2007

# NEXT GENERATION BIOMETRICS:

## Achieving Strength in Molecular Recognition and Transport

WEST VIRGINIA **EPSCoR**

Annual Report to the
National Science Foundation

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## Achieving Strength in Molecular Recognition and Transport

West Virginia's **Research Infrastructure Improvement (RII)**
**Award # EPS - 0554328**

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# OVERVIEW

## NEXT GENERATION BIOMETRICS:

### ACHIEVING STRENGTH IN MOLECULAR RECOGNITION AND TRANSPORT

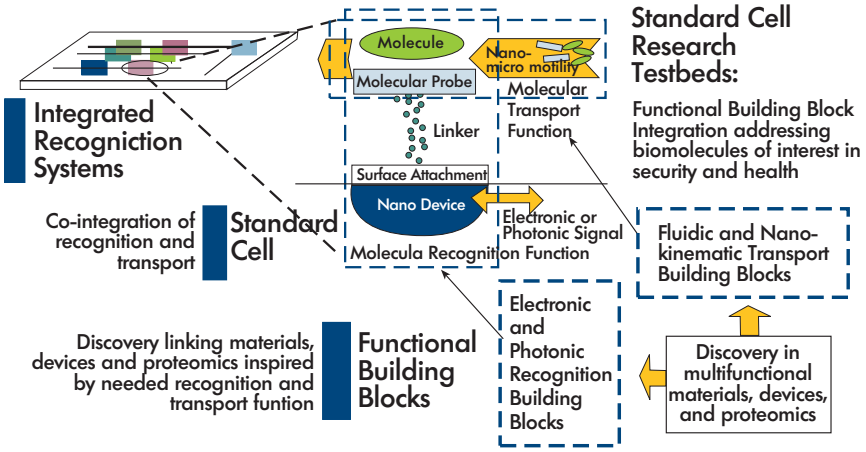
West Virginia's Research Infrastructure Improvement grant

This award is focused on creating a world-class capability in molecular recognition, more specifically "molecular biometrics." Robust, low-cost instruments that can quickly and reliably identify minute quantities of molecular species will provide great advances in homeland security, health, forensic science, and other fields.

A center of research excellence in this field is a logical and realistic extension of established and emerging research and education programs in biometrics, nanotechnology, forensics and molecular biology at West Virginia University, Marshall University and West Virginia State University. Although this research program has its genesis in physiological identification technologies, its potential application is envisioned to include many scientific fields.

**RII RESEARCH OBJECTIVE.** Chip-level integrated recognition systems capable of renewable and rapid direct detection of a spectrum of molecular targets are of intense interest to the security, defense, and health communities. As with mature integrated technologies, a standard cell approach to building complex system functions from key device functional building blocks will ultimately emerge. This notion of standard cell recognition devices provides a useful conceptual framework within which to see the challenges facing realization of these systems and to motivate our central research objective. (See Figure 1.)

**Figure 1:** Integrated Recognition System Design




At the functional building block level, research individually advancing molecular recognition and transport is an area of growing interest. The 2002 RII defined and strengthened our core capacity for discovery in materials, devices, and proteomics. We have successfully achieved nucleation of critical interdisciplinary teams connecting these core groups, which are now addressing discovery targeting needed functional building blocks. The standard cell level is characterized by co-integration of specific molecular recognition and transport building blocks to achieve a desired recognition device function. Connectivity to the chip-level molecular transport network not only defines overall chip-level system function, but also establishes the material interface with the macro-world. This complements the electronic and photonic interface required for the physical transduction of molecular recognition.

Despite its importance, the standard cell level remains comparatively under-explored in part due to the added challenges it presents. These include co-integration of a range of potentially multifunctional materials and design of not only the recognition components (e.g., transduction device and biolayer for specific probe and target combinations) and transport components (layout, field strengths, electrode structure, fluid dynamics) individually, but also their interdisciplinary co-design.

Based on external assessments of our research strengths and the fact that our interdisciplinary groups are still at a relatively formative stage has given us a unique position to solidify research in functional building block areas around achieving testbed standard cell device functions of application interest. Through these testbed efforts, solid contributions to the field can be made, and the basis of strength established. As a result, our RII research objective is to identify enabling technologies for achieving viable integrated molecular recognition standard cells through the testbed exploration of novel co-integrated molecular recognition and transport functional building blocks. Our selected testbed device standard cells will be inspired over the project period by an evolving set of security and health applications. Based on current research efforts, biomolecules of interest are bioagent and chromatin/histone targets and enzyme probes.

## STRATEGY AND TARGETED ACTIVITIES.

Our strategy to achieve this objective has four elements.

1. Organizing our research plan, teams and group collaboration dynamics around functional building blocks with which to construct integrated molecular recognition testbed devices.
2. Building and bridging cross-cutting faculty team through strategic cluster hires and development of early career faculty, mid-career faculty and hires of postdoctoral associates at WVU and MU.
   These hires will address barriers to the pursuit of testbed-inspired research.
3. Building strategic collaborative relationships with academic and industry partners which help bridge our capability voids, complement our strengths and accelerate targeted research.
4. Enhancing, institutionalizing and continually improving the shared facility and academic environments necessary to promote discovery and learning activities of these groups and the institutional initiatives and culture changes that these groups' activities have precipitated.

To date, 8 of 11 faculty hires have been completed. Thirty-five faculty members from all three universities are working in collaborative research teams to achieve our research objective. Collaborative relationships with industrial and government partners through the NSF-funded Center for Identification Technologies Research at WVU have grown with the growing molecular biometrics research enterprise in West Virginia.

## **ACTIVITIES** AND FINDINGS (Year Two):

Because project activities and spending were begun to correspond with the State's fiscal year (July 1) and the Year One report covered the six months between July-December 2006, the Year Two report covers the period from January-December 2007.

### **ADMINISTRATIVE** ACTIVITIES

**The Division of Science and Research,** West Virginia Higher Education Policy Commission, **provides strategic leadership** for **infrastructure advancement** and **development of competitive research in science, technology, engineering** and **mathematics (STEM) disciplines.** The office also coordinates **scientific research grants to academic institutions** from federal agencies, especially the National Science Foundation's **Experimental Program** to **Stimulate Competitive Research** (EPSCoR)**,** and **administers state-based awards** from the **West Virginia Research Challenge Fund.**

WVEPSCoR central office personnel have been managing the financial, communication and administrative tasks for the project. Second-year funding increments have been added to university sub-awards via amendments to those agreements.

WVEPSCoR staff and the WVEPSCoR Advisory Council have been working to implement Vision 2015, the state's science and technology strategic plan. Through the efforts of Paul Hill, WVEPSCoR project director and RII award principal investigator (PI), and the council, **Governor Joe Manchin proposed a $50 million investment in STEM eminent scholars** during his 2008 State of the State address. The State Legislature has passed the bill which became effective on passage. The WVEPSCoR office is drafting emergency legislative rules to provide the details of how the funds will be used and monitored. This bill provides matching funds to new fundraising by West Virginia University (WVU) and Marshall University (MU) for research endowments that can be used to attract highly qualified STEM research faculty to West Virginia. Hill has been named vice chancellor for science and research and will be responsible for managing the West Virginia Research Trust Fund for the West Virginia Higher Education Policy Commission. This investment by the State of West Virginia is an indication of a shift in policy toward a more knowledge-based economy and the sustainability of the EPSCoR investment in West Virginia's molecular biometrics research enterprise.

RII award participants continue to report research activities /findings and Education, Human Resource Development and Outreach (EHRDO) activities to the WVEPSCoR office on a semi-annual basis. Rose Shaw, external evaluator for the project, is actively evaluating the project and is in constant communication with WVEPSCoR staff and the Executive Leadership Team (ELT) so the project can be managed to meet its goals.

WVEPSCoR has greatly expanded its **outreach and communications** efforts over the past year. A communications manager was hired in January 2007. The following is a summary of communications/outreach activities completed during the year.

The **office's quarterly newsletter, The Neuron,** was re-designed, expanded and refocused this year to be a more comprehensive view of the scientific research community in West Virginia. In addition to including a greater volume of news relevant to the research community at large, the newsletter highlights research/economic development advancements made possible through EPSCoR funding. Each issue of The Neuron contains at least one faculty profile and at least one tech-transfer /tech-based economic development article. The "News and Announcements" section of the magazine recognizes research faculty for professional accomplishments, including publications and professional/honorary organization activities.

The **WVEPSCoR website** was also expanded to include more up-to-date information about research developments and opportunities. The "Press Center," which is used for news releases and articles related to WVEPSCoR programs and services, was revised and is being updated on a regular basis. Another new feature of the

website, "West Virginia Research Forum," serves as a clearinghouse and blog for news and information related to the state and national research community. The forum is updated on a regular basis and viewers can comment on postings.

**WVEPSCoR and the state's research enterprise have been frequent subjects in the popular press.** Stories have appeared in local and national magazines, local and statewide newspapers and on the op-ed pages of the largest circulation newspaper in the state.

In a commentary, titled **"Sputnik ,"** Dr. Paul Hill and Jay Cole argued that **it is time for another science education drive in the United States**

WVEPSCoR was featured in the February 2007 issue of State News, the monthly magazine of The Council of State Governments. The article, "Learning to Compete: The EPSCoR Experience in West Virginia," was co-authored by Governor Joe Manchin and West Virginia Senate President Earl Ray Tomblin. The article focuses on how West Virginia has benefited from its participation in the national EPSCoR program.

The spring 2007 issue of Views & Visions, published by the law firm of Bowles Rice McDavid Graff & Love, featured an article by Hill titled, "Technology-Based Economic Development: The Brightest Star in West Virginia's Future." The entire issue was devoted to research and technology-based economic development in the Mountain State.

The spring 2007 issue of **Capacity Magazine,** published by the Robert C. Byrd Institute for Advanced Flexible Manufacturing in Huntington, included an article, "Building Intellectual Capital: Stimulating Ingenuity and Innovation in West Virginia," by Hill.

Governor Joe Manchin's weekly column for March 23, 2007, titled, "Research is a Good Investment for West Virginia," was drafted by WVEPSCoR staff. The column was distributed to newspapers and other publications statewide by the governor's communications staff.

Hill met with **Charleston Gazette** editorial page editor Dawn Miller to talk about the importance of research and the EPSCoR program in West Virginia. As a result, Miller wrote an editorial, "Plenty of Room in Research Pool," in the March 24, 2007, edition of the newspaper.

WVEPSCoR placed two op-ed commentaries this year in Charleston's daily newspapers. The first, "Research, Technology Lead to Brighter Future," was written by Hill and made the case for investing more in research and technology development at both the state and national levels. It was published in the Charleston Gazette on May 8, 2007.

The second op-ed commentary, co-written by Hill and Jay Cole, education advisor to Governor Joe Manchin, appeared in the Oct. 7, 2007, issue of the Sunday Gazette-Mail. In the commentary, which was titled "Sputnik: It's Time for Another Science Education Drive in the United States," Hill and Cole argued that it is time for another science education drive in the United States and cited the America COMPETES Act.

**Consortium on Undergraduate Research and Engineering (CURE)** - WVEPSCoR staff collected information about K-12/higher education STEM partnerships and developed a website (www.wvcure.org) to facilitate sharing of reports prepared by members of the statewide CURE committee.

**"Lab 304" Public Television Series** - Officials at WVEPSCoR and West Virginia Public Broadcasting (WVPB) have signed a memorandum of understanding to collaborate on a series of television news segments focusing on science, technology and research in West Virginia. The series, called "Lab 304," will be part of WVPB's weekly news and public affairs television program "Outlook." WVEPSCoR provides story ideas, technical expertise and underwriting support for the series. Filming for the series began in October 2007. The first "Lab 304" episodes began airing in early 2008. The first two episodes are available online and can be viewed by visiting www.wvresearch.org and clicking on the "Lab 304" link on the left.

**STaR Symposium** - More than 170 members of West Virginia's business, science, technology and research communities gathered at WVEPSCoR's statewide Science, Technology and Research (STaR) Symposium in Morgantown on Sept. 17-18, 2007, to share developments, ideas and collaborations.

More than 40 students in both undergraduate and graduate categories presented their work in poster sessions and competed for best poster.

The participant evaluations were very positive, with the quality of the overall symposium rated "Excellent" by most of those who responded to the survey. The symposium planning committee met in November to evaluate the symposium and make preliminary plans for the next event, which will be held in April 2009.

"Science Education and Research at Primarily Undergraduate Institutions" Forum - This free forum for research administrators and faculty at West Virginia's 17 undergraduate institutions of higher education was held in Charleston on Dec. 17, 2007. The program featured speakers and panel discussions focused on the role of undergraduate institutions in West Virginia's growing research enterprise; information about undergraduate opportunities provided through WVEPSCoR and the State's Research Challenge Fund (RCF); and an opportunity to provide state policymakers with feedback about the needs of the undergraduate research community. More than 95 percent of respondents to the follow-up survey rated the quality of the overall forum as either "Good" or "Excellent."

Visit from National Science Foundation (NSF) Director - NSF Director Arden Bement visited WVU's nanotechnology and biometrics facilities on Dec. 3, 2007. While in Morgantown, he met with WVU President Mike Garrison, as well as WVU research faculty and students. Bement also hosted a roundtable luncheon for researchers and members of West Virginia's high-tech business community to discuss how to advance innovation and meet the challenges of global competitiveness. Congressman Alan Mollohan (D-WV) joined Bement for the site visit and roundtable luncheon.

NSF Day in West Virginia - Nearly 200 state researchers and research administrators participated in an "NSF Day in West Virginia" workshop in Morgantown on Dec. 4, 2007. Representatives from the seven NSF directorates and the Office of International Science and Engineering made presentations about their programs and were available individually for specific discussions about potential research proposals.

Her Lab in Your Life: Women in Chemistry - WVEPSCoR co-sponsored this national traveling exhibit in conjunction with the American Chemical Society, Dow Chemical Company's Women's Innovation Network and MU. The exhibit, which explores the role chemistry plays in everyday life and the contributions women have made to the field, was on display at St. Albans High School in January and February 2007. It then traveled to the MU campus, where it was on display through March.

WVEPSCoR co-sponsored Undergraduate Research Day at the Capitol on Jan. 31, 2007. The annual event highlights research projects conducted by college and university students from around the state. Student research projects were displayed in the Capitol Rotunda and outside the House and Senate chambers. In a special ceremony, Governor Joe Manchin presented $1.2 million in grants to help advance scientific research at West Virginia's colleges and universities. The grants were funded primarily through the RCF, which is managed by WVEPSCoR.

To promote the state's research agenda, fact sheets, talking points and graphs to help illustrate WVEPSCoR's impact were developed and distributed to policymakers during the 2007 session of the State legislature. WVEPSCoR continues to provide information and data on science and research to legislators and other policy-makers statewide.

## SPECIAL AWARD CONDITIONS

**1. WVEPSCoR will submit within the first two months of the award's effective date, a three-year strategic plan aimed at ensuring the successful recruitment and retention of the new research positions, including specific timelines and progress indicators.**

**Hiring update:** The West Virginia RII award proposal included the hiring of 11 science and engineering faculty members to populate the interdisciplinary research teams. Through December 2006, WVU hired the following five faculty members to participate in Functional Building Block Group (FBBG) work: Andrew Cao, Lloyd Carroll, Nick Wu, Feruz Ganihkanov and James Lewis. Two of these faculty members (Cao and Wu) are in the College of Engineering and Mineral Resources and three others (Carroll, Ganihkanov and Lewis) have been hired in the Eberly College of Arts and Sciences. MU hired Elmer Price to lead the biomolecular research team and Bin Wang in the Chemistry Department. Wang has research interests in RNA biochemistry and nanotechnology. Both MU hires have been completed.

At WVU, permission was received from the Office of Social Justice to conduct targeted searches for individuals from protective classes. Representatives of two of the colleges and the Provost's Office attended the annual Southern Regional Education Board (SREB) Minority Doctoral Conference in Arlington, VA, on Oct. 25-27, 2007, to identify and recruit individuals for the four advertised positions. The targeted search process allows for any faculty member of the WVNano Initiative to nominate an individual for any of the fourpositions.

A department-based search committee with representatives from the respective department, the WVNano Initiative, and in some cases from a dean's office, were appointed to each committee. Each committee is permitted to advertise for each position in addition to identifying specific individuals directly. Thus, the searches were changed from WVNano Initiative centric to departmental centric as a potentially more successful approach to recruiting individuals to the positions. Each dean confirmed they would accept a candidate into one or more specific departments within their college if offers of hire were made.

The West Virginia RII award proposal included the hiring of **11 science and engineering faculty members to populate the interdisciplinary research teams.**

The office of the vice president for research and economic development and the provost's office provided assurances that support for new hires could be extended from three years to four or five years, if necessary, before colleges were expected to assume payment of salary for new hires, in order to ensure that college administrators were willing to place a new hire into a particular department.

WVU has recently hired Dr. Letha Sooter for the nanobiosciences position in the Department of Biology. An offer is being extended to another female candidate for a second position in active nanostructure-based devices in the Lane Department of Computer Sciences and Electrical Engineering. A female is being interviewed on March 10-11 for the nanoscale science and engineering position in the Department of Chemical Engineering. A targeted candidate has not yet been identified for the position in supramolecular devices within the School of Pharmacy. Targeted searches are continuing until all hires have been completed.

WVU President Garrison established a dual career program (http://www.dualcareer.wvu.edu) during fall 2007 to support spousal hires as a way to encourage more candidates to accept positions at WVU. See http://wvutoday.wvu.edu/news/page/6062/ for the program announcement, which includeda campuswide coordinator.

The search for a founding director of the WVNano Initiative at WVU was unsuccessful in 2005. Consequently, co-directors were appointed from the senior WVNano faculty in June 2006 to provide leadership of the initiative and the RII project. The co-director approach has worked very well, but now the process to identify a permanent director is being refined to begin the search process in early spring 2008. The intent is to have a permanent director in place by the close of 2008. The interim vice president for research and economic development is meeting with the WVNano Deans' Advisory Board and the co-directors to develop the process for searching and screening. These discussions also will include the provost, so all administrative leaders are in accord as to the most effective methods for recruitment. The intent is to search for a candidate who will provide both administrative leadership and research oversight.

**2. Broadening participation: Using FY 2005 as a baseline, the annual progress report must identify the numbers of women and members of other underrepresented groups in staff positions and as participants in the activities funded by the award.**

Our pursued outcome is a diverse, internationally competitive and globally-engaged West Virginia workforce of scientists, engineers and well-prepared citizens. The tables below show progress made versus FY2005 levels. The FY2007 data were recorded in LSAMP WebAMP. LSAMP Baseline data are 5-year averages from AY 2000-2005.

## **PROGRESS** INDICATORS

| UREP Minority STEM | UREP Minority STEM Graduates Minority Undergrad Students | | | Bachelors Degree | | | PhD and Masters Degrees Awarded | | |
|---|---|---|---|---|---|---|---|---|---|
| | WVU | MU | WVSU | WVU | MU | WVSU | WVU | MU | WVSU |
| Proposed FY2007 | 152 | 50 | 66 | 23 | 7 | 4 | 4 | 2 | 1 |
| Actual Metrics | | | | | | | | | |
| LSAMP Baseline | 142 | 45 | 60 | 22 | 6 | 3 | 4 | 2 | 0 |
| FY2007 | 231 | 142 | 20 | 26 | 5 | 21 | 0 | 4 | N/A |

Enrollment numbers of underrepresented students in STEM undergraduate majors show a strong increase at WVU and MU, exceeding the milestones for FY2007. Bachelors Degrees awarded to UREP Minority STEM students have increased at WVU and WVSU. UREP Minority STEM graduate degrees have shown no increase, although this is not unexpected since the EHRDO programs and LSAMP have only been undertaken since the summer of 2007.

## **PROGRESS** INDICATORS (EHRDO Activities are for Summer 2007)

| | Total Number of Women and Minorities in FBBG Faculty Positions | | Number of Women and Minorities in Project Activities | | | Number of Women and Minorities as Role Models EHRDO Activities | | |
|---|---|---|---|---|---|---|---|---|
| | WVU | MU | WVU | MU | WVSU | WVU | MU | WVSU |
| Proposed FY2007 | 1 | 2 | IE | IE | IE | IE | IE | IE |
| Actual Metrics | | | | | | | | |
| FY2005 Baseline | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| FY2007 | 1 Hispanic | 1 White | 14 | 2 | 25 | 2 | 0 | 6 |

Because the FBBGs were only developed at the initiation of this RII project, the 2007 data are the women and minorities initially engaged in the project. During FY2007, there were a total of 41 women and minorities involved in project activities. For EHRDO activities, 8 women and minorities served as role models.

Currently, FBBGs have one Hispanic man and one woman among the scientists. This did not meet our expectation of three minority and women scientists in 2007. However, strategies to increase this number as described in the hiring section have resulted in an additional female hire to date and an offer tendered to another.

# **PERFORMANCE INDICATORS:**
## DISAGGREGATED FBBG STUDENT AND POST-DOC DATA

## **ACTUAL** PROGRESS INDICATORS FOR FY2007

Disaggregated Demographics of Undergrads, MSs, PhDs and Post-docs Working with FBBG Faculty

| Marshall University | Total US | Race/Ethnicity of U.S. Citizenry | | | | U.S. Citizenry | | International Students | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Citizenry | African American | Hispanic | Pacific Islander | Percent UREP | Disabled | Women | Total | Men | Women |
| Undergrads | 9 | 1 | 1 | - | 22% | | 3 | 1 | 1 | 0 |
| Masters | 3 | - | - | - | 0% | | 2 | 1 | 1 | 0 |
| PhDs | 2 | - | - | - | 0% | | 0 | 0 | 0 | 0 |
| Post-docs | 2 | - | - | - | 0% | | 0 | 5 | 4 | 1 |
| TOTAL | 16 | 1 | 1 | - | 13% | | 5 (31%) | 7 | 6 | 1 (14%) |

Because of missing WVU FBBG data, breakdowns for major categories are displayed on the next page, followed by a table displaying disaggregated data.

[1] These only include Chemistry majors; LSAMP data are incomplete.
[2] These data have been requested by LSAMP at WVU.
[3] IE will be the number of women and minorities initially enrolled or participating in each of the grant activities.

## **WVU** FBBG

| | US Citizenry N = 67 | International N = 30 |
|---|---|---|
| Undergraduates | 24 | 1 |
| Masters | 3 | 7 |
| PhD | 17 | 15 |
| Post-doc | 8 | 1 |
| Unknown classification | 12 | 6 |
| | | |
| Male | 48 | 21 |
| Female | 19 | 9 |

WVEPSCoR is **developing a workshop** tentatively titled **Increasing Student and Faculty Diversity in STEM Fields.**

## **ACTUAL** PROGRESS INDICATORS FOR **FY2007**

Disaggregated Demographics of Undergrads, MSs, PhDs and Post-docs Working with FBBG Faculty

| West Virginia Virginia University | Total US Citizenry | Race/Ethnicity of U.S. Citizenry | | | | U.S. Citizenry | | International Students | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | African American | Hispanic | Pacific | Percent | Disabled | Women | Total | Men | Women |
| Undergrads | 24 | 2 | - | - | 8% | | 12 | 1 | 1 | - |
| Masters | 3 | - | - | - | | | - | 7 | 5 | 2 |
| PhDs | 17 | - | - | - | | | 5 | 15 | 9 | 6 |
| Post-docs | 8 | 1 | - | 1 | 25% | | 1 | 1 | 1 | - |
| Unknown | 15 | 1 | 2 | - | 20% | | 1 | 6 | 5 | 1 |
| TOTAL | 67 | 4 | 2 | 1 | 10% | | 19 | 30 | 21 | 9 |

The following table displays disaggregated FBBG student and post-doc data for WVU and MU pooled.

## **ACTUAL** PROGRESS INDICATORS FOR **FY2007**

Disaggregated Demographics of Undergrads, MSs, PhDs and Post-docs Working with FBBG Faculty

| West Virginia Virginia University | Total US Citizenry | Race/Ethnicity of U.S. Citizenry | | | | U.S. Citizenry | | International Students | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | African American | Hispanic | Pacific | Percent | Disabled | Women | Total | Men | Women |
| Undergrads | 33 | 3 | 1 | - | 12% | | 15 (43%) | 2 | 2 | 0 |
| Masters | 6 | - | - | - | 0% | | 2 (14%) | 8 | 6 | 2 (25%) |
| PhDs | 19 | - | - | - | 0% | | 5 (15%) | 15 | 9 | 6 (40%) |
| Post-docs | 10 | 1/10 | - | 1/10 | 20% | | 1 (6%) | 6 | 5 | 1 (17%) |
| Unknown | 15 | 1 | 2 | - | 20% | | 1 (7%) | 6 | 5 | 1 (17%) |
| TOTAL | 68 | 4 | 1 | 1 | 9% | | | 37 | 27 | (27%) |

WVEPSCoR intends to invite additional members to join the RII award's External Technical Advisory Board and will focus on recruiting women or minority faculty who will help evaluate the project and advise our management team simultaneously serving as mentors. In addition, WVEPSCoR is developing a workshop tentatively titled **Increasing Student and Faculty Diversity in STEM Fields.** The workshop is being planned with specific goals and objectives and with the assistance of a Diversity Workshop Advisory Committee. Our overall intent is to identify "best practices" in diversification of our STEM faculty and student pipeline, and statewide policies that relate to these issues.

**3. The project's annual report must include a description of efforts, accomplishments, commitments, and plans to ensure that the positive outcomes of the project will be sustained beyond the duration of the grant. This may include quantitative data (e.g., numbers of new hires recruited and retained, proposal submissions, and award success rates, and students involved in research). The report may also include descriptions of policies or programs proposed or implemented to enhance the competitive research culture, integration of research and education, and broadening participation of underrepresented groups.**

Integration of research and education is enhanced by a **State-funded STEM Fellows** program. The fellowships provided by this program are competitive (at or near NSF Fellows levels) and allow recruitment of quality graduate students. At both WVU and MU, the State funds fellowships for PhD students who are working with FBBG faculty. At WVU, the STEM Fellows are involved in cancer nanotechnology and at MU, the fellows are working in a variety of biomolecular laboratories which may link with FBBG work. While this integration is not required by the award, its linkage is encouraged and supported by the State of West Virginia.

David Lederman is the PI of a **Research Experience for Undergraduates (REU) Site Award** leveraging the RII award research activity that is targeting underrepresented students. The REU students will be working in FBBG research projects. This is the second year of the grant.

Dimitris Korakakis is the PI of a newly awarded NSF **Nanotechnology Undergraduate Education (NUE) grant.** At WVU, a pilot program, Nanosystems Emphasis, was designed to be compatible with majors in science and engineering and was implemented as a freshman course, Introduction to Nanotechnology Design. The grant will allow the program to expand to an emphasis that students can incorporate into the requirements of their science or engineering majors through interdisciplinary research and seminars throughout their undergraduate education. A major emphasis is on recruiting women and minorities to the program.

Since the number of FBBG scientists was expanded during FY2007, productivity per individual FBBG scientist was computed based on the metrics established in the evaluation plan. Baseline data were for 15 faculty members who comprised FBBGs as described in the proposal and FY2007 (Year 1) data were for 25 faculty members of the FBBGs. Productivity for the number of awards and award sizes are displayed here:

| Year | Measure Description | Measure Total | Number of FBBG Scientists | Productivity Quotient |
|---|---|---|---|---|
| Baseline | Number of Awards | 8 awards | 15 | .53 awards/scientist |
| FY2007 | Number of Awards | 17 awards | 25 | .68 awards/scientist |
| Baseline | Average Award Size | $361,974 | 15 | $24,132 av. size/scientist |
| FY2007 | Average Award Size | $239,175 | 25 | $9,567 av. size/scientist |

The number of awards has more than doubled, and the productivity quotient also shows a slight improvement. On the other hand, award size has dropped from an average of $361,074 to $239,175 with a sharp drop in the productivity quotient.

When junior faculty members are added to the FBBGs, there is an expectation that they will not be competitive in their first few years. Therefore, it is not surprising that the award sizes have declined with the addition of 10 junior faculty members to FBBG research. It is expected that when these faculty become competitive (four or five years), the average size of the awards will be much larger.

To accommodate productivity differences between established faculty and junior faculty, we will begin evaluating productivity per scientist by core members and by new members of FBBGs as well as overall. Funding milestones and goals are being reassessed in light of the productivity per capita measurements. The ELT approved this change after consideration of the NSF RSV comments in September 2007.

Sustainability of this program is also enhanced by support from the State. Currently, **WVEPSCoR administers the RCF (approximately $4 million/year)** which supports the current RII award and other related research initiatives. In March 2007, the West Virginia Legislature added additional support with the **$10M Eminent Scholars program** which is administered by WVEPSCoR. As mentioned earlier, this program has been strengthened by the 2008 Legislature by providing **$50M in the West Virginia Research Trust Fund** also to be administered by WVEPSCoR.

The competitive awards described below also enhance the sustainability of our research enterprise.

**4. The project's annual report must include evidence of linkages, coordination, and collaboration with other NSF-funded projects in the State that enhance the West Virginia-proposed Research Infrastructure Improvement activities.**

The NUE award described above is clearly connected to the nanotechnology focus of the RII award. Co-Pis on the award are Robin Hensel, Kasi Jackson, Phyllis Barnhart, Boyd Edwards and Larry Hornak.

At WVU, David Lederman, one of the FBBG Leaders, and his co-PI, Michelle Richards-Babb, are continuing the work of their **Research Experience for Undergraduates** grant from NSF titled "Multifunctional Nanomaterials REU Site." The main objective of the REU is to motivate underrepresented minorities, women and economically disadvantaged STEM students from West Virginia and the Appalachian region to pursue careers in science. This is done by providing the REU Site participants with a challenging and stimulating interdisciplinary scientific research program in nanobio/solid state multifunctional materials. This REU Site is expected to increase the retention of underrepresented minorities and women in science and engineering programs and to encourage them to pursue post-graduate advanced degrees.

At MU, Marcia Harrison of the Department of Biology is PI of an **ADVANCE grant** from NSF. The MU ADVANCE team successfully worked with the search committee that led to the hiring of Bin Wang (female) as the second MU RII hire.

Finally, the **KY-WV LSAMP** (Louis Stokes Alliance for Minority Participation) awarded in fall 2006 is continuing. The West Virginia RII award EHRDO program is working closely with campus LSAMP coordinators to leverage our programs intended to broaden participation. The three institutions collaborating through the RII award are also the West Virginia sites for the LSAMP. WVEPSCoR assists with this linkage through research sponsorships for 8 LSAMP students annually.

**5. WVEPSCoR will develop, within six months of the effective date of this award, a thorough evaluation plan focused on the gathering and interpretation of data relevant to the maturity and advances made by the project. The plan must clearly describe the specific goals, strategies and activities, expected outputs, pursued outcomes, the type of data to be gathered, and appropriate metrics (progress indicators) to assess both the implementation process and the overall impact of the project. The analytical processes to ensure the self-sustainable level of each of these efforts must be specifically stated.**

WVEPSCoR submitted the evaluation plan as specified within the first six months of the award.

**6. The project's annual report must include evidence of the implementation of its evaluation plan, including its use for project performance and documentation of progression and attainment of the stated project goals and objectives.**

The External Evaluator has provided the Executive Leadership Team (ELT) with frequent formative evaluation reports to assist the ELT with its management responsibilities.

The evaluation plan is being implemented with external evaluation results used to refine the project.

- An unanticipated result of involving the ELT and RII components in the evaluation process is that going through the thinking process that evaluation requires has resulted in organization learning. (e.g., We now realize that because of the various interpretations of "collaboration", assessing col laboration is not yes/no; a result is that the ELT is working with the evaluator on defining meaningful three stages of collaboration: Initial Collaboration-Phase I, Full Collaboration-Phase II and Results-Phase III);
- capacity building (e.g., Initial programming for collecting metrics in the WVEPSCoR office is being reconceptualized because, through the evaluator's guidance, the ELT learned that data need to be collected using very specifically defined terms and user-friendly processes.);
- data-informed problem solving (e.g., We better understand that we can more meaningfully assess increases in R&D competitiveness and productivity over time if metrics are aligned with cohorts of researchers because new members of the FBBGs are less productive than researchers who have been in the FBBGs for one year, etc.: initial researchers-cohort 0, FY2007-cohort 1, FY2008-cohort 2, and FY2009-cohort 3). Our evaluator is in the process of going back to

our FY2007 data to re-analyze the data for the group of FBBG researchers when this RII was proposed and the cohort of researchers who joined the FBBGs in the first year of the project. We anticipate that this approach will help us better understand the impact of the project on R&D over time;

- questioning of basic assumptions (e.g., As we studied evaluation data we questioned our assumption that infrastructure strengthening was primarily related to FBBG research activities and EHRDO activities as related, but separate entities. It has become apparent as collaboration between education and re searchers has increased with the new REU and NUE NSF grants that we need a better way to understand productivity resulting from collaboration within the context of the intermingling of FBBG research and education.); and,
- knowledge transfer ( e.g., FBBGs researchers conduct both core research and research specific to the FBBGs that is interdisciplinary and collaborative. Productivity and competitiveness metrics will be divided into core and FBB research areas to gain better under standing of what happens to core research as FBBG research increases.)

In FY2007 we attained or exceeded our performance measures, but also have realized that in order to better understand project performance, metrics will have to be broken down into more specific categories than originally planned.

In FY2007 we **attained** or **exceeded our performance measures**, but also have realized that in order to **better understand project performance**, metrics will have to be broken down into **more specific categories** than originally planned

# **RESEARCH** ACTIVITIES:

## OVERVIEW OF FUNCTIONAL **BUILDING BLOCK** GROUPS (FBBGS)

Our research efforts are organized and reported at the **Functional Building Block Group** (FBBG) level. Each detailed FBBG report captures **activities, findings** and **output** from both the **interdisciplinary research** in the building block area as well as from the **core groups** upon which the **interdisciplinary work is based.**

Overall performance to date indicates the research effort is largely on track, though some global areas of concern must be addressed to enable efforts (see below). Linkages continue to grow between recognition/transduction and transport FBBGs. These linkages initially occurred currently between the Photonic and Nano/microfluidic FBBGs. The nanokinematic FBBG is now also linking to the Nano/microfluidic FBBG to achieve needed fluidic addressing functions. Over the past period, the Electronic Transduction FBBG has linked with the Nanokinematics and fluidics FBBGs for surface modification expertise.

MU research activity is integrated with the Nanokinematic (Blough), Photonic and Fluidic (Georgel), and Electronic (Norton) FBBGs. Interaction has been to varying extents. Norton has had his personnel trained and has used the WVU fabrication facilities. Blough's f-actin and myosin preparation and characterization is integral to the nanokinematic efforts. Contact and reporting for MU faculty is through their respective FBBG leaders. Conventional teleconferencing has been used and the means to web conference via NetMeeting has been disseminated and used, though sparingly. While levels of interaction vastly exceed past RII awards, they are regular only in the case of the Nanokinematics FBBG because there is a critical need within the group for the frequent interaction. This collaborative depth is the key to building real collaboration. In this regard, initial discussions with Bin Wang, MU's new faculty hire, appear promising, given her extensive work in RNA and surface functionalization. We are instituting more technical presentations as part of our WVNano meetings and Wang will be the second presentation to occur by video conference between MU and WVU.

External collaborations have developed between the FBBG efforts and the U.S. Department of Energy's National Energy Technology Laboratory (NETL), the Centers for Disease Control's NIOSH (National Institute for Occupational Safety and Health) facility, the Mary Babb Randolph Cancer Center at WVU, and local biotech companies in Morgantown (Protea Biosciences LLC) and Huntington (Vandalia Research Inc.). These collaborations span the application areas of health and energy, and their value is evidenced by resulting proposal development, activity co-funding and intellectual property (IP) ; actions. Regionally, increased research and professional interaction has been developed with the University of Pittsburgh and Carnegie Mellon University through interdisciplinary awards. Our faculty members are also collaborating nationally with companies in the semiconductor materials and devices sectors; with the University of Tennessee at Knoxville, Jackson State University and Oak Ridge National Laboratory in the development of preconcentrator technology to enhance current chemical explosive detection capabilities; and with faculty at the University of North Carolina, Stony Brook and Penn State University.

Internationally, we have established a cooperative agreement and initial contract with IC Innova USA/Japan for the mutual research and development of wide bandgap semiconductor devices and nanophotonics for solid state lighting. This two-year award in excess of $1 million is enabling to the efforts of our Photonic FBBG, as the technologies developed are essential building blocks for many sensor architectures as well. As a technology developer, IC Innova is already in discussions regarding other potential areas of mutual interest and is in negotiations with WVU regarding establishment of a technology center with sites in Morgantown and Japan.

Through the efforts of James Lewis, a relationship has been solidified with Jilin University in China. The relationship has been supported by WVNano and an additional grant from the State of West Virginia EPSCoR Office. A series of reciprocal conferences has been established which feature visiting faculty from each campus. The kick-off conference has been held in China and the West Virginia conference will be held in Morgantown in April 2008. This interaction is serving as the foundation for graduate student international experience as part of the nanosystems emphasis area WVU is developing at the graduate level.

A number of areas of continued focus remain. A common denominator in almost all efforts is the recurring need for quality graduate students, post-doctoral associates and research assistant professors. Significant sharing of capable

personnel (graduate students and post-docs) already on the ground must occur to advance FBBG projects. This creates both a beneficial sharing and detrimental issues due to excessive time sharing and loss of focus. The challenge in staffing with quality personnel and the interdisciplinary complexity of some building block efforts have resulted in a longer time to achieve initial results than anticipated. WVNano graduate and undergraduate programs described in the EHRDO section are building the graduate student pipeline to improve the graduate student pool. The WVNano Graduate Bridge Program was implemented this year in order to achieve more competitive stipends. The outcomes of this program are expected to improve graduate recruitment in WVNano over time. WVEPSCoR is also addressing the need to improve the graduate student pool. A key impediment to attracting high-quality graduate students has been identified as low, non-competitive stipends and fellowships. The WVEPSCoR STEM Fellows grant program provides WVU and MU with fellowships that are competitive and nearly as high as NSF Fellows. This state-level program has become a key driver for increasing graduate stipends at the institutional level. Currently, the STEM Fellows program supports 20 doctoral students.

Another systemic issue is the time to full activation of new faculty labs. New faculty members requiring renovations and purchase of major equipment may have to wait up to a complete academic year before their lab modifications are ready resulting in a delay of productivity. The research office at WVU, in coordination with the deans and physical plant, has responded by creating a rapid response team. The effectiveness of this approach is unknown at this time, but this is a needed first step.

### Bridging Expertise – Faculty and Post-Doctoral Hires(FBBGs)

Ten key technical areas were identified between MU (one) and WVU (nine) where faculty expertise is needed to grow the foundation needed for the FBBGs' work. Six hires have been successfully made in the following areas:

1. Nanobioscience (MU)
2. Nanophotonic and Optoelectronic devices and fabrication (WVU)
3. Nanoelectromenchanical Systems (WVU)
4. Nanostructure and material characterization (WVU)
5. Biophotonic and Ultrafast Phenomena and Characterization (WVU)
6. Ab initio modeling (WVU)

As part of the hiring processes of the RII award and WVNano, and that of WVU and MU departments, the following individuals have begun to make contributions to the FBBGs. Numbering corresponds to the list above:

**1.) Bin Wang:** An RII/WVNano hire at MU in fall 2007 t through a search in which a WVU faculty member served as a committee member. She is building the integrated microfluidic system for RNA structural analysis and applying the newly developed RNA structural analyzing technology (called SHAPE, which stands for Selective 2'-Hydroxyl Acylation analyzed by Primer Extension) to determine RNA-therapeutic drug binding and RNA-protein interactions. She is also developing a nanopore-based single molecule detection system and working with Mike Norton at MU.

**2.) Andrew Cao:** An RII/WVNano hire who arrived at WVU in fall 2006. His core expertise is optoelectronics and device fabrication. He builds our core competency base in devices and materials, enabling us to pursue optoelectronic sensor device and solid-state lighting and research. He is building his lab in Electrical Engineering and establishing shared facilities for his work. He is currently engaging in the FBBG through the PhC and source work.

**3.) Lloyd Carroll:** An RII/WVNano hire, joining WVU in fall 2005. His focus is Nanomaterials composed of metals or metal oxides for many potential applications in biomedical technology, composites, energy materials and nanoscience/nanotechnology.

A search was activated for **four technical faculty positions** in the areas of **supramolecular chemistry, surface modification, structural biology/biophysics and active nanodevices.**

Carroll is also working in biomimetics, quantum dots and energetic materials. He is engaged in the electronics, fluidics and the nanokinematics FBBG.

4.) **Nick Wu:** An RII/WVNano hire in nanoimaging and characterization who joined in fall 2005, he is a WVU Department of Mechanical and Aerospace Engineering faculty member and has established his lab in engineering. He has led the nanowire and QD work and assisted in SPARROW SAM characterization and contributes in the area of PhC structure characterization.

5.) **Feruz Ganihkanov:** An RII/WVNano hire joining WVU in fall 2006, he is establishing his lab in the Physics Department and establishing a lab in Neurosciences in the health sciences center. His ultrafast optical measurement and biophotonics capability should be enabling to projects such as the DNA hybridization-activated QD-Au optical assay project.

6.) **James Lewis:** Hired by RII/WVNano in fall 2006. Lewis's group is working synergistically with experimentalists to contribute a theoretical component in interdisciplinary research teams and to understand the properties of a variety of materials including, but not limited to, ceramics, semiconducting nanocrystals, interfaces between biomolecules and semiconductors, surfaces of geo-materials and energetic materials (explosives). He is engaged in the electronics and nanokinematics FBBG and leads our international initiative.

In addition, Elmer Price was an RII hire by MU as senior leadership for junior faculty involved in FBBG work. He directs the activities of MU's molecular biology research faculty.

A search was reactivated for the final four technical faculty positions to be hired under this award. The final four positions are in the areas of supramolecular chemistry, surface modification, structural biology/biophysics and active nanodevices. In prior years, this search was operated as a university level cluster search with faculty participating from the WVNano group as well as the departments and colleges in which likely candidates would seek tenure homes. As discussed under "Special Award Conditions," the search for these four positions was unsuccessful last cycle and a new department centric approach is underway, which is also a targeted search to better recruit underrepresented groups in STEM. At the writing of this report, an offer has been extended to two female scientists. The structural biologist offer has been tentatively accepted.

The WVNano website, which was planned and implemented at the start of this award, has been extremely effective in developing interest in the initiative and its positions. The website at http://wvnano.wvu.edu was put in place in advance of the ads being placed in order for applicants to be able to receive a comprehensive summary of the organization, research and education activities of WVNano. Through this website, a password-protected site is provided and is being used by WVNano to disseminate applications to the search committees. This is the first such use of the web for a search at WVU.

**Challenges**

The supramolecular and nanodevice positions are now in their second search cycle and the surface modification position is in its third. The advertisements for all positions have been further modified based on perceived needs from past searches in order to increase their clarity and better direct them to the targeted candidate pool. We are utilizing both a common ad that advertises for all four hires across these general areas, as well as specific ads crafted within the departments with the help of the WVNano committee members, one for each position.

The FBBG groups have expressed continued need for improved surface modification and characterization while the lack of a device person has hampered efforts in our electronic and photonic FBBG. Needs have been met where possible through post-doctoral hires; however, hires of quality post-docs in these areas have proven equally as challenging. Despite this, we have had good success in meeting our metrics of performance. However, solidification and growth of research and education in West Virginia at the interface of the bio and nanosciences requires hiring and retention in these critical areas.

Three searches for post-doctoral associates in Nano/microfluidics (2) and Nanokinematics (1) were undertaken and one was successful. A post-doc was committed to accelerate the supramolecular efforts of Shi through the Photonic FBBG. A research assistant professor search was initiated by the WVNano co-directors to help fill the productivity void left by their commitment of half-time each to WVNano administration. Jeremy Dawson was hired from local industry and has thus far been very successful in establishing his activities within the Photonic FBBG.

## TOOLS – SHARED RESOURCE DEVELOPMENT AND STEWARDSHIP

**WVNano Shared Resource Working Group Established:** We have established the Shared Resource Working Group (SRWG) at WVU and made it a part of the WVNano organizational structure. This group has representatives from each college that is a major user or steward of nanoscale science and engineering (NSE) resources. The group has developed the criteria for classification of shared equipment, identified the set of shared equipment and worked through initial technical criteria for equipment location among the distributed shared facility sites on campus.

A number of **collaborations** have been developed that help meet both tool needs and provide expertise; **X-ray magnetic circular dichroism, Neutron scattering, Spatially resolved Chemical Characterization of surfaces, Biolayer Characterization and Laser Design** and **Characterization.**

The SRWG has successfully launched the processes necessary to support the coordinated and collective operation and management of NSE equipment resources on the WVU campus. Efforts to date have focused on the WVU campus given the majority of the State's NSE equipment resources resides at this location. Documentation and process information has been shared with MU via Mike Norton. One MU faculty member's research team is already using the facilities. MU's new faculty hire has said that the existence of the facilities were an important consideration in her decision to come to MU.

**WVNano Shared Resources Group Established:** This campuswide group presently is comprised of Kolin Brown as coordinator and Eric Schires, a bachelor's-level staff technical associate. These individuals previously worked separately in Computer Science and Electrical Engineering (CSEE) and in Physics, and now work together to coordinate the operations of the equipment resources they oversee across the colleges of Arts and Sciences and Engineering. This group worked with the SRWG to develop the cost structure for support of the shared resources. A third individual is now coming on board half-time to help in the technical support for major new equipment (XPS, XRD, E-Beam Writer).

**Shared Resource Financial Operations Integrated:** The finances supporting the NSE shared resources operation (Shared Resources Group salaries, maintenance and operations costs) have all been put under a single accounting umbrella, enabling effective management and assessment. This integration enables complete accounting of fund income and expenditures for shared resources. A recharge account to collect user fees has been established and has run through its first annual cycle and audit successfully.

**WVNano Shared Resource Support Plan Finalized and Operational:** A plan for the support of the shared resources identified by the SRWG was developed in coordination with the WVNano Deans Advisory Group, the Research Office and WVEPSCoR officials representing the State of West Virginia. The version finalized at the end of 2006 put in place a plan that by its fifth year will establish a shared commitment on the part of users (40%), WVU (40%) and the State (20%) to support this set of shared resources. Agreement on the part of the State and university were signed at the close of 2006. The internal university agreement distributing the commitment among colleges was executed by all parties in spring 2007. The plan was fully implemented in the spring 2007 semester. To date, the system has been an unqualified success.

**External User Policy:** The SRWG has received multiple inquiries from faculty regarding mechanisms available for external use of the shared resources by regional federal lab personnel, industry or other members of higher education in West Virginia. A document is now being vetted within the university regarding policy issues associated with use and access to these facilities by organizations external to WVU and RII award partners.

**Challenges:** Needs expressed previously by the FBBGs in the areas of characterization and high resolution lithography are being met by purchases of an XPS (arrival pending), E-Beam Writer (bid process underway), XRD (planning underway) and TEM (NSF MRI submitted). A common need of several of the FBBGs is for a scanning elecron microscope (SEM). The WVU

Chemical Engineering SEM system is excellent, however it is available only one day a week and only to electrical engineering students. The system is paid for under a College of Engineering departmental arrangement and open five \days a week from 9 a.m.-5 p.m. The system is not under the WVNano Shared Support Plan. We are engaging in discussions with Chemical Engineering and through our Deans Advisory Board to expand access to needed equipment resources on campus.

Critical issues that have emerged are that of major equipment resource placement and the need to plan for contiguous space for shared facilities. Many of the resources now are distributed across many labs, making their monitoring, management and upkeep more difficult than if they were in a contiguous location. Discussions among faculty and administration reveal the need for a process for shared facility space planning that takes a global view of the benefits and needs of research and education, and weighs these against expectations and unit concerns regarding space, access and ownership in an open and evaluative process.

The SRWG addressed this set of issues with the new XPS system by seeking recommendation from the WVNano Deans Advisory Board chaired by the vice president for research. The success of these shared facilities as a universitywide experiment requires not only consolidation of personnel and financial management which have already been achieved, but also commitment by the institution to quality space dedicated to shared facilities contiguous with the interdisciplinary faculty research efforts that use it.

A number of collaborations have been developed that help meet both tool needs and provide expertise. Current collaborations include:

**X-ray magnetic circular dichroism (XMCD)** – Lawrence Berkeley Lab, Advanced Light Source; Stanford Synchrotron Research Laboratory

**Neutron scattering** – Los Alamos National Laboratory, Argonne National Laboratory and NIST-Gaithersburg

**Spatially resolved Chemical Characterization of surfaces** – XPS (Northwestern University)

**Biolayer Characterization** – FTIR (Duquesne University)

**Laser Design and Characterization** – Woodruff Lab (DOE – NETL)

## **CONTRIBUTIONS** BEYOND SCIENCE AND ENGINEERING

WVNano participants' **core discovery activity** is the **foundation** of **competitiveness** upon which they **build their interdisciplinary collaborations.**

Innovations have leveraged both core and FBBG discovery. The WVNano group's core and FBBG research has resulted in the following intellectual property actions:

### CORE AREA IP ACTIONS:

**Disclosure 157: Aaron Timperman.**
"An integrated microfluidic system for proteome analysis"; status: US application 11/729,437 filed on 3/28/2007.

**Disclosure 215: Aaron Timperman.**
"Novel interface for coupling a microfluidic chip system and electrospray ionization -mass spectrometry"; status: US application 11/495,905 filed on 7/28/2006.

**Disclosure 255: Aaron Timperman.**
"Saw toothed shaped gradient"; status: Technology licensed to the US Government on 8/11/2006.

**Disclosure 310: Lisa Holland.**
"Thermoelectric liquid crystal flow control in microfluidic devices: componentless switching, pumping, and concentration"; status: Nonprovisional application 11/716,900 filed on 3/12/2007.

**Disclosure 338: Peter Gannett.**
"Discovery of anti-cancer peptides, identification of a cancer therapeutic target and design and chemical synthesis of novel compounds"; status: Nonprovisional application 11/480,814 filed on 7/3/2006.

**Disclosure 360: Peter Gannett.**
"A drug targeting the PH domain of AFAP modeled on phosphatidic acid"; status: Office of Technology Transfer received disclosure on 8/1/2006.

**Disclosure 368: Bingyun Li.**
"Method of surface coating biomedical devices to incorporate bioactive agents"; status: Provisional application 60/900,498 filed on 2/9/2007.

**Disclosure 390: Aaron Timperman.**
"Method and design of photolabile detergents for use with electrospray ionization mass spectrometry"; status: Office of Technology Transfer received disclosure on 4/2/2007.

### FBBG IP ACTIONS

**Disclosure 369: Boyd Edwards, Lloyd Carroll** & **Aaron Timperman.**
"Traveling wave fluidic device for separations"; status: Office of Technology Transfer received disclosure on 9/27/2006.

**Disclosure 373: Nick Wu & Peter Gannett.**
"Cisplatin biosensor chip"; status: Provisional application 60/875,263 filed on 12/15/2006.

**Disclosure 378: Lawrence Hornak, Dimitris Korakakis, Andrew Cao, Aaron Timperman** & **Nick Wu, T. Myers, X. Shi.**
"Integrated molecular detection device using photonic crystal fluidic and optical excitation focusing and resonant fluorescence emission enhancement"; status: Office of Technology Transfer received disclosure on 12/8/2006.

**Disclosure 382: Aaron Timperman** & **Lawrence Hornak.** "Amplifying detection events using cleavage gels and linkers"; status: Office of Technology Transfer received disclosure on 2/23/2007.

## FBBG ACTIVITIES AND FINDINGS

In the following section the activities and finding of the individual FBBGs are summarized.

### FBBG REPORT: ELECTRONIC TRANSDUCTION

Period of Performance: July 1, 2006 – Dec. 31, 2007

The Electronic Transduction Functional Building Block Group focuses on the **ability to obtain electronic signals from nanostructures.** Work during this period **emphasized obtaining signals from biomolecular systems.** This included **molecular electronics, protein immobilization, multifunctional electronic materials** and **microcantilever biomarkerdetectors.**

### ACTIVITIES

#### Molecular Electronics

**Electronic Structure of Heme:** Lederman and Gannett have been working on measuring the electronic signatures of single heme-containing proteins, namely CP450 and myoglobin. Myoglobin measurements have been performed with apo-myoglobin (no heme group) and myoglobin. Single-electron-transistor behavior has been observed. Lewis's group has performed some preliminary calculations to understand the electronic states of the Heme group. We are currently trying to make comparisons with the experimental work so that we can better comprehend the experimental results and new experiments are underway. Additional work by Norton at MU and Lederman has been performed to immobilize DNA via Pt nanodots to create novel electronic circuits. Magnetic nanoparticles are also being explored to be studied via electronic means in collaboration with Carroll. During 2007 the transport of actin nanowire bundles was measured by Lederman's group in collaboration with Carroll and Blough. This required alignment between nanocontacts using MHz-AC electric fields.

#### Protein Immobilization

Gannet and Lederman have been developing cytochrome P450 2C9 (CYP2C9) immobilized on chips

with the overall construct displaying enzymatic activity analogous to its in vivo activity. This has never been achieved but has been a sought-after target as it could be used for fundamental mechanistic studies and also practical applications. We have successfully attached CYP2C9 to gold substrates via a carboxyl-bearing self assembled monolayer (SAM). The attachment is by formation of an amide with the carboxy group of the SAM and the N-terminus of the protein. The resulting construct retains the ability to reversibly bind model substrates and conditions that utilize endogenous co-factors have been discovered which permit the enzyme to metabolize model substrates in a fashion analogous to what is observed in vitro and in vivo. Novel methods for detection binding have been developed and were based on magnetometry (SQUID). We are currently working to optimize these chips with respect to metabolite formation, devising methods for improved sensitivity for metabolite detection, and generation of regular arrays for mechanistic studies of protein-protein interactions. Additional work in optical characterization of these proteins was being performed by Jaroslava Miksovska at MU prior to her departure.

### Multifunctional Electronic Materials

Myers and Lederman have synthesized ferroelectric and multiferroic (ferroectric and magnetic) layers on wide bandgap semiconductors that can then be used for developing new device functionality. This effort is a high-risk/high payoff investigation into understanding the physics of such a disimilar heterostructure, which has the potential to make structures with tunable doping, for example, or high sensitivity stress or temperature sensors. One possible application is to detect the polarity of bio molecules selectively bound to field effect transistor sensors.

### Microcantilever Biomarker Detectors

The second project is the development of a microcantilever based method of detection for a cancer marker protein, VEGF and a related protein, MMP-9. The long term goal is to develop a rapid, highly specific and sensitive assay that can be used as a pre-screen for cancer, especially in patients identified as at risk for cancer (e.g., smokers). The initial studies were conducted prior to July 1, 2006. The focus since July 1, 2006, has been to refine the fabrication of the microcantilevers (attachment of the molecular probe, etc) so that they can be reproducibly prepared and results from different cantilevers can be compared. This work is being carried out by Lederman, Flynn, Gannett and Holland.

### Spintronics

This effort, led by Urazhdin, seeks to under stand the magnetoelectronic properties of magnetic nanostructures, especially those dealing with magnetic excitations generated by spin-polarized currents. Lederman also studies the properties of interface magnetic interactions between dissimilar materials. Eventually, we seek to study whether these magnetic signals can be used to detect biomolecular species.

### DNA-based Electronics

The core of Norton's research revolves around the design, fabrication, immobilization and characterization of DNA-based nanostructures to be used as substrates for the growth of sensing nanoarchitectures. Significant progress was made in 2007 both in the design and fabrication of novel DNA-based systems and in the generation of new multithiol dendrimer based chemistries for immobilizing DNA on surfaces. In the domain of characterization, the focus has been on improving/optimizing MU's Near Field Scanning Optical Microscope (NSOM). In addition, Gannett, Lewis and Lederman are studying the idea of using various forms of DNA (e.g., Z-DNA) to be used as sensing devices by measuring their electronic conduction properties.

### Nanowire Biosensors

It remains a challenge to improve the performance of sensors in terms of selectivity, sensitivity, response time and reliability. One of Wu's goals is to make nanostructured sensors to detect trace chemical species or even single biological molecules. We attempt to achieve small size, easy integration into devices and low cost. The current work is focused on electrochemical sensors and quantum dots-based fluorescent resonance energy transfer (FRET) sensors, which are used to detect anticancer drugs, proteins, pathogens and heavy metals.

Understanding the inherent sensing mechanism and the chemical and physical process involved in sensing is the prerequisite for design of sensors. It is necessary to perform in parallel the classical electrochemical, the catalytic and surface analytical studies on sensors. In particular, an in-situ study is underway on single molecular events, local electric and ionic transport in sensors on the nanoscale under the sensing environment. The group is exploring the correlation of the sensing properties with the crystal structure, the chemical structure and the electronic structure of materials. They are also studying the interaction of chemical species with the surface of sensing materials. Gannett and Flynn are collaborating in these projects.

**Challenges and Avenues for Solution:**

Spatially resolved Chemical Characterization of surfaces – The group requires a local system for rapid turnaround of samples. To address this, an order for a XPS system has been completed. Enhancements to our current FTIR system will be explored, however initial assessment is that a new system may be required.

Robust, easily used e-beam direct write – The current SEM-based system is inadequate for efficient research use. We are in the process of ordering a state-of-the-art field emission SEM to be used as an ebeam writer to meet this need.

High quality transmission electron microscopy (TEM) – There is no state-of-the-art TEM facility on campus. This is crucial for multilayer and nanoparticle characterization. WVNano is currently collaborating with the Department of Mechanical and Aerospace Engineering to acquire a new high resolution TEM that should address this need.

## Technical Personnel

Post-Doctoral Associates -

The FBBG had four post-docs in 2007. Odille Myers was funded 50% by Protea Biosicences for the cantilever project and 50% by a NIH COBRE award. Jianhua Gu is funded by the project and has played a key role in the molecular electronics portion of the project. Two other post-docs worked with Norton at MU studying DNA-based nanoarchitectures.

## **FBBG REPORT:** NANO-MICROFLUIDICS

Period of Performance: July 1, 2006 –Dec. 31, 2007

The Nano and Microfluidics Functional Building Block Group focuses on the **exploration of mass transport through nanoscale channels** and the **development of microfluidic systems for sample delivery to nanoscale transducer elements.**

### ACTIVITIES

Nanoscale channels have particularly large surface area to volume ratios and small diameters allow for double layer overlap inside of the channels. These unique characteristics create true nanoscale behavior as mass transport through nanoscale channels differs from their larger counterparts and is not fully understood. Nanofluidic/microfluidic interfaces (NMIs) are being explored to use as analyte concentrators and as valves in microfluidic systems. In particular, mechanisms of ion transport are being investigated in electrically driven systems, through a combined experimental and theoretical modeling approach. In support of other efforts, the FBBG has extended its focus to include coatings to minimize surface fouling and to impart biomolecular recognition. Projects in these areas include the detection of specific histone phosphorylation (Philippe Georgel), biomolecular recognition with photonic crystals (Jeremy Dawson) and RNA structural analysis (Bin Wang).

Additionally, microfluidic systems are being used to couple real-world samples with nanoscale transducers, such as nanoparticles and photonic crystals. A patent application has been submitted for a potentially revolutionary electrophoretic separation, traveling wave electrophoresis, in July 2007 by Edwards, Carroll and Timperman. A prototype has been built and performance evaluation began at the end of 2007.

Both the nano and microfluidic systems are essential functional elements of integrated sensor systems in security, health, energy and environmental applications. Therefore our FBBG will serve projects in all of the other FBBGs while having its own focus on NMIs.

### NANOFLUIDIC/MICROFLUIDIC INTERFACES (NMIS):

Timperman, Edwards

* Assistant Professors, ** RII/WVNano Hires

A nanofluidic-microfluidic interface is reported that rectifies ionic current using uncoated symmetric nanocapillaries that connect a microfluidic channel and a larger reservoir. The device uses nanocapillary membranes (NCMs) with uncoated symmetric nanochannels, achieving ionic current rectification with a simple design. In addition to the current-voltage (I-V) curves, the behavior of an anionic dye, fluorescein, was imaged as a function of applied voltage and time. The conductivity of the solution in the microchannel appears to be critical in the formation of the low "off" state current and the high "on" state current. The "off" state current is low due to the formation of an ion depletion zone in the microchannel. The I-V curve for the "on" state is more complex and exhibits three regions, while having many similarities with I-V curves previously noted for ion-exchange membranes in macroscopic systems. The first region of the "on" state current (at low voltages) has increased current in comparison to the ohmic current that results from formation of a zone of enhanced concentration in the microchannel and three-dimensional diffusion in the macroscopic reservoir, the second region is current limited as concentration polarization occurs and the third region again has enhanced current due to the development of convective processes. In the "off" state, ionic species can be concentrated 1000-fold in ~8 min in front of the depletion zone.

Ionic current rectification can be achieved with a simple device design in which a NCM is used to connect a microfluidic channel and a larger solution reservoir. By decreasing the volume of the solution reservoir at the microchannel NCM, the response time can be decreased. The decrease in response time is most dramatic for the "on" to "off" state transition. For this transition, the response time decreases from ~50-s to ~3-s. The decrease in response time for the "off" to "on" state is smaller, from 100-s to 60-s, but the decrease in response time is accompanied by a decrease in the deviation of the current from the steady state values. The features in the i-t plots can be accounted for with conceptual models that show the migration of zones of ion depletion and enhanced concentration. In addition to the ionic current rectification the device can be used for the concentration of ionic species, and concentration factors up to 1000-fold have been achieved. Further support for the conceptual models is gained through imaging zones of enhanced concentrations of fluorescein, an anionic fluorescent dye. It is expected, that an im-

proved understanding of the mechanisms of analyte concentration and ionic current rectification will aid in application of these components in reliable microfluidic systems.

Our main contribution to understanding the mechanisms of NMI concentration is considering the contributions of the electro-osmotic flow (EOF). Timperman's group is fabricating devices in which the EOF is varied, and Edward's lab is developing theoretical models that integrate the effects of EOF into ionic mass transport from first principles.

### TRAVELING WAVE ELECTROPHORESIS:

Edwards, Carroll**, Timperman
* Assistant Professors, ** RII/WVNano Hires

The traveling wave electrophoresis device is a microfluidic separation platform that has not been demonstrated previously, and therefore represents a new method of electrophoretic separation. This idea came about directly as a result of the NMI work and a research presentation in a WVNano group meeting. Edwards has modeled the device and Carroll and Timperman are building the device. The most exciting aspect of this separation is that it should provide a non-dispersing separation. Zone dispersion degrades the quality of the separation, and no current method is capable of providing dispersion separation while transporting analytes through a capillary or channel. Modeling of the system has continued and this modeling was submitted for publication but has not yet been accepted. A prototype has been developed and the performance evaluation of this device was initiated at the end of 2007.

## OTHER EFFORTS:

### VOLTAGE SWITCHING MICROFLUIDIC /MASS SPECTROMETER INTERFACE

Fluid dynamics and mass transport modeled by Edwards. Fabrication and evaluation of the device by Timperman group.

### PHOTOLABILE DETERGENT

Synthesized at end of 2007 by Xiadong Shi. Will be tested in 2008.

### BIOMOLECULAR RECOGNITION IN MICROFLUIDIC CHANNELS

Published paper on coating of sapphire and alumina that is used in a microfluidic biosensor. Coatings minimize biofouling and can attach a biomolecular recognition element to the surface. Worked with Philippe Georgel to couple antibodies for specifically modified histone detection, which are prostate cancer diagnostic and prognostic indicators for prostate cancer.

## CHALLENGES AND AVENUES FOR SOLUTION:

**Real-time imaging of EOF using both**:
Hot Embossing system for rapid fabrication of microfluidic devices with PMMA and other thermoplastics.

**Photobleaching** – need 200-1000mW Ar/Kr Ion Laser. Have inverted fluorescent microscope.

## PEOPLE

Post-Doctoral Associates
Xiuli Mao has been supported fully by the FBBG. Kyoo Jo has been supported half-time by the FBBG and half-time by a WVU PSCoR grant. We searched for a theoretical post-doc and one accepted but then declined the position at the very end of the process.

**Graduate Students.**
We have graduate students from chemistry and physics in the effort. With the institution of the graduate bridge program this year at WVU, the group was able to make competitive offers to a set of chemistry students late in the recruiting cycle. While the timing was not optimal initially to achieve maximum success in recruitment, we look to the next recruiting cycle for this program to positively impact our focused graduate student pool for WVNano.

## FINDINGS

**Nanofluidic/Microfluidic Interfaces (NMIs):**
Two papers are in preparation regarding our work in this area. The group has discovered that asymmetric NMI rectify ionic current and we are in the process of determining the mechanisms of this process.

# **FBBG REPORT:** NANOKINEMATICS

Period of Performance: July 1, 2006 – Dec. 31, 2007

The Nanokinematics Functional Building Block Group focuses on the **exploration of molecular motion** and **transport approaches** that can be used as building blocks for **integrated Lab-on-Chip** or **sensor systems in security, health, energy** and **environment applications.** Our FBBG focuses on **all molecular transport, characterization,** and **sensor transducer** and **actuator functions** that are **electromechanically controlled in nature.**

## ACTIVITIES

The group is currently exploring two areas of research in nanokinematics. 1.) The actomyosin molecular transport systems, and 2.) piezoelectricity of Aluminum Nitride (AlN) thin films.

### ACTOMYOSIN TRANSPORT SYSTEMS:

Blough, Carroll**, Famouri, Holland*, Hornak, Li*, Wu**
* Assistant Professors, ** RII/WVNano Hires

A fundamental understanding of the governing mechanics of biological molecular transport mechanisms can serve as a foundation for their direct use in integrated biomolecular systems or the development of nanoengineered systems that mimic these biological processes. Actin-myosin system represents a protein-based system being explored as basic building blocks for realization of linear biomolecular motor based on biological nanoscale transport phenomena. Harnessing the motion of these biomolecular systems to achieve nanokinematic functions requires actuation rate control, directional control, cargo attachment to filament or motor molecules and the viability of the proteins in a non-cellular environment. Moreover, as these biomolecular transport systems evolve and mature, it is critical that an interface be established between their nanoscale motion and the chip-level microelectronic environment that will enable reconfigurable control of their nanoscale motion via electronic signaling. Building on prior work which has established the macroscale electromotility characteristics of the myosin-actin (actomyosin) system, the scope of this FBBG research encompasses the first fundamental exploration of the interaction of electric fields localized on the micron scale with the nanoscale actin-myosin motility assay. Electric fields established with integrated electrode structures under the assayed surface are used to experimentally characterize their effect on nanoscale linear biomolecular motor filament alignment, direction of motion and assay ambient. Fluorescence techniques are being used to optically observe actin motion in assay. This work will lay the groundwork for subsequent research of electronically controllable nanoscale cargo delivery systems able to arbitrarily address chip surface locations.

### PIEZOELECTRICITY OF ALUMINUM NITRIDE

(AlN) thin films: Famouri, Korakakis*, Hansel**, Thornton**
* Assistant Professors, ** DOE Nat. Energy Technology Laboratory (NETL)

Advanced Power systems for the 21st century will be expected to operate at higher efficiency and at or near zero emissions. These systems will likely be a "Hybrid" design integrating state-of-the-art power technologies such as gas turbines and SOFC fuel cells. To meet reliability and durability expectations, at or near zero emissions, will require precision control of the fuel delivery system and the hot gas paths coupling these technologies. Unfortunately, responsive high-temperature actuators required to achieve this finely tuned control are not available. The objective of this research collaboration is to evaluate materials suitable for a high temperature actuator design primarily targeted for distributed flow control in advanced power systems.

MEMS micro-valves have been proposed as a means of performing cell-to-cell flow balancing in PEM fuel cell stacks to allow these stacks to be run at the highest possible fuel utilization. A study at NETL has already demonstrated the negative effects of steady-state flow imbalances on stack performance and a dynamic cell-to-cell flow control system is currently being evaluated to determine the level of performance improvement that such flow control might provide. NETL is considering bringing this kind of technology to the area of solid oxide fuel cells (SOFCs.) The SOFC environment, presents a whole new set of challenges to this en-

deavor, especially at much higher operating temperature (up to 1000  C).

WVU has the ability to grow high quality III-V materials which provides an opportunity to investigate Aluminum Nitride (AlN) as a micro-valve material, first through the growth, using sputtering of amorphous or polycrystalline layers, to prove its reliability at high temperature and then through the MOCVD growth to investigate the fundamental material properties that can distinguish it in high temperature micro-valve applications.

Basic cantilevers are being designed with amorphous and crystalline AlN for proof of concept with basic room temperature and eventually at high temperature testing.

**Technical Personnel**

Post-Doctoral Associates

We are in the process of hiring a post-doc for nanobiokinematics research. Twenty-two applications have been received worldwide thus far. A challenge continues to be attracting qualified and self-motivated post-doc applicant to WVU. There is risk on the part of a post-doc when they join a group in which work is in the formative stage rather than a group which is well established. This might be counterbalanced by offering post-docs more professional development opportunities, perhaps making the positions more attractive for the best post-doctoral candidates.

**Graduate Students.**

We involve graduate students in engineering, biology and chemistry in the group's research at both WVU and MU. The bridge program is helping to provide one more tool to retain students to enter the PhD program; however, in engineering, the FBBGs must work to advance direct PhD program acceptance among the faculty.

The group has been mentoring an undergraduate McNair Scholar of Hispanic origin. The student has applied to graduate school at WVU and will join this research group, which will be a tremendous plus to the research program.

## FINDINGS

**Actomyosin transport systems:**

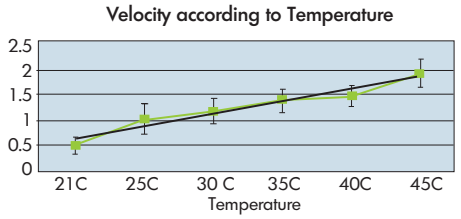
The nanokinematics work has been progressing, developing steadily towards successful proposals and publications. Blough's group at MU has been able to isolate and purify actin and myosin from rabbit muscle and the development of bacterial expression system to manufacture proteins of interest. Overexpressed fascin and purified using column chromatography and used expressed protein to bundle actin filaments have been achieved. They also have begun to derive the " design rules" which govern myosin-mediated actin bundle motility- i.e. how myosin concentration affects bundle size, velocity, efficiency of translation and trajectory and how bundle size affects bundle stability.

**Myosin (HMM) and F-actin**

HMM was provided from Blough's group at MU. When kept at -80ºC, HMM was stable and kept its motility abilities for at least six months.

Filamentous actin (F-actin) was purified from rabbit muscle acetone powder (Pel-Freez Biologicals) in Gannett's lab at HSC. Globular actin (G-actin) was obtained as rabbit muscle acetone powder in 1mM NaHCO3 solutions, then filtrated and ultracentrifuged several times. G-actin was polymerized into F-actin as 3M HCl was added. F-actin was labeled with rhodamine phalloidin (Invitrogen) and biotin-xx phalloidin(Invitrogen). The labeling process helped the observation of F-actin because F-actin was made to fluorescet with rhodamine. The A streptavidin coated bead (Spherotech Inc.) was attached to F-actin labeled with biotin. Labeled F-actin was stable in -4ºC for at least three months.

The group has also designed a bead coupling strategy that McNair scholar Lenin Leon is implementing. Furthermore, the group has studied the dielectrophoresis crossover frequency for latex and modified polystyrene beads with quadruple electrodes. This work demonstrated the significance of the suspending medium. In particular, the buffer necessary for actin-myosing motility shifts the crossover frequency to significantly higher frequency than phosphate buffers typically reported in the literature. Currently, Xingwei Wu, a graduate student in Chemistry, is investigating the

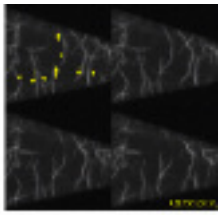



Average velocity of F-actin according to temperature

behavior of different particles and particles loaded with different cargo according to their susceptibility relative to suspending medium. Previously, Yongkuk Lee, a graduate student in Electrical Engineering, demonstrated the use of dielectrophoresis to direct actin filaments. Based on these efforts, the dielectrophoresis will be harnessed to manipulate actin-myosin transport of bead cargo.

**Thermal control system**

The group has controlled the assay temperature by implementing thermo-electric module technology. The thermoelectric module which was two or more of n and p-type doped semiconductors mounted between ceramic substrates worked as a heat pump. As two of the modules (Ferrotec Corporation), one of which was located on the left side of microscope lens and other one was located on the right side of lens, were mounted between the aluminum stage of the fluorescent microscope and heat sinks, the thermal control system provided various temperatures to the assay. DC voltage was applied to the modules and an 80 mm fan was used to dissipate heat on the heatsink in order to provide precise temperatures.



Bi-directional movement of F-actin under dielectrophoretic force in 30° angular electrode. 20Vp-p at 2MHz was

The velocity of movement in F-actin was related to the activity and condition of the HMM. If storage or purification of HMM failed, activity of the HMM becomes dramatically lower and as a result movement of F-actin also slow down. However, if the condition of the HMM was unchanged, the activity of the HMM mainly depends on the temperature variation. In the experiments, the flow cell was in contact for 1 min with the stage to give enough time for the adjusted flow cell temperature to stabilize to the desired temperature. We have acquired results for average velocity of movement in F-actin at different temperatures. The average velocity of F-actin increased linearly according to temperatures from 21°C to 45°C.

Furthermore, attachment of actin filaments to microbeads via biotinylation was successfully achieved. This is basically an assay in which actin and myosin are combined on a microslide and the interaction between the two molecules is observed via an inverted microscope. The protocol for the standard motility assay involved applying a nitrocellulose layer onto microslides. This material allowed the myosin to be immobilized onto the slides. Next, two stocks of actin, one with adenosine triphosphate (ATP) and one without ATP were prepared. The ATP allowed the interaction between myosin and actin to occur, namely the movement of the myosin head region, which propelled the actin. The microslides were then observed to determine that a successful interaction between myosin and actin molecules was taking place in the presence of ATP. This ensured that a proper concentration of functioning myosin was present because too high a concentration of myosin causes the actin filaments to be pulled in too many directions resulting in shorter filament lengths. In addition, if the actin moved too slowly, that indicated the actin stock may have expired and beyond its useful lifetime.

**Piezoelectricity of Aluminum Nitride (AlN) thin films:**

Work continues to establish the set of results needed to publish work achieved thus far. Needed work and results include recalibrating the laser vibrometer (used to measure the piezoelectric coefficient of the AlN films) and further C-V measurements of AlN stacks using p-type and n-type silicon substrates to confirm the results achieved to date.

AlN actuator (cantilever and microbridge) production efforts continue with mask design and the refinement/optimization of fabrication techniques using Reactive Ion Etching with tetrafluoromethane gas (RIE-CF4). Fabrication of diaphragms using laser ablation also continues.

## **FBBG REPORT:** PHOTONICS

Period of Performance: July 1, 2006 – Dec. 31, 2007

The Photonic Functional Building Block Group focuses on **exploration of photonic molecular recognition** and **transduction approaches that can be used as building blocks for integrated sensor systems in security, health, energy** and **environment applications.** Therefore our FBBG brings under one umbrella **all molecular recognition, characterization and sensor transducer functions that are photonic in nature.**

### ACTIVITIES

The group is currently exploring four primary photonic sensor test beds. 1.) The SPARROW device, 2.) Photonic crystal (PC) – based molecular recognition systems, 3.) Quantum Dot – based systems, and 4.) Raman source - detector systems. The application inspiration for these testbeds is broad-based and currently spans security (SPARROW – Anthrax), health (SPARROW – chromatin, PC – enzyme), energy (Raman - NG gas constituents) and environment (Hg detection via QD-Au DNA binding).

#### SPARROW:

Georgel, Hornak, Korakakis*, Norton, Shi*, Timperman, Wu**

* Assistant Professors, ** RII/WVNano Hires

This project combines the guided-wave and materials core expertise in the Photonic FBBG with the microfluidics core competency in the Fluidics FBBG to establish a portable evanescent wave biosensor device capable of nano to picogram per mm Limit of Detection (LOD) and surface regeneration and reprogramming for detection of multiple analytes. This period we completed year four under no-cost extension (NCE) of a three year ONR award and submitted our final report to ONR in November. Full test by microfluidically addressing the sensor surface with sucrose solution was initially hampered by difficulties achieving stable e-beam film growth for the waveguide stack. This was overcome through the careful characterization of the growth process and the introduction of an annealing step which resulted in the lowest loss waveguides to date ( < 1 dB/cm). Low loss waveguide stacks have now been tested with low concentrations of sucrose solutions presented to the sensor surface through a PDMS microfluidic channel following a surface rinse protocol. Initial results indicate a sensitivity of 10 pg/mm is readily achievable. Further tests are underway to establish the repeatability and error associated with this first measurement in order to better determine the experimental sensitivity. We will then measure the output of the device as a function of attached latex bead surface coverage, both with and without the biolayer. In addition, achieving and maintaining adequate biotin functionalized bead attachment to the functionalized SAM is an area of continued investigation. Both these areas are the objects of our attention next period. We are beginning discussion of the use of the SPARROW as a platform for other analytes and potential funding as the performance is now becoming clear.

To date, two journal publications appeared from the group's efforts (one this period) based on the advances in waveguide layer and biolayer growth, in addition to two conference proceedings papers. Another journal paper is in review which models the waveguide interaction with targets on the surface. We anticipate three additional journal papers from this work will be submitted next period. These will stem from the annealed waveguide study, the channel bead attachment kinetics and the transducer sensitivity measurements.

In addition to bioagent detection, chromatin detection is a targeted use for the SPARROW in the health application domain. Georgel's laboratory has been working on histone purification from different cell lines. The cells were treated with chemicals that induce specific post-translational modifications that will be used as targets for detection of histones. The presence of modifications and quality of histones was assessed by gel electrophoresis and used to assemble mono-nucleosomes (the building blocks of chromatin). To assay for recognition and detection of nucleosomes, Georgel and Timperman have designed a procedure involving quantum dots that should be functional in the context of the SPARROW biosensor. This has also since been explored through a new collaborative effort between Norton and Georgel. Mono-nucleosomes have been deposited on slides using a special spotting device, and then detected using quantum dot-conjugated antibodies. Unmodified histones are currently being used to validate this new

approach. Specifically modified histones (linked to prostate cancer development) are being generated and will be used in future studies.

**PHOTONIC CRYSTAL (PHC) – BASED MOLECULAR RECOGNITION:**

Cao**, Dawson***, Homak, Korakakis*, Myers, Shi*, Timperman, Wu**

* Assistant Professors, ** WVNano Hires, *** WVNano Research Professor Hire

This thrust focuses on architectures using the optical properties of photonic crystals for molecular detection. Current studies emphasize PhC architectures with fluidic as well as gas flow addressing. Our initial broad focus resulted in positive NIRT reviews and a disclosure now being finalized. We also came to recognize the challenges in obtaining needed preliminary results for the complex approaches and architectures proposed. As a result, significant time was spent reassessing and focusing our efforts. The group arrived at a single architecture in which the materials growth, biomolecular and PhC components are largely separable enabling smaller scale proposals better suited to a broader range of solicitations.

This single, simplified architecture is the basis of two disclosures. The PhC architecture we are pursuing uses conventional tagging of the molecules of interest with a fluorescent species or quantum dot. The means whereby this tagging is achieved can itself be novel under a separate research thrust. For example, the quantum-dot based systems described below can be directly applicable. For fluidic implementations, what is required is that the tagged molecules be charged so they can be moved electrophoretically. The PhC channels the motion of the charged molecules through a small volume, focuses the fluorescence excitation on this volume, provides resonance enhancement of the molecule's fluorescent emission when in the volume, and transfers the resonantly enhanced emission for detection.

Our new architecture relies on the use of a GaN photonic crystal so that the visible fluorescence excitation wavelengths lay in the PhC pass band and the molecule fluorescence emission lays in the PhC bandgap. The PhC is a thin plane that will be fabricated to separate two fluidic regions, one with the source of the tagged molecules, the other the region into which the molecules will be drawn with suitably engineered potential application to the two fluids. The PhC is a sealed structure with the exception of one or more PhC cells that connect the two fluidic regions through a volume in the nano to attolitter range. These cells are now being designed to serve simultaneously as a crystal defect or defect cluster. This defect serves as a resonator to the radiation at the fluorescence wavelength. The passage of the molecule through the volume will result in resonance enhancement of its emitted electric field enabling enhanced detection out of the PhC plane or in plane through design of a line defect waveguide in the PhC.

We adapted this idea for a successful proposal to the U.S. Department of Energy National Energy Technology Laboratory (NETL) for PhC – based gas constituent detection. This funding was enabling as it has allowed us to do foundational work including definition of the biomolecular species and fluorescent tag and its optical pump and emission efficiency, modeling of species transit dynamics through the PhC and modeling of the PhC structure and the hole defect. With these further results we were able to prepare a successful proposal to National Consortium for Measures and Signatures Intelligence (MASINT) Research (NCMR) from which we just received a three year award to develop the original fluidic photonic crystal concept. This award will enable pursuit of the fabrication, testing and characterization of the PhC detector.

**QUANTUM DOT – BASED SYSTEMS:**

Edenborn***, Homak, Perrotta, Shi*, Wu**

* Assistant Professors, ** RII/WVNano Hire, *** DOE National Energy Technology Laboratory (NETL)

This thrust explores the development of new classes of synthetic nanoparticle assays for detection applications in health and environmental applications. The health science effort links the capabilities of Wu, Perrotta and Shi to explore the use of quantum dots - gold nanoparticle assays for monitoring blood coagulation proteins. This synthetic nanoparticle assay is intended to monitor levels of blood coagulation (clotting) proteins in physiologic media.

The other effort builds on a collaboration with NETL in Pittsburgh and explores a nanosensor based on a DNA hybridization – driven quantum dot – gold nanoparticle optical assay. The effort builds on prior work and significantly advances the state of the art for detection of toxic metal ions in water. The molecular recognition approach established through this work can be integrated to achieve

needed portable, rapid monitoring of water quality for drinking, industrial and agricultural applications.

This nanosensor system is expected to be capable of simultaneously detecting multiple heavy metals with high sensitivity, selectivity and reliability. This nanosensor system is created by utilizing fluorescent (Föster) resonance energy transfer (FRET), whereby the luminescent emission of quantum dots (QDs) is quenched by the gold nanoparticles (NPs). Green, yellow and red QDs are employed to sense Hg2+, Cu2+ and Pb2+ ions, respectively. The target ions selectivity can be achieved by selected DNA sequences. Specifically, the thymine-thymine mismatching in the DNA double helixes is known to be a good base pair to selectively bind with Hg2+, while non-nature nucleobase hydroxypridone produce stable helixes through the cooperation with Cu2+. The G-riched DNA-conjugated system can serve as an excellent binding sequence for Pb2+ in the course of the formation of G-quartet quadruplexes.

The effort draws on preliminary results from Shi on G-quartet quadruplexes, Shi on Au nanoparticles and QDs and Edenborn on preliminary FRET Hg detection, with Hornak providing optical characterization and integration architectures. A proposal was submitted to the NSF CBET Division and though granted verbally, an award was not forthcoming this for budgetary reasons. We have resubmitted the proposal to NSF at the strong recommendation of the program director. Shi has submitted a number of proposals in support of the G-quartet and other supporting supramolecular components.

**INTEGRATED PHOTONIC SOURCES AND SYSTEMS:** Cao**, Korakakis*, Myers
*Assistant Professors, ** RII/WVNano Hire

This new effort focuses on the research of efficient visible sources and nanophotonics based on wide band gap semiconductors targeting application in integrated molecular sensing and high efficiency light sources. The group is responsible for materials growth and the development and implementation of novel patterning and fabrication techniques of these materials for PhCs. The integration of similar PhC structures into blue and green LEDs is under study as a new light extraction strategy. Other device structures, such as micro-mesa LEDs and gateless transistors, will also be explored as alternative approaches to building robust and high-sensitivity biosensors. These projects will help to further bind and advance the already formulated research working groups built on the foundation of WVNano research assets.

**RAMAN SOURCE - DETECTOR SYSTEMS:**
Chen^, Falk^, Hornak, Korakakis*, Woodruff***
* Assistant Professors, *** DOE National Energy Technology Laboratory (NETL), ^University of Pittsburgh

Our regional team is focusing on a proof-of-concept prototype of a Raman-based optical detection system for gas detection suitable for operation over wide pressure and temperature range conditions and consistent with integration and economical manufacture. The work brings together the Nd:YAG slab laser research at WVU and NETL, fiber source and sensor technology from the University of Pittsburgh and wide band gap semiconductor detector materials and devices at WVU to establish a sensor system testbed in which the viability, benefits and trade-offs of Raman gas molecule detection in the near IR and visible range will be determined. This initial application of this system will be for the NETL application of natural gas constituent detection. The source and detector components investigated through this effort provide important functional building blocks for integrated optical spectroscopy systems.

This work has successfully received funding for the first of three years via the DOE – NETL Regional University Initiative. Slab laser work focuses on hybrid integration of the Nd:YAG slab with the pump laser and coupling optics as well as optimization of the slab for maximum output power for introduction of the saturable absorber and assessment of Q-switching capability. InGaN Multi Quantum Well structures have been grown and characterized as a first step towards achieving MQW photodetectors for use in a completely integrated system. Studies are underway to determining the mechanism and the dependence of the absorption edge on InN mole fraction and quantum well width.

**BIOPHOTONIC SYSTEMS:**
Ganikhanov**, Spirou^, Wu**
** RII/WVNano Hire, ^Neuroscience Center, WVU Health Sciences Center (HSC)

This new area led by Ganikhanov stresses three areas: 1) biophotonics and biological/bio-medical applications of nonlinear optics, 2) ultrafast condensed matter spectroscopy (including soft matter, e.g. tissue, bio-cell and their molecular

constituents), and 3) broadly tunable solid-state lasers/photonics (including mode-locked fiber lasers).

The first area implies experiments on cellular and tissue structures where nonlinear optical techniques are used to detect and track certain sub-structures of interest and produce high spatial resolution (~200-300 nm) images that carry important biological information. Molecular sensitive spectroscopic imaging (accomplished by CARS) allows the noninvasive probing of morphology, structure and certain intracellular interactions. Processes like cell division, differentiation, necrosis and phagocytosis that are accompanied by large structural and spatial reorganizations of the cell constituents will be under prime experimental focus in this program.

Currently, the major effort is applied towards building and optimizing the experimental system that will serve the outlined goal. The system is expected to reach its full operational capacity in January 2008. The experimental capabilities offered by the system are of great interest to G. Spirou for collaborative neurosciences research and as a result the system is being housed in the new Neuroscience Lab building close to other well equipped facilities. The experimental system is designed and built for shared use and is expected to mutually benefit and strengthen this program and those in HSC.

The second area is being served through building of an ultrafast laser system. The second area is being developed initially though experimental research efforts exploring ultrafast energy redistribution and transfer mechanisms in metallic nano-particle structures as well as microspectroscopy of biological interfaces (membrane or membrane-like structures) with insight into vibrational energy stochastization and transfer across the interfaces. Currently, the new pump laser has been purchased and sub-20 fs Ti:sapphire laser is under construction. This complete ultrafast spectroscopy system (includes tunable 50-fs OPO, pump-probe and four-wave mixing unit, etc.) will enable experiments that will provide a collaboration interface to other WVNano members and, in particular, the research conducted by N. Wu.

The third area has not yet started in earnest, other than submission of a proposal to the NSF.

## CHALLENGES AND AVENUES FOR SOLUTION:

**Spatially Resolved Chemical Characterization of Surfaces** – Require a local system for rapid turnaround. An XPS system is being installed to address this as well as enhancements to our current FTIR system being explored.

**High Power ICP** – System in place now and process recipes being established for dry etching of vertical sidewalls in the fabrication of PhCs, and other nanoscale electronic and optical structures.

**High End Workstations** – Two large memory workstations for rapid PhC modeling were purchased to meet needs.

## PEOPLE

### Technical Personnel

#### Research Assistant Professors

Myers and Hornak searched successfully for a research assistant professor to help advance common projects and replace the presence they have lost in the lab due to their WVNano co-director appointments. The search was concluded successfully in spring 2007 with the hiring of Jeremy Dawson. Previously in local high-tech industry, he has already established himself and is receiving competitive funding.

#### Post-Doctoral Associates

The FBBG had one post-doc, Min Soo Lim, who was funded full-time by ONR through the SPARROW project. He provided limited surface modification capability for this and other projects. Lim took an academic position in summer 2007. Timperman has involved another post-doc who is beginning his work with the group. Other post-docs are those of specific faculty (Shi, Wu) and become involved as required in support of the efforts.

### Graduate Students

The research of this FBBG involves students from engineering, physics and chemistry.

## FINDINGS

**SPARROW:**

The full test by microfluidic addressing of the sensor surface with sucrose solution was achieved. Initial poor waveguide performance was overcome through the careful characterization of the growth process and the introduction of an annealing step which resulted in the lowest loss waveguides to date ( < 1 dB/cm). Low loss waveguide stacks have now been tested with low concentrations of sucrose solutions presented to the sensor surface through a PDMS microfluidic channel following a

surface rinse protocol. Initial results indicate a sensitivity of 10 pg/mm is readily achievable. Further tests are underway to establish the repeatability and error associated with this first measurement in order to better determine the experimental sensitivity.

**Photonic crystal (PhC)** – based molecular recognition:
Modeling of a hexagonal air hole PhC structure based on the most recent architecture have been completed including basic defect geometries. Results indicate adequate Q factor and line defect coupling for resonant energy transfer. Consideration of fluorescence efficiency indicates an improvement of nearly 1000 is possible in detection using the PhC over the state of the art. A preliminary fabrication process for the GaN PC based on ICP etching continues to be developed. Initial growth results showing the efficacy of a lateral polarization heterostructure approach for realizing high aspect ratio photonic crystal structures have been concluded. Current work focuses on achieving patterned growth with lithographically defined patterns.

**Quantum Dot – based systems:**
Shi successfully achieving the anion bridged nanosheets from self-assembled G-quadruplexes that are a critical element of this work. He continues development of a fluorescence active sensing system for the formation of the effective biological target sensing. Shi's current activity is development of a new methodology with the discovery of synthesis of novel 4,5-disubstituted-1,2,3-NH-triazoles. One disclosure was made for this novel fluorescence active system. Wu has published on the shape-controlled growth of micron-sized gold crystals by slow reduction which will be used as a foundation for Au nanoparticle synthesis.

**Integrated Photonic Sources and Systems:**
A AlInGaN-based visible and UV light-emitting diodes (LEDs), the "engine" of solid-state lighting (SSL) was designed, fabricated and characterized at WVU. The effort draws on new fabrication capabilities and processes developed in the shared facilities as well as the new optoelectronic characterization lab established by Cao.

**Raman source - detector systems:**
The CW lasing performance of our initial Nd:YAG slab laser geometry was published and the slab was successfully Q-switched and used with a saturable absorber and frequency doubling obtained at 532 nm. Grown InGaN Multi Quantum Well structures were characterized and transmission data indicated that the absorption edge of the structures can be engineered to be tuned at the wavelengths of interest.

**Biophotonic Systems**
No findings yet.

## **EDUCATION**, HUMAN RESOURCE DEVELOPMENT AND **OUTREACH** (EHRDO)

**Education, Human Resource Development and Outreach (EHRDO)** is an integral component of the RII project. **Striving for cost-effectiveness** and **greater impact,** the RII project not only initiates opportunities but **partners with, builds upon** and **extends other NSF-funded EHRDO projects** and **university-supported efforts.** Threaded throughout the development of the EPSCoR RII proposal was a heightened awareness of the need to diversify the West Virginia workforce by **providing increased access to individuals** underrepresented in STEM and, in particular, the **nanoscale science** and **engineering field.** Model programs for retention and enhancement of students in STEM, including those focused on underrepresented (UREP) groups including **minorities, women, persons with disabilities, the economically disadvantaged and first-generation college students** have been implemented. The WVNano Initiative under the RII award is incorporating proven components from **successful strategies** and **national model programs** that focus on **education** and **human resource issues.**

An EHRDO Working Group of RII/WVNano participants has formed. Two sub-committees for NSE Graduate Leadership Emphasis and NSE Undergraduate Emphasis Area have been populated and are functioning.

### PRIMARY EMPHASIS ACTIVITIES

**Multi-institutional Collaboration**. Periodic meetings of EHRDO representatives from WVU, MU and West Virginia State University (WVSU) were held in Institute on the WVSU campus and at the WVEPSCoR office in Charleston. These meetings served to identify components for implementation and collaboration to help achieve statewide consistency in the EHRDO efforts.

**Joint Efforts with LSAMP.** Due to low minority populations in both states, Kentucky and West Virginia forged a regional partnership to form a multi-institutional alliance in order to secure NSF-funding under the Louis Stokes Alliance for Minority Participation (LSAMP) program. Of 10 colleges and universities, WVU, MU, WVSU and West Virginia State Community and Technical College are participating in West Virginia. The RII/WVNano Initiative and the WVU-LSAMP have partnered to maximize resources to enhance UREP student opportunities for undergraduate students. At WVU, the LSAMP Campus Coordinator is collaborating with Phyllis Barnhart, RII award EHRDO coordinator, to implement EHRDO activities. Michael Mays, professor of mathematics, served as the LSAMP campus coordinator until October 2007 and was succeeded by David Miller, assistant professor of mathematics.

Due to the timing of the award, the majority of the EHRDO activities were implemented in summer 2007.

**UREP Undergraduate Retention Initiative.** The design of the initiative includes a comprehensive set of enhancement activities ranging from academic support to mentoring, research experiences, and social and cultural development activities for undergraduates. Charles Woolston, former associate provost and co-founder of the University of Maryland–Baltimore Campus Meyerhoff Scholars program, serves as an expert advisor in this endeavor.

The RII award EHRDO initiative is implementing a modified version of the Meyerhoff Scholars program. The following components are included:

- Summer Bridge Program for Rising Freshman
- Peer Mentoring and Tutoring
- Freshman Academic Year Program for "Gatekeeper" Courses
- WVNano NSE Authentic Research Summer Program for Rising Sophomores/Juniors Seniors

**Summer Bridge Program for Rising Freshman.** The three-week WVNano/LSAMP Summer Launch program was implemented in 2007 to better pre-

pare 14 UREP students entering STEM fields. Promising first-year students accepted at WVU who expressed interest in STEM disciplines were targeted. Admission was by competitive application. UREP students enrolled in pre-calculus course (Math 129) or Biology 115 and university orientation course (University 101); interacted with peer mentors and faculty; and engaged in special academic support including class scheduling, career workshops and other opportunities to become familiar with campus life including service activities.

At WVSU, the summer bridge program focused on mathematics and life skills. The purpose of WVSU's Math Enrichment Program was to strengthen mathematics content knowledge. Of the 25 students (24 of whom were UREP minority students; 18 were African-American males) nine were from West Virginia, eight were from Maryland, two from South Carolina, two from Florida and one each from Pennsylvania, Ohio, Delaware and Washington, D.C. One of the important features of this program was that it provided African-American young men with African-American male role models. The program included a highly rated life skills class.

**Peer Mentoring and Tutoring.** Proactive peer mentoring during the summer program was provided to encourage retention in STEM disciplines through degree completion. A Mentoring Team was established, consisting of the course faculty member, an upper-class peer mentor and the student. Peer mentors were part of the Seamless Transition Program and received training in campus resources, community resources and life skills techniques. Peer mentors were also trained at WVSU and were vital mentors to students in the Math Enrichment program.

**Freshman Academic Year Program.** Students participating in the summer program at WVU were provided the opportunity to enroll in a dedicated calculus course in fall 2007. In addition, WVNano/LSAMP collaborated on offering the Guaranteed 4.0 Study Skills Seminar program (see http://www.guaranteed4.com/g4/ ) to UREP STEM students. The program emphasized a systematic approach to learning and practical insight into the unwritten rules of the classroom. Guaranteed 4.0 is a proven system combining innovative study methods with effective stress and time management techniques to provide an overall framework for academic success. Guaranteed 4.0 adds value to our UREP Retention Initiative by:

- Preparing students for university level academics
- Identifying and addressing underlying barriers to academic success
- Reaching at-risk students
- Empowering students with knowledge of unwritten classroom rules
- Providing additional motivation
- Training staff members and mentors to assist students on the 4.0 Plan

Guaranteed 4.0 began Aug. 28, 2007, with a seminar and workshop given by Donna Johnson, the Guaranteed 4.0 Learning System founder. Follow-up seminars were held on Sept. 10, Sept. 25, Oct. 23 and Nov. 27. Individually scheduled meetings with teams of students were conducted in the afternoon, with a common evening presentation for all participants. Guaranteed 4.0 activities included training for the mentor/faculty "coaches" of the student teams. The mentor/faculty members were Todd McFadden, David Miller, Maria Watson, Florita Montgomery and Ed Cole.

**WVNano Authentic Research Program for Sophomores/Juniors/Seniors.** Through a competitive application process, a cohort of 21 rising sophomores, juniors or seniors were selected to participate in an eight-week summer research program in the research laboratories of WVNano faculty. This program was offered in collaboration with the WVU Honors College SURE program. Students learned the WVNano research agenda and were exposed to specialized equipment. The students "shadowed" an assigned research team member (post-doctorate or graduate fellow), assisting based on their level of skills. At MU, a cohort of six students–four females and two males–worked with WVNano faculty under the aegis of MU's SURE program. Both the WVU and MU cohorts participated in a weekly Seminar Series presented by faculty. Culminating poster presentation sessions were held to showcase the summer research work of the SURE students.

**Graduate Student Recruitment and Retention Initiative.** The design of this initiative included the provision of supplemental funds to attract highly qualified UREP graduate

students for a summer bridge program prior to the first semester of their PhD program. Nominations for the WVNano Graduate Bridge Award were received from STEM department chairs and STEM department graduate committee chairs. Nineteen awards were accepted. Approximately one-half of the students participated in research laboratories in summer 2007 with the remaining students to work in May-June 2008. Students who have demonstrated exemplary progress are eligible to apply for a second year of funding from the WVNano Graduate Bridge Award program.

**NSE Graduate Education Leadership Emphasis Area.** A committee for an emphasis area for NSE graduate education was formed and is lead by Lisa Holland, assistant professor of chemistry. The committee is charged with reviewing Graduate Bridge Award nominations and defining the courses and requirements for the emphasis area. The committee developed a graduate course, Seminar in Nanoscience, offered in fall 2007.

All WVNano Graduate Bridge awardees participated in the inaugural WVNano Graduate Seminar Series. They joined graduate students from the WVNano Cancer STEM program, lead by Pete Gannett, and other graduate students working in the WVNano faculty research laboratories. The Seminar in Nanoscience targets the facilitation of interdisciplinary research at the nanoscale by providing a forum for discussion and exploration of nanoscale science and engineering from a variety of perspectives including research and development of nanoscale devices and systems. The course was presented as a mix of student presentations of their research and the current nanoscience literature coupled with presentations by invited experts in the fields of nanoscience, intellectual property, ethics and social concerns related to nanoscience, and industry. Approximately half of the course was student lead.

**Early-Career/Junior Faculty Development Initiative.** Grant writing seminars were held in July 2006 with 99 faculty members participating and again in July 2007 with 110 faculty members attending. Fifteen faculty members, including two WVNano participants, were selected for the 2006 Grant Writing Workshop cohort. The workshop began in September 2006 and concluded in February 2007. The workshop entailed dedicated one-on-one assistance from grant writing consultants to produce a competitive proposal. Thirty faculty members, including eight WVNano participants, were identified for the 2007-08 one-on-one workshop that concludes in March 2008. At MU, regular Grant Chats are planned in coordination with MU's ADVANCE grant. More than 50 junior faculty members regularly attend these activities.

## SECONDARY EMPHASIS ACTIVITIES

**NSE Undergraduate Emphasis Area**

**Introduction to Nanotechnology Design Course.** The first course of a proposed emphasis and/or minor in nanoscale science and engineering was developed during fall 2006. The interdisciplinary course was designed by eight faculty and team taught in spring 2007. Design and course delivery was coordinated by Boyd Edwards, physics professor. Ten students were enrolled in the course. The course served as a pilot for the successful proposal submission, below, under the NSF's NUE program.

**NSF NUE Award**

**The Nanosystems Emphasis – Valuing Disciplinary Depth and Differences in Nanoscale Science and Engineering Teams**

PI: Dimitris Korakakis; Co-PIs: Phyllis Barnhart, Boyd Edwards, Robin Hensel, Lawrence Hornak, Jennifer Jackson

The Nanosystems Emphasis is a creative, broadly applicable and interdisciplinary approach to achieving the challenging objective of preparation of students for the NSE workplace. This is an objective shared by the State of West Virginia for development of its workforce. The program's focus on student understanding of and engagement in the NSE discovery and innovation cycle will enhance learning and retention for all segments of the student population, particularly for underrepresented groups, enabling students to understand early in their programs the relevance of their disciplines in the realization of nanosystems of societal importance. Through the program's unique seminar and research components, engineering and science students will participate as colleagues in interdisciplinary teams and graduate equipped to understand and use to advantage their disciplinary differences to collaborate effectively in the NSE workforce. Fully implemented, the program will directly affect 120 students annually at WVU across six departments and two colleges. Partnerships with existing programs (e.g. UREP STEM Student Retention, LSAMP) especially those recruiting younger students to STEM fields, such as WVU's NSF STEP award, Engineers for T omorrow program, are in place to increase participation of underrepresented minorities and women in engineering and science.

**Goals:** Enable students to understand the role of their chosen disciplines in the realization of nanosystems of societal impact, function in interdisciplinary teams, and both value and use team disciplinary diversity for solution of nanoscale engineering problems.

**Objectives:** These goals will be achieved within the framework of a Nanosystem Emphasis Area designed to meet the objectives of:

a) Easy integration with the programs of both engineering students and those in the physical and life sciences;

b) Enhancing and promoting interdisciplinary interaction amongst engineering and science students throughout the duration of their major studies;

c) Providing access to a capstone experience of interdisciplinary nanosystems research;

d) Preparation of students to enter the workf force in graduate school or industry with the skills and understanding necessary to contribute and shape a nanoscale science and engineering (NSE) based economy; and,

e) Increasing the participation of underrepresented groups to capture their interest and foster the desire to continue their education as research scientists and engineers.

The approach builds on the learning community developed among the crosscutting STEM student cohorts of the second-semester freshman common course, Intro to Nanotechnology Design, through the establishment of a crosscutting Nanosystems Emphasis.

First, a series of progressively advancing seminars focus on motivating the critical relationship and importance of each student's work in their major program to NSE device and system innovation and acceptance. Through the guided learning community in these seminars over the sophomore and junior years, professional relationships initiated in the common Intro class mature among students as they themselves advance and develop in their majors. Social, ethical and economic considerations are first introduced in the Intro class and developed further through the seminars in the context of the impact of new devices and system. The Nanosystems Emphasis culminates with students fulfilling their majors' capstone requirement by engaging in interdisciplinary NSE nanosystems research within faculty labs to which they have been introduced through the seminars.

**WVNano NSF REU Site Award**

Multifunctional Nanomaterials Research Experience for Undergraduates Site

PI: David Lederman Co-PI: Michelle Richards-Babb

The main objective is to motivate underrepresented minorities, women and economically disadvantaged STEM students from West Virginia and the Appalachian region to pursue careers in science. This is done by providing the REU Site participants with a challenging and stimulating interdisciplinary scientific research program in nanobio/solid state multifunctional materials. The participants not only develop scientific and collaborative skills in the laboratory, but outside the laboratory as well with team-building activities such as weekly talks and informal meetings, field trips to national laboratory facilities and several outdoor outings. Ten students finishing their junior or sophomore years were recruited from four-year colleges in West Virginia, as well as Ohio, Kentucky, Southwestern Pennsylvania and Virginia. With one-half of the students from UREP groups, the project contributes toward increasing the retention rate of underrepresented minorities in science and engineering majors in the state of West Virginia and the surrounding Appalachian region. It is also designed to increase the number of students from the region that pursue post-graduate degrees, thus improving the quality of the future workforce in the region.

**Joint University-CTC Curriculum to Train STEM Technicians.** The WVNano Initiative has forged a memorandum of understanding with West Virginia Northern Community College to develop and implement an associate degree program in nanotechnology to produce a highly skilled, diversified workforce that can meet current and future nanotechnology needs of emerging private sector industries, university research laboratories and government laboratories and enhancing economic development in the region in general, and northern West Virginia specifically. The WVNano shared facilities will be utilized to deliver the capstone (fourth) semester of the associate degree. The program is modeled after the Penn State Nanotechnology Fabrication and Education Center. Funding is currently being pursued.

**Teach the Teachers/Informal Science Education in collaboration with SMART-Center.** Work begun under the previous RII award continues with the SMART-Center of West Liberty State College. Follow-up nanotechnology workshops, with teachers receiving classroom kits, were conducted at the 2006 West Virginia Science Teachers Association Annual

Conference Oct. 19-21, 2006, and regional workshops in 2007. Presentations on the WVNano/LSAMP Summer Launch Bridge Program for Rising Freshman were also provided to alert teachers to opportunities for their students.

## CHALLENGES AND AVENUES FOR SOLUTION:

**Underrepresented Group Participation.**
West Virginia is not an ethnically diverse state – approximately 95% of the population is white. At WVSU, a historically black university, 18% of the student body is composed of students from underrepresented minority groups. As a result, WVEPSCoR has focused on improving the retention and graduation of minority students, including first-generation Appalachian students, in STEM programs. The EHRDO programs are working to recruit additional minority students, particularly at the graduate level, through partnering with the KY/WV LSAMP.

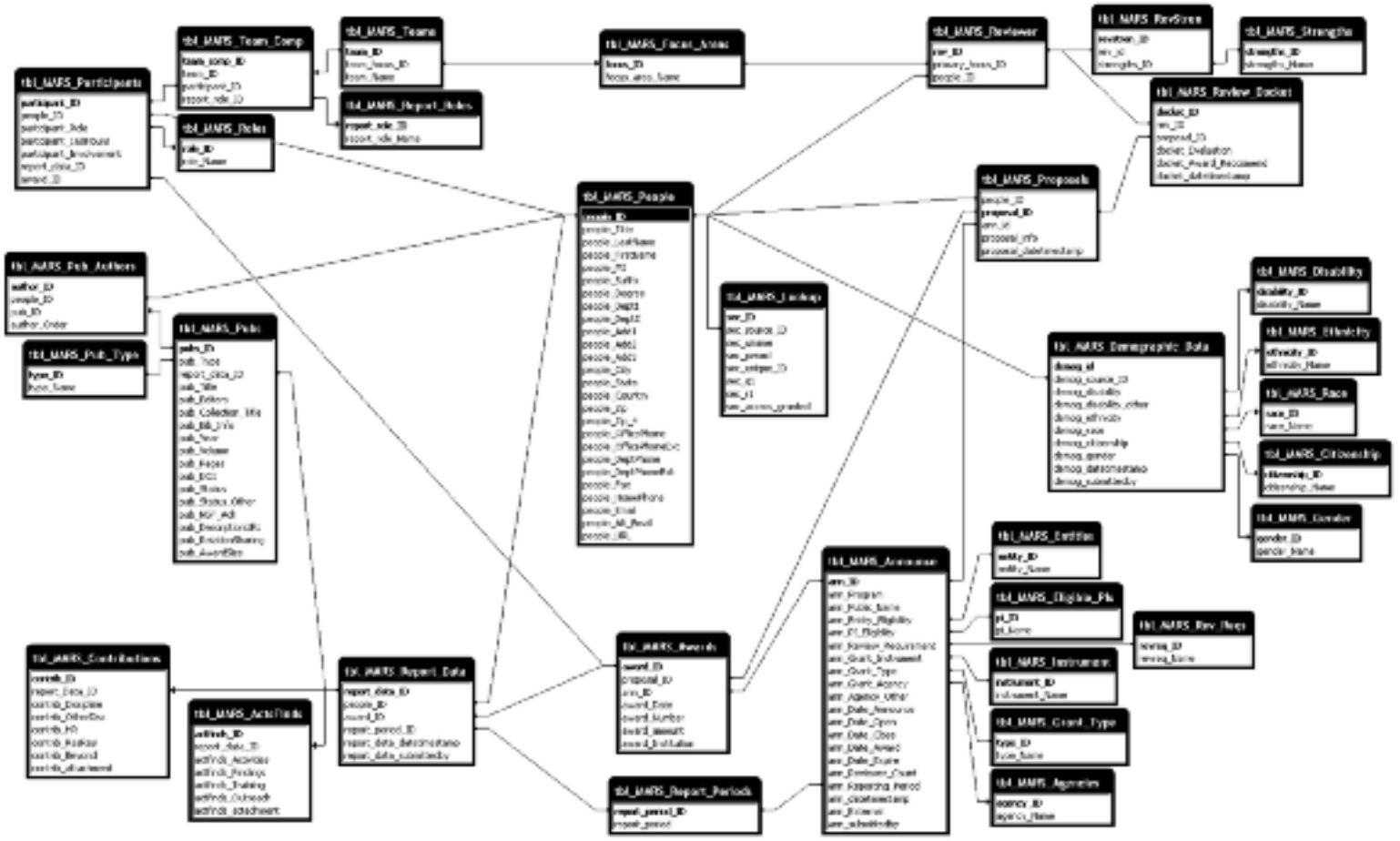
More could be accomplished in broadening participation at the upper levels of the RII management structure and in faculty hiring. The NSF Reverse Site Visit team noted that only one female had been hired as a faculty member (Wang at MU). WVU has implemented a targeted hiring program that has yielded a female hire in nanobioscience and has extended an offer to a second woman, as indicated in the report on "Special Conditions."

The Reverse Site Visit team also noted that there are no women and only one underrepresented minority on the project's External Technical Advisory Board. WVEPSCoR intends to invite additional members to join the external advisory board and will focus on recruiting women or minority faculty who will help evaluate the project and advise our management team. The current six-member executive leadership team (ELT) includes one female and one ethnic minority.

In addition, WVEPSCoR is developing a workshop tentatively titled Increasing Student and Faculty Diversity in STEM Fields. The workshop is being planned with specific goals and objectives and with the assistance of a Diversity Workshop Advisory Committee. Our overall intent is to identify "best practices" in diversification of our STEM faculty and student pipeline, and statewide policies that relate to these issues.

APPENDIX

## **MARS V2.0** TABLE RELATIONSHIPS (PRE-ALPHA)



The diagram above describes the initial framework for the web-based system that will eventually replace MARS.

This new system will be used to announce grant opportunities to researchers at institutions across the state and allow them to submit and track their proposals in response to these RFPs.

With this system, WVEPScoR/Division of Science and Research Staff will be able to monitor the entire grant process – across varying grant vehicles–from initial application, to award, to data collection, to evaluation, and finally reporting and to enable meaningful impact assessment.

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