.44 mA/cm^2; V_{oc} is 0.71 V, with a fill factor of 0.63, yielding a PCE of 9.14%. In contrast, the cell that ended with SWCNH/carbon

https://doi.org/10.1021/acsaem.1c02087
ACS Appl. Energy Mater. 2021, 4, 11225−11233

Table 1. Fabricated DSSC Photovoltaic Parameters

parameter	carbon	SWCNH	SWCNH/carbon	Pt
V_{oc} (V)[a]	0.71	0.72	0.72	0.71
J_{sc} (mA/cm^2)[a]	20.44	16.99	23.76	21.04
fill factor (FF)[a]	0.63	0.63	0.65	0.63
efficiency (η) (%)[a]	9.14	7.74	11.12	9.41

[a] V_{oc}: ±30 mV. J_{sc}: ±0.20 mA/cm^2. FF: ±0.03. η: ±0.10.

harvested η = 11.12% with V_{oc} = 0.72 V, J_{sc} = 23.76 mA/cm^2, and FF = 0.65. For comparison, SWCNH and Pt based test cells are fabricated, and their photovoltaic parameters are tabulated in Table 1.

The overall performance of the SWCNH/carbon based DSSC is high due to the conductivity of carbon and the high electrochemical activity of SWCNH; the composite DSSC exhibited a higher PCE. The stability of the materials and device performance are provided in the Supporting Information, Figure S3a,b.

EIS (electrochemical impedance spectroscopy) measurements were performed to examine the interfacial charge-transfer process that occurs at the electrode−electrolyte−electrode interfaces of symmetrical dummy test cells. The Nyquist plots consist of two semicircles as shown in Figure 7.

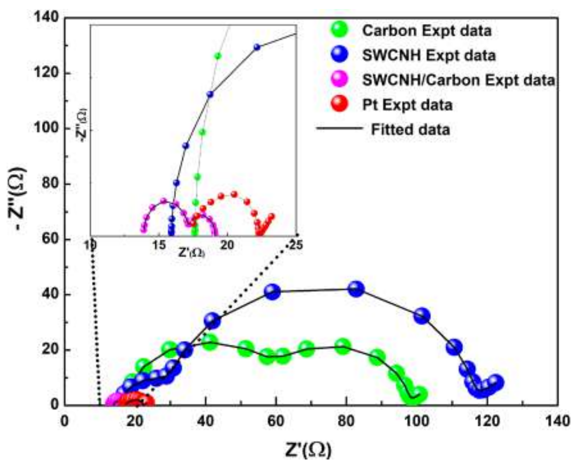

Figure 7. EIS of dummy test cells made with the same CEs.

At the higher-frequency region, the first semicircle intercept on the real axis is assigned to series resistance (R_S) of the FTO−SWCNH/carbon interface, whereas, at the lower-frequency range, the intercept on the real axis signifies R_{CT} (charge-transfer resistance). The R_S and R_{CT} values are evaluated through the fitted equivalent circuit (inset of Figure 7), tabulated in Table 2.

From this, we can conclude that SWCNH/carbon offers a better performance. The R_{CT} value depends on the counter electrode's catalytic materials; the fitted R_{CT} for the SWCNH/carbon CE is effective compared to that of the Pt CE; the higher value R_{CT} of SWCNH/carbon indicates a higher ability for the reduction of I_3^- to I^- in an electrolyte solution compared with that of the Pt CE.

Table 2. EIS Parameters and J_O of Dummy Test Cells Fabricated with the Same CEs

parameter	SWCNH	carbon	SWCNH/carbon	Pt
Rs	15.92	17.60	13.81	17.41
R_{CT}	21.01	37.90	19.40	19.68
J_O (mA/cm^2)	1.50	3.77	10.43	8.75

The Bode phase plots are presented as Figure 8; from the peak values, the electron lifetime (τ_e) is evaluated for carbon,

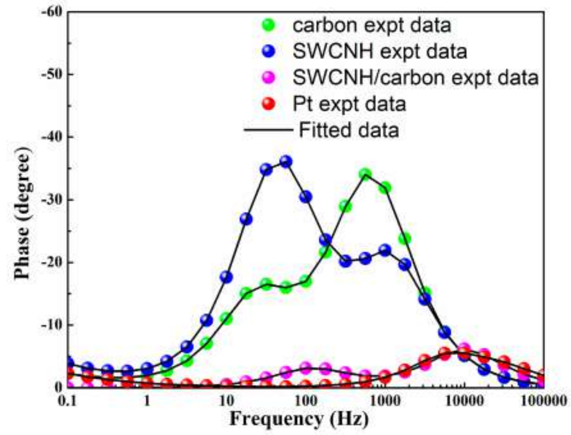

Figure 8. Symmetric dummy cell Bode phase plots.

SWCNH, SWCNH/carbon, and Pt based devices. Here, the frequency peaks confirm the charge transfer at different interfaces for these devices. The SWCNH/carbon test device's characteristic peak frequency is present at the lower-frequency side, demonstrating a longer electron lifetime of 1.3 ms, which is evaluated by using the equation $\tau_e = 1/2\pi f_{max}$.

Bifacial DSSM Performance. Dye sensitized solar cells are potentially useful as photovoltaic technology for indoor as well as outdoor applications. In particular, a bifacial DSSC is a promising candidate for oriented building integrated photovoltaics (BIPVs), which enables harvesting both direct sunlight and diffused light (indoor light) for power conversion. The present work demonstrated a W-type module which consists of six individual DSSC test cells in a connected series, named DSSM; the potential for power conversion of sunlight and indoor light is illustrated in Figure 9.

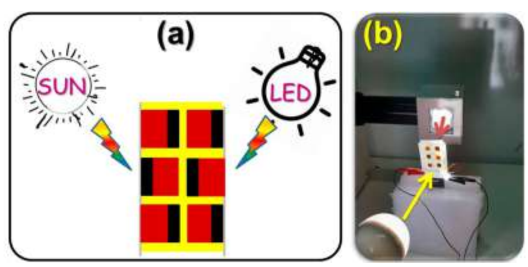

Figure 9. Developed W-type DSSM module taking advantage of both (a) sunlight and (b) indoor light conversion.

The developed bifacial DSSM was exposed to light power of 100 mW/cm^2 in addition to indoor light of 1000 lx; the performance is measured, and the obtained results of J−V characteristic performance are depicted in Figure 10. Photovoltaic parameters are summarized in Table 3. Here, the DSSM part exists in the W-type design in which photoelectrodes interchange between the front side and the back side of the submodule as represented in Figure 1. The DSSM revealed a

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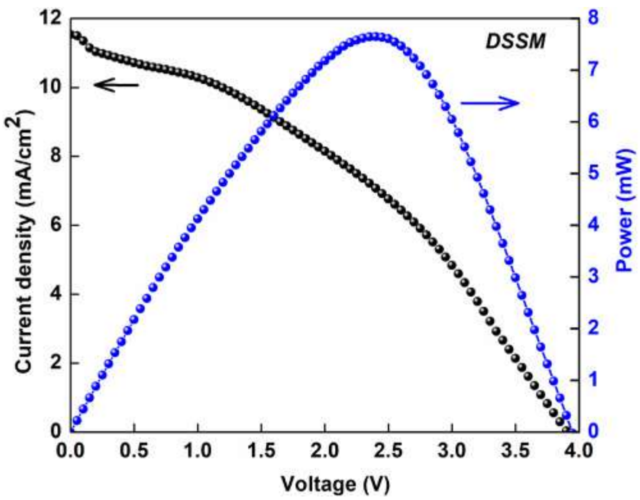

Figure 10. $J-P-V$ plot of fabricated dye sensitized solar module.

Table 3. Photovoltaic Parameters of DSSM

parameter	DSSM
V_{oc} (V)	3.94
J_{sc} (mA/cm^2)	11.53
fill factor	0.53
efficiency (η) (%)	19.71

V_{OC} of 3.94 V, J_{SC} of 11.53 mA/cm^2, and FF of 0.53, which leads to a PCE (power conversion efficiency) of 19.71%.

Figure 10 also presents the power−voltage characteristic of bifacial DSSM. Here, particular attention has to be paid to the shape of the curve, since that can provide precious information about the photocharging process. The power has a maximum value at 2.4 V. As reported, the overall efficiency increases quickly in the first part of the photocharge, since the storage of energy increases almost linearly in this region.

Supercapacitor Performance. The performance of the fabricated supercapacitor using SWCNH/carbon is made through cyclic voltammetry, EIS, and galvanostatic charge−discharge (GCD) measurements. The supercapacitor is loaded with efficient electrolyte. Cyclic voltammetry plots are recorded from 10 to 200 mV s^{-1} scan rates over a voltage window from 0 to 1.5 V, and the results are shown in Figure 11a. The obtained curves are in a quasirectangular shape. From CV, the SWCNH/carbon based SC encircles a larger area, which indicates superior capacitance performance. The GCD plots are measured in the range of current densities from 0.5 to 1.5 mA/cm^2 over the voltage window from 0 to 1 V (Figure 11b), which is shown in a nearly triangular shape. Areal capacitance (ASC), power density (P), and energy density (E) in the two-electrode mode are evaluated by using the equations mentioned below, and the evaluated parameter values are tabulated in Table 4.

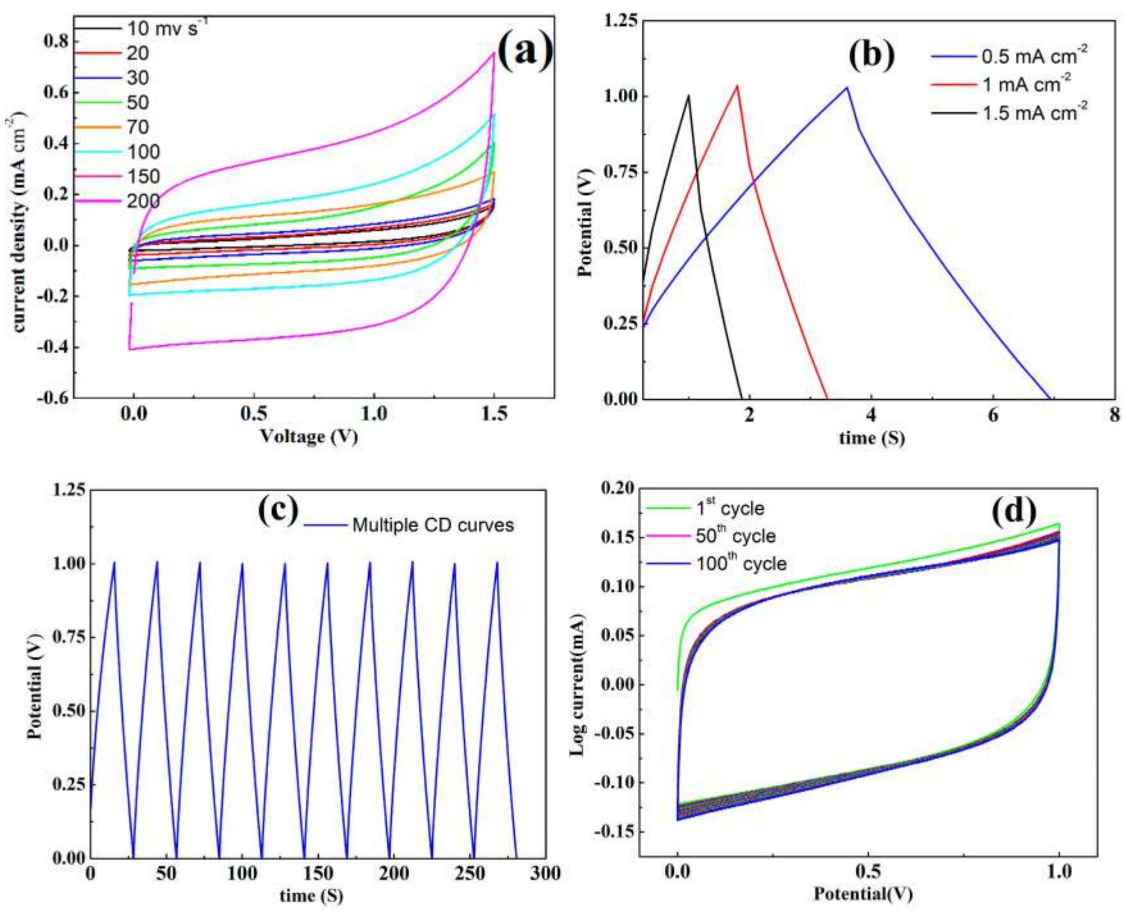

Figure 11. (a) CD curves of SWCNH/carbon SC at different charge−discharge current densities. (b) CV curves of the SC from 10 mV s^{-1} to 200 mV s^{-1} scan rates. (c) Galvanostatic charging and discharging curves versus time plot. (d) 100 cycles of CV curves at a scan rate of 100 mV s^{-1}.

$$ASC\ (F\ g^{-1}) = (I \times \Delta t)/m \times \Delta V$$

$$E\ (Wh\ kg^{-1}) = 0.5 \times ASC \times \Delta V^2$$

$$P\ (W\ kg^{-1}) = E/\Delta t$$

Table 4. Electrochemical Properties of Symmetric Supercapacitors

current density, I (mA/cm^2)	ASC (F g^{-1})	E (Wh kg^{-1})	P (W kg^{-1})
0.5	74.27	38.16	6.51
1.0	72.21	37.43	13.72
1.5	64.19	35.48	19.71

In the above equations, the current density is I in mA/cm^2, the discharge time is Δt in s, and the voltage window ΔV is in V. From a decrease in current density from 1.5 to 0.5 mA/cm^2, the discharge time is increased, which confirms that the charge storing capacity of the developed material is higher owing to the accessibility of a greater number of active sites which are electrochemically available and have a lower charge-transfer resistance. The SWCNH/carbon electrode galvanostatic charge−discharge performance up to 10 cycles for voltage starting from 0 to 1 V is demonstrated in Figure 11c, and the obtained curves have a triangular-like shape. The areal specific capacitance (ASC), energy density (E), and power density (P) are evaluated, with the values of 74.27 F g^{-1}, 38.16 Wh kg^{-1}, and 6.51 W kg^{-1}, respectively, by applying a current density of 0.5 mA/cm^2. The SWCNH/carbon electrode is higher in electrical conductivity, with greater electrocatalytic active surface sites which improve the overall storage of charge (Figure 11b). Figure 11d shows that the CV is constant during 100 cycles of measurement, evidencing stable performance.

An electrochemical impedance spectroscopy measurement for SC is also performed, and the results are depicted in Figure 12. At the higher-frequency side, the series resistance value found as R_S is 33.98 Ω for the SWCNH/carbon based supercapacitor in $EMIBF_4$ based acetonitrile electrolyte.

DSSM Working Demonstration through an Electronic LED. The DSSM delivered a higher power conversion efficiency (η) of 19.71% and the energy density of the most of reported studies.[20,41−43] By considering the advantage of this as well as bifacial illumination of the 100 mW/cm^2 light condition at one side, and the indoor light of 1000 lx on the other side, DSSM which demonstrated an open-circuit voltage of 3.94 V (experimental setup shown in Figure 13) is adequate to charge the supercapacitor. With the discharge of SC, it lit up a light emitting diode (LED) which is shown as an inset for Figure 13, demonstrating its potential as a power source. This is suggesting the better electrochemical features for the SWCNH/carbon device. Figure 13 evidenced lighting of the LED by the supercapacitor under dark conditions.

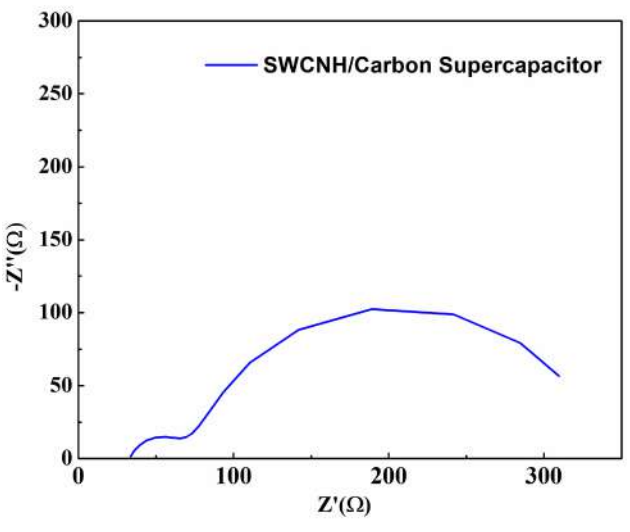

Figure 12. Electrochemical impedance spectroscopy of supercapacitor.

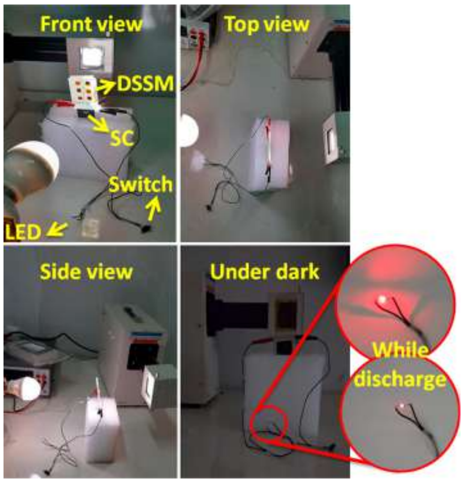

Figure 13. DSSM illumination from both sides, under dark condition discharge of SC lighting an LED.

The overall photoconversion and storage efficiency ($\eta_{overall}$) of the photocapacitor (PC) device are calculated by use of the following equations.

$$\eta_{overall} = (E_{PC} \times A_{SC})/(E_{light} \times t_{ch} \times A_{DSSC})$$

In the above equation, E_{PC} is the energy density of PC, E_{light} is the incident light power density (100 mW/cm^2), t_{ch} is the photocharging time, A_{SC} is the effective active surface area of supercapacitor part, and A_{DSSC} is the effective active surface area of the solar cell part in PC.

The energy storage efficiency of the PC is given by the following equation.

$$\eta_{storage} = \eta_{overall}/\eta_{conversion}$$

In the above equation, $\eta_{storage}$ is the energy storage efficiency of the supercapacitor part in the PC, and $\eta_{conversion}$ is the PCE of solar cell in the PC (19.71%). Thus, $\eta_{overall}$ and $\eta_{storage}$ of the PC device are determined to be 10.46% and 53.3%, respectively.

5. CONCLUSIONS

The photovoltaic performance of a single wall carbon nanohorn (SWCNH) assisted carbon counter electrode (CE) based DSSC demonstrated a power conversion efficiency (PCE) of 11.12%, which is a motivation to develop a submodule (DSSM) which consists of six DSSCs connected in series. This setup acted as a bifacial module. This notable performance drove the fabrication of a SWCNH/carbon based photocapacitor, which exhibited excellent performance and

https://doi.org/10.1021/acsaem.1c02087
ACS Appl. Energy Mater. 2021, 4, 11225−11233

demonstrated an electronic light emitting device (LED) function upon discharge of the SC. The DSSM is capable of converting light illuminated from both sides into electric power, which showed a remarkable power conversion efficiency of 19.71% and an open-circuit voltage of 3.94 V; this reflects the potential for building integrated photovoltaics (BIPVs).

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acsaem.1c02087.

EDAX, XRD, and details about the stability of the materials and test devices (PDF)

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Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

G.M. is thankful to the Department of Science and Technology (DST)-INSPIRE for financial support through IF 160564. R.M. thanks DST-SERB (EMR/CRG) EMR/2016/007049 for the utilized equipment purchased through this financial support. A.M. is thankul to DST for WOS-B through DST/WOS-B/ER-7/2021.

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IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

GROWING INDOOR PLANTS TO GENERATE MORE OXYGEN

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ABSTRACT:

This research is motivated by the poor oxygen level indoors. The purpose of this research is to increase public awareness on sustainable development of oxygen level by growing indoor plants. Because of not having proper oxygen indoors, creating health problems in peoples like headache, giddiness, nausea, asthma etc. A field survey was conducted in Mahabubnagar district, Telangana by questionnaire method and found that due to urbanization and overcrowding congested situation are observed. Not only the outdoor environment is polluted, but also the indoor environment is also much more polluted because of toxic chemicals like benzene, formaldehyde, toluene etc, which are seen in the room because of paints, cleaners, personal care products, perfumes and deodorants and also from printers, fridge etc. Majority of the people already know the importance of indoor air quality, but they are not having the knowledge to increase the air quality indoors. The cost effective easy to implement methods are needed to increase oxygen level indoors. As an alternative we can grow indoor plants. People are growing house plants for beauty and aesthetic value but if they grow indoor plants they benefit more.

Key words: Indoor plants, air quality, health problems, pollution, environment.

INRODUCTION:

India is the largest populated country. In this modern period day by day the area of urbanization is seen increasing in an alarming way. Mahabubnagar district is one of the populated district of Telanagana State. Due to urbanization the outdoor air as well as the indoor air is polluted. This is a great concern of human health. We have conducted the field survey in the Mahabubnagar district from different sources like work places, environmental places and residential areas, because all these places are not ventilated properly, with many occupants in a small area with a minimum required amount of fresh air. The present investigation is an attempt to provide awareness to people on indoor plants for sustainable development of oxygen levels and also to stop the spread of SARS-CoV-Virus it is necessary to live in rooms with ventilation and fresh air.

MATERIALS AND METHODS:

The authors have conducted an extensive field survey in the Mahabubnagar district from different sources like work places such as offices, banks, net centers, schools, colleges, entertainment places such as cinema hall, shopping malls and residential places such as apartments and homes etc. Because all these places are not ventilated properly with many occupants in a small area with a minimum required amount of fresh air.

First hand information is gathered through interaction with school childrens, college students, inhabitants of apartments, houses and common people. Further interaction sessions and workshops were held at Mahabubnagar district to tap the information on indoor plants. In the interaction we have gathered information on indoor plants of people they posses and have done questionnaire. To ascertation the benefits of these indoor plants the earlier published scientific literature sources like research has shown that "plants remove many indoor air pollutants, including ozone, toluene and benzene(Darlington et al, 2001, Wood et al, 2002, PapinChak et al,2009). Plants in room, however, have been found to improve performance(eg Shabita & Suzuki, 2004) and Lower feeling of physical discomfort (Lohr & Pearson-Mims, 2000).

RESULT AND DISCUSSION:

The indoor plants used for sustainable development of oxygen level indoors are enumerated with their vernacular name, scientific name, family, habitat and benefit were mentioned in table -1.

Table-1. List of some mention indoor plants develop oxygen levels indoors.

S.No	Vernacular name	Scientific name	Family	Habitat
1	Snake plant	Dracaena trifasciata	Asparagaceae	Herb
2	Areca palm	Dypsis lutescens	Areceae	Tree
3	Money plant	Crasula ovata	Areceae	Climber
4	Aloe	Aloe vera	Asphodelaceae	Herb
5	Spider plant	Chlorophytum comosum	Asparagaceae	Herb
6	Gerbera	Gerbera jasmisonii	Asteraceae	Herb
7	Lucky bamboo	Dracaena sanderiana	Asparagaceae	Herb
8	Chinese evergreen	Aglonema comotatum	Areceae	Herb
9	Peepal	Ficus religiosa	Moraceae	Tree
10	Arrow headvine	Syngonium podophyllum	Arecaea	Vine

A total number of 10 plants of 5 families are reported as indoor plants grown in Mahabubnagar district, Telangana state, India. Arecaceae (figure 1b,c,h,j) Asparagaceae (figure 1 a,g) Asphodelaceae (figure 1.d) Asteraceae (figure 1. f) Moraceae (figure 1.i). All these plants produce oxygen not only in day time even in nights also.

Figure 1. (a) Sansevieria trifasciata (b) Dypsis lutescens (c) Crasula ovata (d) Aloe vera

(e) Chlorophytum comosum (f) Gerbera jamisonii (g) Dracaena sanderiana (h) Aglonema comotatum

(i) Ficus religiosa (j) Syngonium podophyllum

Many of the above mentioned plants develop oxygen level indoors have been supported by the literature (B.C.Wolverton, and J.D. Wolverton 1993)(Tennessen and Cimprich, 1995)(Lohr et al 1998) (Wood, A Ronald et al 2006) (K.D.Kobayshi, A.J.Kaufman, J.Griffs and J.Mc Connell 2007) (T. Bringsmark, T.Hartik, G.Patil 200).

The information provides enough incentive to study the active principle involved in sustainable development of oxygen levels indoors.

CONCLUSSION:

A critical study of 10 indoor plants have the properties to develop oxygen levels indoor. So there is a need to provide awareness to people of Mahabubnagar district. As the global concern during the pandemic, people are staying at home. People are growing house plants in their gardens and lawns for beauty and aesthetic value. But if they grow indoor plants they can get benefit of it. It is necessary to live indoor with good ventilation and fresh air.

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Volume 10 Issue 2 , Date of Publication:February 2022 2022-02-03 23:22:26

UGC Approved Journal No: 49023 (18)

PAPER ID : IJCRT2202064

Registration ID : 215619

ISSN 2320-2882 IJCRT

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JOURNAL OF MANAGEMENT & ENTREPRENEURSHIP
ISSN : 2229-5348
UGC Care Group 1 Journal

CHALLENGES FOR SOCIAL ENTREPRENEURS IN INDIA

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ABSTRACT

"If everyone is a change maker, there's no way a problem can outrun a solution"
– Bill Drayton

Poverty and Unemployment are the two major obstacles faced by every country throughout the world. Being "Young India" or "Youngistan", our country has not exempted to face these major obstacles. Entrepreneurial development could be a good source of solution. But almost all Business Entrepreneurs ultimately aim to achieve maximum profits. It's difficult to aim at sustainable development goals in Indian context. Social Entrepreneurship is one of the best alternative sources to address this issue. Social Entrepreneurs are the individuals with innovative solutions to society's most pressing social problems. Social Entrepreneurs has the potential to create impact on economic system as it creates solutions to address social problems and leads the beneficiaries to a better standard of life. Present study is in descriptive in nature and based on secondary data sources. An attempt made to present challenges faced by Social Entrepreneurs and concluded with few suggestions to overcome these challenges.

KEY WORDS: Social Entrepreneurs, Sustainable Development Goals, Economic Growth

I. INTRODUCTION:

Considerable progress has been achieved in every field by human beings due to the scientific and technological advancement. The advancement in technology facilitated humans to lead life smoothly and conveniently. But at the same time it has faced the worst times in the history of human life. Covid-19 or pandemic situation is one among them. It is observed that most of the countries in the world suffer from unemployment and poverty. The lockdown situations throughout the world have given fire to increase in unemployment and poverty. Even though ranked as sixth largest economy in the world, our country is not exempted from these issues. India has ranked 100^{th} among 119 countries in Global Hunger Index, 2015 by International Food Policy Research Institute. Relentless efforts by the Government of India do not fulfill the needs of increased population. Apart from unemployment and poverty issues, social issues like adequate educational facilities, appropriate medical and health provisions and many more issues need to be addressed. A Social Entrepreneur identifies practical solutions to social problems by combining innovation, resourcefulness and opportunity. A Social Entrepreneur develops innovative solutions to social problems and then implements them on a large scale. (Dr. Brijesh, 2013). Social Entrepreneurs need to be boost up in large scale to achieve Sustainable Development Goals in Indian context.

II. REVIEW OF LITERATURE:

Sudha Menon, "Social Entrepreneurship in India: SEWA Experience" (2010) discussed about the grass root initiatives have combined passion of social mission with business to transform the lives of marginalized people. A case study of Self Employed Women's Association (SEWA) was analyzed. Author has presented a brief explanation about concept, definition of social enterprise, SEWA's experience as Social Enterprise and various challenges faced in the due course.

"The Meaning of Social Entrepreneurship" by J. Gregory Dees (2001) is convinced that we have always had social entrepreneurs in the world. He accepted views of Peter Drucker stating starting a business is neither necessary nor sufficient for entrepreneurship. Accordingly he says that not every new small business is entrepreneurial or represents entrepreneurship. The paper explains about the need and role of social entrepreneurs to help us find new avenues toward social improvement. The author explained about theories of Entrepreneurship in terms of value creation, innovation and change agent, pursuit of opportunity and resourcefulness. Differences between business and social entrepreneurs presented and finally concept of Social Entrepreneur is defined.

"Challenges for Social Entrepreneurship" by Dr. Brijesh Sivathanu and Dr. Pravin V.Bhise (2013) is convinced that Social Entrepreneurship by its nature is essentially only bound by the social mission and theory of change. He explains social Entrepreneurs are individuals with innovative solutions to society's most pressing social problems. They play role of change agents in the social sector. They generate employment; provide new goods and services with innovation, ability to create social capital and promoting equality in the society.

III. SIGNIFICANCE OF THE STUDY:

India has one of the world's largest urban populations, with about 350 million people living in cities. The percentage of people living under the poverty line in urban areas is higher than in rural areas, and these numbers are rising. Despite being the second fastest growing economy after China, India is home to around 40% of the world's poor, with just under 30% of the population living below the poverty line (CIA website). The country is still battling with socio-economic issues like illiteracy, malnutrition and poor health care. Social Entrepreneurship could be the best solution to address these situations. As such ultimate objective of any Business Entrepreneur is to take care of his own wealth creation. Where others see problems, Social Entrepreneurs see opportunities. An Entrepreneur targeted at profits with social cause i.e. Social Entrepreneur will be the one of the best suitable to handle the present situations and to step up towards achieving Sustainable Development Goals. In this context present study has lots of significance to study.

IV. OBJECTIVES OF THE STUDY:

Entrepreneurship Development could be the solution to handle unemployment and poverty in the world's context. Social Entrepreneurs are individuals with innovative solutions to address society's most pressing social problems. (Dr. Brijesh, 2013). The objectives of the present paper "Challenges for Social Entrepreneurs in India" are as follows:

- To present the Conceptual frame work of Social Entrepreneurship
- To examine the Challenges for Social Entrepreneurs in India
- To enlist few suggestions to face the Challenges

V. RESEARCH METHODOLOGY:

The paper "Challenges for Social Entrepreneurs in India", is an attempt to explore the need and necessity of Social Entrepreneurs in India. This paper presents the challenges of Social Entrepreneurs in Indian context. This is a conceptual paper with descriptive in nature. The data is based on Secondary data sources like articles, research paper published in various journals and magazines. Some data is collected from UNDP reports and Google.

VI. CONCEPTUAL FRAMEWORK OF SOCIAL ENTREPRENEURSHIP:

The term "Entrepreneur" is originated from the French word "Entreprendre" and German word "Unternehmen", as early as the 17th and 18th centuries. It means "someone who undertakes". Entrepreneurs create value. According to Joseph Schumpeter, Entrepreneurs are the innovators who drive the "Creative-destructive" process of capitalism. By creating new ways of doing things they serve new markets to move the economy forward. As such Schumpeter views Entrepreneurs as "Change Agents."

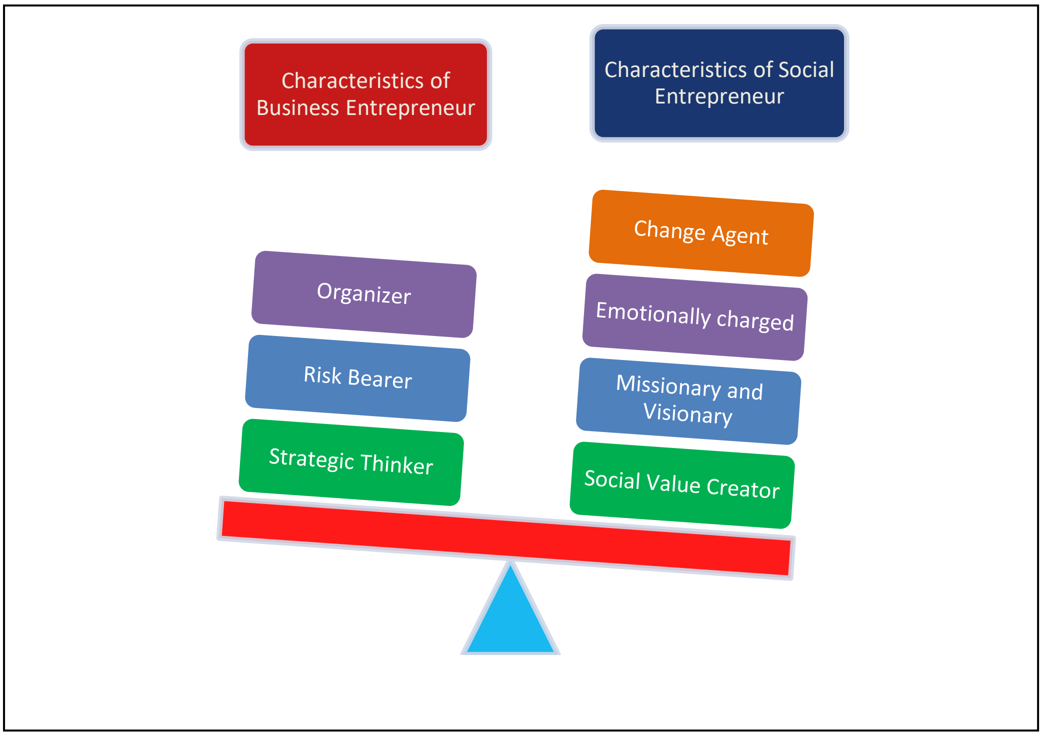
In 1960's and 1970's, 'Social Entrepreneur' and 'Social Entrepreneurship' terms were used first in the literature on social change. Due to the efforts made by Bill Drayton these terms came into

widespread use in 1980's and 1990's. The word "social" simply modifies entrepreneurship. The term "Social" refers to initiatives aimed at helping others (Prabhu, 1999). The concept of Social Entrepreneurship has attracted the attention of world with the efforts done by Professor Mohammad Yunus, Founder and the manager of Grameen Bank established in Bangladesh aimed at empowerment of women and to eradicate poverty in Bangladesh. His relentless efforts has been recognized and awarded with prestigious Nobel Peace Prize in 2006.
Social Entrepreneurs are individuals with innovative solutions to society's most pressing social problems. They are ambitious and persistent, tackling major social issues and offering new ideas for wide-scale change.

According to ***Mort et al. (2003, p. 76),*** *social entrepreneurship leads to the birth new social enterprises and the sustained innovation in existing enterprises and conceptualize social entrepreneurship as "a multi-dimensional construct involving the expression of entrepreneurially virtuous behavior to achieve the social mission, a coherent unity of purpose and action in the face of moral complexity, the ability to recognize social value-creating opportunities and key decision-making characteristics of innovativeness, pro-activeness and risk-taking."*
The following definition combines an emphasis on discipline and accountability with the notions of *value creation* taken from Say, *innovation and change agents* from Schumpeter, *pursuit of opportunity* from Drucker and *resourcefulness* from Stevenson. In brief, this definition can be stated as; Social Entrepreneurs play the role of change agents in the social sector by:

- Adopting a mission to create and sustain social value (not just private value)
- Recognizing and relentlessly pursuing new opportunities to serve that mission
- Engaging in a process of continuous innovation, adaptation and learning
- Acting boldly without being limited by resources currently in hand, and
- Exhibiting heightened accountability to the constituencies served and for the outcomes created. (Based on J. Gregory Dees, 2001)

FIGURE 1: CORE CHARACTERISTICS OF BUSINESS ENTREPRENEUR AND SOCIAL ENTREPRENEUR



(Source: Samer Abu-Saifan (2012) Social Entrepreneurship: Definition and Boundaries; Author's Creation)

Figure 1 explains the Core Characteristics of Business and Social Entrepreneur. The figure clearly exhibits the characteristics of Business Entrepreneur as a Organizer, Risk bearer and a good Strategic Thinker. Whereas the Social Entrepreneurs posses' characteristics like Missionary and Visionary, Social Value Creators, Emotionally charged and plays the role of Change Agent. It shows that Business Entrepreneurs primary objective as profit and Social Entrepreneur works with Social mission.

VII. CHALLENGES FOR SOCIAL ENTREPRENEURS IN INDIA:

"Social Entrepreneurs are not content just to five a fish or teach how to fish. They will not rest until they have revolutionized the fishing industry." – Bill Drayton, Founder of Ashoka.

Social Entrepreneurs are keeping efforts to fulfill the basic needs of marginalized group of people in the society. They are making a valuable contribution to fulfill the basic necessities of the population. Entrepreneurship in India is still encumbered by the traditional educational system of the country (Suresh Seth, 2011). Some of the major challenges faced by the Social Entrepreneurs are outlined in the following text:

Lack of Entrepreneurial based curriculum in the Indian Education System: Indian Education system is lacking behind practical aspects of entrepreneurship in the education system. Yet today, traditional education system is followed. It is found most of the curriculum is based on theoretical based. Practical aspects were lacking. Get employment is the outcome of the system. But needs of the growing population can't be fulfilled with this. The seeds of entrepreneurship must be planted in the brains of the learners of the present education system. Ultimately it results in creation of new employment and making one to be self-reliant.

Lack of Financial Support for Capital Formation: Lack of financial sources for establishing and scaling of the Social Enterprise is one of the major challenges faced by the Social Entrepreneurs in India. Generally Social Enterprises main objective is to serve and secondary objective is to earn profits. Most of the financial institutions, banks and even friends and relatives hesitate to come forward to lend money to a Social Entrepreneur. Social Entrepreneurs gives innovative solutions to solve the problems. These innovative solutions are difficult to reliable unless they proven successful. Hence, most of the bankers and financial institutions do not provide non collateral loans. Finally, they depend on local money lenders to raise funds as seed capital. But with the high rate of interest creates more additional burden to the Social Entrepreneurs.

Lack of Infra-Structural Facilities: Social Entrepreneurs face Challenge like Infra-Structural facilities. Infra-Structural facilities like machines, power, water, roads and transportation, marketing etc. are lacking. Even most of the consumers do not have awareness about products manufactured by the Social Entrepreneurs. Advertisement and vast publicity is needed to encourage Social Enterprises. Technological Support and know-how has to be facilitated from the Government at reasonable costs.

Lack of Skilled Human Resources: Where others see a problem, there Social Entrepreneur saw an opportunity. Social Entrepreneur takes initiation to solve social problems with innovative solutions. Social Enterprises established based on an innovative creation. It needs skilled manpower to execute. Social Entrepreneurs recruits marginalized group of people and train them. Retaining those skilled man powers is one of the biggest challenges for the Social Entrepreneurs.

Lack of Government Initiatives: Initiatives from the Government to encourage Social Entrepreneurs is not up to the mark. Recently, Telangana Government has come forward to encourage Social Enterprises with launch of T-Hub. But such type of initiatives found lacking thorough out the country. Government has to be more liberal in policy making, providing tax rebates and subsidies to the Social Entrepreneurs.

Lack of support from Family: Social Entrepreneurs do not receive much support from family, friends and relatives. Even it is observed that business entrepreneurs also not encouraged to enter into the field of entrepreneurship as such lot of risk is involved and no regularity of income flow. The traditional, cultural and other aspects will restrict the scope of Social Entrepreneurs to emerge in the field to support the society. A better educational level of family members may change their attitude towards supporting and encouraging their family member as a upcoming Social Entrepreneur in near future.

VIII. SUMMARY, CONCLUSION AND SUGGESTIONS:

Indian economy is one among the fast growing economies in the world. Tremendous advancement has achieved in various fields. At the same time it is observed that basic necessities like food, clothing and shelter are not enjoyed by deprived communities of the society who comes under below poverty line. No doubt, Government puts its hundred percent efforts to serve the needy. Having second largest population and fulfilling needs of all is not an easy task only for the Government. We, people of India together may find a solution to this i.e. Social Entrepreneurship. Everyone can be a Change Maker. With collective efforts may address these social issues and pave the way towards achieving Sustainable Development Goals. Social Entrepreneurs finds an opportunity for every problem. They combine profits with social problems. Innovative Solutions were given to address the social issues. Social Entrepreneurship is growing trend in Indian business. Sustainability and Scalability, Finance/capital formation and Personal Challenges are top constrains to the Social Entrepreneurs. A little bit more attention should be given to these Social Entrepreneurs in the form of provision of seed capital, subsidies and tax rebates may strengthen contributions of Social Entrepreneurship in Indian business.

Suggestions:

- Social Entrepreneurs/social enterprises need to be strengthened by providing sufficient financial support and marketing facilities.
- Public and Private partnership to be encouraged more in the field of business.
- Need of encouragement and publicity to create awareness among customers about products produced by Social Enterprises.
- Government has to be more liberal in policy formulation, tax rates and subsidies with regard to Social Enterprises.
- Social Entrepreneurs efforts could be appreciated and recognized with suitable Awards and Certificates.

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Factors of Social Entrepreneurship

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Abstract: Developing countries are not under developed, they are under managed" – Peter F. Drucker Unemployment and Poverty are the two major obstacles faced by our country. Being "Young India", our country has achieved tremendous development in all sectors. Technological advancements helped out in this regard. Yet on the other side of the coin, it is difficult to provide the basic needs of marginalized group of population who lives below poverty line. Even though Entrepreneurship establishments help in to decrease unemployment, it couldn't be the permanent solution to address social issues. Social Entrepreneurs are more innovative and creative to find the solution to address the social issues. In this context, an attempt has made to understand the factors of Social Entrepreneurship, multi-dimensional model of Social Entrepreneurship. It is a concept paper based on descriptive case study analysis. The paper concluded with discussion on factors of Social Entrepreneurship.
Key Words: Wealth Creation, Social Entrepreneurship and Sustainable Development

Introduction:

India is the sixth largest economy in the world. It is the second largest populated country in the world after China. Our Country consists of more youth population and popularly known as Youngistan throughout the world. No doubt, India has achieved tremendous progress and success in many sectors. Even the up gradation and techno savvy culture and environment has added boost to achieve the economic development. But fulfilling the basic needs and providing employment opportunities to the growing population itself is a big challenge for any Government. Unemployment and Poverty are two major problems faced in the development of the economy. Entrepreneurship is could be a suitable solution to the handle these problems. Business Entrepreneurs are most concerned with wealth creation. Whereas Social Entrepreneurs are most concerned with finding a innovative solution to address the social issues. Social Enterprises are social mission-driven organizations. They apply market based strategies to achieve a social purpose. Social Entrepreneurs are innovative, highly-motivated and Critical Thinkers (Suresh Seth, 2011). Developing country like India, need to be assisted with more number of Social Entrepreneurs to achieve Sustainable Development.

Research Methodology:

Objectives Of The Study:

The present study aimed at the following Objectives:

1. To understand the bounded multi-dimensional model of Social Entrepreneurship.
2. To explore the factors and constraints of Social Entrepreneurship

Methodology Of The Study: The present study "Factors of Social Entrepreneurship" is a concept paper. It is descriptive in nature. The data consists of primary and secondary data sources. The primary information has been obtained from the personal interactions with Social Entrepreneurs (while pursuing Ph.D.). The secondary information is collected from various articles and research papers published in journals, magazines, Google search and web search etc.

Factors Of Social Entrepreneurship:

Social Entrepreneurship is the process of pursuing innovative solutions to social problem (Dr. Brijesh, 2013). Social Entrepreneurs plays the role of change agent in the society. Their primary motive is to serve followed by earning profits. Usually they start with adoption of a mission and try to create and then sustain social value. Social Entrepreneur recognizes a social problem and uses entrepreneurial principles to organize, create and manage a venture to make social change (Dr. Brijiesh, 2013).

Social Enterprises, like any other business firm is affected and constrained by environmental dynamics. In this regard Prabhu (1998) and Sullivan Mort et al. (2003) have identified the three factors of Innovativeness, Pro-activeness and Risk taking (from Covin & Slevin, 1986) as central to Social Entrepreneurship. The constraints faced by the Social enterprises were categorized into two, i.e. Static and Dynamic Constraints. Having Innovativeness, Pro-activeness and Risk taking as factors and facing Static and Dynamic Constraints Social enterprises need to work to achieve their Social Mission. Let us have a look at the factors or features central to a Social Enterprise, which forms a part of the Dynamic Environment faced by them:

Innovativeness: Resource procurement and sustainability are the two major challenges faced by the Social enterprises. In order to face competition and to sustain in the market the Social enterprises have to create the targeted Social Value through Innovativeness.

Pro-activeness: In order to face today's dynamic environment, every Social enterprise needs to be pro-active. Social enterprise need to anticipate the changes before they exert an impact by implementing a new decision in the organization. They have to be prepared in advance to handle the situations arise due to environmental effects and to remain intact with their mission.

Risk Management: Social enterprises face risk in terms of operating, managing and funding. The primary goal of Social enterprise is not earning more profits. It turns as a constraint in terms of access to various sources of funds; short term as well as long term and also for monetary return on investments. Therefore every Social Enterprise need to forecast their revenue streams to do proper risk management before committing with financial resources.

Sustainability: Primary aim of Social enterprises is to sustain in the market rather than attaining growth. In order to sustain their model for social value creation in the market they need to face today's dynamic environmental constraints.

Social Mission: The primary objective of any Social enterprise is to achieve their Social Mission. Their entire transactions and operations revolve around their Social Mission or Vision to serve social welfare.

Opportunity seeking/recognition: Social Entrepreneur identifies the opportunities in the market which were ignored by the corporate enterprises. Social enterprises find opportunities where the Corporate Enterprises finds problems. They identify opportunity to create better social value for their current and potential clients.

A multidimensional Model of Social Entrepreneurship consists of dimensions and constrains described by Weerawardena, Jay and Mort (2006) presented in the following figure 1.

Figure 1: A Multidimensional Model of Social Entrepreneurship

Fig. Bounded multidimensional model of social entrepreneurship.

(Source: Weerawardena, Jay and Mort, Gillian Sullivan (2006): Investigating Social Entrepreneurship: A multidimensional model, Journal of World Business 41 (2006) pp. 21-35)

Figure 1 presents A Multi Dimensional Model of Social Entrepreneurship describing the Dimensions/Behaviours and Constraints of a Social enterprise. Innovativeness, Pro-activeness and Risk Management as dimensions and Static & Dynamic constraints consists of sustainability, social mission and environment. Dynamic constraints include the ever changing Environment in which the Social enterprise has to operate. As such financial resources are less in availability for the Social enterprises; they need to first ensure their survival, sustainability and then growth. Before taking a decision they have to think about their Social Mission. All the activities and strategies should act as a means to achieve their social mission. Today's environment is very dynamic for Social enterprises to operate due to continuous changing Government policies, scarcity of funds, ever changing social needs, competition from others, concentration towards social value creation etc. Thus Social Entrepreneurship can be viewed as a Multi Dimensional Model consisting of dimensions and constraints aimed to achieve Social Mission. This relationship stated as follows:

$$SVC = f(I, P, RM) \text{ subject to } S, SM, E$$

Where SVC = Social Value Creation; I: Innovativeness; P: Pro-activeness; RM: Risk Management; E: Environment; S: Sustainability; and SM: Social Mission.

Case Study Analysis:

A multi dimensional model of Social Entrepreneurship consists of dimensions and constraints faced by a Social Enterprise; the researcher has made an attempt to study the dimensions and constraints of four Social Enterprises by using interview method while pursuing research work. The summary of the case studies as presented below:

Table 1: Dimensions of Social Enterprises

Social Enterprise	Innovativeness	Pro-activeness	Risk-management
Allika	The Weed- Water Hyacinth used to prepare beautiful handicrafts	Sustainable and fashionable weavening products	BVIC is overall whelmed by the success of Allika and strengthened it
Umeed	Simple, beautiful newspaper made handicrafts	Environmental friendly products and create future leaders and women entrepreneurs	BVIC by way of mentoring seed capital to thousands of under privileged women and achievements
Vijaya Sree Jute Designs	Manufacturing of eco-friendly handbags and other products	Manufacturing the products to satisfy needs of different customers to cover market scope	Surge Impact provides technical as well as funding support.
Naari Enterprise	Training and counseling to acquire skills to preparing jute bags, hand bags college bags etc.	Customer satisfaction is very important to enhance the sales. According to their changing tastes and requirements changes in products took placed.	Good communication and maintaining good relations with Government Officials and Bankers able to generate loans at lower rate of interest.

(Source: Compiled by the Researcher from Personal Interactions in the field visit, Ph.D. thesis and secondary sources of web: https://www.umeed.in, https://yourstory.com>2017/10, www.bvic.in>start-ups, http://www.bitgiving.com>unitdhydall, and www.mycitykinks.in>neha-an-odia-social)

Table 2: Constraints of Social Enterprises

Social Enterprise	Environment, Opportunity seeking / recognition	Sustainability	Social Mission
Allika	Reducing environment pollution, reducing health risks indirectly	Women skill development, employment and trained up women in creating products, increased income levels of rural women	Empowerment of women, create sustainable livelihood and eliminate water contaminant weed from water hyacinth
Umeed	Overall empowerment of women and environmental friendly products creation and skill development	Skill development to women, employment and financial stability	Skill development by giving training, values and mindsets and exposure to society and women empowerment
Vijaya Sree Jute Designs	Creating environment of equal opportunities to all workers to prove their ideas in preparing products.	People were getting aware of Eco-friendly products. More comfort and saving the Environment theme lead to sustainability.	Creation of Employment and enhancing the living standards of women of marginalized section of the society.
Naari Enterprise	Aimed to create self confidence among women to come forward to create their own entity in the society.	The products are eco- friendly and offered at reasonable low prices. Good Quality of products made University people and Government officials to place orders on regular basis.	Creation of Employment and enhancing the living standards of women of marginalized section of the society.

(Source: Compiled by the Researcher from Personal Interactions in the field visit, Ph.D. thesis and secondary sources of web: https://www.umeed.in, https://yourstory.com>2017/10, www.bvic.in>start-ups, http://www.bitgiving.com>unitdhydall, and www.mycitykinks.in>neha-an-odia-social)

2. Tamanna Sharma, Delhi

Earthling First Pvt Ltd is a sustainable event and event waste management company started by Tamanna Sharma and is a venture of its own kind. A company tries to empower women and always has an equal ratio of men and women

3. Sobita Tamuli, Telana

Sobita Tamuli from Assam's Telana village brought an entrepreneurial revolution wave by manufacturing and selling kehusaar (organic manure) and Japes (traditional hats from Assam) without involving middlemen.

Seuji, a self-help group started by Sobita, made it possible for the farmers to access organic manure

4. Thinras Chorol, Ladakh

Thinras Chorol founded Ladakhi Women's Travel Company in 2009 promoting ecotourism in Ladakh and encouraging mountaineering and traveling among women. This is Ladakh's first travel company owned and operated by women with over 30 working staff.

Some Interesting Statistics on Women Entrepreneurs in India.

1. About 58% of the female entrepreneurs were in the age range of 20-30 when they started out.
2. Nearly 73% of them report revenue of approximately Rs 10 lakhs in a financial year.
3. Almost 57% of these women started out solo, i.e., without any other member.
4. About 35% of the women had a co-founder.

Roughly 71% of the Indian female entrepreneurs employ five people or less.

Conclusion –

In a country like India where most of the women aren't encouraged to think big (especially in the rural parts of the nation), there are some who have soared higher than one would expect in a constrictive setup. These wonder women are inspiring other ladies to venture on the path of entrepreneurship through their success stories comprising personal struggles and challenges and also their struggle is changing the thinking of society. As a result, India is steadily rising up the ranks when it comes to a favourable start up environment coupled with some solid backing from the Indian government. Indians need to learn from these role models. Their ventures and initiatives are more than just a source of profit. The ladies covered in this post are some of the most successful female entrepreneurs in India and demonstrate the results of creativity and innovation. Gender is not a deterrent for achieving success.