U.S. Agency for International Development (USAID)
and
The American Council on Education (ACE)
office of Higher Education for Development (HED)

University of Cincinnati and Cape Town University Partnership "Nano power Africa"

February 18, 2011 – December 31, 2013

FINAL ASSOCIATE AWARD REPORT
March 2014

USAID/South Africa Associate Award
Cooperative Agreement # AEG-A-00-05-00007-00
Associate Cooperative Agreement # 674-A-00-11-00018-00

PARTNERSHIP INFORMATION

Lead Partner Institutions: University of Cincinnati; University of Cape Town
Secondary Partner Institutions: Haramaya University (Ethiopia), Kigali Institute of Education (Rwanda)
Region, Country: Sub-Saharan Africa, South Africa
Performance Period: *February 18, 2011 – December 31, 2013*
Funding Level: Associate Award: $1,374,806 and Subaward: $1,100,000
Proposed Cost Share: $216,313

Table of Contents

List of Acronyms

ACE	American Council on Education
AFOSR	Air force Office of Scientific Research
ANL	Argonne National Laboratory
API	African Partner Institutions
BOTEC	Botswana Technology Center
BSc	Bachelors of Science
HBCU	Historically Black Colleges and Universities
HED	Higher Education for Development
HICD	Human and Institutional Capacity Development
HU	Haramaya University
KIE	Kigali Institute of Education
LSU	Louisiana State University
M&E	Monitoring and Evaluation
MSc	Master of Science
NGO	Non-Governmental Organization
NPA	Nano-Power Africa
NSF	National Science Foundation
OHHS	Oak Hills High School
ORNL	Oak Ridge National Laboratory
PhD	Doctorate degree
PRIME	Partnership Results & Information Management Engine
PST	Printed Silicon Technology
RU	Rhodes University
SLA	Solar Light Africa
UB	University of Botswana
UC	University of Cincinnati
UCT	University of Cape Town
USAID	United States Agency for International Development
USAID/AFR	United States Agency for International Development/Africa Bureau
USG	United States Government

1. Executive Summary

This report is submitted for the Associate Cooperative Agreement No. 674-A-00-11-00018-00 between USAID/South Africa and the American Council on Education/ Office of Higher Education for Development (ACE/HED), and a sub-cooperative agreement between the University of Cincinnati (UC) and ACE/HED, for a two-year award of $1,374,806 effective February 28, 2011.

Over the two years of implementation, the partnership has directly benefitted over 150 individuals through the following key accomplishments:

- Developed a Solar Power for Africa web-based course on the potential of photovoltaics in Africa
- Enrolled five faculty from Rwanda and Ethiopia in MSc/PhD programs at the University of Cape Town (UCT).
- Trained over 80 individuals through the web-based course and short-term professional development visits to laboratories in the U.S.).
- Reached more than 60 individuals through its community outreach activities
- Installed solar panels in a school and clinic in rural villages in Ethiopia, NGOs and government agencies.

Contributing to human capacity development, the partners have facilitated the enrollment of faculty from partner African higher education institutions for postgraduate study at UCT. Individuals from South Africa, Rwanda, Botswana, and Ethiopia participated in the Solar Power for Africa web-based interactive course. Furthermore, the U.S. faculty from Haramaya University (HU), Kigali Institute of Education (KIE) and Rhodes University (RU) visited UCT conducting research on printed electronics technology.

In its outreach programs, the partners have collaborated on installing solar panels in the Qeransa-Darraba village clinic and a school in Ethiopia, involving undergraduate students from UC and from HU. Additional outreach activities included *Nano-Power Africa* (NPA). In this project , undergraduate and graduate students installed solar cells and lighting under the Solar Power for Africa program which focuses on entrepreneurial dissemination of technology through a franchising of printed electronics technology.

Throughout implementation, the partners have worked together on several research projects. Those include a flame made synthesis of titania and printed silicon technology at HU in Ethiopia, the ongoing development of a solar panel assembly plant HU/Dire Dawa University in Ethiopia and the ongoing development of a printed electronic water sensor project, and printed electronic solar cells. Partnership activities have strengthened the capacity of UCT in South Africa, KIE in Rwanda and HU in Ethiopia, contributing to African development goals related to access to alternative, cost-effective and locally developed energy supplies.

Data in this final, end of project report are based on semi-annual reports that were submitted by University of Cincinnati (UC) throughout implementation. At the time of writing this report, the partners did provide answers to HED queries and failed to submit a final partnership report, as stipulated in the agreement signed between UC and ACE. This incompliance has affected HED's ability to fully apply its data quality filters and procedures in order to bridge some of these data gaps and inconsistencies, as pointed out in the narrative in reference to specific instances.

2. Partnership Overview

Background

Energy production is one of the greatest hurdles to development in Southern Africa and other countries in sub-Saharan Africa. One approach to investigate low cost solutions is to research the relationship between nanostructure and electronic properties, which is the focus of the Nano-Power Africa project. The NPA addresses the scientific and technological development of inexpensive and indigenously produced solar cells for use in rural and peri-urban regions. These devices produce sufficient electricity to provide energy for lighting, heating, cooking, refrigeration and communication at a cost that can be supported by local economic circumstances.

Funded by the United States Agency for International Development (USAID) through a grant to Higher Education for Development (HED), the partnership is the result of the Africa-U.S. Higher Education Initiative, a collaborative effort started in 2007 by a number of higher education associations and other organizations to advocate for increased engagement in African higher education capacity development. NPA is unique in combining technological development, an entrepreneurial approach and leveraging existing capabilities in South Africa for South-South outreach effort coupled with support of U.S. National Labs, corporations, NGOs and other sponsors and affiliates using Cincinnati as a U.S. coordinating hub.

NPA is working in South Africa, Rwanda, Ethiopia and Botswana to develop higher education through academic training and joint work on solar cells in Africa for use by Africans. The partnership has enhanced research efforts to develop low-cost, indigenously produced photovoltaic devices based on nano-materials that can be manufactured in the challenging business environments of sub-Saharan Africa. The partnership has also strengthened the infrastructure of the Nano Sciences Innovation Centre at UCT and reinforced its status as an African hub of a research and innovation network.

Goals and Vision

The project was designed to leverage knowledge gained in African research towards solving technical problems in the application of nano-materials to provide off-grid power at a low cost, training faculty and students to develop research programs and entrepreneurial endeavors in their home countries.

The long-term vision of this partnership is to use the enhanced research capacity and technical, business and government networks to drive entrepreneurial business growth in order to benefit the local community. To that effect, the partners have envisioned UCT as the primary African institution for outreach to other African Universities, whose Nano Sciences Innovation Centre would serve as a platform where other institutions could develop a research and innovation network.

The goal of this partnership was to enhance teaching and research capacity, as well as their reputations for research and innovation in all the African partner institutions, seeking to link growth in higher education with growth in entrepreneurial business.

Partnership Objectives

The partnership aims to develop UCT as a hub for the growth of African education, by creating a strong "pipeline" between UC and the UCT for exchange of students, faculty and scientific interactions and developing infrastructure at HU in Ethiopia and KIE in Rwanda. The partnership also strives to improve faculty development at African universities to ensure the success and sustainability of their academic and research programs in Nano-science. The partners have developed the following objectives:

1. Improved academic programs and scholarships at African Partner Institutions
2. Improved human capacity at African Partner Institutions
3. Improved research capacity at African Partner Institutions
4. Improved outreach capacity at African Partner Institutions

Collaborating Stakeholders

NGOs

- **Solar Light for Africa (SLA)** participated in proposal writing, advisory services concerning the development of photovoltaic technology and assisted in the planning and implementation of a live interactive course, Solar Power for Africa.
- **Rotary Club of Cincinnati** has been actively involved in mentoring and hosting visiting African scientists and arranging contacts with the local Rotary Clubs in Addis Ababa and in Cape Town.
- **Bole/Addis Rotary Club** in Ethiopia was involved in the development of a solar panel assembly plant at HU and Dire Dawa University.

Business

- **Printed Silicon Technology (PST)** sensors assisted with device manufacturing development, business and academic contacts for the project.
- **Eclipse Film Technologies** has actively participated in the development of reel-to-reel processing with African and U.S. scientists working at Eclipse labs producing photovoltaic (PV) layers using Eclipse facilities.
- **Michelman Corporation** participated in the project by providing support for conductive and barrier coating technologies for photovoltaic development work.

Government

- **Oak Ridge National Laboratory** - NPA has a post doctorate candidate stationed at Oak Ridge performing organic synthesis and neutron scattering measurements. Oak Ridge has served as a host to visiting African scientists.
- **Argonne National Laboratory** has hosted visiting African scientists during this reporting period and co-authored one publication from the NPA project.
- **Air Force Office of Scientific Research (AFOSR)** provided financial and technical support to the partnership.
- **U.S. Embassy in Ethiopia** provided support for travel to install solar panels around HU in Ethiopia.

Universities

UCT, UC, HU, Dire Dawa University, Mekelle University, KIE, RU, University of Botswana, Addas Ababa University. These universities participated in the Solar Power for Africa course. Visits were made to HU, Mekelle University and Addis Ababa University by faculty and students from UC. HU and Dire Dawa University are currently planning a solar panel assembly plant.

3. Partnership Results and Performance

This section presents results and performance against the partnership's FY11-13 targets. Structured around the partnership's M&E plan, section three examines the partnership's achievements and progress in relation to the objectives, outcomes and outputs. The partnership's M&E plan and reporting in FY11 was not systematized as well as the later years of the program affecting the quality of data and reports. Furthermore, reporting by the lead institutions (UC and UCT) were of poor quality, with little substantiation and articulation of some of the accomplished activities.

3.1 Achievements and Implementation Progress

Objective 1: Improved Academic Programs and Scholarships at African Partner Institutions (APIs)

Outcome: APIs offer degree programs related to nano-technology

- Revised Curricula
- Programs New

Solar Power for Africa Web Course
The partners developed a new web-based live interactive course called Solar Power for Africa[1] collaborating with Solar Lights for Africa, an NGO, and involving five African Universities and the UC. The web-based method can now be ported to (a) U.S. to Africa courses, as well as (b) Africa to Africa and (c) Africa to U.S. courses to enhance the teaching environment. This course is offered annually in the fall semester and discusses development issues in Africa that can be addressed with photovoltaic technology. This course will serve as a test bed for development of the technology to co-teach other courses in other institutions in Africa. Refer to Appendix A for additional information about Solar Power for Africa and the web based course.

New MSc program in Physics at HU
The partnership also contributed to the start-up of a new MSc program in Physics at HU (Ethiopia) in 2011/12. Development of other new academic programs and curricula revisions were not implemented.

Objective 2: Improved Human Capacity at APIs

Outcome: API faculty have improved teaching and research skills

- Short-Term Training
- Long-Term Training (Enrolled)

Short-Term Training
Eighty three sub-Saharan Africa (SSA) faculty and students benefitted from short-term training programs, offered mainly through the Solar Power for Africa course and measurements and instrumentation time at Argonne National Laboratory (ANL) and Oak Ridge National Laboratory (ORNL) (Table 1).

[1] http://www.eng.uc.edu/~gbeucag/Classes/SolarPowerforAfrica.html

The *Solar Power for Africa* course was conducted via live web link to five campuses in the partnering institutions; HU, Rhodes University, KIE, University of Botswana and UCT. In FY11, 30 academic staff (faculty) and students attended the course. This course is offered annually in the fall semester and links five universities in sub-Saharan Africa with the UC to learn about and discuss development issues in Africa that can be addressed with photovoltaic technology.

Table 1: Number of Individuals who Attend Web Class

FY11-13 Target	FY11-13 Trained
7	83

In FY12, a total of 35 individuals (faculty and students) benefitted from short-term trainings. The web-based course was provided to 27 individuals (15 students at UC, two students at HU, seven students at UCT and three students at Rhodes University). Eight faculty from sub-Saharan Africa visited UC and UCT for short-term training.

In FY13, a total of 18 individuals (faculty and students) benefitted from short-term trainings. Thirteen individuals participated in the web-based course, *Solar Power for Africa*. Five faculty members from the Africa Partners institutions also participated in short-term trainings – most notably at ANL and ORNL. Measurements were conducted at ANL and at ORNL, by five African faculty (one RU, one KIE, one HU and two UCT) with capacity development on Reel-to-Reel Processing & Development, Eclipse Film Technology and purchase of Reel-to-Reel equipment. As a result of these visits, partners were able to develop ink formulation capabilities and the production of conductive inks using flame synthesis of doped titiania at UC.

The project supported twelve female undergraduate students enrolled at HU and 2 female post-graduate students enrolled at UCT, improving access to individuals from underserved or disadvantaged groups.

Long-Term Training – Enrolled and Completed

The NPA Nano-Science Innovation Centre supported 13 individuals who enrolled in MSc and PhD programs at UCT. Five of these (three from Ethiopia and two from Rwanda) were directly sponsored by the project (Table 2), while the remaining benefited from the capacity built at the Center through the project. These students enrolled at the *Nano-Sciences Innovation Centre* of the UCT were groomed with African faculty positions in their respective institutions. Refer to Appendix B for list of students enrolled in the NPA long term training programs.

Table 2: Number of Individuals Enrolled and Completed in Long-Term Training who benefited directly from the partnership

	FY11-13 Target	End of Project Result
Long-Term Training – Enrolled	5	5
Long-Term Training – Completed	0	2

Two students completed their studies (Table 2) David Moweme Unuigbe from KIE completed his MSc studies at UCT in June 2012. Tsige Yared Atilaw from HU also completed her honors degree studies in October 2013 (Table 2).

Although not directly sponsored by the NPA project, but benefitting from the work of the project, Batsirai Magunje from Zimbabwe submitted his PhD thesis in December 2012 and successfully completed his PhD at UCT. Since January 2013, Batsirai Magunje has been employed as a post-doctoral research fellow on the NPA project.

The termination of the partnership in September 2013 has incapacitated the ability of the HCI to support the studies of some of the students who are funded by this partnership. However, PST Sensors, a private enterprise in Cape Town provided financial support to four PhD students at the Nano Innovation Center at UCT by employing them part-time for scientific and technical duties related to their academic research programs.

Objective 3: Improved research capacity at APIs

Outcome: Research, development and innovation projects undertaken towards improved indigenous solar panel technology.

- Joint Research
- Number of Publications
- Research Exchanges

Overall, the partners have reported 13 joint research projects during the life of the project, as shown in table 3. Some of these research projects have contributed to the development of faculty skills and overall institutional research capacity at participating African institutions. For instance, HU developed flame made synthesis of titania and printed silicon technology replicating work done at UCT. In addition, HU/Dire Dawa University is planning a solar panel assembly plant.

Table 3: Number of Joint Research Projects

FY11-13 Target	End of Project Result
2	13

Partners conducted nine joint research projects in 2011/2012. These were:

1. Screen Printed PV systems.
2. Reel to Reel coating PV systems.
3. Conductive titania nanoparticles.
4. ZnO Nanoparticles.
5. Silicon Nanoparticles by commutation and by CVD processes.
6. Printed Medical Temperature Sensors.
7. Printed Agricultural Water Sensors.
8. PV roofing materials at ORNL.
9. Organic photovoltaic thin films.

In 2012/2013 partners conducted additional four joint research projects. These were:

1. Construction of a solar panel assembly plant at HU/Dire Dawa University in Ethiopia.
2. Printed electronic water sensor project at HU/RU/Mekelle U. in Ethiopia.
3. Printed electronic solar cells HU.
4. Conductive doped titania for transparent conductive oxide in solar cells at HU.

UCT's Nano-Technology Center reported several advances towards its goal of creating affordable solar cells that can be produced in Africa. Partners reported that rResults were obtained from transmission electron tomography studies of isolated silicon nano-particle clusters, which seem to show a broad agreement with results from the USAXS measurements performed at the ANL.

Toward meeting the goal of producing photovoltaic cells for solar powers, NPA students Rudolf Nuessl and Getinet Yenealem Ashebir produced and tested in January 2013 the first photochemical cell that functions without a dye. . The cell had a higher efficiency than the inorganic-organic hybrids previously tested, but had a very short lifetime of the order of minutes. Other constructions, including the addition of a dye, which have been tested now, have lifetimes measured in weeks.

Research Exchanges

The partners have reported four research exchanges which included scientific site visits (Table 4). In those visits scientists from UCT and the secondary partner universities (KIE, HU, RU and UB) worked on developing manufacturing technologies for indigenously produced solar cells. Participants of the research exchanges have also produced papers that enhanced the scientific base in the secondary partner universities.

Table 4: Number of Research Exchanges

FY11-13 Targets	End of Project Result
2	4

The partners reported the following research exchanges:

1. Three African professors from HU, KIE and RU spent 1 month at UCT performing research on printed electronics technology. The main activities during this visit were to plan and prepare samples for experiments at ORNL and ANL.
2. The U.S. Partnership Director visited HU in December as part of a trip with five UC undergraduates who traveled to Ethiopia to install solar panels at a village clinic.
3. Synchrotron Measurements were conducted at the ANL.
4. Neutron scattering measurements were conducted at ORNL.

Publications

Table 5: Number of Publications

FY11-13 Target	End of Project Result
5	4

During the life of the partnership, the partners published four articles focusing on nano-technology development (Table 5):

1. *Topological investigation of electronic silicon nanoparticulate aggregates using ultra-small-angle X-ray scattering*. Jonah, E. O.; Britton, D. T.; Beaucage, P.; Rai, D. K.; Beaucage, G.; Magunje, B.; Ilavsky, J.; Scriba, M. R.; Haerting, M.; JOURNAL OF NANOPARTICLE RESEARCH; Volume: 14; Issue: 11; Article Number: 1249; November 2012
2. *Quantitative investigations of aggregate systems*. Rai, D. K.; Beaucage, G.; Jonah, E. O.; Britton, D. T.; Sukumaran, S.; Chopra, S.; Gonfa, G. Goro; Haerting, M **;** JOURNAL OF CHEMICAL PHYSICS; Volume: 137; Issue: 4; Article Number: 044311; July 2012
3. *Interfacial and Network Characteristics of Silicon Nanoparticle Layers Used in Printed Electronics*. Maennl, Ulrich; Chuvilin, Andrey; Magunje, Batsirai; Jonah, Emmanuel Ohieku; Haerting, Margit; Britton, David Thomas**;** JAPANESE JOURNAL OF APPLIED PHYSICS, Volume: 52, Issue: 5, Part: 2; Special Issue: SI; Article Number**:** UNSP 05DA11; May 2013
4. *A novel mode of current switching dependent on activated charge transport*. Britton, David T.; Walton, Stanley D.; Zambou, Serges; Magunje, Batsirai; Jonah, Emmanuel O.; Haerting, Margit; AIP ADVANCES; Volume: 3; Issue: 8; Article Number: 082110; August 2013

Refer to **Appendix C** abstracts.

Objective 4: Improved Outreach Capacity

Outcome: Increased outreach to community and access to resources and skills through linkages and networking

- Outreach/Extension activities
- Linkages with NGOs and Stakeholders
- Proposals produced

Outreach/Extension Activities

Table 6: Number of Outreach/Extension Activities

FY11-13 Target	End of Project Result
2	5

Overall during implementation, the partnership reported on five major outreach activities (Table 6). These include

1. The partners coordinated a plan of action to facilitate the purchase and installation of two photovoltaic systems at the Kersa Farmer's Association Primary School and Clinic in the Haramaya District. .During this trip the team of undergraduate students from the two universities installed two small PV systems to power four LED classroom lights. This experience gave the team exposure to the problems associated with installation and maintenance of PV

systems in sub-Saharan Africa. The PV system will facilitate charging of portable electronic devices such as radios, cell phones and computers in the Haramaya district. The partners hope that the Farmers' Association will work with faculty and students at Haramaya and at Cincinnati, as well as with members of the Rotary Club in Cincinnati to develop additional business plans for long-term maintenance of the PV system following a fee structure

2. Undergraduate students from Cincinnati collaborated with students from Haramaya University to identify, design and deliver a solar powered refrigerator, computer and video system to a small village clinic near Harar, Ethiopia. The village clinic services about 2,000 farming families with basic medical services and training. In the absence of refrigeration many of the medical supplies such as vaccines, drugs and cell cultures will spoil. Often more than half of the medicines provided to clinics spoil due to the lack of refrigeration. Further, electricity to power lights, computers and video equipment are vital to training and record keeping in the clinic.

   Coupling funds and manpower from undergraduates at UC, with the skills, knowledge, and day-to-day, long-term support provided by HU students, the team was able to install a solar powered electrical system in the clinic with a refrigerator. The project involved five students from Cincinnati and ten students from HU as well as one UC faculty member and faculty from HU including the Dean of the College of Natural and Computational Sciences, Dr. Girma Gonfa. The visit to Haramaya was featured on the local radio station at HU.

3. The team installed a small demonstration PV system in the Model school at HU, that will be used for teaching the viability of photovoltaics as a source of renewable off-grid power in Africa. Funding for these demonstration units came from a small grant from the U.S. Embassy in Addis Ababa.

4. The team from the U.S. interacted with members of the HU community who are involved in developing a radio station with funding from the U.S. Embassy. The team also made a brief visit to Addis Ababa University.

5. Three NPA team members gave presentations at UB to representatives of the Botswana Ministry of Energy, Ministry of Education, UB, and BOTEC about the potential of printed electronics in rural Botswana.

Refer to Appendix D for additional information on outreach activities.

Additional activities:

a) **NPA represented at Conferences in Japan and Ukraine**.
   Ulrich Männl, a PhD student in the NanoSciences Innovation Centre, presented his research at two major international conferences[2]. Awarded for most outstanding poster presentation at both conferences, Männl presented at the 2012 International Conference on Flexible and Printed Electronics, held in Tokyo from September 6 - 8, and at the International Conference on Nanomaterials: Applications and Properties, held from Sept 17 - 22 in the Ukraine. The

[2] (http://www.uct.ac.za/mondaypaper/archives/?id=9344).

proceedings for this conference were published online[3] Mr. Männl was invited to submit a paper to both conferences for publication in special issues of major international journals.

b) **Oak Hills High School Cincinnati**
Oak Hills High School in Cincinnati has been involved with donations to the village school that the partners have previously worked with in Ethiopia. NPA scientists have been monitoring the interactions and helped with the installation of solar panels funded by OHHS students.

Research Proposals

Table 7: Number of Research Proposals Submitted for Funding

FY11-13 Target	End of Project Result
1	7

The partners submitted a total of six research proposals for funding (Table 7 and five of these proposals are provided in **Appendix E**):

The seven proposals include three research proposals that have been funded, i.e. Neutron scattering and x-ray scattering beam time, and four proposals that have not been funded, i.e. two proposals submitted to National Science Foundation and two others submitted to National Research Foundation, South Africa.

Partners also submitted several other proposals for funding to support partnership activities. These include (a) three proposals that have been funded by the US Embassy Cultural Affairs Office in Ethiopia for UC undergraduate students visiting HU, (b) three proposals to Rotary International to support interactions between UC and HU, of which two have been funded, and (c) two proposals for support to travel to American Physical Society Meeting and two proposals for Fulbright Fellowship that have not been funded.

Number of Linkages

During the life of the project, partners have established linkages and collaborations with a number of government and non-government organizations and higher education institutions (Table 8). The list of these collaborating organizations is provided in table 9.

Table 8: Number of Linkages with NGOs and Stakeholders

FY11-13 Target	End of Project Result
5	13

[3] (http://nap.sumdu.edu.ua/index.php/nap/nap2012/paper/view/403/9)

Table 9: Stakeholders collaborating with the NPA project

Solar Light for Africa (SLA)	NGO	SLA has participated in proposal writing, given advice concerning development of photovoltaic technology and participated in the planning and implementation of a live interactive course, Solar Power for Africa, as well as support through funding and implementation of the NPA project.
Bole/Addis Rotary Club, Concordia Humana	NGO	The Rotary Clubs were involved in development of a solar panel assembly plant at HU and Dire Dawa University. Funding is being negotiated with Sharp Electronics through Rotary connections. The Rotary also funded PV materials for installation of a PV in Haramaya at a primary school in an agrarian village.
Rotary Club of Cincinnati	Community Organization	The Cincinnati Rotary Club has been actively involves in mentoring and hosting visiting African scientists. They have been instrumental in arranging contacts with the local Rotary Clubs in Addis Ababa and in Cape Town, providing business advice, financing links and other help with development of technology based business plans in sub-Saharan Africa.
Printed Silicon Technology (PST) Sensors	Business	PST Sensors has assisted with device manufacturing development, business and academic contacts for the project.
Eclipse Film Technologies	Business	Eclipse has actively participated in the development of reel-to-reel processing with African and US scientists working at Eclipse labs producing PV layers using Eclipse facilities.
DuPont	Business	DuPont provided financial support for the implementation of some activities of the project.
Michelman Corporation	Business	Coating and laboratory equipment has been transferred from Eclipse Film Technology to Michelman Corporation due to organizational restructuring. An agreement was signed which will allow Michelman to participate in the project by providing support for conductive and barrier coating technologies for photovoltaic development work using State of Ohio funds from the Third Frontier Program.
Oak Ridge National Laboratory	Government	NPA has a post doc stationed at Oak Ridge doing organic synthesis and neutron scattering measurements. Oak Ridge has also been host to visiting African Scientists during this reporting period.

Argonne National Laboratory	Government	Argonne has been host to visiting African Scientists during this reporting period and been co-author on one publication from the NPA project.
Air Force Office of Scientific Research (AFOSR)	Government	AFOSR provided financial support and technical support to the partnership.
U.S. Embassy in Ethiopia	Government	The Embassy provided financial support for the implementation of some activities of the project
Dire Dawa University/ Mekelle University/Addas Ababa University	Higher Ed. Institutions	Collaborative relationships have started with these institutions.
University of Botswana	Higher Ed. Institution	Collaborative relationships have started with this institution.

3.2 Challenges

Funding
The partnership's period of performance ended in September 2013, leading to the termination of the program for the graduate students from Ethiopia and Rwanda. The partners attempted to secure support for these students, who may have to return to their countries prior to completion of their degrees due to lack of funding.

Reporting & Data Limitation
Throughout implementation the partners have provided HED with inconsistent targets, data, narratives and supporting documentation with little elaboration on accomplished activities, and poor reporting quality. The partners were generally not responsive to HED's attempts to engage in discussion and to address the data quality issues. These inconsistencies have significantly limited HED's capacity to conclude its data quality verification processes.

Financial Reporting and Reimbursement of Expenses
Severe delays in the submission of invoices and supporting documentation by UCT to UC affected UC's ability to effectively manage the award. UC invoices to ACE/HED also did not reflect most of UCT's expenses, despite repeated attempts by UC and HED's assistance to obtain the necessary documentation and accurate invoices. The situation improved slightly after UCT hired a full-time financial administrator to work exclusively on these billing matters.

Collaborative Relationships between Partners
The collaboration and communication between the UC and UCT was ineffective, which affected the completion of activities, despite a no-cost extension through September 30, 2013. UC was also reluctant to extend the performance period for the sub-sub, i.e. UCT, in the same manner.

Administrative support at UC
While the financial team at UC was effective in its reporting, it had met with major challenges because of inadequate staffing. Funds were not made available for support staff at the university, which made management of the project difficult given the need for timely and quality reporting requirements, budget revisions, and implementation plans.

3.3 Lessons Learned

Importance of Leveraging Resources
The capacity to leverage funding was vital for the partnership's success. The ability to secure funding allowed the partners to continue with implementation of activities and expand the work of the partnership to other institutions in the region. The continued relationship between UC and partner institutions in Rwanda and Ethiopia will help expand capacity development in the region.

Collaborative Linkages
Expanding collaborative linkages with NGOs, government and local institutions provides opportunities for expanding the goals and objectives of the partnership. This was demonstrated in the ability of the partners to collaborate with several stakeholders, such as the SLA and Rotary Clubs, ANL and ONRL, Office of Scientific Research and U.S. Embassy and Ministry of Energy and local institutions (HU, Dire Dawa University, Mekelle University, and Addis Ababa University) in Ethiopia.

Administration
It is essential to have clearly agreed upon guidelines and procedures in place as early as possible. A dedicated administration at all sites is essential to maintain oversight of all project activities and facilitate communication on contractual and administrative matters between institutions.

HED/ACE Programmatic Support
HED/ACE's programmatic support to partners ensured effective implementation of partnership activities and provided essential technical assistance to partners in the areas of developing and periodically revising results framework (RF), partnership monitoring plan (PMP) and partnership implementation plans (PIP), as well as reporting in PRIME. The continuous monitoring of progress, technical assistance and troubleshooting helped UC and UCT in submitting quarterly financial expenditure reports and semi-annual reports.

4. Sustainability

Alignment to Development Goals of Host Country
The development goals of South Africa, Rwanda and Ethiopia are aligned with the goals of the NPA project. The Ministry of Energy in Ethiopia has offered to consider supplementary support to the Ethiopian component of the project. Taking a pan-African approach, the partners have also successfully expanded their NPA institutional network into Rwanda, Ethiopia and Botswana, with plans to further expand into other sub-Saharan African countries, such as Nigeria and Uganda. Moreover, UC is in discussions with other U.S. universities to expand the U.S. end of the network.

Leveraging Funding

The partners' ability to leverage funding established relationships that will continue to expand and strengthen the works started by the project. ORNL, ANL, Air Force Office of Scientific Research, Printed Silicon Technology and Eclipse Film Technology provided financial support and technical support for the development of printed electronic solar cells (Table 10). The South Africa National Research Foundation, NSF, U.S. Embassy in Ethiopia, IDTechEx and DuPont Corporation also contributed funding for implementation of activities of the project. In addition, the Rotary also funded PV materials for installation of a PV powered well in Haramaya at a primary school in an agrigarian village linked to the Solar Power for Africa joint web-based course.

Table 10: Leveraged funding from stakeholders collaborating with the NPA project

Collaborating Organizations	Leveraged Funding, USD	Collaborating Organizations	Leveraged Funding, USD
Oak ridge National Laboratory	$492,340	U.S. Embassy, Ethiopia	$10,000
South Africa National Research Foundation	$218,000	IDTechEx	$27,250
Eclipse Film Technology	$180,000	Rotary club Cincinnati	$22,000
University of Cape Town	$151,000	Solar Power Africa	$20,000
Argonne National Laboratory	$80,000	PST Sensors	$15,000
U.S. Air Force Office of Scientific Research	$54,200	DuPont Corporation	$2,000
NSF	$50,000		

The partnership's submission of several grant proposals attests to the potential for continued collaboration and sustained collaborative efforts. Awards for presentations at the Printed Electronics meeting in Santa Clara, CA and Frost & the Sullivan Award for PST Sensors in October 2012 are encouraging signs that the collaboration will continue with potential results that will have impact on community.

Collaboration with Local Institutions

The partnership laid the foundation for sustainability for its programs through the participation of many local universities and institutions, as well as relationships with government and non-government organizations. Locally, SLA participated in internet courses and student trips to HU while Printed Silicon Technologies in Cape Town supported the development of printing technologies. The Rotary Club of Cincinnati and Rotary International committed to host African visitors in Cincinnati and related projects at the installation of PV systems ceremonies in the secondary partner university communities.

The U.S. Embassy in Addis Ababa remains to be involved in the discussions USAID missions in Kigali and in Addis on implementation and possible direct support of secondary partner universities in their countries. These discussions focus on targeting printed humidity sensors for agriculture in Ethiopia and printed thermal sensors for medical applications in Rwanda. The Energy Ministry in Ethiopia is interested in the designation of HU as the Ethiopian center for PV research based on this project as well as directly supporting researchers at HU in the project, particularly entrepreneurial aspects of the project that relate to energy.

Collaboration with Technology Institutions

The partners have developed the technology for cost effective solar panels, both at UCT and HU. With expanded collaborations, including those with the Rotary Clubs in Cincinnati and Addis Ababa, the ORNL, ANL, the Air Force Office of Scientific Research, Printed Silicon Technology, and Eclipse Film Technology, the development of printed electronic solar cells established at HU and UCT can be strengthened and expanded to Rwanda with a potential impact on energy resources for rural communities. Internationally, Dupont and Eclipse Film Technologies contributed by developing new binders for printed electronics and reel-to-reel processing, respectively.

Durable Relationships between Partner Institutions

The partners have established a close working relationship. In doing so, they forged important collaborative relationships with local government and non-government agencies and other funding sources. These relationships will help partners in the short and long-term toward effective implementation of planned activities, coordinate initiatives and resources and ensure local ownership.

5. Success Stories

Among the many successes that have occurred as a result of the UCT- UC partnership, four stories are highlighted in this report (refer to **Appendix F** for detailed stories):

1) **Undergraduate Students Bring Solar Power to Rural Clinic in Ethiopia**
   A group of undergraduate students at the University of Cincinnati are teaming with undergraduates in Ethiopia to address the need for off-grid power in rural settings across sub-Saharan Africa.
2) **Nano-Power Africa: Best in Show at Silicon Valley**
   Professor David Britton, co-director of the NanoSciences Innovation Centre said, "The large-area sensor looks like a novelty gimmick, with the active sensor printed in the form of a graphic design, a zebra for example, using silver ink for the contacts with the black silicon nanoparticle ink for the active semiconductor, or even a tiger, using a copper ink."
3) **HED/USAID Supports Pan African Interactive Internet Course on Solar Power**
   Nano-Power Africa (NPA), a partnership between the University of Cincinnati (UC) and the University of Cape Town (UCT) funded by USAID through HED, has recently used these internet capabilities to develop a course studying the implementation of photovoltaic technology to solve development problems in Sub-Saharan Africa. The course is simultaneously taught at UC, UCT, HU in Ethiopia, KIE in Rwanda, RU in South Africa and at the University of Botswana.
4) **New applications mark Nano-Power Africa's center at Cape Town**
   A center of 'nanovation', UC's spin-out firm and a Norwegian technology company collaborate to develop more efficient temperature sensor system for perishables packaging. "Our work with thin-film has the potential to unlock significant new market opportunities, and is an excellent example of the transformative impact that printed electronics will have on the entire supply chain," said Margit Härting, associate professor in physics at UCT and founder and chief strategy officer of PST Sensors. "For many applications we need to know not only the average temperature, but its distribution. This isn't possible using conventional sensors, especially over a large area or an oddly shaped surface," she said.

6. Appendices

Appendix A: Solar Power for Africa – Web-based Course

http://www.eng.uc.edu/~gbeaucag/Classes/SolarPowerforAfrica.html

Learning Objectives: *Solar Power for Africa* will introduce students from a broad range of backgrounds to the potential of photovoltaics in Africa for developing clean energy sources to replace fossil fuel systems; the course will discuss energy infrastructure in Africa in the context of development; students will learn about the Millennium Development Goals of the United Nations and how this can impact Southern and East Africa; simple technologies for photovoltaics that are applicable to indigenous manufacture and use in sub-Saharan Africa will be considered mostly from a broad technical perspective; students will understand the basic installation of a photovoltaic system and other technologies for the utilization of solar energy; students will be exposed to how the culture and politics of Africa need to be considered in implementation of technological development on a local level; students will learn of the intricate web of stake holders in the sub-Saharan Africa region and specifically how these stake holders can work together using photovoltaics towards development goals; the implication and use and meaning of micro-finance in the spread of new technology in Africa will be discussed; students will learn specific case studies of the application of photovoltaics in various underdeveloped regions particularly focusing on success stories; Students will learn of some of the various NGO's involved in bringing photovoltaics to Africa and particularly how these organizations have grown and how they function in Africa; finally the students will discuss a particular effort at the University of Cincinnati involving a USAID program to develop higher education in Africa.

Students will develop a group design proposal taking advantage of the backgrounds and interests of team members that will present a simple PV based problem that can be addressed through a new NGO. Students will propose a location, technology and finance scheme as a white paper that could be sent to an organization such as USAID or other private organizations for funding. The students will present their proposals as a group at the end of the quarter.

The course is taught with a web/video link to three African Universities: University of Cape Town (South Africa), Haramaya University (Ethiopia), and Kigali Institute of Education (Rwanda), University of Botswana (Botswana), the Rhodes University (South Africa), Mekelle University (Ethiopia) and Addis Ababa University (Ethiopia). Interaction between Cincinnati and African students will be encouraged. The group design projects will involve members from African and US universities who will interact using Skype video conferencing.

Pedagogy: The course will be presented as a seminar series of 40 to 50 minute presentations followed by a discussion of the presentation. Each presentation will have an associated assignment meant to reinforce the subject. Reading materials associated with the presentations will be made available. Students will be assessed by their participation in the discussion or, at their discretion, by presenting written comments on the presentation each week (1 to 5 pages).

A design project/proposal will be required from small groups of students (3 to 5) seeking to develop a viable photovoltaic system that involves some component of local production and indigenous entrepreneurship. The project will propose a technology, location, micro-finance model and possible funding sources. The design proposal will be presented at the end of the quarter to the class.

Syllabus: (Some of the links below can only be opened from the University of Cincinnati Computer Network). **Topics** covered include:

1. Energy in the Third World and Off Grid Power: Practical Action's "three A's" of Affordable, Accessible and Appropriate technology.
2. Photovoltaic Devices and Technology: How to build a solar panel part 1, part 2, part 3 Non-PV Solar Technology.
3. Social Entrepreneurship and Microfinance.
4. Southern and East African Culture and Politics.
5. The role of stakeholders in photovoltaic development: Governments, NGOs, USAID, World Bank, private sector and educational institutions.
6. Case Study for Government Sponsored Photovoltaics in the Third World.
7. Case Studies for NGO Sponsored Photovoltaics in the Third World: *Village Life Outreach Project, Emily Roush; Solar Electric Light Fund & Solar Light for Africa; Engineers Without Borders Kevin; Literature from Solar Light for Africa, Solar Electric Light Fund: Sun Power Foundation; One Million Lights; Practical Action Foundation; Sustainable Development for All-Kenya; Solar-Aid: Solar Energy for Africa; Solafrica.ch:; Rural Energy Foundation; Energy for Opportunity;* Chasing the Sun: Solar Adventures Around the World. Neville Williams

(2005).Case Studies for Photovoltaic Production in the Third World: India, Indonesia, Uganda, others cases.

8. Chasing the Sun: Solar Adventures Around the World.
9. Higher Education and Photovoltaics in sub-Saharan Africa.
10. Presentation of Design Proposals.

Appendix B: Students Enrolled in graduate programs

UNIVERSITY OF CAPE TOWN
NanoSciences Innovation Centre

Dept. of Physics · University of Cape Town · Rondebosch 7701 · South Africa

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http://www.phy.uct.ac.za/nano

2012/11/23

Nano Power Africa Student Offers and Enrollment

To whom it may concern,

I hereby confirm that during the period April 1 2012 to September 30 2012:

The following applicants gained *access to a tertiary education program* through being offered a place of study in the NanoSciences Innovation Centre.

- Modupeola Florence Idowu (PhD)

The following students were *enrolled* for postgraduate study

- Getinet Yenealem Ashebir (PhD)
- Dereje Mekkonen Woldemariam (PhD)
- David Moweme Unuigbe (PhD)
- Rhyme Kagiso Setshedi (PhD)
- Tsige Yaraed Atilaw (BSc Hons)

The following students were continuing their studies towards a postgraduate degree

- Batsirai Magunje (PhD)
- Emmanuel Ohieku Jonah (PhD)
- Stephen David Jones (PhD)
- Ulrich Männl (PhD)
- Stanley Douglas Walton (PhD)
- Serges Zambou (PhD)
- Claire van den Berg (MSc)

The following students completed their studies

- *none*

The following students graduated on June 8 2012

- David Moweme Unuigbe (MSc)

Yours faithfully,

D. Britton

Prof. D.T. Britton

From: Girma [mailto:girmag@gmail.com]
Sent: Monday, June 25, 2012 9:08 AM
To: David Britton; Alemneh, Teshome
Subject: brief report

Dear Prof Britton, and Dear Dr Teshome

Please find attached herewith some of my communication letters in utilizing the fund from Nanopower Africa. So far we paid female students in the department of physics to purchase themselves basic teaching materials. The second round payment will be during the beginning of the new academic year (Sep/Oct 2012). I am also working to get a 3G type internet connectivity which will help us in tackling the persistent internet disruptions we have. This will help us for classes we are planning to have via video-conference.
Regards

Girma Goro Gonfa (PhD)
Associate Dean
College of Natural and Computational Sciences
Haramaya University, Ethiopia
HRA NanoSciences Innovation Center, Department of Physics
University of Cape Town, South Africa
Tel: +251255530033
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The following is the list of undergrad physics students who benefited from the Nanopower Africa Project. The second round will hopefully include female students from postgrad program. At the moment two female students have registered with department for postgraduate study. It is believed that awarding best performing undergraduate students will motivate students to join the department. To facilitate this selection committee is already formed. Before the admission of the new coming students the award giving ceremony will take place and the same will be announced via poster all over the campus. This may serve as a mode of promoting the department.

Table1. Name list of undergrad students who benefited from the Nanopower Africa Project

No	Name	Year
1	Zewdu Hagos	I
2	Seida Munir	II
3	Emebet Alehegn	II
4	Banchu Mekonnen	II
5	Sisay Fekadu	II
6	Zenebu Alemayehu	II
7	Abeba Bayecha	III
8	Bilkisa Sied	III
9	Emiwedish Alazar	III
10	Halewuya Hassen	III
11	Hayat Suleiman	III
12	Tilaye Mengistu	III

Appendix C: Publications

Topological investigation of electronic silicon nanoparticulate aggregates using ultra-small-angle X-ray scattering

Jonah, E. O.; Britton, D. T.; Beaucage, P.; Rai, D. K.; Beaucage, G.; Magunje, B.; Ilavsky, J.; Scriba, M. R.; Haerting, M.; JOURNAL OF NANOPARTICLE RESEARCH; Volume: 14; Issue: 11; Article Number: 1249; November 2012

Abstract

The network topology of two types of silicon nanoparticles, produced by high energy milling and pyrolysis of silane, in layers deposited from inks on permeable and impermeable substrates has been quantitatively characterized using ultra-small-angle X-ray scattering, supported by scanning electron microscopy observations. The milled particles with a highly polydisperse size distribution form agglomerates, which in turn cluster to form larger aggregates with a very high degree of aggregation. Smaller nanoparticles with less polydisperse size distribution synthesized by thermal catalytic pyrolysis of silane form small open clusters. The Sauter mean diameters of the primary particles of the two types of nanoparticles were obtained from USAXS particle volume to surface ratio, with values of similar to 41 and similar to 21 nm obtained for the high energy milled and pyrolysis samples, respectively. Assuming a log-normal distribution of the particles, the geometric standard deviation of the particles was calculated to be similar to 1.48 for all the samples, using parameters derived from the unified fit to the USAXS data. The flow properties of the inks and substrate combination lead to quantitative changes in the mean particle separation, with slowly curing systems with good capillary flow resulting in denser networks with smaller aggregates and better contact between particles.

Quantitative investigations of aggregate systems

Rai, D. K.; Beaucage, G.; Jonah, E. O.; Britton, D. T.; Sukumaran, S.; Chopra, S.; Gonfa, G. Goro; Haerting, M.**;** JOURNAL OF CHEMICAL PHYSICS; Volume: 137; Issue: 4; Article Number: 044311; Published: July 2012

Abstract

Nanomaterials with disordered, ramified structure are increasingly being used for applications where low cost and enhanced performance are desired. A particular example is the use in printed electronics of inorganic conducting and semiconducting nanoparticles. The electrical, as well as other physical properties depend on the arrangement and connectivity of the particles in such aggregate systems. Quantification of aggregate structure and development of structure/property relationships is difficult and progress in the application of these materials in electronics has mainly been empirical. In this paper, a scaling model is used to parameterize the structure of printed electronic layers. This model has chiefly been applied to polymers but surprisingly it shows applicability to these nanolayers. Disordered structures of silicon nanoparticles forming aggregates are investigated using small angle x-ray

scattering coupled with the scaling model. It is expected that predictions using these structural parameters can be made for electrical properties. The approach may have wide use in understanding and designing nano-aggregates for electronic devices. (C) 2012 American Institute of Physics.
[http://dx.doi.org/10.1063/1.4737947]

Interfacial and Network Characteristics of Silicon Nanoparticle Layers Used in Printed Electronics
Maennl, Ulrich; Chuvilin, Andrey; Magunje, Batsirai; Jonah, Emmanuel Ohieku; Haerting, Margit; Britton, David Thomas**;** JAPANESE JOURNAL OF APPLIED PHYSICS, Volume: 52, Issue: 5, Part: 2; Special Issue: SI; Article Number: UNSP 05DA11; May 2013

Abstract

In printed electronics the use of semiconducting silicon nanoparticles allows more than the simple printing of conductive materials. It gives the possibility of fabricating robust and inexpensive, active and reactive components like temperature sensors which are shown as an example. In our approach high quality silicon nanoparticles with stable, essentially oxide-free surfaces are used to replace the pigment in water-based graphic inks, which on curing have unique semiconducting properties, arising from the transport of charge through a percolation network of crystalline silicon nanoparticles. In this study scanning electron microscopy (SEM) and high-resolution transmission electron microscopy (HRTEM) were employed to investigate the mesoscale structure of the particle network and, more importantly the structure of the interface between particles. An intimate contact between lattice planes of different particles was observed, without the presence of an intervening oxide layer. (C) 2013 The Japan Society of Applied Physics

A novel mode of current switching dependent on activated charge transport
Britton, David T.; Walton, Stanley D.; Zambou, Serges; Magunje, Batsirai; Jonah, Emmanuel O.; Haerting, Margit); AIP ADVANCES; Volume: 3; Issue: 8; Article Number: 082110; August 2013

Abstract

We demonstrate a fully printed transistor with a planar triode geometry, using nanoparticulate silicon as the semiconductor material, which has a unique mode of operation as an electrically controlled two-way (double throw) switch. A signal applied to the base changes the direction of the current from between the collector and base to between the base and emitter. We further show that the switching characteristic results from the activated charge transport in the semiconductor material, and that it is independent of the dominant carrier type in the semiconductor and the nature of the junction between the semiconductor and the three contacts. The same equivalent circuit, and hence similar device characteristics, can be produced using any other material combination with non-linear current-voltage characteristics, such as a suitable combination of semiconducting and conducting materials, such that a Schottky junction is present at all three contacts. (C) 2013 Author(s). All article content, except where otherwise noted, is licensed under a Creative Commons Attribution 3.0 Unported License.

Temperature sensing device used in various applications has resistors e.g. temperature dependent resistors that are supported on substrate in which size can be reduced without changing average resistance value

Patent Number(s): WO2013114293-A1;

Inventor(s): BRITTON D T, HARTING M

Patent Assignee Name(s) and Code(s): PST SENSORS PTY LTD (PSTS-Non-standard)

Derwent Primary Accession Number: 2013-M19469 [71]

Patents Cited by Examiner: 5 **Articles Cited by Examiner: 1**

Abstract: NOVELTY - A temperature sensing device has temperature dependent resistors (10) connected in series and parallel with each other to form a network that is topologically equivalent to the square resistor network. The temperature sensing device also has terminals (14) at which average resistance value can be measured. The temperature dependent resistors are supported on a substrate in which size can be reduced without changing average resistance value.

Sensor device e.g. temperature sensing device for obtaining temperature of object e.g. liquid container, has external instrument to record and display physical variable independently measured by temperature sensing elements

Patent Number(s): WO2013114291-A1

Inventor(s): BRITTON D T, HARTING M

Patent Assignee Name(s) and Code(s): PST SENSORS PTY LTD (PSTS-Non-standard)

Derwent Primary Accession Number: 2013-M19473 [67]

Patents Cited by Examiner: 5 **Articles Cited by Examiner: 3**

Abstract: NOVELTY - The sensor device has an array of spaced apart temperature sensing elements (28) that are arranged in a pattern on a substrate (30). The temperature sensing elements are connected electrically and provided with a resistive component, so that a physical variable independently measured by the temperature sensing elements is recorded and/or displayed by an external instrument. The temperature sensing elements are provided with temperature dependent resistors and negative temperature coefficient (NTC) thermistors.

Sensing device for strain compensated temperature sensor has thermistor and substantially temperature independent resistor, which are both sensitive to mechanical strain

Patent Number(s): WO2013114289-A1

Inventor(s): BRITTON D T, HARTING M

Patent Assignee Name(s) and Code(s): PST SENSORS PTY LTD (PSTS-Non-standard)

Derwent Primary Accession Number: 2013-M18451 [65]

Patents Cited by Examiner: 1

Abstract: NOVELTY - The sensing device has a thermistor (10), a substantially temperature independent resistor (12) connected in series with the thermistor, and at least one electrical contact by which an electrical potential difference can be applied across both resistors simultaneously. Both the thermistor and the substantially temperature independent resistor are sensitive to mechanical strain. The thermistor and resistor are of substantially similar construction and hence have a similar response to a mechanical force applied to them.

Forming nanoparticles involves providing fluid with precursor fluid(s) and generating electrical spark in fluid to cause pyrolysis of precursor fluid(s) to form radical species, and form nanoparticles by nucleation in cooler reaction zone

Patent Number(s): WO2013008112-A2

Inventor(s): BRITTON D T, SCRIBA M R

Patent Assignee Name(s) and Code(s): PST SENSORS PTY LTD (PSTS-Non-standard)

Derwent Primary Accession Number: 2013-B10503 [08]

Abstract: NOVELTY - Method (M1) to form nanoparticles of 1-1000 nm through synthesis of at least one precursor fluid involves: providing a fluid medium comprising at least one precursor fluid and generating an electrical spark within the fluid medium to cause pyrolysis of at least one precursor fluid in a relatively hot plasma zone to produce at least one radical species, and to form nanoparticles by nucleation in the fluid medium in a cooler reaction zone about the plasma zone, where at least one radical species acts as reactant or catalytic agent in the synthesis of material composing the nanoparticles.

Producing a temperature sensing device comprises forming at least one silicon layer and at least one electrode or contact to define a thermistor structure, or at least the silicon layer being formed by printing

Patent Number(s): WO2012035494-A1 ; EP2616784-A1 ; US2013203201-A1 ; JP2013538462-W ; CN103210290-A

Inventor(s): BRITTON D T, HARTING M

Patent Assignee Name(s) and Code(s): UNIV CAPE TOWN (UYCA-Non-standard)
PST SENSORS PTY LTD (PSTS-Non-standard)
BRITTON D T(BRIT-Individual)
HARTING M(HART-Individual)
PST SENSOR PRIVATE CO LTD (PSTS-Non-standard)

Derwent Primary Accession Number: 2012-D46892 [72]

Patents Cited by Examiner: 6 **Articles Cited by Examiner: 1**

Abstract: NOVELTY - Producing a temperature sensing device comprises forming at least one silicon layer and at least one electrode or contact to define a thermistor structure, at least the silicon layer being formed by printing, and at least one of the silicon layer and the at least one electrode or contact being supported by a substrate during printing.

Fabrication of electronic component by using substrate or layer of electrically insulating material comprising packaging material

Patent Number(s): WO2012035493-A1 ; EP2617270-A1 ; US2013199826-A1 ; JP2013539908-W ; CN103210703-A

Inventor(s): BRITTON D T, HARTING M, BRITTON D

Patent Assignee Name(s) and Code(s): UNIV CAPE TOWN (UYCA-Non-standard)
PST SENSORS PTY LTD (PSTS-Non-standard)
PST SENSOR PRIVATE CO LTD (PSTS-Non-standard)

Derwent Primary Accession Number: 2012-D46894 [72]

Patents Cited by Examiner: 2

Abstract: NOVELTY - Fabricating an electronic component comprises printing a component structure comprising semiconducting ink(s), an insulating ink and a conducting ink onto a substrate (10), where the component structure defines contact area(s); disposing a connecting lead against or adjacent to the contact area(s); and applying layer(s) (22) of electrically insulating material to enclose the component structure. The substrate or the layer of electrically insulating material comprises packaging material.

Appendix D: Outreach/Extension

Ethiopian and South African Scientists Work with The Cincinnati Rotary Club and Rotary International to Develop Business Plans.

African scientists from five universities involved in the HED/USAID funded NanoPower Africa Project are working with members of the Cincinnati Rotary Club, one of the oldest chapters of the US Rotary Club, to develop business plans for startup ventures in SubSaharan Africa targeting the manufacture of indigenously produced photovoltaic devices for charging cell phones and laptop computers. The PV technology has been developed under the NanoPower Africa project through collaboration with the University of Cape Town, the University of Cincinnati, Eclipse Film Technologies, Oak Ridge National Laboratory and Argonne National Laboratory. Business leaders from Cincinnati are using their expertise to guide the young entrepreneurs and to develop contacts with business leaders in Ethiopia, Rwanda, Botswana and South Africa through their Rotary connections. Through this stewardship it is hoped that the African scientists can more effectively implement business plans that will develop local economies, create jobs and provide a new source of off-grid power with a minimal carbon footprint.

From right, Prof. Goro Girma Gonfa, Haramaya University, Ethiopia, Prof. Schadrack Nsengiyumva, South Africa, and representatives from the Rotary Club; Carl Sedacca, and Kay Atkins

Informal meeting of African Scientists and the home of Deborah Schultz with Cincinnati Rotary Club business advisors. Cincinnati Rotary Club members Janet Metzelaar and Dan Gist with Schadrack Nsengiyumva and Goro Gonfa.

USAID/Higher Education for Development Grant Supports Haramaya University/University of Cincinnati Program for Student & Faculty Interaction and Community Outreach

A program led by Prof. Greg Beaucage involving interaction between students and faculty and students at Haramaya University and the University of Cincinnati was conducted from December 13 to December 29, 2012. The program involved meetings between US students, Ethiopian students, faculty and community leaders. Undergraduate students from Cincinnati collaborated with students from Haramaya University to identify, design and deliver a solar powered refrigerator, computer and video system to a small village clinic near Harar, Ethiopia. The village clinic services about 2,000 farming families with basic medical services and training. In the absence of refrigeration many of the medical supplies such as vaccines, drugs and cell cultures will spoil. Often more than half of the medicines provided to clinics spoil due to the lack of refrigeration. Further, electricity to power lights, computers and video equipment are vital to training and record keeping in the clinic. Coupling funds and manpower from undergraduates at UC, with the skills, knowledge, and day-to-day, long-term support provided by HU students, the team was able to install a solar powered electrical system in the clinic with a refrigerator. The project involved five students from Cincinnati and ten students from HU as well as one UC faculty member and faculty from HU including the Dean of the College of Natural and Computational Sciences, Dr. Girma Gonfa. The visit to Haramaya was featured on the local radio station at HU.

The Cincinnati and Ethiopian team was brought together in an interactive web-based course, *Solar Power for Africa*, offered annually in the Fall semester that links 5 universities in Sub-Saharan Africa with the University of Cincinnati to learn about and discuss development issues in Africa that can be addressed with photovoltaic technology. The course is part of the *NanoPower Africa Project* funded by USAID through HED. Haramaya University is the second oldest University in Ethiopia and is located approximately 12 hours by car from Addis Ababa in the arid and mountainous Oromai Region of Ethiopia.

The trip also included visits to several cultural and natural sites in Ethiopia including the medieval, walled city of Harar, one of the holy cities of Sufi Islam. In addition to HU the Cincinnati students and faculty visited Addis Ababa University School of Design and had lunch with the Cultural Affairs Officer of the US Embassy. The students at HU and UC gained insight into how their engineering, science, and design skills can be utilized to address development needs in sub-Saharan Africa. Two of the UC students are pursuing graduate studies next year coupling development work and engineering.

UC students working on the design of a solar panel mount with HU students.

Ceremony presenting solar panels to the villagers and local politicians and religious leaders

Village children and UC/HU students.

UC and HU students installing solar panels at the clinic while villagers watch.

Appendix E: Other Research Grants and Activities

Neutron Scattering Knowledge-Based Material Architecture Design for Efficient Hybrid Solar Cell

Mussie Alemseghed, Michael Hu, Greg Smith
*ORNL-UTK Joint Faculty Professor, ORNL SNS Staff, University of Cincinnati
Contact: zhu1@utk.edu or hum1@ornl.gov

Abstract: This proposal aims to develop large-scale collaboration between UTK, ORNL, CNMS, University of Cincinnati, and industrial partners. *We will investigate and understand the fundamentals of molecular organization of shaped quantum dots in organic photovoltaic thin films.* Our organic-inorganic hybrid solar cell will be comprised up of thiol terminated poly (3- hexylthiophene) as the organic conducting polymer (electron-donor) and, lead sulfide (PbS) quantum dot, as the semiconductor material (electron-acceptor). Modifying P3HT with thiol functional group is expected to enhance the interaction of PbS quantum dots with the semiconducting polymer at the surface and thus decreasing the phase segregation of the blend and improving the power conversion efficiency. This effort will establish a new teaming capability in the areas of Advanced Functional Materials and Devices as well as Hybrid Materials.

I. Background and Key Challenges: A clean, renewable, and affordable energy sources are at high demand. For the past two decades, inorganic semiconductor based photovoltaics have grown tremendously due to their tunable optical and electronic properties. On the other hand, polymer based photovoltaics are becoming more attractive due to their low-cost, large area coverage and film flexibility. Poly (3-hexylthiophene) is one of the most promising semiconducting polymers for photovoltaic applications due to its solution processability, optoelectronic properties (hole mobility as high as 0.1 cm-2 V-1s-1) and relative stability. When fabricating a hybrid photovoltaic device, minimizing the effect of charge recombination and choosing the right inorganic semiconductor with the right band gap are top of the main concerns that should be addressed. Previous works have confirmed that quantum dots do not blend well with conducting polymers and, therefore, create compatibility issue during solution processing. We will tackle this problem by modifying the P3HT itself and functionalize it with thiol functional group. The presence of thiol functional group in the P3HT is expected to increase the surface contact between the polymer and the quantum dot, making the blend suitable for thin films processing.

II. Target and Outcome: In this proposal, we will build organic-inorganic hybrid solar cell consisting of P3HT as the electron-donor, and PbS, as an electron-acceptor. We will explore the efficiency of the device at the interface. Nearly 50% of all the solar energy reaching the earth is in the infrared and most of it in the near infrared region.12-14For this proposal, we select PbS quantum dot as the electron-acceptor as it has band gaps that can be tuned into the far infrared (has broad band visible light absorption), and additionally, does not exhibit strong carrier recombination caused by the surface states and defect centers, opening the possibility of capturing much more energy cost-effectively. When blended with the modified P3HT, we expect to obtain higher power conversion efficiency of the photovoltaic cell compared to the existing ones.

III. R & D Approach: Organic-Inorganic Hybrid Heterojunction Solar Cell Design. Grignard Metathesis Method15 will be employed to synthesize the organic semiconductor (thiolterminated P3HT) from Br/allyl-terminated P3HT precursor. The inorganic semiconductor (PbS quantum dot) will be synthesized using previously established synthetic protocol by Kumacheva and co-workers. Synthesis of thiol-terminated P3HT Once the PbS quantum dots are synthesized separately, they will be blended with the thiolterminated P3HT in dichlorobenzene/pyridine mixture (95/5, v/v), in different ratios and then the blend will be spin-casted followed by annealing. The photovoltaic response of the blend on the device will be studied. Optical characterization studies, Transmission and scanning electron microscopy measurements (TEM and SEM) will be acquired to see the overall morphology of the blend and X-ray photoelectron spectroscopy (XPS spectra) will be taken to see the bonding structure. Neutron scattering studies will be conducted to further investigate the morphology and interface structure of the blends at the interface.

Budget Request: Total $50K covers the materials and supplies, and personnel time in new program funding development. This effort is leveraged with one existing postdoc funding to conduct the proposed work at ORNL.

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Partners for International Research and Education (PIRE): *NanoPower Africa*

The proposed work will support US-based research efforts in support of a new USAID project at UC, *NanoPower Africa*, that has organized a network of Universities in Africa coordinated by the University of Cincinnati for the development of indigenously-produced, nanomaterial-based photovoltaic and related devices. The USAID project is funded at $1,100,000 for a two-year startup period. The USAID program, Higher Education for Development, intends to fund this project for 15 years at approximately $2,500,000 per year when fully funded. The project includes a main site at the University of Cape Town and second-generation sites in Rwanda, Ethiopia, South Africa and Botswana. At each of these second generation sites implementation of technologies and expertise unique to the local situation are being used to leverage USAID funds towards development goals. The University of Cincinnati serves as a US hub for interactions with industrial and National Lab participants in the project and as the financial and administrative manager of the project. The US research role is partly aimed at development of technology that can be used to mass-produce nanomaterial based photovoltaic devices at costs that will be competitive in Africa using processing and materials that can be implemented in a low-tech environment. Some of the US based work is aimed at development of scientific capabilities in the African partner institutions through exchange programs and research efforts utilizing x-ray, neutron and light scattering as well as facilities at the NanoMaterials Research Center at Oak Ridge. Nanoparticle synthesis for printed electronics and reel-to-reel manufacturing as well as characterization are areas of research focus at Cincinnati.

The proposed work under NSF funding will 1) support interdisciplinary research and education at the University of Cincinnati aimed at sustainability especially in sub-Saharan Africa. This work will synthesize new nanomaterials for use in printed electronics using flame synthesis and milling, study printing and coating technologies in collaboration with Sun Chemical and Eclipse Film Technologies and develop structure/property relationships for nanoaggregates using facilities at Oak Ridge, Argonne and the University of Cincinnati. 2) build linkages among existing projects and partners in the *NanoPower Africa* network and add new participants and nodes of activity at the University of Botswana as well as expanding educational exchange and co-taught courses with the other participating universities and 3) develop a US workforce trained in interdisciplinary scholarship needed to understand and address the complex issues of sustainability by tackling the problem of development of indigenous technology and scientific approaches amenable to sub-Saharan Africa. The project will address sustainable energy research in science and engineering and its socioeconomic and environmental implications through interaction with Prof. Cheddi Kiravu at the University of Botswana. Participation of other UC faculty is anticipated.

Title of Proposed PIRE Project: ***NanoPower Africa***
Principle Investigator: **Prof. Gregory Beaucage**
Length of Study: **5 years**
Estimated Total Budget: **$2,500,000**
Lead Institution: **University of Cincinnati**
Partner Institutions and Key Personnel:

South Africa:	**University of Cape Town, Prof. David Britton**
	Printed Silicon Technology, Dr. Margit Härting
	Rhodes University, Prof. Schadrack Nsengiyumva
Rwanda:	**Kigali Institute of Education, Prof. Evariste Minani**
Ethiopia:	**Haramaya University, Prof. Girma Goro Gonfa**
Botswana:	**University of Botswana, Prof. Cheddi Kiravu**
	Botswana Technology Centre (BOTEC), Dr. J. J. Molenga
US	**Eclipse Film Technology, Dr. Ryan Breese**
	Oak Ridge National Laboratory, Dr. Gregory Smith
	Argonne National Laboratory, Dr. Jan Ilavsky

Funding Partner Agency:
United States Agency for International Development (USAID)
Program: **Higher Education for Development (HED)**
Project: ***NanoPower Africa***
($1,100,000 current with ~ $2,500,000/yr x 15 years planned)

Other funding will be solicited from the USAID missions in Pretoria (Southern Africa Mission); Kigali (Rwanda Mission); Addis Ababa (Ethiopian Mission) to support second generation Universities.

Additional current funding from the African Materials Initiative of the *Air Force Office of Scientific Research* (AFOSR) to the University of Cape Town through *NanoPower Africa* ($25,000) and from *Sun Chemicals* (Cincinnati) to University of Cape Town ($50,000) and *Oak Ridge National Lab* to UC ($30,000).

Transparent, conductive oxide layers from flame-spray pyrolysis.

Statement of objectives and methods to be employed.

Photovoltaic devices, LCD displays and other electronic components require a thin film of transparent conductor (TCO) such as indium tin oxide (ITO). In the production of some low-cost photovoltaic devices using nanomaterials, the cost of the ITO layer out weighs the combined cost of all other components. The proposed work is allied to a large USAID funded development project targeting the development of indigenously produced PV devices in sub-Saharan Africa (SSA) that does not fund research in the US. One goal of this USAID project is to indigenously produce small PV devices in Africa that can be manufactured in a price range comparable to a battery, $1 per 8.5x11 sheet. One need of this project is a replacement for ITO. Here it is proposed to use doped titania nanoparticles produced using flame-spray pyrolysis (FSP). The project seeks to develop new microporous TCOs; and, moreover, to understand the relationship between the ramified fractal structure presented by nano-aggregates and the electrical performance of these conductive layers. Similar analysis will be applied to printed electronic layers made of silicon nanoparticles in prototype layers for PV devices targeted in the USAID project. The method to understand the aggregate/property relationship involves a new theoretical description of fractal networks and use of small-angle x-ray scattering at synchrotron facilities coupled with measurements of the electrical performance. The project involves interaction with the leading FSP lab in the world at ETHZ in Zürich, Switzerland, an expert in small-angle scattering, as well as with underdeveloped labs in Ethiopia, Rwanda, Botswana and South Africa in collaboration with the top technical university in SSA, the University of Cape Town, leveraging USAID funding from the Department of State.

The intellectual merit of the proposed activity.

Many technically important devices include aggregate or ramified materials as electronic components. This is true of new PV technologies such as the Grätzel Cell, printed electronic devices and organic photovoltaic devices. A stumbling block to control of properties in these materials is the lack of a quantitative description of nano-scale structure in these disordered materials and a link between structure and electrical properties. This proposal seeks to address this scientific issue through the use of a new scaling model coupled with x-ray scattering measurements and quantification of electrical properties for doped titania films and printed electronic layers. The project also addresses the issue of development of alternative materials to ITO for transparent conductive layers and the effect of doping level and type in titania for this targeted application. Resolution of these coupled issues could lead to breakthroughs in our understanding of new PV devices and other technology.

The broader impacts resulting from the proposed activity.

The proposed work targets development in sub-Saharan Africa (SSA) through interaction with the NanoPower Africa project. The development of low cost indigenously manufactured PV devices for the SSA market can reduce the carbon foot print of the developing world, allow for recharging of electronic devices and improve the economy of SSA. Understanding the relationship between aggregate structure and electrical properties will impact the development of new nano-structure based electronic devices such as printed electronic PV's. The project will train a post-doctoral scientist and will enhance interaction between US researchers, Swiss researchers and scientists, and faculty in SSA improving higher education in the developing world. Web-based interactive classes are planned with the Swiss and SSA universities.

SusChEM: Collaborative: Optically Transparent Conductive Layers

Statement of objectives and methods: Photovoltaic devices, LCD displays, touch screens and other electronic devices require a thin film of transparent conductor (TCO) such as indium tin oxide (ITO). In the production of some low-cost photovoltaic devices using nanomaterials, the cost of the ITO layer out weighs the combined cost of all other components (Grätzel Cells for instance). The proposed work seeks to find low cost alternatives to ITO as well as alternatives with improved performance for flexible transparent conductive layers (FTCL). This will be achieved through the use of new conductive, doped titania nanoparticles and composites with polyimides as well as through graphene/polyimide composites. These nanostructures rely on percolation networks and a detailed understanding of charge transport through such networks. The project will involve modeling of these systems aimed at understanding a mechanistic basis for device improvement. PV devices will be produced using organic semiconductors and fullerenes (PCBM/P3HT composites) and the novel FTCL's as well as printed electronics nanosilicon solar cells. The project will involve interaction with Central State University (CSU) that is a historically black university as well as involvement in the Agency for International Development (USAID) Nanopower Africa Project (NPA) that aims to manufacture small-scale PVs in sub-Saharan Africa. The project will involve a collaborative effort between two senior and one junior faculty at the University of Cincinnati (UC) who offer complimentary expertise in several areas as well as a faculty of CSU. Prof. Beaucage is an expert at characterization of nanostructures using small-angle scattering and has extensive experience in the synthesis of nanoparticle oxides using flame synthesis. He has recently produced doped titania that displays conductivity similar to ITO at a fraction of the cost. He is also the director of the NanoPower Africa Project. Prof. Iroh is an expert in polyimide chemistry and in the production of nanocomposites of polyimides and layered structures. He has expertise in synthesis of polyimides and polyimide nanocomposites, as well as IR, and DMA targeting control over nanocomposite materials. Prof. Kuppa is an expert at computer modeling of complex systems involving polymers and composites. He has recently published in studies using graphene to modify PV devices in organic based PVs. The team will share three graduate students and three undergraduate students who will be trained in the PV device field and be exposed to work at national labs and with the NPA scientists.

Intellectual merit: The project offers two complimentary approaches to optically transparent conductive layers, doped titania based composite layers and graphene based polyimide composite layers. The PI's will work together to optimize these systems targeting OPV devices built in the lab of Kuppa. All of these composite layers as well as the active PV layer involve percolation of nanostructures for device performance. The exact relationship between nanostructure and performance in these complex systems is not well known. The PIs offer a unique combination of expertise in small-angle scattering and other characterization techniques as well as expertise in modeling of complex systems that can be applied to addressing the control of nanoparticle percolation for different functional layers in PV devices.

Broader impacts: The proposed work targets development in sub-Saharan Africa (SSA) through interaction with the NanoPower Africa project. The project also targets a historically black university with an outreach effort aimed at student exchanges between UC and CSU. Involvement of CSU students and faculty in research and the NPA project are planned. Web-based interactive classes are planned between CSU, UC and five African Universities targeting PV devices and semiconductor physics. The development of low cost indigenously manufactured PV devices for the SSA market can reduce the carbon footprint of the developing world. The project will train three graduate students and three undergraduates per year.

HARAMAYA UNIVERSITY

Production and Characterization of nano-material based Indigenous Solar Cell

A Project Proposal Submitted to the office of Vice President for Research Haramaya University

Girma Goro (PhD)

November, 2011

Appendix F: Success Stories

Undergraduate Students Bring Solar Power to Rural Clinic in Ethiopia

A group of undergraduate students at the University of Cincinnati are teaming with undergraduates in Ethiopia to address the need for off-grid power in rural settings across sub-Saharan Africa. In December, the Cincinnati students will travel to Haramaya University with the goal of installing a photovoltaic system to power a refrigerator for vaccines, lights, computers and medical equipment in a rural clinic. The Cincinnati team was brought together in an interactive web-based course, Solar Power for Africa that links 5 universities in Sub-Saharan Africa with the University of Cincinnati to learn about and discuss development issues in Africa that can be addressed with photovoltaic technology. The course is affiliated with the Nano-Power Africa Project funded by USAID through HED. The project is coordinated by Prof. Greg Beaucage at Cincinnati and Prof. Goro Girma Gonfa at Haramaya. Haramaya University is the second oldest University in Ethiopia and is located approximately 6 hours by car from Addis Ababa in the arid and mountainous Oromai Region of Ethiopia. Ethiopia, being located near the equator, with a large rural population offers some of the highest potential for solar power on the earth. The students hope that their effort can serve as a proof-of-concept for a new approach for off-grid rural electrification in sub-Saharan Africa. Nano-Power Africa is using this project to explore the feasibility of African universities serving as hubs for the entrepreneurial introduction of photovoltaics targeting local development needs.

Administrative building at Haramaya University, Ethiopia (left) and Qeransa-Darraba health post about 7 km from Haramaya University.

New applications mark Nano-Power Africa's center at Cape Town a center of 'nanovation'. University's spin-out firm and Norwegian tech company to develop more efficient temperature sensor system for perishables packaging

The NanoSciences Innovation Centre at the University of Cape Town, funded by USAID through the Higher Education for Development Program, and the center's spin-off company, PST Sensors, have recently introduced joint developments in thermal imaging and sensor imaging technology that can increase efficiency and safety in a number of industries, including food and pharmaceutical packaging, retail, transport and logistics, aerospace and automotive engineering, healthcare, marketing and advertising.

As a result, PST Sensors and Thin Film Electronics, a leading provider of roll-to-roll printed, rewritable non-volatile memory products based in Norway, today announced a partnership to jointly develop a printed sensor system that will monitor the temperature of perishables such as food and pharmaceuticals. The printed sensor system can be manufactured in high volumes for a fraction of the cost of traditional silicon microelectronics. It will be able to monitor individual packages to ensure that their contents have been kept at optimal temperature.

"Our work with Thinfilm has the potential to unlock significant new market opportunities, and is an excellent example of the transformative impact that printed electronics will have on the entire supply chain," said Margit Härting, associate professor in physics at UCT and founder and chief strategy officer of PST Sensors. "For many applications we need to know not only the average temperature, but its distribution. This isn't possible using conventional sensors, especially over a large area or an oddly shaped surface," she said.

Christer Karlsson, chief technology officer of Thinfilm, said: "The team behind PST has been working with the printed silicon technology over the last decade, and PST Sensors is the leading company in its field," said Christer Karlsson, chief technology officer of Thinfilm. "Its printed silicon sensor technology is uniquely easy to manufacture and offers a low cost point."

Nano-Power Africa: Best in Show at Silicon Valley

PST Sensors and UCT's presentation of a large-area temperature sensor received the Best in Show Award at the recent 2011 Printed Electronics USA Conference in Silicon Valley, California at the end of November. This is their second major award, following their 2010 Printed Electronics Europe Academic R&D Award. The temperature sensor was designed to look like a decorative graphic. Professor David Britton, co-director of the NanoSciences Innovation Centre, said: "The large-area sensor looks like a novelty gimmick, with the active sensor printed in the form of a graphic design, a zebra for example, using silver ink for the contacts with the black silicon nanoparticle ink for the active semiconductor, or even a tiger, using a copper ink." Conventional electronic temperature sensors can measure temperature at a specific point only. By contrast, the large-area sensors developed by UCT and PST Sensors can be printed onto a container – or even wrapped around it – to measure the average temperature over a large volume.

Professor Britton said: "The averaging over a large area makes the temperature reading more stable, avoiding the influence of hot or cold spots and poor thermal contact with the object whose temperature is being measured. Imagine the temperature of a fridge or incubator, or even a room, being measured on all the walls at the same time instead of at one position near the door." The team also displayed a thermal-imaging mat in Silicon Valley. Like an infra-red camera, this device produces a picture of an object's temperature profile – but unlike a camera, it doesn't need a clear line of sight. The technology has many potential applications in advanced engineering, particularly in the aerospace sector, where engineers need to pinpoint temperature distribution in airframes or engine housing. There is also great potential in chemical processing and nuclear engineering, to monitor the process in a reactor vessel.

Professor Härting said: “We’re investigating uses in health care and the NanoSciences Innovation Centre is working with a broader consortium that includes members of the Faculty of Health Sciences at UCT.”

David Britton and Margit Härting win Award	Burning bright: UCT NanoSciences Innovation Centre's Prof Margit Harting (right) and students Ulrich Mannl, Batsirai Magunje and Stanley Walton show off a newly printed tiger design large area temperature sensor, produced in collaboration with Austin-based company Novacentrix, using their unique copper ink and processing methods. The design is the first step towards replacing expensive silver inks. For this and other innovations, UCT's nanovators won the recent 2011 Printed Electronics USA Best in Show Award.

HED/USAID Supports Pan African Interactive Internet Course on Solar Power

African Universities generally lack highly trained senior faculty in the sciences and engineering. One short term solution to this problem is to supplement existing faculty by sharing faculty at different African institutions and through incorporation of US faculty into the African curriculum. This might be achieved using live internet connections via Skype Meeting or in a more professional way with commercial software such as Polycom Classroom. NanoPower Africa (NPA), a partnership between the University of Cincinnati (UC) and the University of Cape Town (UCT) funded by USAID through HED, has recently used these internet capabilities to develop a course studying the implementation of photovoltaic technology to solve development problems in Sub-Saharan Africa. The course is simultaneously taught at UC, UCT, Haramaya University in Ethiopia, Kigali Institute of Education in Rwanda, Rhodes University in South Africa and at the University of Botswana. Since some of the universities have been unable to implement PolyCom a hybrid system using Skype Meeting and Polycom Classroom has been implemented. The course has used guest lectures from each of the sites as well as guest lectures from off campus speakers. Interaction between African students and with US students has encouraged a pan-African atmosphere unique to this multi-site, interactive course. A live webcast of the course can be found at **http://goo.gl/wQJZK** and the course web page including web based reading material can be found at **http://goo.gl/F9w4F**. The NPA partnership plans to extend this live web based teaching to technical and entrepreneurial courses related to the development of indigenously produced photovoltaic devices targeting development issues in sub-Saharan Africa.

Live web class showing speaker from Cape Town (Prof. David Britton on left screen) and students in the US asking questions with Course Coordinator Prof. Greg Beaucage at UC. Students in Rwanda, Ethiopia, and at Rhodes University in South Africa are also participating.

Live internet class with speaker from the University of Botswana (Prof. Cheddi Kiravu right), Students in Cincinnati (left), students in Kigali, Haramaya and Rhodes (bottom. Students in Cape Town are not *shown since a question is being fielded from Cincinnati. Image is a screen capture of the live webcast on the open internet. The course uses a hybrid of PolyCom Classroom and Skype Meeting, students and speaker are on Skype that is ported into a Polycom class. This allows for flexibility where network limitations prevent the use of Polycom.*

USAID/Higher Education for Development Grant Supports Haramaya University/University of Cincinnati Program for Student & Faculty Interaction and Community Outreach

A program led by Prof. Gregory Beaucage of the University of Cincinnati (UC) involving interaction between students and faculty and students at Haramaya University (HU) and UC was conducted from December 13 to December 29, 2012. The program involved meetings between U.S. students, Ethiopian students, faculty members, and community leaders. Undergraduate students from UC collaborated with students from HU to identify, design and deliver a solar-powered refrigerator, computer and video system to a small village clinic near Harar, Ethiopia. The village clinic services about 2,000 farming families with basic medical services and training. In the absence of refrigeration many of the medical supplies such as vaccines, drugs and cell cultures will spoil. Often, more than half of the medicines provided to clinics spoil due to the lack of refrigeration. Further, electricity to power lights, computers and video equipment are vital to training and record keeping in the clinic. Coupling funds and manpower from undergraduates at UC, with the skills, knowledge, and day-to-day, long-term support provided by HU students, the team was able to install a solar powered electrical system in the clinic with a refrigerator. The project involved five students from UC and seven students from HU as well as one UC faculty member and faculty from HU including the Dean of the College of Natural and Computational Sciences, Dr. Girma Gonfa. The visit to Haramaya was featured on the local radio station at HU.

The Cincinnati and Ethiopian team was brought together in an interactive web-based course, “Solar Power for Africa,” offered annually in the Fall semester that links 5 universities in Sub-Saharan Africa with UC to learn about and discuss development issues in Africa that can be addressed with photovoltaic technology. The course is part of the NanoPower Africa Project funded by USAID through Higher Education for Development (HED). HU is the second oldest University in Ethiopia and is located approximately 12 hours by car from Addis Ababa in the arid and mountainous Oromai Region of Ethiopia.

The trip also included visits to several cultural and natural sites in Ethiopia including the medieval, walled city of Harar, one of the holy cities of Sufi Islam. In addition to HU, the Cincinnati students and faculty visited Addis Ababa University School of Design and had lunch with the Cultural Affairs Officer of the U.S. Embassy. The students at HU and UC gained insight into how their engineering, science, and design skills can be utilized to address development needs in sub-Saharan Africa. Two of the UC students are pursuing graduate studies next year coupling development work and engineering.

Appendix G: University of Cape Town/University of Cincinnati Final Report

University of Cincinnati has not submitted the final report for the partnership program (February 2011 – September 2013), per its obligation in the sub-award agreement signed between American Council on Education and University of Cincinnati. Despite HED's several attempts to assist and review the report .