# The International Research and Educational Programs of Clark Atlanta University's Center for Functional Nanoscale Materials

Malik Maaza[1,2], Myron N. V. Williams[1,3*], Ishrat M. Khan[1,3], Alfred Msezane[1,4], James L. Reed[1,2]
[1] Center for Functional Nanoscale Materials, [2] iThemba LABS, West Somerset, South Africa, Departments of [3]Chemistry or [4]Physics, Clark Atlanta University, Atlanta, GA 30314 USA. [*]Corresponding author.

## INTRODUCTION

Clark Atlanta University (CAU) intends to become a major international site for nanoscience research and education. Because of the history of CAU, a comprehensive, Historically Black College & University (HBCU) with high research activity, and its established relationships with many African institutions, CAU has initiated the development of mutually beneficial research and educational partnerships in the area of nanoscience with African institutions. The University leadership understands that of such partnerships present new opportunities and the necessity for such partnerships have been articulated by NSF Director Arden Bement, who writes:

> *Developing effective ways to transcend traditional boundaries, and bring very different scientific cultures together for the benefit of science and society, without compromising excellence, is a critically important challenge for the Foundation [1].*

The international nanoscience research and education programs at CAU are being developed as part of the broader programs of the Center for Functional Nanoscale Materials. In 2006, CAU established the Center for Functional Nanoscale Materials for the purpose of:

- •Conducting beneficial and innovative research for the benefit of the Nation and all humanity.
- •Increasing the number of students pursuing graduate and undergraduate degrees in the natural and physical sciences.
- •Enhancing the research productivity of its researchers.

The Center was established at CAU to be both **inter-disciplinary** and **inter-institutional**, and includes Cornell University, University of Illinois, Emory University and Georgia Perimeter College as domestic partners. In 2007, the Center initiated collaborative international research and educational programs with scientists at iThemba Laboratory for Accelerator-Based Sciences (iThemba LABS) and the African Laser Center (ALC). In addition, the Center has been designated as the North American Node for NANOAfnet (Nanosciences African Network). The goals of the Center have been expanded to include:

- The development of a diverse, globally engaged science workforce.

Working within the traditional academic units of CAU, the Center is carrying out activities which will not only enhance research excellence, but is intentional in its design to develop the next generation of globally-engaged scientists. The programmatic elements that are being developed will permit faculty, students and staff from different countries and nations to work together side-by-side and in scientific teams. Examples of our current activities are:

- Research collaboration with the ALC, Pretoria, and iThemba LABS, Somerset West, South Africa. This relationship is being developed around research on composites of gold nanoparticles and synthetic polymer for nanobiosensors.
- Nanoscholars Abroad, a pilot international Research Experience for Undergraduates (IREU) program where students do research at both CFNM and iThemba LABS in South Africa.

## THE NEED FOR INTERNATIONAL SCIENTIFIC PARTNERSHIPS

The distribution of scientific knowledge and the pursuit of new knowledge has shifted from being largely centralized within the so-called developed countries (the G7: Canada, France, Germany, Italy, Japan, United Kingdom, and United States), and is becoming distributed among an increasing number of middle-income countries (e.g. India, Turkey, China, Mexico, Russia, Brazil, South Africa) [2]. The mobility of highly skilled and talented workers and the ready movement of scientific and technological information through electronic communication facilitate the redistribution of scientific knowledge at the global level. Increasingly the global science and technology industries are decentralizing not only their production facilities, but also their Central R&Ds [3]. This trend is expected to keep growing over the next few decades. US students studying

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science and technology will find that their career positions will thrust them into an environment which values global diversity. Because of transformations in the scientific and technological industries, employers will seek employees who have the ability to thrive in the new global science and technology environment. The scientific and technological disciplines in US academia must focus on developing students who will be successful within this emerging global community. Historically, study abroad has been largely limited to the non-science areas, with the natural and physical sciences having few international programs. In order to develop a generation of scientists who are globally engaged and comfortable working in the new environment, US institutions must develop and sustain mutually beneficial scientific partnerships with academic institutions, governmental and industrial laboratories outside the US.

Science has been and is quite global in nature as evidenced by the national origin of scientific publications and patents. Furthermore, the fact that a larger number of countries and regions are becoming scientifically and technologically accomplished translates into the study of problems which are more local in nature. This has been a driving force for the diversification of science and technology into application areas which have been ignored previously, which is particularly important for socioeconomic development in many African countries. At the same time science and technology are becoming increasingly complex and expensive. Therefore, global and regional partnerships are crucial from both an economic and talent aspect. The modern international scientific community by its nature is a network of interacting laboratories through its use of the published scientific literature. A variety of new modes of electronic communication have greatly advanced collaborative possibilities, but it is generally agreed that they do not effectively substitute for meeting face-to face, particularly in collaboration across cultural and disciplinary boundaries.

> *personal interaction helps to build trust and confidence, which are critical to forming collaborations and making them successful. Personal interaction also is key to many capacity-building activities that require the learning of physical skills and exchange of tacit knowledge*. [4]

Thus, given the necessity and benefit of scientific partnerships, the Center seeks to develop international partnerships, which will strengthen its research programs and broaden the experiences of its students. International experience will not only contribute to the training of a new generation of globally engaged scientists but also a cadre of scientists who will successfully address technical and societal problems that cannot be solved locally. An example of a highly successful regional and international partnership is the International Rice Research Institute (IRRI) [5]. IRRI's mission and accomplishments are succinctly stated in the following paragraph from its website:

> *Established in 1960, we are the largest non-profit agricultural research center in Asia, with headquarters in the Philippines and offices in 14 nations. Supported by donors and partners around the globe, we are known as the home of the Green Revolution in Asia. We help feed almost half the world's population. Our mission is to reduce poverty and hunger, improve the health of rice farmers and consumers, and ensure that rice production is environmentally sustainable*.

The Center for Functional Nanoscale Materials has now expanded its goal to include the development of globally-engaged scientists. The Center's goal is consistent with Clark Atlanta University's focus and its understanding of the necessity and value of study abroad. CAU's Study Abroad Program document states,

> *We believe that real education begins with the student's introduction into the global community, where he/she has the opportunity to exchange ideas and discuss differences, in their proper context, in an effort to come to a better understanding of, and have a greater appreciation for, the way of life of other peoples. This type of interaction engenders a new corpus of knowledge which did not previously reside in either of the preexisting cultures, American or the foreign one. This hybrid culture is the new source from which the study abroad student is to drink.*

## PILOT PROGRAM: CFNM AND ITHEMBA LABS, 2009-2010

In 2008, the Center for Functional Nanoscale Materials, received an NSF CREST supplement to carry out a pilot program to develop meaningful and mutually beneficial collaborative relationships with the African Laser Center, Pretoria, and iThemba LABS, Somerset West, South Africa. The pilot program has been developed around the research topic "Gold Nanoparticle/Synthetic Functional Polymer Nanofibers (Nanocomposites) by Electrospinning: Novel Materials for Amperometric and Photonic Bionsesors". The collaborative study is being carried out with the intention that this study will lead to the development of mutually beneficial long term research and education collaborations among CFNM, ALC and iThemba LABS. The research team comprises senior scientists, undergraduate and graduate students trained in biology, chemistry, mathematics and/or physics. The current senior scientists for this collaborative effort are: Drs. Khan, Msezane, Reed, Williams (CAU, CFNM), Maaza (iThemba and NANOafnet) and Aboubaker Beye (ALC and NANOafnet). With this supplement we also piloted an IREU program during the summer of 2009, in which four (4) summer REU students engaged in nanoscience research for eight weeks, two weeks at CFNM and six weeks at iThemba LABS.

The 2009 Nanoscholars Abroad Program was a pilot effort and among our goals was to move towards development of a sustainable and externally funded IREU. For this we developed a "student-centered' program which

is sensitive to the needs of not only CAU students, but also to the participants in CAU summer research program, many of whom come from regional HBCU's with less research capacity.

*Program Requirements*

Participation in the program was open to undergraduate students, who were majoring in one of the science or mathematics disciplines and who planned to attend graduate school after graduation. Applicants were required to be rising sophomores, juniors or seniors in good academic standing at their home institution. Interested students could apply as early as possible by completing the application found on the CFNM Web site [6]. Applicants were required to be US citizens or permanent residents. All applicants had to have a valid passport (or immediately apply for a passport) that was valid throughout the program period. Applicants were required to submit an official undergraduate transcript as well as an essay (200 words or less) on their science interests and what they expected to accomplish in their career. In addition, two letters of recommendation were required, at least one of which had to be from one of the candidate's college science instructors. The deadline for applying was April 1, 2009.

*The Application Process*

To advertise the Nanoscholars Abroad Program, we mailed over one hundred posters promoting the program to US institutions, and every effort was made to ensure all the HBCUs and other MSIs were informed about the program. The CFNM Web site was redesigned to include a detailed description of the program.

Online Application instruction was as follows*:* Step One: Print out or save to disc the application form accessible via the Online Applications button on the left of this Web page.

Step Two: Arrange to have your transcript from your current undergraduate institution sent to the address given on the application form.

Step Three: Secure a valid passport or verify the validity of your passport for the time of the program.

Step Four: Arrange to have two letters of recommendation sent to the address on the application form.

Step Five: Prepare a 200-word essay on your science interests and what you expect to accomplish in your scientific career.

Step Six: Send the application form and essay to the address on the application form.

Completed applications received by April 1, 2009 were quickly processed and by April 15, 2009, we had informed successful applicants of their acceptance into the program. Accepted applicants were given a timeline, to confirm to us that they had had the necessary vaccinations, passport requirements, insurance and other trip preparations.

*Applicant Selection*

For the Nanoscholars Abroad Program, a total of twenty-nine complete applications were received from students at 14 undergraduate institutions (including 11 MSIs). Seventy five percent of the applicants were female, 29% were sophomores, 18% juniors, 41% seniors, and of those who had declared majors, 50% were chemistry, 29% were biology, and 21% were mathematics. Cumulative GPA's of applicants ranged from 2.5 to 3.89, with a mean of 3.29 and a median of 3.5.

From the pool of applicants, the committee (composed of Drs. Khan, Williams and Msezane) selected three (3) females and one (1) male from four (4) different institutions (CAU, Savannah State University, Winston-Salem State University, and Emory University). Three of the accepted applicants were seniors and one was a junior, with majors in Chemistry and Math. Three of these students had previously travelled abroad (Mexico, Germany, and Ghana); all had previously participated in undergraduate research at their home institution and/or other institutions. Applicants were given ten days to respond to the offer.

TABLE I

| **PROGRAM DEADLINES AND ACTIVITIES** | |
|---|---|
| 21 May | Complete vaccinations |
| 25 May | Deadline for Passport Verification |
| 1 June | Complete pre-trip checklist |
| 7 June | Participants arrive in Atlanta |
| 8 June | Program Part One<br>• laboratory health and safety<br>• travel and living abroad<br>• project literature research<br>• using technical literature<br>• introduction to the nanosciences<br>• introduction to quantum mechanics<br>• introduction to characterization techniques<br>• research Phase One |
| 20 June | Pre-departure Celebration |
| 21 June | Departure for South Africa |
| 23 June | Program Part Two |
| | Outings to Cape Town<br>• Cape of Good Hope<br>• Garden Parkway<br>• Khayelitsha Township<br>• Johannesburg,<br>• Pretoria<br>Research Phase Two with Instrumentation & Collaborators<br>• University of Cape Town<br>• University of the Western Cape<br>• Stellenbosch University<br>• African Laser Center<br>• Tshwane University of Technology<br>• National Research Foundation, |
| 31 July | Return to United States |
| 6 August | Final Report due |
| 7 August | Final stipend check mailed provided required materials are received |

Figure 1.

**Program Rules and Guidelines**

The Participants in the Nanoscholar Abroad Program are legal adults and have been selected not only for their intellectual abilities but also because of their maturity and focus. This having been said, it is nonetheless necessary to establish minimum rules and guidelines that will help insure the safety of the Participants as well as the realization of the Programs goals.

1. It is expected that Participants will be productively involved in Program activities at least forty hours per week. Both the stipend and continuation in the program are based on this level of commitment. Participants are entitled to three work days (non-weekend days) for their personal use. However, these days must be approved by their supervisor at the Host Site and the local CFNM administrator.
2. When abroad the local CFNM administrator is solely responsible for the supervision of the Participants and decisions the safety of Participants and operation of the Program.
3. Participants are expected to comply with local laws at all times.
4. Use of illegal drugs by Participants will not be tolerated.
5. The CFNM does not condone, condemn or regulate the use of alcohol. However, Participants are expected to be compliant with all local laws that govern the use of alcohol.
6. If in the opinion of the local CFNM administrator's it is in the best interest of the Program a Participant may be sent home. Should this be necessary;
   - The Participant is expected to return home as soon as transport can be arranged.
   - The Participant's stipend will be prorated based on the date that the decision was made to send the Participant home.
   - Any additional expense resulting for a Participant being sent home prematurely will be charged against the Participant's stipend.
   - Should the Participant fail to return home as per arrangements made by CFNM, CFNM becomes no longer responsible for returning the Participant to the United States.
7. Participants may not take part in behaviors that endanger the safety of others or the successful completion of the Program.

*Program Implementation*

The summer 2009 (June- July) program for the four (4) summer IREU students took place over eight weeks, two weeks at CFNM and six weeks at iThemba LABS (See Program timeline and details Table I). During the first two weeks, the students were housed in the Clark Atlanta dormitories, and board was provided for in the student cafeterias. The IREU students were joined in the dormitories and in many scientific activities by eight (8) undergraduates in the Center's domestic summer REU program, who were engaged in research for 6 weeks at CAU. The students were introduced to nanoscience research which included hands-on fabrication of nanofibers by electrospinning and fiber characterization by SEM and AFM. During this period, all four IREU students were integrated into the collaborative research team project and specific roles/functions were assigned. Ms. Laurisa London, a doctoral student at Clark Atlanta University, served as Nanoscholar group leader. In addition to hands-on experiments, all students participated in a Problem Based-Learning workshop and a weekly Journal Club led by CAU graduate students. A booklet with health information, the travel checklist, cultural and practical advice on day-to-day living abroad in South Africa and program rules and


Figure 2: CFNM team (a) with colleagues in front the Materials Research Building and (b) in front of the Main Building at iThemba LABS

guidelines (Fig 1) was developed and made mandatory reading for the students. The Clark Atlanta University study abroad Director, Dr. Paul Brown, held a workshop for the Nanoscholars Abroad on traveling and living abroad.

On Monday, June 22, 2009, the five Nanoscholars Abroad accompanied by Drs. Khan and Msezane travelled to Cape Town (via Johannesburg). In Cape Town, the team was received by Dr. Malik Maaza. Housing for the team was arranged by iThemba LABS personnel and the team was housed in condominiums, in Strand, with excellent views of the Ocean. Strand (Afrikaans for 'beach') is a seaside resort town on the northeastern edge of False Bay and at the foot of the Hottentots Holland Mountains. The accommodations were excellent and the team is grateful to our South African colleagues and host for their overall hospitality. Strand is located twenty-five kilometers from the iThemba LABS and local transportation was arranged by our host. The six-week stay in South Africa was productive for the collaboration. In addition to the students carrying out quality research in nanoscience, they had the opportunity to interact with physicists, chemists, engineers and computational scientists from throughout Africa (Morocco, Cameroon, Nigeria, Tanzania, as well as South Africa) and other parts of the world. Faculty participants were able further develop the collaboration with our South African colleagues, and generate new collaborative opportunities. The students, in addition to working at iThemba LABS, also carried experimental work at the Stellenbosch University (AFM, preparing electronic chips using photolithography) and University of Cape Town

(TEM) and University of the Western Cape (FTIR). Additionally, our host arranged for visits by the US group to the Tshwane University of Technology, the National Research Foundation and National Laser Center, in Pretoria, South Africa. The cost for this particular trip was graciously covered by iThemba LABS.

During the six-week stay in South Africa, at any given time; our programmatic structure included the presence of at least one CFNM/CAU faculty with the student team. In fact, except for a one week period, at least two CAU faculty members were present with the student team. This was an important aspect of our program and most likely is the reason why the program operated smoothly. Drs. Msezane and Khan were replaced by Drs. Reed and Williams at the halfway point of the program. The faculty not only worked as part of the team but also facilitated several trips for the students during the weekends. Figure 2 and 3 are photographs of the team at iThemba LABS and during the visit of the team to the Cape of Good Hope.

*The Collaborative Research Project*

Essential to the success of the Program was an ongoing research collaboration between the laboratories in the CFNM and those at the iThemba LABS. The collaboration

Fig. 3: Figure 3: CFNM team (a) visiting an African Penguin Colony and (b) at Cape Point

was concerned with the functional nanostructures that have had a wide variety of applications including their utilization as the active components in nanobiosensors. An effective method for preparing functional nanostructures is electrospinning. Under investigation is the preparation of nanostructures which have embedded with gold nanoparticles. The importance of gold to the South African economy was an element in project design.

The gold nanoparticles required for this investigation were prepared by two methods. The first is a technique known as the liquid-liquid interface method. The nanoparticles were prepared at the interface of a solution of a gold derivative dissolved in toluene and an aqueous layer containing a reducing agent. The gold nanoparticles were formed at this interface. Gold nanoparticles prepared by the liquid-liquid interfacial method show an even spacing among the nanoparticles, from which it can be inferred that there is a bonding interaction occurring among the nanoparticles.

The second method used to form gold nanoparticles was a one-phase synthesis technique. The particles were prepared in a solution containing a nonionic surfactant and a gold salt. In one-phase synthesis, some of the gold nanoparticles, which formed were suspended freely in solution, but most settled to the bottom of the reaction vessel. The gold nanoparticles ranged in diameter from approximately 3 to 43 nm. Figure 3 shows a TEM (transmission electron microgram) of gold nanoparticles, prepared by the liquid-liquid interface method. Furthermore, some of the gold nanoparticles formed with faces that were perfect polygons. Investigation of gold nanoparticle growth dynamics was carried out using UV-Visible spectroscopy and measurements of the refractive index.

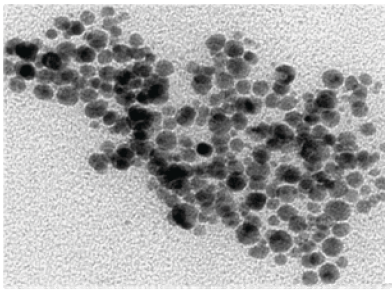

Figure 3: TEM of gold nanoparticles

Nanofibers were electrospun from a solution containing poly(vinylalcohol) and gold particles. Careful control of the viscosity of solutions used for electrospinning are necessary, in order to form long fibers with small diameters. Polyvinyl alcohol and 0.05 millimole of gold nanoparticles were combined to form a 21% (w/w) solution. This nanocomposite solution was electrospun onto several substrates: glass, indium tin oxide (ITO), silicon, ITO on plastic and aluminum foil. Characterization of the fibers and gold nanoparticles was carried out using AFM, SEM, TEM, ATR, UV- Visible spectroscopy, and STM. Scanning electron microscopy was used to examine the gold/PVA nanofiber composites that had been electrospun onto several different substrates for different amounts of time. These studies indicate that the electrospinning was successful, however there was very little alignment of the fibers. The ITO-PET and the aluminum substrates showed almost no alignment of the fibers, and the gold/silicon lithography and the plain silicon substrates showed some alignment towards the edges of the substrates. The fibers also appeared to have a larger diameter than desired (<100nm). We anticipate that the diameter can be decreased by increasing the voltage used for electrospinning.

Currently, we are developing conditions for preparing fibers with smaller diameters and we are also developing strategies to ensure a better distribution of the nanoparticles within the electrospun fibers. Once the appropriate conditions have been developed, functionalized nanofibers will be prepared and then used as the active component in nanobiosenors.

On July 31, 2009, the CFNM team returned to Atlanta after a highly successful summer research engagment.

## PROGRAM EVALUATION

The pilot IREU has been evaluated and we plan to use the data from evaluation to develop a regular NSF funded IREU. Questionnaires to record the students' opinions about their knowledge, plans, and other aspects of the program were administered at the beginning of the program to both IREU and domestic REU students, and again in a more extensive form at the end. Several of the applicants we accepted into the Nanoscholars Abroad Program had also applied to and been accepted in other summer programs. Their declared reasons for participating in this program included:

"*Experience of traveling abroad, cultural diversity in the science world*"

"*Stipend, faculty, length of program, university reputation*"

The most important value of the Nanoscholar Abroad Program for the students included:

"*Being able to work with a wide range of students from different places, therefore being able to see different viewpoints and different ways of attacking a problem*"

"*I found that I much rather work alone with the help of faculty*"

"*An immersive experience of cultures, personal experiences and scientific research*"

"*Domestic and overseas research experiences would provide a different value for me because [my overseas experience allowed] me to gain another perspective in [how one's] life experiences effect how one sees research*"

"*It was a very peaceful and learning-friendly environment*"

"*This program provided a great learning experience in the field of science, and learning about other cultures*"

The program had positive effects on the future career plans of our students:

"*I'm very interested in working as part of the global economy*"

"*The global influence, not only where we are interacting with local South Africans, but also individuals from all over the world*"

"*I have declared my interest in a career in research and teaching*"

"[*I'm now] interested in doing research in nanotechnology in graduate school!*"

"*I would like to continue work on the research I have started with the program*"

As illustrated in Figure 5, the student group's perceived knowledge of the concepts underlying nanotechnology increased by a more than a full point (on a 5 point scale). Similarly, their interest in pursuing a career in nanotechnology significantly increased, and there was a marginal increase in the students desires to pursue a career in scientific research. Their overall interest in pursuing graduate study did not significantly change, nor did their excitement about how nanotechnology can improve the world, nor their interest in nanotechnology research. In comparison to the group of domestic REU students, the

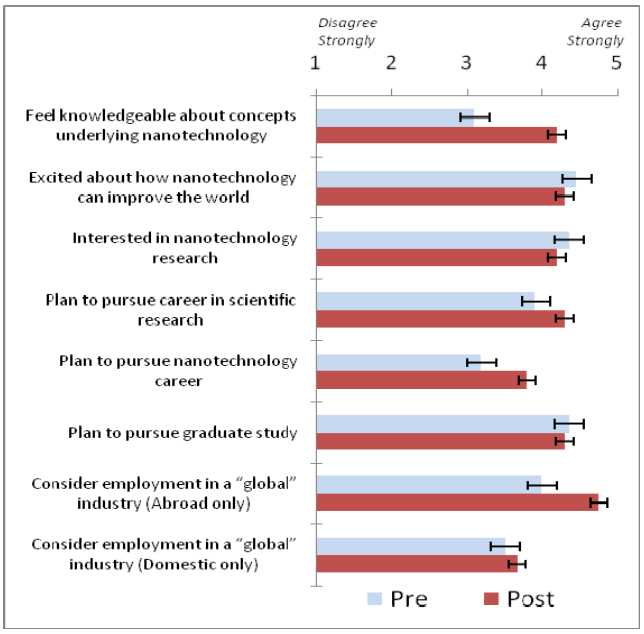


Fig. 5: Effect on Student Attitudes & Plans. Error bars represent 1 standard deviation

Nanoscholars Abroad began with greater interest in employment in a global industry. Strikingly, this interest of Nanoscholars Abroad students increased following their research experience in South Africa, while the interest of the Domestic Nanoscholars in global industries did not change significantly.

## CONCLUSION

The formal collaboration and partnership of CFNM with iThemba LABS has been successfully implemented. Based on our research outcomes and a better understanding and appreciation of our colleagues in South Africa, we will keep moving forward in a very holistic manner i.e. science, culture and friendship integrated in all our efforts. This is the first time we operated a summer IREU and it was a success, resulting in positive scientific and educational outcomes. We will use our programmatic element from this summer IREU to formally develop Clark Atlanta University into an international REU site for South Africa.

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