Faculty Innovator Grant 2010
Center for Learning and Teaching

Final Report Form

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Project Title: (10 words or less)	Using video and simulation tools to enhance "renewable energy education"

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Final Report Form

1. Describe the specific teaching and learning issues being addressed by the proposal.

For the last two decades, advances in renewable energy, particularly photovoltaic technology, have been phenomenal and this scientific field continues to be a subject of fascination and speculation requiring much more basic scientific understanding and exposure in educational settings. Therefore, a strong educational infrastructure is desirable to continually support, strengthen, and promote rapid technological advances. Since photovoltaic technology covers broad educational topics that span the fields of optoelectronics, materials science, and device physics, it requires fundamental understanding of underlying physics and exposure to experimental research fields. Hence, development of educational tools to convey fundamental physics effectively and introduction of research environment available to students are a key aspect of this educational program.

Currently, there is no course related to “renewable energy technologies” at the Electrical and Computer Engineering Department. However, an undergraduate course (ECE 473/573) that introduces the classical microelectronics and the solid-state electronics, fundamental theory and practical design methodology for various devices can be modified to introduce “photovoltaic technologies”. Historically, this course has been taught through traditional lecture style that heavily relies on presentation of complicated formulas to describe the physics and operational modes of the electronic devices. Even though it is indeed important to learn and understand the underlying physics of these devices via deriving/solving mathematical models, it is very hard to attract student attentions using lecture-style approaches in class. Therefore, we will develop interactive simulation and modeling tools to effectively convey a fundamental scientific understanding. In addition, this course will introduce more advanced class materials such as hands-on experiences upon photovoltaic materials, device operation, fabrication processes and animations using video clips recorded in the PIs’ research laboratories.

2. Describe the revised specific teaching and learning issues being addressed by the proposal (if applicable):

None

3. Describe the development activities involved addressing the learning or teaching issue.

First we focused on the development of interactive virtual learning laboratories that facilitate inquiry-based learning. Virtual laboratories are modern tools and flexible media that allow students to create an individualized experience based on a student’s skill and knowledge. Since the complexity of a virtual laboratory can be overwhelming to inexperienced undergraduate students, the model interface should be designed to allow students to exclusively focus on probing the underlying principles of systems at multiple learning levels. Virtual laboratories consist of two major components of optical and electrical models.

The optical model describes light interactions with materials as a form of electromagnetic (EM) propagation. Electromagnetics is a notoriously difficult subject for engineering students even though it is a fundamental keystone of solar technologies. To transform the way the light interaction with materials is taught, visualization is used with virtually stacked planes consisting of dielectric, organic semiconductor, and metallic electrodes through which EM wavelengths propagate. Transfer matrix methods (TMM) was employed since it enables precisely descriptions of EM propagation by taking into account the cumulative effects of reflection and transmission at all interfaces and absorption in each layer of the system.

For the electrical model, innovative bulk heterojunction (BHJ) blends, where randomly-networked (disordered) donor: acceptor phases have offset energy levels at the interface, is modeled. Figure 1 (a) illustrates the complex dynamic nature of charge transport occurring at the BHJ interface in disordered organic solar cells. The absorbed photons in organic blends generate electron-hole (e-h) pairs or excitons, some of which subsequently dissociate into free charge carriers at the bulk heterojunction interfaces as described by Onsager-Braun theory. The subsequent transport of dissociated free charge carriers and Langevin bimolecular recombination are incorporated into a drift-diffusion model and used to estimate the current density and efficiency of organic solar cells. These processes are unique features and concepts inherent in disordered organic materials which are solved numerically under illumination. Figure 1 (b) shows examples of free carrier distributions inside organic layers simulated in our group.

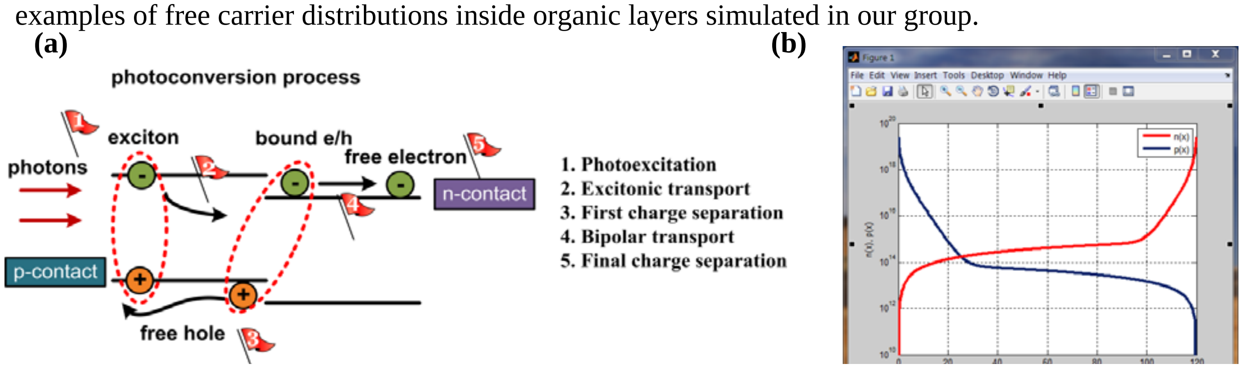

Figure 1. (a)Photoconversion process of disordered system and (b) distribution of electron and hole concentration inside organic solar cells.

Figure 2 shows the developed interactive GUI for optical model using Matlab. This program has been used for ECE 473 and ECE 486/487 senior design projects.

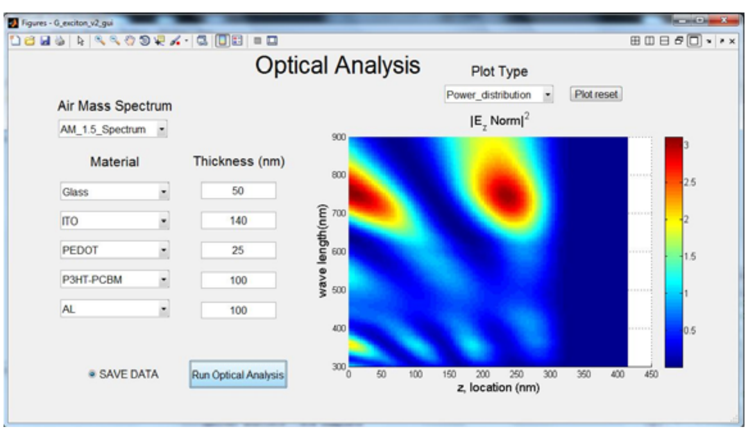

Figure 2. Example of interactive graphical user interface (GUI) developed for the optical model developed by Matlab

Furthermore, video clips have been produced for some equipment that operates in the PI's laboratory. Figure 3 shows the video clips for reactive ion etcher (RIE) system which undergraduate students are not allowed to directly access but these video clips can be easily demonstrated in the class.

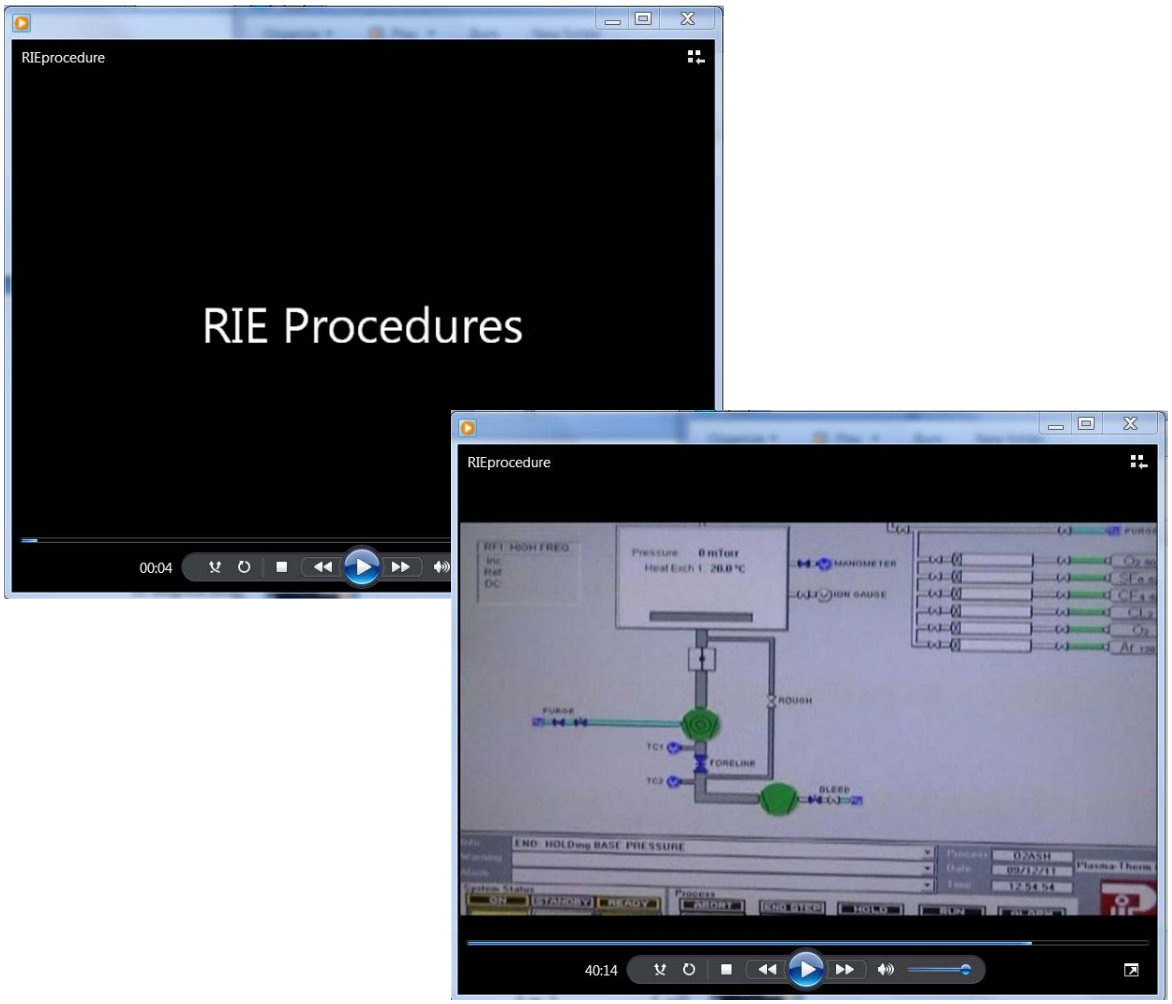

Figure 3. Video clips for RIE system.

4. Describe the learning outcomes attained by the project.
This simulation program has been implemented into senior design courses to assist students to enhance their scientific knowledge which becomes very effective. For example, this simulation tool greatly assisted students' reasoning and problem-solving skills virtual learning. This approach is in contrast with the typical senior design courses where only limited resources are available for planning experiments. Using virtual learning or simulation tools, students are able to revisit or learn new background theories and principles and identify and test a hypothesis before they actually engage in physical hands-on activities. This reinforced learning strategy efficiently guide students in preparing, confronting, and tackling the open-ended, inquiry-based problem with solid theoretical knowledge and principles. As a result it provides better planning for the physical hands-on activities. When engaged with physical hands-on activities, virtual laboratories are also used to identify the disparity between theoretical and experimental results and additional activities designed to interpret the differences. This practice truly allow students to experience the entire scientific process from solid theoretical reasoning obtained from virtual laboratories, to designing their own activities, to initial observations, and to follow-on activities based on the results of earlier activities.

Furthermore, the introduction of video clips increased students' understanding of laboratory facilities and how to fabricate photovoltaic devices and characterize devices.

5. Describe unexpected outcomes, if any.
None

6. Describe the impact of the completed project on your colleagues, department, college, or community.

Simulation tools developed can be used for many elective and core courses as shown in Table 1 (which is only considered for ECE but there should be more courses when considered for other colleges). Thus the virtual labs will benefit more than a hundred students every year. Our innovative teaching strategies will also help the retention of underrepresented students by increasing students' interest and motivation using virtual learning and hands-on activities.

Table 1. Impact of virtual learning on other ODU and NSU

Models	**ODU (# of enrollment)**
Electrical	ECE 313 Electronic Circuits (36) ECE 473 Solid State Electronics (35)
Optical	ECE 323 Electromagnetics (30) ECE 474 Optical communications (33)
Combined	ENGN 110 Explore Engineering-I (30)

7. Describe how the project can be a model, template, or prototype for use by other instructors.

Since this simulation is already available for optical and electrical models, individual model can be adapted into different courses. If they need to be modified, Matlab codes can be easily modified with appropriate coding. Video clips can be used without editing.

8. Describe the technology used to help address the issues described in the proposal.

We developed Matlab based simulation tools which consist of optical and electrical models to assist students' inquiry-based learning. Movie maker was used to edit video clips.

9. Describe products, if any, that are a result of the project.

Simulation tools for optical and electrical modules. Some movie clips for fabrication tools are developed.

10. Describe the future plans for this project, if any.

We are planning to implement these tools into other courses. Furthermore, we want to create a new course such as "numerical methods for engineering with Matlab". Since ECE students at the ODU require the critical skills to explore numerical solution for many cases, we will try to introduce numerical methods using Matlab. Moreover, more video clips will be made by including many other systems and devices' characteristics.

11. Attach a financial report with updated Budget Plan Matrix.

Final Budget Matrix

			Source of Funds	
Budget Item (equipment, personnel, software, etc.)	**Qty**	**Total Cost**	**Amount from FIG**	**Amount from Other Source**
Two computers	2	$2930	$2930	
Software – Parallel desktop	1	$30	$70	