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Chris Christman
Michael Morris
Nick Smith
Wright State University
Dayton, OH, 45435

November 7, 2015

Department of Mechanical
And Materials Engineering
Wright State University
Dayton, OH, 45435

Dear Department,

Research utilizing multiple disciplines leads to more meaningful results and to an enriching experience for those involved. This project is unique in that it combines students with backgrounds in Materials Science and Mechanical Engineering. This allows the perspective of each team member to be applied to the development of the research. Concepts learned in chemistry, electrical engineering, thermodynamics, and polymers classes are all relevant to this project. The goal is to develop thin films that would have applications as transparent electrodes in photovoltaic devices. Our team, along with a graduate student, will create conductive polymer films doped with carbon nanotubes, starting from micron thicknesses and working down to the nanometer range. The project advisor, Dr. Amer, who has extensive experience working with polymers, plans to use the results of this project to compose an academic paper. These results can be used to further the research and development of transparent electrode technology, which plays a critical role in the creation of efficient photovoltaic devices.

Sincerely,

Meshary Alrubaeya
Chris Christman
Michael Morris
Nick Smith

Transparent Polymeric Electrodes

December 10, 2015

Meshary Alrubaeya, Christopher Christman, Michael Morris and Nicholas Smith

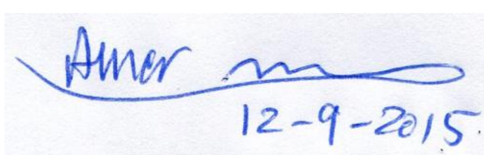
Faculty Advisor:
Dr. Maher Amer

ME-4910-01, Capstone Design I, and Fall 2015

Course Instructor:
Dr. Raghavan Srinivasan

Institutional Data:
Wright State

Approval:



ABSTRACT

Renewable energy sources are becoming increasingly important in today's world and are desired to replace fossil fuels, which cause high levels of pollution. Among these sources are photovoltaic devices that convert solar energy into electrical energy. Traditional solar cells use semiconducting materials such as silicon, as well as other metallic components. These cells are costly, rigid, and fragile, making them less desirable for certain applications. Recently, there has been interest in using thin film solar cells that employ organic materials, such as polymers. This study will attempt to find a conductive polymer based on poly-methyl-methacrylate (PMMA) for use as a transparent electrode in a solar cell. Different amounts of single-walled carbon nanotubes (SWCNT) as well as multi-walled carbon nanotubes (MWCNT), which are too small to significantly affect transparency, will be added to the polymer films to enhance conductivity. As the fraction of CNT particles is varied, conductivity and transparency measurements will be taken. This data will be graphed so that two equations comparing CNT content to conductivity and transparency, respectively, can be cross-analyzed to determine the best CNT amount. The results will be compared with existing transparent electrode technology, which is mainly based on silver nano-wires.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Solar cells work by using semiconductors to convert photons (light energy) directly into electricity. Materials have valence bands (highest occupied energy levels) and conduction bands (lowest unoccupied energy levels) that are separated by an energy band gap. The band gap is: nonexistent in metals/conductors, large in insulators, and intermediate (0.5-3 eV) in semiconductors. When photons with energy greater than the band gap are absorbed by the solar cell, electrons can jump from the valence to the conduction band, creating an electron-hole pair. These electrons and holes then flow through an external circuit to generate a current, and then recombine at the electrodes [1].

There are three types of wavelengths that can be collected from the sun: ultraviolet (<400nm), visible light (400-800nm), and infrared (>800nm). When light hits the surface of the solar cell, photons can be reflected, absorbed, or transmitted. Only part of the absorbed energy can be used to generate electron-hole pairs by accelerating electrons across the band gap; the remainder is lost through kinetic energy, phonons (lattice vibrations), etc. The opposite of generation is recombination, which occurs when electrons, traversing back along the band gap, recombine with holes and release energy. Energy levels/sections develop in the band gap; because electrons seek the lowest energy, they fall back to the valence band. These energy losses decrease the efficiency of solar cells, making them less economically viable [1].

One way to decrease the recombination losses is to use multiple solar cells in a multi-junction/tandem structure such that each individual cell can collect different wavelengths of the visible spectrum [2]. Figure and **Error! Reference source not found.Error! Not a valid bookmark self-reference.** show the difference between single junction and multi-junction solar cells.

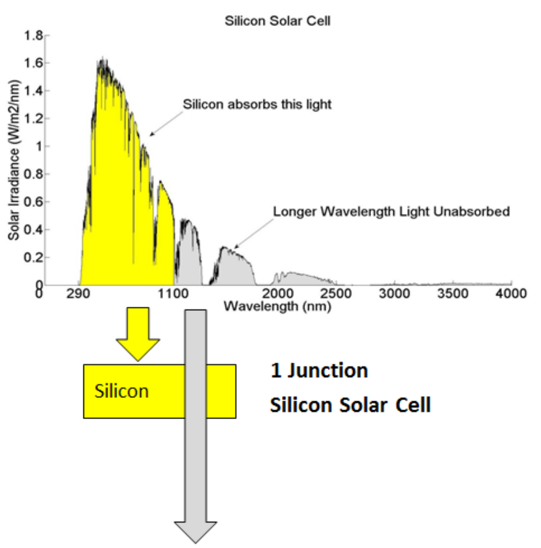


Figure 1: Single junction solar cell. Source: [14]

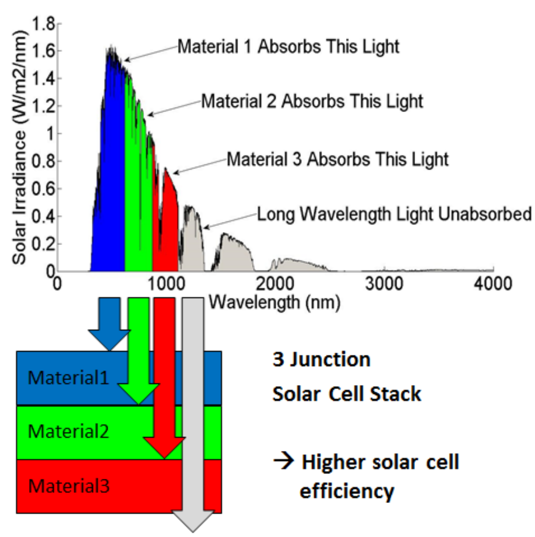


Figure 2: Multi-junction solar cell. Source: [14]

The silicon in the single junction cell harvests a range of wavelengths, whereas each layer in a multi-junction layer contains a different material to harvest a specific energy range. The multi-junction structure serves to shorten the region over which recombination takes place, and hence improve solar cell performance [3]. In tandem cells, the middle electrodes between the sub-cells determine the final efficiency; they must be conductive but also highly transparent so that light can pass through them to the next sub-cell [2]. The tandem cell structure is shown in Figure ; the middle transparent electrode serves as a charge recombination layer.

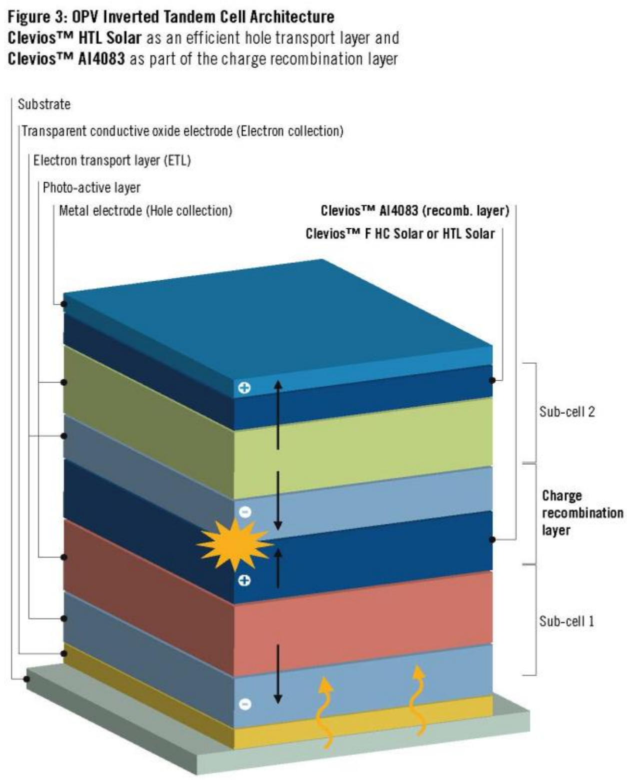


Figure 3: Tandem solar cell. Source: [16]

The traditional material used for transparent electrode applications is indium tin oxide (ITO), indium being a scarce, expensive metal. Thin films made from this material have several disadvantages. Because ITO is a brittle ceramic that can fracture at low strains, it is more easily damaged during manufacturing, handling, and device assembly. Once it is in the device, the film can develop microcracks caused by cyclic stresses, causing decreased electrical conductivity. The lifetime of an ITO film is also decreased if it is exposed to salts or acids that can cause corrosion. ITO has a high index of refraction, which requires anti-reflective coatings if used with materials of lower index. Finally, its high cost and inefficient deposition process make it less economically favorable [4].

An alternative to ITO is to use conductive polymer films that can be processed from solution, making them more commercially viable. These films were recognized in the 1980s to exhibit high conductivity when chemically doped. To further improve electrical stability, nanoscale materials such as carbon nanotubes (CNTs), graphene, and metal nanowires can be added; this results in transparent, conductive films which can be made ultrathin (1-100 nm) and used as transparent electrodes. CNTs have very good optical, electrical, and mechanical properties. They cannot yet be produced with suitable purity, although techniques to do so are improving. The best method to solubilize CNTs is direct dispersion in organic solvents, without the addition of solubilizing agents that could compromise conductivity. In order to facilitate this dispersion, energy must be added to the CNT bundles to separate them into single tubes; this is usually done through sonication, in which a vibrating tip is placed in the solution. This results in gas bubbles that expand and contract, causing high temperature regions that serve to separate the nanotubes. Sonication serves to decrease the diameter of the CNT bundles, which allows them to be more evenly dispersed throughout the polymer film [4].

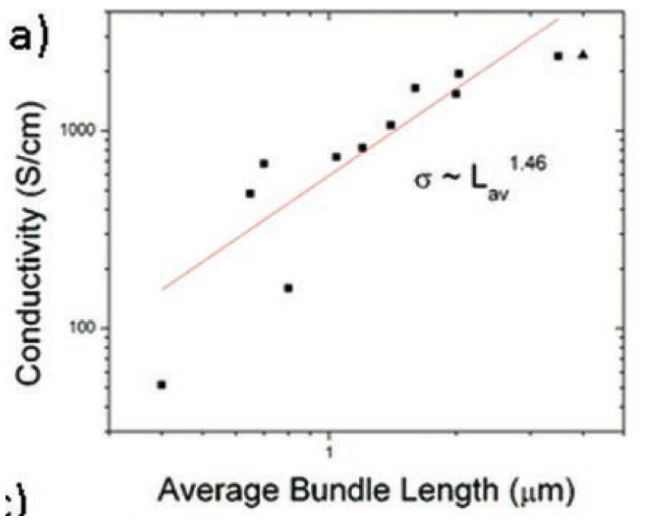


Figure 4: Conductivity vs Avg. bundle length. Source: [4]

One way to increase the DC conductivity of the films is to increase the carrier (i.e. electrons and holes) mobility. A single CNT can have conductivity of 200,000 S/cm and a mobility of 100,000 cm^2/Vs but a CNT film has only achieved a conductivity of 6600 S/cm and a mobility of 1-10 cm^2/Vs. This loss is caused by the resistance between overlapping CNTs, and can be reduced by lengthening the tubes according to the relationship $\sigma_{dc} \sim L^{1.46}$; this can be seen in Figure 4. Unfortunately, it is currently difficult to cheaply grow pure CNTs with length 10-20 μm. Another parameter to consider is film thickness; conductivity increases exponentially as until the thickness reaches 5 μm, at which it obtains bulk conductivity. Thin films in the nanometer range suffer from conductivity losses as well as variations in sheet resistance caused by changes in the density of the films. It is also important to consider the size of the nanotube bundles and the type of CNT being used. Decreasing the diameter of the nanotube bundles increases conductivity, which is why sufficient sonication is necessary. Films that use multi-walled CNTs, rather than single or double-walled CNTs, have lower conductivity because the inner walls of the tubes don't carry current. Therefore, the most conductive films are adequately thick and contain small bundles of long, single or double-walled nanotubes [4].

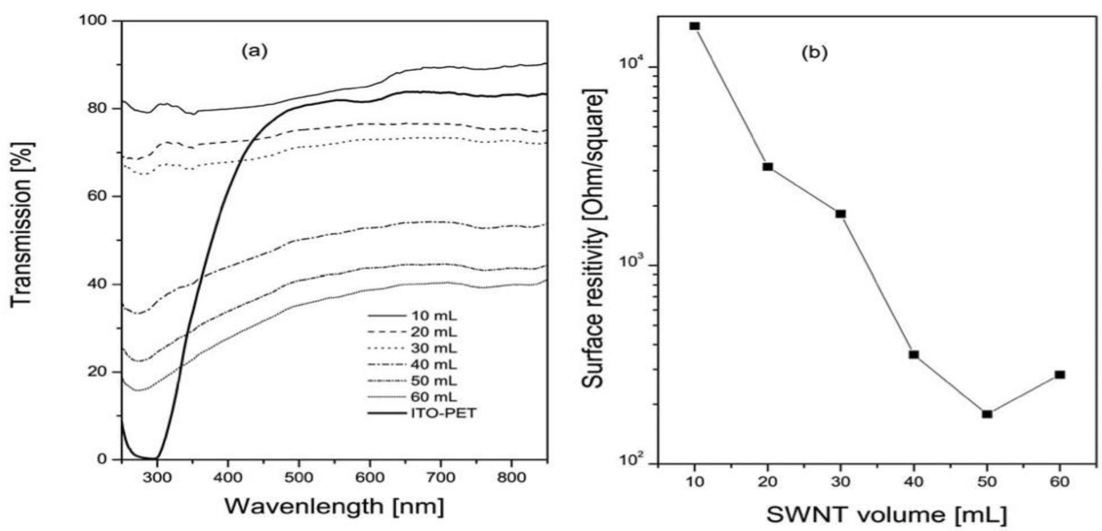


Figure 5: Transmission and resistivity for CNT films. Source: [6]

The best efficiency is achieved using conjugated polymers such as P3HT (Poly (3-hexylthiophene)), which provide good hole transport, and fullerenes, which provide efficient exciton dissociation (the separation of generated electron-hole pairs). In one experiment, single walled carbon nanotubes (SWCNT) were dispersed in a solution. Volumes of the solution ranging from 10-60 mL, in 10mL increments, were used to create six films of various thicknesses. The 10 mL sample was found to be more transparent, whereas the lowest resistivity was found in the 50 mL sample, which was 300 nm thick [5]. This is shown in Figure 5, above. Solar cells using the best SWNT film as well as an ITO film as electrodes were compared at the same illumination (100 $\frac{mW}{cm^2}$); the results are shown in Table 1 below.

Values at 100 $\frac{mW}{cm^2}$	ITO film	Best SWNT film
% Efficiency	0.69	0.99
FF (Fill Factor)	0.32	0.3
$I_{sc}(\frac{mA}{cm^2})$	5	6.65
$V_{OC}(mV)$	426	500

Table 1: ITO vs. SWNT film. Source: [5].

In the left column of Table 1, I_{sc} is the short circuit (maximum) current, V_{OC} is the open circuit (maximum) voltage, and FF is the fill factor defined by the equation:

$$\boldsymbol{FF = \frac{P_{max}}{I_{sc} * V_{oc}}} \quad \textbf{(1)}$$

P_{max} is the maximum power produced by the solar cell. The % efficiency of the solar cell is defined by the equation relating output to input power:

$$\% \, \boldsymbol{efficiency = \frac{P_{out}}{P_{in}} * 100} \quad \textbf{(2)}$$

Table 1 shows that the solar cell using the SWNT film has a comparable fill factor, as well as a better overall efficiency, than the solar cell using the ITO film. A graphical representation relating I_{sc}, V_{oc}, P_{max}, and FF is provided in Figure 6.

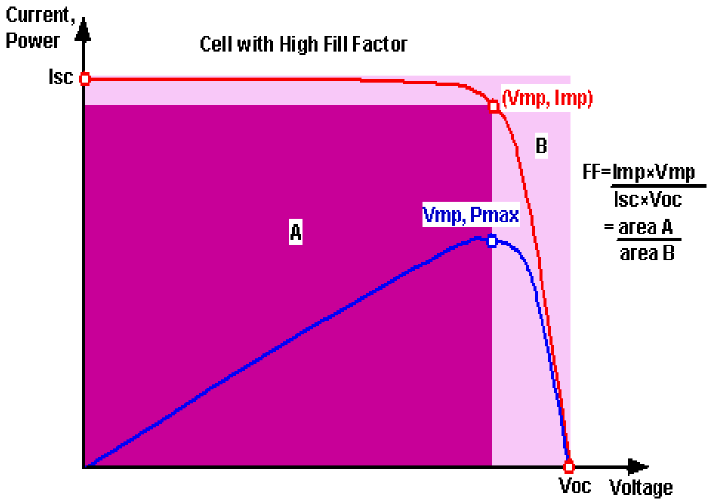


Figure 6: High Fill Factor Graph. Source: [15]

Transparency is also important in thin films; unfortunately, materials such as polymers are highly transparent, but generally suffer from low conductivity. The photoactive layer of a solar cell should transmit photons in the visible range and absorb photons from the ultraviolet and near infrared ranges. One study used a blend of two polymers as the photoactive layer: PBDTT-DPP, which is very absorptive at 650-850 nm, and [6,6]-phenyl-C_{61}-butyric acid methyl ester (PCBM), which is absorptive below 400 nm. This resulted in an average transmission of 68% across the 400-650 nm range, while allowing for absorption of the near infrared and ultraviolet photons. ITO was used as the anode and a silver nanowire composite was used as the cathode; unlike polymer films, which are usually destroyed during deposition, this composite is easily spray-coated onto the photoactive layer. After adding ITO nanoparticles as fillers to the films, which were 400 nm thick, the average transmittance across the 400-1000 nm range was measured as 87%. This resulted in polymer solar cells that had 61% average transmittance across the 400-650 nm range, with a peak value of 66% at ~550 nm [6].

Of the various solution-processed carbon-based thin films, those using silver nanowires have achieved transparency and sheet resistance similar to ITO. One issue with these films is the surface roughness caused by the wire-wire junctions. Poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT: PSS) polymer films of thicknesses 25, 50, 75, 100, and 125 nm were embedded with nanowires (50-100 nm diameter) by applying pressure. As thickness of the films increased, surface roughness decreased, with the 125 nm film having the flattest, most acceptable surface. Table 2 shows a comparison between the films and ITO measured on both glass and PET plastic.

	ITO (glass)	Polymer films (glass)	ITO (PET)	Polymer films (PET)
Sheet Resistance ($\frac{\Omega}{sq}$)	20	12	42	17
Transmissibility (350-800 nm range)	90%	86%	91%	83%

Table 2: Polymer films vs. ITO. Source: [7]

The silver nanowire films had better sheet resistance but less transparency than ITO; solar cells made from the films had similar or better figures of merit compared to those made from ITO [7].

In addition to CNTs and nanowires, graphene networks can be used in polymer films to make transparent electrodes. These sheets are electrically conductive and have low optical absorption; as of 2011, they have achieved 700 $\frac{\Omega}{sq}$ and 90% transparency. Annealing the films at up to 500 C increases conductivity, improving the $\frac{\sigma_{DC}}{\sigma_{OP}}$ (DC conductivity vs. optical conductivity), which is used to compare different films (see section 4). The higher the ratio number the better; values are usually 10-50 for CNT electrodes, 200-500 for Ag nanowires electrodes and ~1 in graphene electrodes. Hence Ag nanowires are currently the best technology for use in electrodes, followed by CNTs and graphene networks. Doping can also be used to improve the sheet conductance of graphene sheets, by increasing the charge carrier number [4].

Transparent electrodes can potentially be used for a many applications, such as lighting/LEDs, touch panels, displays, solar cells, etc. These devices have various design requirements that may make one type of film (CNT, Ag nanowire, graphene) better than the others. Resistive touch panels require transparent conductors; over time, the stress of point activation applied on an ITO-based panel results in microcracks that decrease electrical conductivity, requiring the user to apply more pressure. Alternatively, CNT films are conductive at up to 20% strain on PET plastic and hold up better under cyclic stresses. They also allow for the possibility of curved touch panels, which cannot be achieved with mechanically rigid ITO. Projected capacitive touch panels (used in iPhones) are not subject to the same compressive stresses, but they require patterned conductors with 10µm features, which are more stable if made with polymer films rather than ITO [4].

Transparent polymer electrodes are also used in devices such as light emitting diodes (LEDs) and solar cells. These films can be conveniently fabricated from solution, their flexibility makes them suitable for applications requiring flexible solar cells, and they are better able to transmit infrared light. It has been shown that a CNT based device can be bent to a ~5 mm radius of curvature with no loss of efficiency and bent to a ~1 mm radius with ~20% efficiency loss. ITO based devices, on the other hand, fail permanently under the same strains. One issue with polymer solar cells is the high sheet resistance (100-300 $\frac{\Omega}{sq}$) of polymer electrodes, compared to 15 $\frac{\Omega}{sq}$ for ITO electrodes; this problem is reduced by using conductive Ag nanowires in the films, which reduces the sheet resistance to around 20 $\frac{\Omega}{sq}$. Other applications include electromagnetic and microwave shielding, infrared imaging, transparent heaters, stretchable electrodes for artificial actuators, and many more. Much research has been done to advance conductive polymer technology over the last 20 years. While CNT films have been the most studied, those using graphene and Ag nanowires are also promising. As this technology continues to improve, new transparent devices with increased flexibility will be made possible [4].

2. STATEMENT OF WORK

<table>
<tr><td>TITLE:</td><td>Transparent Electrodes Project</td><td>DATE:</td><td>11/17/2015</td></tr>
<tr><td colspan="4">BACKGROUND & JUSTIFICATION (BENEFITS/EXPECTED RESULTS):</td></tr>
<tr><td colspan="4">The traditional materials used in solar cell electrodes are transparent conducting oxides such as indium tin oxide. This ceramic fractures at low strains, has a low fatigue life, and is very expensive. Alternatively, conductive polymers, which are naturally transparent, can be doped with carbon nanotubes to increase conductivity.

This project will investigate thin films made of Poly methyl methacrylate (PMMA) loaded with different fractions of single and multiple-walled carbon nanotubes. If the fraction of nanotubes is increased the film conductivity should increase, while the transparency of the film will decrease. Therefore, this project will look to find the optimal fraction of carbon nanotubes that will increase conductivity without sacrificing transparency.</td></tr>
<tr><td colspan="4">OBJECTIVES:</td></tr>
<tr><td colspan="4">1. To find the fraction of carbon nanotubes that optimizes both transparency and conductivity of the polymer thin films.
2. To understand how those properties are dictated by the structure of the films.</td></tr>
<tr><td colspan="4">SUMMARY OF PLANNED TASKS:</td></tr>
<tr><td colspan="4">1. Research past work to find what to improve upon.
2. Find the best solvent for PMMA and SWCNT.
3. Test the films.
4. Find an equation(s) to fit the data collected.
5. Documentation of the information collected and improvements to be made to further even more research.</td></tr>
<tr><td colspan="4">MILESTONES:</td></tr>
<tr><td colspan="4">1. Finish Proposal – November 17, 2015
2. Conclude Experiment – March-April, 2016
3. Prepare Final Presentation – April 23, 2016</td></tr>
<tr><td colspan="4">DELIVERABLES:</td></tr>
<tr><td colspan="4">1. Final Report
2. Presentation</td></tr>
<tr><td colspan="4">BUDGET:</td></tr>
<tr><td colspan="4">$3225.00</td></tr>
<tr><td colspan="4">SCHEDULE:</td></tr>
<tr><td colspan="4">August 31, 2015 to April 23, 2016 - 8 months</td></tr>
</table>

Contact Information:

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Michael Morris: morris.199@wright.edu
Nicholas Smith: smith.1517@wright.edu

3. EXPERIMENTAL PROCEDURE/METHODOLOGY/APPROACH

After consulting [8], Toluene was selected as the best solvent for PMMA. A solution consisting of 4 grams of poly-methyl-methacrylate (PMMA) in 100mL of Toluene will be prepared, using a magnetic stirrer to dissolve the PMMA. Several amounts of this solution will be cast on the surface of water in a clean evaporation disk in order to determine the necessary amount required to produce PMMA films that are a few hundred microns thick. This thickness will make the films easier to handle without tearing. A solution of 0.066 grams of single-walled carbon nanotubes (SWCNTs) will be added to 200 mL of Toluene, using a sonication machine to disperse the nanotubes. The PMMA and SWCNT solutions will be added to create solutions with different SWCNT loading, which will be used to cast PMMA films with different SWCNT loads. The nanotubes will be added in 0.5% increments of the PMMA weight, starting with 0.5% and working up to 3%. For example, for 10mL of the PMMA/Toluene solution, the amount of SWCNTs added will be: $C = 0.005 * 0.4 = 0.002$ g. The volume of added solution is given by x in the expression:

$$\frac{x}{C} = \frac{x}{0.002} = \frac{200}{0.066} \quad \textbf{(3)}$$

Solving this expression: $x = \frac{0.002*200}{0.066} = 6.06\ mL$. Therefore, approximately 6mL of SWCNT solution would be added per 10mL PMMA solution in the dish, in order to give the film a 0.5% SWCNT load by weight. After sufficient time, the Toluene will evaporate, leaving a film with a thickness that will be measured and recorded.

After the films are made, their transparency will be measured using a Fluke light sensor, model 941. Cold light that produces very little heat will be used as the light source; this is to remove any infrared radiation that would be present in a typical light source. For this project, we are only concerned with transmission in the visible range of wavelengths and hence want to remove infrared radiation. The intensity of the light will be measured first by itself, and then the intensity of the light passing through the film will be measured. The difference will be used to determine the percent transmissibility of the film.

After performing the light transparency measurements, the conductivity measurements will be conducted. While supported on an isolating substrate, such as a glass slide, either carbon tape or drops of silver paint will be applied to the film to increase the contact area. The probes of a micro-ohmmeter will be carefully placed on the tape or silver drops, so as to not puncture the film. The data from these measurements will be recorded for the films of one particular carbon loading. Then the value of C and x in equation (3) will be changed, and new films will be made with different carbon loadings. The process will be repeated until there is enough data to analyze.

Name	Begin date	End date
Presentation	9/1/15	9/11/15
Team management and Project Plan	9/11/15	9/11/15
Research	9/7/15	10/2/15
Title Page & Abstract	9/15/15	9/15/15
Oral Introduction	9/22/15	9/22/15
Statement of Work	9/29/15	9/29/15
Test PMMA in solvent	10/5/15	10/9/15
Test SWNT in solvent	10/12/15	10/16/15
Introduction	10/13/15	10/13/15
Annotated Bibliography	10/26/15	10/26/15
Approach & Expected Results	11/3/15	11/3/15
Proposal Draft	11/17/15	11/17/15
Presentation	12/8/15	12/8/15
Proposal Due	12/10/15	12/10/15
Collect Data on Films	12/14/15	3/25/16
Data analysis	3/28/16	4/21/16
Report	1/4/16	4/21/16
Conclude Experiment	4/1/16	4/1/16
Prepare Final Presentation	4/21/16	4/21/16

Figure 7: Gantt Chart

4. EXPECTED RESULTS

A goal of 7000 S/cm conductance and at least 70% transparency is expected for the films. The experimental data for percent transparency and for conductivity will be plotted as functions of SWCNT loading wt.% and fitted, separately, to mathematical functions that represent their best fit. The best fit will be determined by the R-squared value found during the curve fitting process. Two mathematical equations will be obtained: one relating carbon content to transparency and the other relating carbon content to conductivity. A max conductivity (disregarding transparency) and a max transparency (disregarding conductivity) can be found. Then a dual plot with conductivity units on the left y-axis, transparency units on the right y-axis, and carbon content on the x-axis can be created. The intersection point on this graph will give the carbon content that optimizes both properties. The entire process will be repeated (see approach) by replacing the SWCNT with Multi-walled carbon nanotubes (MWCNT) in order to determine the optimum weight % loading for that system as well.

In order to compare the thin films to existing electrode technology, a figure of merit from [9] can be determined with the equation:

$$\boldsymbol{T = \left(1 + \frac{Z_0}{2R_{sh}}\frac{\sigma_{OP}}{\sigma_{DC}}\right)^{-2}} \qquad \textbf{(4)}$$

Where the constant Z_0 is the free space impedance, T is the transmittance, R_{sh} is the sheet resistance, σ_{DC} is the DC conductivity, and σ_{OP} is the optical conductivity. By substituting $Z_0 = 377\Omega$ and rearranging terms, the equation becomes:

$$\boldsymbol{\frac{\sigma_{DC}}{\sigma_{OP}} = \frac{188.5}{R_{sh} * [T^{-\frac{1}{2}} - 1]}} \qquad \textbf{(5)}$$

The ratio on the left hand side of $\frac{\sigma_{DC}}{\sigma_{OP}} = \frac{188.5}{R_{sh} * [T^{-\frac{1}{2}} - 1]}$ (5) is a figure of merit that is commonly used to compare transparent electrodes. Ideally the ratio should be as high as possible. Table 3 shows a comparison of some of the $\frac{\sigma_{DC}}{\sigma_{OP}}$ values obtained or referenced in recent studies.

Type of electrode/thin films	$\frac{\sigma_{DC}}{\sigma_{OP}}$ (Ω^{-1})	Reference
Long Ag nanowires (19µm)	339	[10]
Short Ag nanowires (11µm)	300	[10]
Ag nanowires	75-350	[11]
Ag nanowires	344-400	[12]
Ag nanowire networks	~500	[13]
ITO	~400-800	[13]
Nanotubes	25	[11] [13]
Graphene	0.5	[13]
Evaporated thin silver films	143	[13]
Bulk silver	~7	[13]

Table 3: Current $\frac{\sigma_{DC}}{\sigma_{OP}}$ ratios

Table 3 demonstrates that while the $\frac{\sigma_{DC}}{\sigma_{OP}}$ ratio of ITO is quite high, films based on Ag nanowires and Ag nanowire networks are approaching it. Furthermore, the ratio is lower for nanotube films and very low for graphene films. As this project is working with nanotube films, the values desired are greater than 25 Ω^{-1}.

5. BUDGET AND PERSONNEL

1. Budget:

Item	Cost	Donated (Dr. Amer)	Requested Funds
PMMA	$120.00	$0	$120
SWCNT	$400.00	$400.00	$0
MWCNT	$200.00	$200.00	$0
Disposable Glassware	$100.00	$100.00	$0
Solvents	$80.00	$0.00	$80
Microscope Part (Transformer)	$2,000.00	$0	$2,000.00
Light Meter	$250.00	$250	$0
Misc.	$75.00	$0	$75
TOTAL	$3,225.00	$950.00	$2,275

Table 4: Budget

As shown in the proposed budget, the total estimated cost for this project is $3,225. Dr. Amer will donate material that is $950.00 in value and the remaining that needed funds are $2,275. We understand that the typical budget allowed for a team of 4 students is $800.00, hence we are requesting additional $1,475.

2. Personnel:

Meshary Alrubaeya:

He is undergraduate student at Wright State University working in a B.S. degree in Mechanical engineering focus on manufacturing track. Has high information about the safety in the lab as he got OSHA license. He has had some experimental experience. Has knowledge of carbon nanotubes and silver, and has taken a Polymer course with Dr. Maher Amer.

Chris Christman:

He is an undergraduate student at Wright State University working on a B.S. degree in Materials Science/Engineering, as well as a Dual Major in Math. He has experience analyzing the results of experiments to understand the relationships between the known and unknown variables being considered. Has also has strong writing skills, which will be utilized when composing the proposal and other necessary documents, and has taken the polymers course with Dr. Amer, which is particularly relevant to this project.

Michael Morris:

He in an undergraduate student at Wright State University working on a B.S. degree in Mechanical engineering. He has experience analyzing polymer matrix composites, designing test fixtures for elastomeric compounds (i.e. O-rings, gaskets, seals, sealants, multi-directional composites), and writing technical reports. These skills can be utilized to help the group test the films and assist wherever necessary on the report.

Nicholas Smith:

He is pursuing a B.S. degree in mechanical engineering at wright state on the design track. He has had experience with film analysis at the air force institute of technology. Has knowledge of a lab workplace and their procedures. Has also has high interest in the technology behind solar cells and wants to improve the function of the device.

Meshary M. Alrubaeya

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Phone: +1(937) 825-7589
Email: Alrubaeya.2@wright.edu

Familiar with: Microsoft Visual Basic.

Software

Programs: Solidworks, LabVIEW, and MATLAB

Platforms: Windows, Mac OS X.

EXPERENCE

Work

Arabic national bank Dammam,KSA

Manger of safety in the main building.

At 2008 – 2010

ACTIVITIES & AFFILIATIONS

- Association International day 09/2015-Organizer

Education

Wright State University Student

Fairborn, Ohio

Bachelor of Science in Mechanical Engineering

Christopher Christman

1965 Loma Linda Lane
Washington Township, Ohio 45459
Phone: (937) 572-0862
Email: christman.13@wright.edu

TECHNICAL SKILLS

Programs: Solidworks, LabVIEW, MATLAB, Microsoft Excel

Platforms: Windows, Mac OS X

WORK HISTORY

Course Redesign Assistant 09/2015-Present

Wright State University, ME/MSE Department – Dr. Raghavan Srinivasan Fairborn, OH

Worked on redesigning an introductory course in materials science/engineering so that it could be used in active learning classrooms. Created problems to be used in online quizzes, homework.

Recitation Instructor 05/2015-Present

Wright State University, ME/MSE Department – Heather Casto Fairborn, OH

Developed problems that were used in recitation sessions for an introductory course in materials science/engineering. Also graded homework during one semester.

Math Tutor 01/2014-04/2014

Wright State University, Tutoring Services – NA Fairborn, OH

Assisted students for 3 hours per week in the concepts of Algebra and Calculus 1.

AWARDS

- Isaac Weiss Memorial Scholarship — Wright State University
- Finalist, 2014 *Atlas Shrugged* Essay Contest — Ayn Rand Institute

Education

Wright State University Present

Fairborn, Ohio

Bachelor of Science in Materials Science/Engineering

Dual Major: Mathematics

Minor: Music

Michael J. Morris

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Huber Heights, Ohio 45424
Phone: +1(937) 901-1282
Email: morris.199@wright.edu

TECHNICAL SKILLS

- Project management (both long term and short term)
- Fabrication and test low observable, elastomeric, composite, coatings and sealant materials.
- Design and fabrication of test fixtures
- Preparation of test plans, evaluation reports, military required documents such as quad charts, and preparation of formal presentations
- Properly trained working in a laboratory environment and possess the necessary skills in safety and maintenance.
- Trained to work with band-saw, wet-saw, shear press, horizontal and vertical milling, grit blasting, twin screw instron, other basic tools, and ovens.
- Performing wet tape adhesion, tensile strength, roughness, hardness, and overall evaluation of materials testing
- Proficient in using Matlab, Microsoft Office (Work, Excel, PowerPoint, etc.), Solidworks, AutoCAD, and technical writing
- Minor experience working with Six Sigma and the DMAIC process.

EXPERENCE

Research Student at Wright Patt Air Force Base for Air Force Research Laboratory

10/2012-Present

- Performed age testing and mechanical testing on a variety of materials such as sealants, O-rings, fabrics, composites, and low observable.
- Fabrication of polymer matrix composites.
- Revised a process of testing by creating a new contaminant that Is used to test solvent to determine that the solvents are meeting today's standards
- Injection molding (both making the mold and injecting)

REFERENCES

- Maureen T Patterson — (ret) Vice President Dayton Development Coalition
- Don Patterson — Mayor of Kettering, Principal, DEPDayton Commercial RE
- Alan Fletcher — Senior Materials Engineer (DR-04) Air Force Research Lab(AFRL)

EDUCATION

Wright State University — Present

Fairborn, Ohio

Bachelor of Science in Mechanical Engineering

Nicholas A. Smith

2250 Pacer Court	Phone: +1(937) 269-1706	Website: nicholassmith.tk
Beavercreek Township, Ohio 45434	Email: smith.1517@wright.edu	Creation code: 454347

TECHNICAL SKILLS

Languages

Proficient in: MATLAB, PHP and HTML.

Familiar with: C++, Lua, Microsoft Visual Basic, and Java.

Software

Database: MySQL, Access and Excel.

Programs: Solidworks, LabVIEW, and MATLAB

Platforms: Windows, Mac OS X, and Ubuntu.

EXPERENCE

Image Analysis Intern 10/2014-Present

Wright State Research Institute – Robert Myers Fairborn, OH

Hand tracking objects of interest, recording the actual location of the moving objects for sensitive data. Used for *Air Force Research Laboratory*.

Self-motivated, minimally supervised environment.

Administrator/Information Systems Technician 07/2012-Present

Contractor Marketing INC. – Larry Silver Beavercreek, OH

Primary responsibilities includes maintaining computer systems network, website maintenance, website coding and design.

Created a SMTP server for email blasting.

SOCHE Lab Intern 02/2013-06/2013

Air Force Institute of Technology/SOCHE – Dr. Glen Perram WPAFB, OH

Developed and tested new inventory management system using Visual Basic in Excel & MATLAB.

Assisted in lab research.

Background checked, clearance for restricted areas, chemical training, and laser training.

ACTIVITIES & AFFILIATIONS

• Association	Student Alumni Association	09/2015-Present
• GitHub	Minecraft WebStats MySQL/PHP project	02/2012-Present
• Rugby	Dayton Flying Pigs	01/2009-05/2009

Education

Wright State University Present

Fairborn, Ohio

Bachelor of Science in Mechanical Engineering

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transparent films of silver nanowires on arbitrary substrates and their application in touch screens," *Nanotechnology,* vol. 22, no. 24, 2011.

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