

Report to Board
Final Report Summaries as of May 2012 - #09 Projects

#09-07 Development of an ICP Etch Process for Nonlinear Optical Materials

Philip Himmer – Montana State University - Bozeman

\$78,728

Final report approved: January 2011

Summary:

A newly manufactured nonlinear optical material, Stoichiometric Lithium Tantalate (SLT), is of great interest to laser manufacturers due to its potential application in commercial products. While none of the etching proved sufficient to allow the fabrication of ridge waveguides, results of this project:

- Allowed the Montana Microfabrication Facility (MMF) to establish etch rates of SLT with several possible masking materials.
- Established that MMF has the ability to pattern and etch ferroelectric materials.
- Indicated that nano-optical devices may be fabricated with the ICP etcher using wafer bonding techniques.
- Resulted in two subsequent STTR awards from NASA to a local optics company for a related processing effort to fabricate ridge waveguides in proton exchanged Lithium Niobate using ICP plasma etching, totaling about \$700,000.

In summary, the micro and nanotechnology industry, of which this project is representative, is beginning to have an enormous impact on the global economy in areas as diverse as electro-optics and pharmaceutical research development. The investment of state dollars in this type of infrastructure technology has the potential to benefit the local economy through successful product development efforts undertaken by local and also by firms outside of Montana. Quantum Design, a magnetic sensor based company in San Diego, California, is an example of one corporation that has expressed interest in coming to Montana if MMF can offer a process capability that will allow them to quickly develop commercial products.

Commercialization:

Ridge waveguide processing is currently under study using a combination of proton exchange and wafer bonding. Should this technique prove successful, AdvR will commercialize products realized from ridge waveguides fabricated at the Montana Microfabrication Facility. There is no short term plan to attempt device fabrication using only dry etch techniques until plasma gas mixtures are found that allow for chemically enhanced etching without LIF redeposition.

Economic Impacts:

A newly manufactured nonlinear optical material, stoichiometric Lithium Tantalate(SLT), is of great interest to laser manufacturers due to its potential application in commercial products. SLT waveguides will find use in optical devices such as miniature, low power displays for cell phones and PDA's, optical circuits for low power frequency doubling of lasers at unique wavelengths (UV = NASA for instance),

integrated optical circuits such as beam splitters, frequency doublers, and phase/intensity modulators on a single chip. A local company (AdvR) specializing in these types of engineered materials has great interest in seeing this process technology offered locally. Two small business technology transfer contracts were awarded to AdvR and MSU to develop ridge waveguides using proton exchanged Lithium Niobate. This work is ongoing.

After initial etching was completed a phase I was awarded to attempt similar etching on proton exchanged Lithium Niobate. Using a CHF₃+Ar ICP plasma etch with a chrome mask the ridge waveguide shown in figure 3 was fabricated at MMF. This initial result helped obtain follow on funding for the phase II effort. Proton exchange replaces Lithium in the sample with hydrogen, this technique eliminated lithium fluoride allowing lower RIE powers. The lower RIE power greatly increases the mask selectivity allowing micron high ridge waveguides to be etched.

A NASA Phase I STTR was subsequently awarded to AdvR (PI: Will Suckow) and MSU (PI: Dr. Phillip Himmer) to further explore this process fabrication idea using the related material, Lithium Niobate. (Contract 08-1-T4.01-9937 GSFC)

A NASA Phase II STTR was subsequently awarded to AdvR (PI: Todd Hawthorne) and MSU (PI: Dr. Phillip Himmer) to fabricate ridge waveguides on Lithium Niobate using a proton exchange, wafer bonding fabrication process. (STTR Proposal Number: 08-2 T4.01 9937)

**#09-09 A Frequency Agile Digital Beamforming Antenna for WiMAX Radio
Wireless Networks**

Yikun Huang – Montana State University - Bozeman

\$160,235

Final report approved: June 2011

Summary:

The novel antenna array developed under this project offers strategic advantages in the next generation of mobile wireless systems because it is capable of dynamic spectrum access, directional power radiation/reception and automatic target tracking. The array system will open up new opportunities for national security and defense, and economic development, and address pressing social needs in underserved areas. This work has focused on software and hardware implementation. Tasks completed in the first two-year period outperformed those outlined in the proposal to a considerable extent. A six-month extension of the project resulted in a completed system that is compact, robust, light weight and energy efficient. It allows wireless experiments and characterization of various array algorithms under realistic channel conditions.

MSU and its long-term collaborator, Advanced Acoustic Concept (AAC) are pursuing applications of the technology both as an integral system to the U.S. Navy and commercial applications. They are working closely with Harris Radio Company to develop a communications system with the Harris' SeaLancet Radio and the MSU smart

antenna for the U.S. Navy. Negotiations are under way with L3, a Salt Lake City company, for applications of the technology in smart antenna, radio systems and full service.

The research results have been presented in major conferences and 12 papers have been published in IEEE Proceedings. Twenty-one papers (including two accepted papers and five pending papers) have resulted instead of the proposed two papers.

Commercialization:

The goal of this project was to insure that the product and technology achieve successful integration with Advanced Acoustic Concepts (AAC) existing torpedo defense program. The concept of an adaptive beam formed antenna system that is applicable for military and high-quality commercial wireless applications has been determined to be feasible and will be converted to a physical prototype. The ability to achieve full-scale production and fielding of the product or technology is the key to successful commercialization.

Product description

Harris SeaLancet™ is a tactical, wideband EFDM networked radio solution designed specifically to meet the demanding communications requirements of military maritime missions.

Target market including size

Other potential customers for the adaptive antenna beam former project include the U.S. Air Force, FAA, Department of the Interior, U.S. Army, Department of Homeland Defense and commercial utility companies. AAC is currently working on programs managed out of these federal offices in areas in which the wireless data link with adaptive beam formed antenna capability could be applied. Additional commercial industry applications include NOAA Offshore Buoys, Animal Tracking, Farming and Agriculture, First Responder Rescue, Mass Transit Broadband Backbone, and Commercial Shipping Broadband Backbone.

- I. Distributed Mission Package Sensor Support System Network Services
Development, Beam Former Antenna – SeaLancet Radio Integration Plan,
prepared for AAC, September 16, 2010

This section describes the plan to integrate the AAC/MSU beam former antenna, radio receiver board and direction of arrival system with the Harris SeaLancet radio with the goal of a working prototype system that can be used in a field demonstration of a point-to-point radio link with stationary and moving nodes. Total estimated component costs to implement the demonstration (excluding labor or travel) are \$6,900.

- II. Design and Test of an Adaptive Smart Antenna – Prepared for RF Alliance for
Transitional RF Technologies, November 16, 2010

This section describes the goals of the project to design and test an adaptive smart antenna that can accurately estimate direction of arrival of signals, optimally beam form, and is able to communicate simultaneously with multiple users. These

objectives address the fundamental problems facing commercial wireless, emergency and military networks.

III. Beamspace Smart Antenna – Prepared for RF Alliance for Transitional RF Technologies, December 2, 2010

This section discusses a proposal to develop a compact beamspace smart antenna for high resolution direction of arrival estimation and beam forming against strong interference. An 8-element UCA prototype has been constructed and a beam former with an WiMAX radio has been tested over an 18-mile path with excellent throughput.

Economic Impacts

Intellectual Merit – The smart antenna developed in this project allows wireless experiments and characterization of various array algorithms under realistic channel conditions that solve many fundamental problems facing wireless networks. The novel antenna array offers strategic advantages in the next generation of mobile wireless systems since it is capable of dynamic spectrum access, directional power radiation/reception and automatic target tracking. The project is timely since dynamic spectrum access for wireless communications is the forefront of next generation wireless networks. Two white papers (see above) have been submitted to RF Alliance for commercialization.

Broader Impacts – In addition to the commercialization potential, the information obtained from this project will continue to serve the broader scientific community through its educational component. Undergraduates, graduates and postdoctoral affiliates will benefit from a comprehensive learning experience provided by the PI. It will involve minority group students through MSU's Community Outreach program to Native American communities, tribal colleges, the American Indian Research Organization, and Montana Apprenticeship Program. Since summer 2006, 31 undergraduates have been involved in basic smart antenna system design, testing and communication networking research. Three of them are Native American students and three are female students.

Summary – This project brought system design together with architecture and algorithm development to provide new features of smart antenna as well as wireless networks for high speed, reliable communications. The algorithm development as well as new RF front-end design, PC interface design, and array design have been well investigated and are considered well suited as vehicles for achieving an advanced level of education and training in the electrical engineering and computer science areas.

#09-13 Improving Milling and End Use Quality of Montana Wheat
John Martin – Montana State University - Bozeman
\$139,260
Final report approved: March 2011

Summary:

The goal of this project was to create useful new variation in genes that have large impacts upon milling and/or baking quality. Two genes, *Puroindolines*, and *Glutenins*, have major impacts on the amount and quality of flour. Seeds of a soft wheat variety were mutated with a known mutagen to create more than 60 new alleles of the *Puroindoline*. The first objective was to characterize their function at the molecular level and their impact on flour yield and end product quality. The second objective was to use the same approach to identify new genetic variants for *Glutenin* genes.

Results of a series of experiments showed variation in flour yield and loaf volume, and identified mutations that had higher flour yield and/or loaf volume than the most commonly grown *Puroindoline* variant. Objective 2 was accomplished by comparing DNA sequences from plants grown from seeds treated with a mutagen with the known DNA sequence for the target *Glutenin* gene. The results of these experiments are encouraging because different end products require different gluten strength.

The project has created new variations for important milling and dough mixing characteristics that can be capitalized upon in developing new wheat varieties with improved quality and added value.

Commercialization:

The goal of this project was to characterize the *Puroindoline* mutations and to create new mutations for the *Glu-D1* subunit genes. The end product with commercial value is a new winter or spring wheat variety where the useful mutation has been incorporated, which would take more than seven years to develop. New varieties from MSU are commercialized through the Foundation Seed program. Foundation seed is provided to certified seed growers who in turn provide seed to growers.

There are approximately 1.5 million acres of winter wheat and 2.5 million acres of spring wheat in Montana. Any new variety could conceivably be grown on 100,000 acres. A new variety may consistently have 1% more flour yield than an existing variety, and could produce 0.6 pound more flour per bushel, or 15 additional pounds of flour per acre could be gained from a 25 bushel per acre wheat crop. Premium high protein flour can sell for \$0.40 per pound, translating to an added \$6 per acre for the variety with increased flour yield, or \$600,000 in added value from the 100,000 acres per year, or \$3 million projected over a five-year period.

Economic Impacts:

Currently, there are no direct economic impacts from this project as the process from discovery to an end product can take more than seven years. However, generation of new knowledge about the *Puroindoline* and *Glutenin* genes and their function is a major output and has resulted in publication of the work in *Genetics*, one of the most highly regarded genetics publications in the world. A copy of the article co-authored by the PI and accepted for publication September 5, 2009, is attached to the Final Report.

#09-19 PDT Cancer Treatment Depth Efficacy Studies Using the Transplantable Rabbit VX2 Carcinoma

Jean Starkey – Montana State University - Bozeman

\$60,000

Final report approved: November 2010.

Summary:

VX2 rabbit carcinomas were used only to generate depth efficacy information. A mouse model was used to examine the ability of PDT to sanitize tumor involved cervical lymph nodes. Good results were obtained from the mouse 4T1 breast cancer model with overwhelming evidence for tumor cell death by apoptosis. These results make it clear that:

- 1) Targeting the PDT sensitizer to EGF receptor on tumor cells produces satisfactory results in terms of selectivity and efficacy.
- 2) It is possible to treat tumor involved lymph nodes with PDT.

The quality of long-term healing in the cervical lymph nodes in any mice that are cured by the treatment will be assessed later and are not a part of this project. Experiments involving treatment of a sufficient number of rabbits with VX2 tumors to generate maximal depth efficacy have been incorporated into a recently awarded grant to SensoPath/MSU. This award is for \$199,386 over nine months and is to undertake the optimization studies for the novel PDT agents. This is work that was to have been supported by Pacific Horizon Ventures, but its revenue stream dried up in the current economic downturn. MSU has rescinded the rights to the primary patent, and the commercialization plan involves revising the patent. Successful results of the Phase I contract could result in a Phase 2 award in the range of \$1-2 million and an IND application in two to three years. Additional patents would be filed pending success of obtaining the Phase 2 award.

Commercialization:

Pacific Horizon Ventures' revenue stream has dried up due to the recent global economic downturn. MSU has, therefore, taken back all rights to the primary patent. The current commercialization plan involves reviving the patent and proceeding with SBIR funding instead of venture capital funding. SensoPath/MSU recently received a NIH/NCI Phase I SBIR contract for a \$199,386 to undertake the optimization studies for the novel PDT agents. Successful results should lead to a Phase II award in the range of \$1-2 million, leading to a FDA IND application in two to three years. Additional patents will follow if the Phase II application is successful.

A major thrust of the anti-cancer PDT project is to file a FDA IND for Phase I trials in head and neck cancer patients with recurrent disease. Other potential applications include lung cancer or treatment of tumor involved lymph nodes.

It is anticipated that a major pharmaceutical company would purchase rights to manufacture and sell the PDT sensitizers.

Economic Impacts

The NICH/NCI SBIR Phase I between SensoPath and MSU is a direct result of MBRCT's support of the anti-cancer PDT project. Two additional people will be hired to conduct the contract work. The long-term impact of the project is that availability of PDT sensitizers is likely to reduce health care costs considerably. PDT treatment can be carried out on an out-patient basis. Current therapies cost \$25,000-\$60,000 per patient per year, while it is estimated that the PDT sensitizers would amount to a one-time cost of approximately \$2,500 per patient.

#09-20 Development of Bismuth-thiol Based Therapeutic Agents for Treating Chronic Wounds

Philip Stewart – Montana State University

\$100,470

Final report approved: December 2009

Summary:

This project was a collaborative effort between MSU and Microbion Corporation, which holds patents on a class of antimicrobial compounds, called bismuth thiols (BTs) that could be useful in the treatment of acute and chronic wounds. Thirteen BTs were evaluated to determine agents best suited for development as a topical anti-infective therapeutic specifically for treating chronic wounds. Two of the BTs proved highly effective against colony biofilms of *Pseudomonas aeruginosa*. Four BTs demonstrated good efficacy against colony biofilms formed by *Staphylococcus aureus* (MRSA). Three BTs tested against biofilms formed in a continuous flow reactor were very effective against *Pseudomonas aeruginosa* biofilms and more effective than some conventional antimicrobials. . The BTs tested against MRSSA drip-flow biofilms were relatively efficacious and more effective than two antibiotics, but outperformed by silver sulfadiazine. Two BTs have been identified for continued development for the wound care market. The Commercialization Plan indicates the project resulted in the commitment of Microbion Corporation to develop one of the compounds tested in this project as a chronic wound therapeutic drug product.

The project has resulted in Microbion Corporation's commitment to develop one of the compounds as a chronic wound therapeutic drug product. The data generated demonstrated high efficacy of BisBAL and another bismuth-thiol compound in terms of biofilm-cidal activity. Microbion has incorporated BisBAL in its FDA regulatory activities, as well as into other highly related, yet distinct areas, including advanced *in vivo* and *in vitro* efficacy testing and an advanced lead selection program. This data support the use of bismuth-thiols in the treatment of chronic wounds and Microbion is committing financial resources to the development of a topical chronic wound therapeutic drug product.

This data also lends support to Microbion's intention to advance the EPA regulatory process relating to development of the bismuth-thiols in several industrial applications, including ship paint, industrial paint, membrane microfiltration coatings for filtration of water, preservatives, and industrial water treatment.

Commercialization:**Product description:**

Topically applied chronic wound anti-infective, antibiofilm drug product

Target market including size:

The global market for wound care products was over \$12 billion in 2007, and is expected to reach \$17 billion by 2012. The US market accounts for 34% of the global market and the countries in which Microbion holds patent rights with market exclusivity represent 70% of the global market. The market for topical wound antibiotics is growing while the use of systemic wound antibiotics is currently experiencing a flat growth rate. Topical antibiotics are comparatively easy to use by a growing elderly population and can achieve effective concentrations in wounds very quickly.

Commercialization strategy:

Microbion's commercialization strategy is to develop its core products (therapeutic drugs) to key inflection points in value, then to partner with large commercialization partners that have a strong history in the therapeutic drug industry of recognizing and being attracted by companies that have reached those key inflection points in value. This may take the form of out-licensing, or development of joint ventures.

Marketing, production and manufacturing plans:

Microbion plans to achieve its advanced product development, manufacturing and distribution, and marketing and sales through its relationship with its commercialization partners. Microbion will participate most actively in the manufacturing process and in leadership and deployment of its share of the marketing and sales force.

Estimate of sales revenues for five-year period into the future:

Actual revenues from sales of the topical chronic wound care product are anticipated to occur in just over five years. Results of up-front payments and milestone payments from commercialization partners could amount to \$10-\$50 million.

Economic Impacts:**Increase in employment levels:**

Results of this project and concurrent project activities are requiring Microbion to hire additional personnel in Montana.

Patents applied for or granted:

Microbion has made a provisional patent application which includes data produced during this project.

Acquisition of investment capital:

Hiring of additional personnel is supported by equity capital from a Microbion investment opportunity that closed 10/16/09. This occurred in two parts during the current economic downturn and resulted in the generation of equity funds of \$1.1 million.

Other:

During the course of this project, Microbion was asked to join a large orthopedic clinical research consortium, with a data coordination center at Johns Hopkins School of Public Health, which thereafter applied for a \$14 million DOD grant. The grant was awarded to the consortium in September 2009 and potentially includes funds for Microbion to advance Phase I clinical studies for the topical acute wound care drug product.

#09-21 Heat-Tolerant Spring Wheat for Montana**Luther Talbert – Montana State University - Bozeman****\$150,000*****Final report approved: February 2011*****Summary:**

The objective of this research was to rapidly develop hard red spring wheat varieties with the genetic ability to produce a high-quality crop under conditions of increasing summer temperatures. Applied research at fields through Montana using specialized genetic stocks allowed identification of the best combinations of genes for conferring heat and drought tolerance to Montana spring wheat varieties. Findings from this project will provide direction for developing varieties that will tolerate the excessive heat often encountered during the grain fill period of spring wheat in Montana.

Commercialization

There are two tracks for potential commercialization of the research:

- (1) The lines that have been developed will enter the statewide testing process for comparison with other widely grown varieties. The best chances for an immediately useful line as a variety are the semi dwarf lines in Experiment 3 (Height-reducing Genes). Amidon and Scholar have been widely grown varieties in Montana for the past 20 years and the semi dwarf versions of these lines will be tested to determine commercial potential. This testing will commence in 2011. Positive result will lead to commercialization through established seed production and seed sales channels. This involves wheat growers setting aside a small portion of their acreage for seed production, basically as a value-added crop. This is the process from which most wheat acreage in Montana comes, primarily using varieties developed by the MSU program.
- (2) The second path to commercialization is more long-term and requires crossing the identified genes into other superior varieties. The best opportunity is with genes identified for long stay-green period. A second valuable benefit from this work has been elucidation of genes that are not wanted.

There were 2.8 million acres of spring wheat grown in Montana in 2010, over 90% of which is non-irrigated and dependent on rainfall. Improved heat and drought tolerant lines are needed for dryland acreage in Montana and its eastern neighbors, thus creating a large market for new varieties. Initial seed sales from any new varieties identified from this project would likely be 3-4 years away and are dependent on results from statewide yield-testing.

Economic Impacts

The overall economic impact of this work is the identification of the best genes for spring wheat varieties under Montana growing conditions. Economic impacts from this research come from both positive and negative results.

The positive results are:

- (1) Semi dwarf versions containing *Rht-B1* and *Rht-D1* of Amidon and Scholar merit statewide yield-testing.
- (2) Use of the molecular marker for the stay-green trait will increase the efficiency of developing heat-tolerant varieties.

The negative result is that it is better for the research program to illustrate in small trials that *Rht8* varieties are not desirable under Montana growing conditions rather than growers finding this out as a result of poor yields of new varieties.

Based to a considerable extent on data obtained from this project, the research team is part of a large, recently-funded USDA grant entitled “Barley and Wheat Improvement for a Changing Climate”. This data provided excellent background for the inclusion of Montana breeding projects in this endeavor, resulting in an award of \$250,000 per year to the MSU wheat and barley breeding teams for the next five years. This new project will allow the teams to extend the search for genes to improve Montana wheat and barley to accessions from around the world. Participation in this project provides MSU with access to the best technologies for genetic dissection of critical traits, and should help insure sustainable productivity of the breeding programs.

#09-23 WiMAX-Based Relay Node with Smart Adaptive Antennas for Mesh Networking

Jian Tang – Montana State University – Bozeman

\$236,880

Final report approved: December 2010

Summary:

The goal of this project was to develop a new radio node and network software infrastructure based on the emerging WiMAX standards that leverage a compact, low-cost smart adaptive antenna system and new chip-scale radio technologies to provide robust and highly available long-range and high-speed wireless communications for rural and remote areas.

Key outcomes include:

- Relay Node Design – A relay node was developed using off-the-shelf WiMAX radio components and a MSU adaptive antenna system.
- MAC Layer Design – An 802.16-compatible MAC layer solution was developed that jointly computes the communication patterns of antennas, transmission schedule and channel allocation for a WiMAX-based Wireless Mesh Network (WMN) with a single Base Station (BS) and stationary nodes.

- Routing Protocol Design – A complete routing protocol was developed to form routing trees for packet forwarding in a WiMAX-based WMN with a single BS and stationary nodes.
- Extension to Mobile WMN – Research and development was extended to cases in which the mesh network has multiple BSs and mobile nodes.
- Validation and Testbed Implementation – Results of the tasks were initially validated via modeling and simulation, using OPNET Modeler (OPNET) with WiMAX extensions. The proposed relay node, algorithms and protocols were implemented and a WiMAX and smart adaptive antenna based WMN testbed were built.

These outcomes enable creation of new functionalities that expand the capabilities of WiMAX radio systems, which opens new commercial market opportunities for Advanced Acoustic Concepts (AAC), the collaborator on the project. These opportunities include applications in offshore buoys, animal tracking, farming and agriculture, first responder rescue, mass transit broadband backbone and commercial shipping broadband backbones. The products developed in this project also offer the potential to provide commercial Internet services for rural and remote areas where current approaches have not proven commercially viable.

Four papers have been produced:

- Paper published in the IEEE Conference on Sensor, Mesh and Ad Hoc Communications and Networks (SECON) 2009
- Paper accepted by IEEE Global Communications Conference (Globecom) 2010
- Two papers submitted to IEEE International Conference on Computer Communications (INFOCOM) 2011.

Six graduate students in the Department of Computer Science and the Department of Electrical and Computer Engineering were trained under this project, including two Ph.D. students, four Master students and an undergraduate student.

Note: Advanced Acoustic Concepts (AAC) is a company that is engaged in the applications of advanced wireless technologies to provide long range, high speed communications capability to remote sensors for government and commercial applications. With headquarters in New York, Montana is one of nine regional divisions.

Commercialization

The outcome of this project is being commercialized through licensing agreement between Montana State University and Advanced Acoustic Concepts. These entities have entered into an inter-institutional agreement to patent the adaptive antenna system and to jointly seek licenses for the patent and associated intellectual property, including the software developed under this grant. In addition to the ongoing effort to integrate the antenna system and software with the Harris SeaLancet radio for a demonstration to key U.S. Navy personnel, the following commercialization steps have been taken:

- Provisional patent was filed 11/10/09.

- MSU posted a press release on 6/2/10 and the technology was posted on the MSU website. A direct mailing to a list of companies was also accomplished.
- In cooperation with the MSU Technology Transfer Office, a list of potential licensees was developed and the announcement was mailed. The announcement was also circulated to print and broadcast media.
- Inquiries have been received from seven companies with potential interest in licensing the technologies.
- In-depth conversations are ongoing with L-3 Communications.
- Three individuals have inquired as to personal use and whether the technology is available commercially.
- A civilian supporting a Navy squadron has made inquiry.

The breadth of initial interest in the licensing package announcement is indicative of the market for the technology. The defense-related market includes ground, air and sea-borne tactical communications systems. The public safety sector seeks integrated, interoperable and highly agile communications infrastructure and the adaptive antenna system and associated networking software are good candidates to fill this need. Potential for growth in this sector is significant. Commercial interest is reinforced by the federally subsidized program to stimulate deployment of broadband communications infrastructure in rural and sparsely populated areas.

Business risks associated with commercialization of the technology will be assessed by the licensees. Predicting licensing revenues at this point is premature.

Economic Impacts

Local economic impacts of the project will depend on the types of licensing agreements that develop. Since neither MSU nor AAC will manufacture products based on the technology, principal returns will likely be in the form of royalties. Another major revenue stream will occur in the form of consulting on product improvement efforts. Initial discussions with potential licensees indicate interest in MSU continuing to conduct research and advanced development of adaptations of the basic technology to particular application scenarios. This would involve research and engineering staff and local companies to fabricate prototypes and to conduct demonstration tests and field trials.

#09-26 Control of Microbial Processes for Enhanced Water Treatment using Floating Island Treatment Systems

Alfred Cunningham – Montana State University

\$250,316

Final report approved: October 2010

Summary:

The goal of this project was to conduct research on the dynamics of microbial communities occurring in engineered floating islands used for water treatment. Basic microbial process engineering research, which provides a fundamental understanding of the microbial processes at work during contaminant uptake, was carried out.

Highlights of the research findings include:

- Re-circulating, aerated columns have been built and operated at MSU's Center for Biofilm Engineering. The experiments resulted in biofilm growth in all columns readily capable of removing COD and converting ammonia to nitrate and subsequently performing denitrification.
- The microbial biofilm communities associated with each substrate were also examined and shifts in the denitrifying community members were observed when nitrate levels decreased.
- These most recent results have been submitted for publication in the *Journal of Water Science and Technology* (special edition on the use of engineered wetlands for waste water treatment scheduled for 2010).
- This research has provided the basis for improving floating island design and efficacy, as well as comprehensive scientific observations which explain how the floating island water treatment technology works.
- These results are providing much needed scientific validation of floating islands as an emerging technology for nutrient removal from waterways. The focus has been on removal of key waste water constituents including organics, ammonia, and nitrate.

Commercialization:

Floating Island International (FII) LLC is a privately owned company headquartered at the Shepherd MT Research facility. It was founded by a group of partners led by inventor Bruce Kania. The company business model is to develop then license its inventions. FII currently has a total of seven licensees, six of which have manufacturing facilities, located in Montana, Louisiana, California, Minnesota, North Carolina, New Mexico, New Zealand and China. FII has also made agreements with distributors in Canada, South Africa, South Korea, and Pennsylvania, who purchase island products from licensees.

Major product lines are expected to include floating island products for municipal wastewater and storm water treatment, agricultural wastewater treatment, petroleum and mining waste remediation, wildlife habitat, shoreline erosion control and wave attenuation, waterscape beautification, and boat docking.

FII protects its technology with extensive international patents, but piracy is a risk. Another risk is that associated with the company's ability to cash flow in the event of a challenge to its intellectual property.

FII experienced its first profitable year in 2009, with a reported gross income of \$1,585,416 and a net income of \$219,078. Gross and net incomes are anticipated to grow at a rate of about 25% annually over the next five years. As of September 2010, FII had no long-term debt.

Economic Impacts:

- ❑ Royalty revenue from the licensees and distributors is used to support the ongoing research and develop programs at FII in Montana. During 2010 FII hired a Montana marketing firm and contracted with four additional professionals from the engineering and business sectors.
- ❑ Since startup, FII has pursued an aggressive policy of intellectual property protection. It has obtained four patents related to floating islands in the

U.S., as well as five patents in New Zealand, one in China, and one in Macau. In addition, there are numerous patent applications pending in the U.S. and internationally, and several new concepts under development with applications in progress.

- Senator Jon Tester toured the FII facility during July 2010 and conducted an outdoor press conference at a test pond to bring attention to potential floating island applications for the Gulf of Mexico oil spill. The visit was documented on several television stations, as well as a front page article in the *Billing Gazette* newspaper. Senator Tester was informed of the funding provided by the MBRCT, and has indicated strong support for FII and its products. One product (“BioBarrier”) has received initial federal approval for use in marine oil spill mitigation, and a test of this product is currently underway on the coast of Louisiana. There has also been an article in the *Bozeman Chronicle* describing the efforts of Al Cunningham (MSU-CBE) and Frank Stewart (Stewart Engineering) in the floating island research and development program.

#09-28 MEMS Variable Focus Lens: Technology Development for Commercial Applications in Medical Imaging and Consumer Electronics
David Dickensheets – Montana State University - Bozeman
\$150,000

Final report approved: April 2011

Summary:

Montana State University teamed with Bridger Photonics to develop new technology and product concepts for an electronically controlled variable focus optical lens. This project has resulted in moving the technology from proof-of-principle devices to a repeatable batch fabrication process that is now at the commercial prototype stage. Potential markets for the technology have been identified, an entry product definition has been developed, and a partnership with an established commercial vendor of MEMS devices as a pathway to commercialization has been established.

The new variable focus lenses are distinguished technically from competing technologies by:

- Superior optical quality
- High speed response
- Tunable aberration compensation
- Simple electronic interface
- Small size that makes the technology suitable for highly miniaturized instruments (endoscopes and cell phone cameras)

The commercialization strategy emphasizes early sales in the low volume, low barrier, scientific and R&D markets. This strategy will allow bootstrapping subsequently entry into higher volume, higher risk, more lucrative consumer product markets.

Highlights of the Project:

- Moved from “proof of concept” single devices to a wafer-scale batch fabrication process that produces optically superior deformable mirrors in commercially viable numbers
- Successfully transferred MEMS technology from MSU to Bridger Photonics and trained BP employees in the use of the MMF cleanroom facility and the processes used to manufacture the MEMS mirrors
- Developed new techniques to improve variable range of focus by more than 50%, resulting in a competitive commercial advantage
- Defined multiple commercial markets
- Designed and built a “technology demonstrator” for the MEMS device as the active element in a variable focus camera with no translating lenses or motors
- Formed a partnership with a leading optical MEMS company for collaborative development and marketing of the product
- Received additional Federal funding for the project in excess of three times the MBRCT award, with significant additional future funding anticipated
- More than 80% of the award was spent in Montana, and 60% or more was spend on salaries for Montana workers.

Commercialization

Two near-term products and a group of three custom integration solutions are envisioned.

- A bench-top focus control device for general laboratory use. The target market is bench-top biomedical imaging and general research. Anticipated market entry is 2011.
- Add-on to a conventional microscope to provide rapid focus control and correction of sample-induced aberrations. The target market is microscopy and general research. Anticipated market entry is 2012.
- Miniature zoom cameras. The target markets are cell phone cameras and robotic surgery. Anticipated market entry is 2013.
- Focus and aberration controlled mirror for integration into medical imaging system. Once BP has performed proof-of-principle demonstrations for requisite miniaturization, it will seek partnerships with companies specializing in endoscopes for commercialization. The target market is endoscopy/cancer and disease detection and diagnosis. Anticipated market entry is 2014.

Business risk assessment

Competing technologies include liquid crystal lenses and liquid lenses. In comparison to these technologies, Bridger Photonics has four key advantages:

- Response time is faster
- Surface quality is superior
- Aberration correction is a highly desired ability
- Is not sensitive to wavelength and polarization

Estimate of sales revenues for five-year period into the future

Bridger Photonics intends to launch its bench top system in 2011 in collaboration with its partner, Boston Micromachines. 2015 projected revenues from that product offering are

\$2 million. 2015 projected revenues from that product and BP's microscope focus control add-on system, miniature zoom cameras, and confocal endomicroscopy systems total \$11.7 million.

Economic Impacts

Bridger Photonics considers this MEMS technology to be an essential component of its advanced imaging business area. The company is located in Bozeman and will manufacture the device at the Montana Microfabrication Facility (MMF) at MSU. BP is licensing the technology patent rights from MSU, which creates a competitive advantage and prevents others from entering the market place. Bridger and MSU are seeking additional intellectual property (IP) to further secure its competitive advantage.

As a result of MBRCT funding, BP received a Phase II STTR grant from NSF for \$440,000 for two years starting May 1, 2010.

- Commercialization planning and technology demonstrations were critical in convincing NSF of the technology's suitability for Phase II funding.
- The STTR grant includes a partnership with Boston Micromachines Corporation, a world leader in MEMS technology. This collaboration will accelerate product development and unlock key market segments and distribution channels for BP's product lines.

BP has grown rapidly since its inception in 2007. **Part of its success, BP attributes to MBRCT funding.** BP has grown from 1 full-time employee to 13 at the end of 2010. BP's revenues have grown from \$0.1 million in 2007 to over \$2.5 million projected in 2011. The company is transitioning to include a commercialization focus while maintaining current levels of research funding.

#09-33 Research Support for Standardizing a Comprehensive Biofilm Efficacy Test System

Darla Goeres – Montana State University - Bozeman

\$133,970

Final report approved: November 2009

Summary:

This project was conducted in collaboration between the Center for Biofilm Engineering, a MSU Mechanical Engineering Technology Professor, and BioSurface Technologies (a Montana company, and world leader in biofilm research supplies). The objective of the project was to design, build and test specialized tools that would enable laboratory personnel to more efficiently conduct biofilm efficacy testing.

The project produced two products. The first product designed, prototyped and tested is a tool designed to hold biofilm reactor coupons. The Coupon Manipulation Tool (CMT) was demonstrated at the Montana Biofilms Meetings in Bozeman and received favorable reviews from researchers who have used the device in their laboratory experiments. BioSurface Technologies (BST) is considering ways to market the product.

The second product is a Laboratory Organization Tray System (LOTS), which is an organization system that creates an efficient work space for the technician. The concept was demonstrated at a Biofilm Conference in July 2010 with favorable reviews and is now the focus of an undergraduate engineering design project.

Commercialization

The report is provided to the Center for Biofilm Engineering by BioSurface Technologies, its industrial partner.

Product description

- I. Coupon Manipulation Tool (CMT) – an easily held, single-coupon device that holds individual coupons. The CMT is autoclavable and re-useable.
- II. Laboratory Organizational Tray System (LOTS) – a laboratory tray with sampling tools and items organized into fixed holders on a tray to aid the technician by organizing all necessary tools and components in one location.

The CMT is specific to the CDC and RDR Biofilm Reactor sampling protocols, while the LTOS has more broad applications for all types of laboratory sampling and testing.

[For detailed discussions of product reviews, competing products, production development and commercialization, the complete Commercialization Plan is found on pages 23-30.] The CMT will be introduced and available for sale at the Montana Biofilm Meeting in February 2011. The LOTS market premier is planned during the American Society of Microbiology General Meeting in New Orleans in May 2011, although this schedule is pending acceptance of the final manufacturing plan prior to the end of April 2011. The CMT is included on the BioSurface Technology web page (www.biofilms.biz) and the LOTS will be added prior to anticipated product release date of May 20, 2011.

The devices will provide an additional product line for BST. The market will be driven by the acceptance of the CDC and RDR Biofilm Reactor Standard Methods for the testing of biocides and biofilm reactive surfaces. The CMT is under contract with a southwest Montana machine shop for product release at the end of 2010. Profitability is projected 3-5 years. The LOTS has a broad appeal and applicability to a much larger industry and research group that just biofilm researchers. Prototyping, manufacturing, and sales are projected by the end of third quarter 2011.

Economic Impacts

Funding of the proposal capitalized on the expertise found at MSU, helped to secure a global market for a local company, created manufacturing jobs in Montana, and contributed to the education of six undergraduate students.

#09-35 New Fluorescent Biosensors for Drug Discovery
Anne Marie Quinn – Montana Molecular LLC - Bozeman
\$75,000

Summary:

The products which this project advanced are fluorescent assays for cell-based drug discovery that are robust enough for automated high-throughput screening (HTS). The project (to build a FRET-based biosensor) is based on the idea that a drug induced change in target conformation would initiate energy transfer between two fluorescent proteins and produce a signal that could be collected by the automated imaging systems used in drug discovery. Marketing and distribution for these new products will occur by license agreement to a leading supplier of fluorescent detection reagents with established global distribution channels for cell-based assay products. Montana Molecular expects royalties on net sales in the range of 8-10%.

Commercialization:

The final milestone - cAMP Product Launch – with a projected target date of December 1, 2009, (after the termination of this portion of the project) involves commercialization of the biosensor as a cell-based drug screening assay. This will be done in collaboration with the strategic partners and involves testing optimized biosensors in a controlled HTS environment, QA/QC product packaging, and commercialization. The milestone has been moved up for completion after the first of the year due to the schedules of the collaborators and pending availability of the automated plate reader instrumentation. It will take about four months to complete successful HTS read-outs, QA/QC cycle and marketing development. Marketing and distribution rights will be by license agreement to the strategic partner, which is a leading supplier of fluorescent detection reagents with established global distribution channels for cell-based assay products. Royalties on net sales to Montana Molecular are expected to be in the range of 8-10%.

Target market including size

The products that result from this project will target pharmaceutical companies and nonprofit organizations engaged in drug discovery using cell-based, high-throughput drug screening and have invested in an automated fluorescent plate reader. The market segment for these types of products is estimated at \$44 million.

Business risk assessment

Competitive risk in drug discovery platforms is driven by advancements in technology that occur at a very high rate. Strategic partnership will reduce the largest source of that risk. However, as the demand increases for live cell assays, competition from other companies is inevitable. Strategic partnerships will enable Montana Molecular to move products quickly to the marketplace, while maintaining focus on raising capital for research and development and developing additional breakthrough applications for drug discovery and live cell imaging.

Estimate of sales revenues for five-year period into the future

Over a five-year period, Montana Molecular expects to capture 20% of the \$44 million market.

**Economic Impacts:
Follow on Funding**

The current strategy has been to measure the change in the fluorescence intensity and, although a few candidates have been identified with robust signals needed for drug discovery, the inherent variability in intensity measurements has produced inconclusive results in some cases. Therefore, an alternative measurement, fluorescence lifetime measurement, in collaboration with Fluorescence Innovations (FI) in Bozeman will be pursued to use FI instrumentation to measure the lifetime response of Montana Molecular biosensors. This opens up a new avenue for innovation in the drug discovery arena. If preliminary pilot studies are successful, Montana Molecular and Fluorescence Innovations will submit a new SBIR to pursue a strategy of commercializing FRET biosensors packaged with the instrumentation needed to screen drug compounds for fluorescence lifetime responses.

The data generated by this project was used in an SBIR application to the NIH April 1, 2009. Although the application scored in the top 40%, it did not receive funding. The NIH program officer encouraged resubmission, which the PI will do on December 1, 2009.

#09-40 Resource Assessment of Deep Coals in Eastern Montana: Potential Targets for Commercialization by In-Situ Gasification

Jay Gunderson – Montana Bureau of Mines – Billings/Butte

\$149,334

Final report approved: December 2010

Summary:

The objective of this project was to carry out a regional assessment of the resource potential of deep coal seams in eastern Montana and categorize their suitability for the underground coal gasification (UCG) process. UCG is a method of gasifying deep unmineable coal seams, and producing a synthetic gas to the surface for use in power generation or as feedstock for coal-to-liquids. Geophysical logs from over 6,000 oil and gas wells were studied to identify coal beds in the subsurface. From this data, geologic maps and cross sections were constructed depicting areas likely to be most favorable for *in situ* gasification. The Fort Union Formation has enormous potential for UCG, with thousands of square miles in the Power River Basin and Williston Basin of Eastern Montana. Results of this project demonstrate that Montana has considerable deep coal resources that could be exploited by *in situ* gasification or other technology. This information is critical for developers and investors to identify and evaluate potential UCG sites. Several domestic and international companies have shown interest in this study; and, although the number of UCG developers is small, if just one project was pursued in Montana, the investment would be huge – possibly in the 100's of millions of dollars.

Commercialization

Product description

The product is information which is needed by anyone interested in developing coal resources at a depth below the range dictated by surface mining. The information is in

the form of maps and cross sections depicting the geometry of coal beds based on preliminary screening. The maps are digital and can be readily updated as more data becomes available or UCG screening criteria change.

Target market including size

The market size is small; however if a single customer developed a single project, the investment would be enormous, in the magnitude of hundreds of millions of dollars for a single site. At least five companies have contacted MBMG inquiring about sites and, although they request confidentiality, they have expressed great interest in this study. The information obtained from this study is necessary and helps to answer critical questions during the initial stages of exploration for UCG sites.

Marketing strategy

The marketing of this information is meant to sell potential investors and developers on the merits of Montana's deep coal resources. Partners in using these data for marketing will include coal resource owners (private, state, federal), private parties or public officials with interest or responsibility for promoting development of coal resources, and any parties with access to actual development dollars, such as investors or energy companies.

Product Pricing Considerations

Reports are publicly available for free, or for the nominal cost of reproduction. The payback is eventual development of the deep coal resources.

Business risk assessment

This preliminary screening is intended to mitigate the risk of Montana being unable to provide developers with basic information needed to pursue UCG projects. It highlights areas with good potential and eliminates unsuitable sites, putting Montana in a better position to compete with neighboring states. The potential payback from development of a single site is huge, but for this to happen, Montana must be proactive in providing timely and adequate data to the people making decisions regarding UCG.

#09-43 Developing Laboratory Applications for Inhibitors of Fungal Morphogenesis

Kurt Toenjes – Montana State University Billings

\$250,397

Final report approved: August 2010

Summary:

The purpose of this project was to develop an anti-fungal agent with potential for commercialization as a laboratory reagent and a new line of fungicidal drugs. Two specific aims were proposed to clarify the mode of action of BH3I-I, an inhibitor of yeast-to-filamentous growth transition.

Aim I: Utilize proteomic approaches to identify potential BH3I-1 target proteins

This specific aim is well underway with analysis of the soluble fraction. Some technical

challenges have been encountered, but this is not unexpected or unusual for this type of research. Analysis of the membrane fraction is particularly difficult because the hydrophobicity of the proteins interferes with the isoelectric focusing step of the analysis.

Aim II: Take advantage of a powerful “chemogenomic” assay developed in the non-pathogenic yeast *Saccharomyces cerevisiae*

This specific aim has been completed and additional work was performed. Several genetic approaches were undertaken, including a bioinformatic approach combined with a yeast two-hybrid interaction screen, which yielded several potential target proteins.

Commercialization:

The long range goals are to develop BH3I-1 as a commercially available chemical inhibitor of *C. albicans* filamentous growth for *C. albicans* research and to begin to explore its potential as a therapeutic agent. Determining the mode-of-action of BH3I-1 in fungi and determining its therapeutic efficacy are required steps for use of the molecule in a laboratory setting and as an anti-fungal agent. Once these steps are completed, further development of this molecule for laboratory use or as a therapeutic agent will be direct. The steps are necessary in order to obtain additional funding from NIH and Big Pharma. If the molecule does not show therapeutic efficacy, it will be utilized as a tool to elucidate Programmed Cell Death pathways and develop other therapeutic approaches.

Product description

Potential uses of the BH3I-1 molecule will be in a laboratory setting and as an anti-fungal agent.

Target market including size

- 1) One potential application is as an important tool utilized by research labs to control the growth patterns in *Candida*, *Aspergillus*, and *Saccharomyces* species. The shortest path to market with the least investment (5-7 year timeline, \$2-\$4 million) would be to supply the molecule as part of a “lab kit” for direct use by a researcher.
- 2) Another application is as a specific anti-fungal prophylaxis on intimate-contact products. Bausch & Lomb’s interest in preventing colonization of contact lenses leading to fungal infections in the eye would be the most immediate and compelling market given the scale of contact lens use. Other possibilities are feminine hygiene and contraceptive products, diapers, baby wipes, bandages, medical instruments, etc. Companies such as Johnson & Johnson and Procter & Gamble may be interested in a testing and licensing opportunity to gain competitive advantage in consumer products purchased without prescription. This application represents a potentially lucrative market and would require a minimum of 10 years to market and an investment of tens of millions of dollars.
- 3) Anti-fungal products for in-hospital use to reduce deaths from fungal infections is another potentially significant application. The need for human trials and further refinements at research hospitals makes this a minimum of a 10-year-to-market path requiring a Big Pharma investment of hundreds of millions of dollars. It, too, is a compelling market that FDA might expedite approvals for.

- 4) Integration into existing cancer treatment regimens as part of a drug cocktail for chemotherapy patients. Later stage partners would include the National Cancer Institute and the American Cancer Society, with Big Pharma as a next stage investor to commercialization. FDA may fast-track this application given the severity of a cancer patient's initial problem and the rate of fungal infection incidence in these patients. This application is a minimum 10-year path to market requiring the involvement of big partners.

Estimate of sales revenues for five-year period into the future

Commercialization of BH3I-1 will require considerably more than five years.

Economic Impacts

Increase in employment levels

Project funds were used to support two full-time technicians the first year and one full-time technician the second year. It also supported up to four undergraduate students per year who worked up to 35 hours a week in the summer. It also provided summer support for two faculty members.

Patents applied for or granted

A patent for BH3I-1 was filed for previous to the submission of this grant. Additional data generated during the first and second year of this grant was used to respond to questions posed by the examiners. Verbal conversations with the examiner suggest these efforts were successful. Formal notice is expected in the fall 2010.

#09-47 Development of Germination Technique for *Carex*, *Scirpus*, and *Eleocharis* Species

Tim Meikle – Great Bear Restoration - Hamilton

\$39,324

Final report approved: September 2009

Summary:

The project was funded to develop new germination techniques for wetland plant species. The three-fold purpose of the project was to: (1) Develop a seed treatment process which increases and synchronizes germination of wetland species for use at a commercial scale; (2) Reduce agricultural worker risk upon introducing this process to greenhouse operations; and, (3) Reduce the waste stream created by the process. The project achieved the objective of developing effective seed treatment protocols for six varieties of Sedge. New germination strategies were formed for four other wetland plant species. Safety and waste disposal objectives were successfully developed for the procedure.

The project has contributed to the commercial potential for this Montana agricultural business and has resulted in potential for expanded production and sales of wetland plants. The process developed plays a critical role in the development of a pre-vegetated coir product for erosion control and wetland restoration project.

Commercialization:

Product description

Proprietary seed treatment process designed to increase the efficiency of production for several wetland species and to provide for a greater degree of agriculture worker safety. The process will result in revenue from the production of containerized plant material and value-added products: (1) Containerized wetland plants; (2) EcoSod, a potentially high-value product for highly visible, erosive sites; and (3) Pre-treated seed for container nurseries.

Target market including size

Primary markets will be the sale of containerized wetland plant material; secondary market will be EcoSod and the sale of pre-treated seed. Market region consists of Montana, Idaho, Washington, Utah, Nevada, and Wyoming. A total potential market is conservatively estimated at \$4.5 million annually for this region. An attempt has been made to provide basic information on the market for container seedlings, EcoSod, Pre-Treated Seed, and that information is found on pages 3-5 of Appendix E. Commercialization Plan.

Marketing strategy

Marketing efforts are focused on: (1) Direct phone contacts; (2) Attendance and presentation at trade shows; (3) Review of internet bid sites; (4) Upcoming GBR website. Pricing considerations include being more competitive in the existing marketplace and encouraging development of new projects.

Production or manufacturing plan

BGR has a greenhouse facility with seed cleaning, storage, and stratification capabilities in place. Capital upgrades will be made as necessary by January 2010 with the intention of processing seed by February 2010 and providing containerized wetland plants by June 1, 2010. The process will be incorporated into the production of EcoSod (for the first delivery by mid-July) by May 1, 2010.

Business risk assessment

Development of the technology is considered as low to medium risk. Safety is the greatest upfront investment. GBR is an existing business and a competitive player in the native plant supplier marketplace with long-term contracts currently in place. The greatest barrier to market entry is the degree of technical expertise required to complete the process. A review of the literature revealed no competing technologies. BGR will maintain the process as a proprietary trade secret and will review the possibility of a patent application for any apparatus manufactured during the development of the process.

Estimate of sales revenues for five-year period into the future

Total assumed revenues for 2014 approximate \$2.4 million.

Economic Impacts:

Economic impacts are expected in 2010. The primary impacts will be increased capacity for production for wetland plants and opportunities for the further development and sale of a revegetated coir product.

A note about the company - Great Bear Restoration (GBR)

GBR is a small business with six full-time employees and three seasonal employees. It was established in 2006 as an enterprise of Human Interactive Products, Inc., a business incubator in Hamilton. The company provides services to federal and state agencies, municipalities, industry, and private individuals to restore disturbed landscapes to a native condition. The company's revenues have grown from \$2,600 in 2006 to an estimated \$1,247,221 in 2009. Its products and services include environmental consulting, native plant production, and restoration services.

#09-51 Preclinical Development of a Low Dose Methamphetamine as a Neuroprotective Agent Following Stroke and Traumatic Brain Injury

David Poulsen – University of Montana - Missoula

\$202,790

Final report approved: September 2010

Summary:

There were two goals of this project. The first goal was to identify the full dose range of methamphetamine that provides efficacy as a neuroprotective agent following embolic stroke in a rat model. The primary objective of this aim was to identify the dose that provides the maximum level of protection. A single dose of 1.0 mg/kg/hr provided significant and robust neuroprotection when administration was begun at 6 and even 12 hrs after stroke. This is significant because no other compound tested to date has shown neuroprotection when administered this late after injury.

Although not originally proposed, it was determined that it was critical to conduct a pharmacokinetic analysis of methamphetamine in rats under the therapeutic dosing regimen that provided neuroprotection. Additional studies determined the lowest effective dose under conditions of focal embolic stroke.

The second goal of the project involved using the optimum dose to test methamphetamine as a neuroprotective treatment following severe traumatic brain injury. Using the optimized dose on a rat model of pressure induced traumatic brain injury, profound neuroprotection was demonstrated.

Successful completion of these studies has provided essential data, which supported the filing of a fast-track SBIR application with the NIH and an investigational new drug (IND) application with the FDA in preparation for Phase-I human clinical trials. Although the Fast Track SBIR award was not obtained, receipt of FDA IND approval has allowed completion of a successful Phase I human clinical trial. The successful completion of these studies has added significant value to the intellectual property upon which this technology is based, increasing the potential of future licensing agreements.

Commercialization:

University of Montana has licensed the intellectual property to Sinapis Pharma, Inc., which is developing the commercial application of methamphetamine in the treatment of stroke and traumatic brain injury. When proof of concept has been established, the technology will likely be acquired by, or sub-licensed to, a major pharmaceutical company to complete clinical testing and commercialization of the product.

Financing - Sinapis Pharma capitalization thus far has been from founders, board members, grants, a Series "A" convertible preferred financing of \$510,000 from private investors, and a Bridge loan financing of \$300,000, which closed on May 10, 2010. Execution of a Pharma deal after successful proof-of-concept studies could place a \$100-\$200 million value on Sinapis Pharma.

Product description

The patents-pending cover the company's new clinical indications for methamphetamine in the treatment of stroke and traumatic brain injury.

Target market including size

Biotechnology industry - The biotechnology industry is experiencing exponential growth worldwide. The U.S. biotechnology industry reached the value of \$68.6 billion in 2005 and grew at a rate of 13.3% during that year alone. Public biotechnology firms generated nearly \$75 billion in revenue in 2006, a 47% increase from 2005 revenues.

Potential market for stroke - The potential market is multibillion dollars annually. Assuming a relatively conservative cost of treatment of \$1,000, the market is potentially worth half a billion dollars annually in the US alone. Additionally, the technology should be ideal for the treatment of stroke victims in other countries, particularly those with low-technology health care systems where more than 15 million people suffer stroke each year.

Potential new market – head injury - During 2006, branded drugs with total sales exceeding \$18 billion lost patent protection, and an additional \$21 billion of branded drug sales were expected to come off-patent during 2007. Large-pharma collaborators have begun to gravitate earlier to offer biotechnology firms increasingly attractive terms for early-stage drugs. Analysis of more than 40 large-pharma licensing deals completed during 2004 and 2005 revealed that deals involving preclinical and Phase I compounds provided an average of about US \$16 million.

Intellectual property

An international patent application was filed on August 15, 2007, claiming priority to U.S. provisional application filed on August 23, 2006, and is directed to a method of reducing the occurrence of neuronal cell damage, including death, using methamphetamine. National stage patent applications have been filed to preserve foreign patent rights, and additional patent applications directed to improvements to the invention were filed in 2009. A second international patent application was filed on March 1, 2010, claiming priority to an application filed on February 28, 2009, directed to improvements

relating to methods of reducing brain cell damage or death caused by traumatic head injury, transient cerebral hypoxic and/or ischemic condition also using methamphetamine.

Business risk assessment including (but not limited to):

Competition – There is only one drug approved for use in stroke by the FDA. It is Alteplase, with the trade name Activase® and is sold by Genentech. It is not a neuroprotective agent like methamphetamine and would not compete with Sinapis Pharma’s drug in the market. Methamphetamine is off-patent, inexpensive to manufacture, stable, easy to hand, can potentially be administered up to 16 hours or longer after a stroke occurs, has low toxicity, and minimal side effects. Sinapis Pharma’s intellectual property protection strategy is sound, which puts the company in a good position for negotiations with a large pharmaceutical company after proof of concept for stroke and traumatic brain injury has been established.

Negative reputation of methamphetamine as a recreational drug – Although it is a popular recreational drug with significant abuse potential and health risks, methamphetamine has full governmental approval for human use only in the U.S. where it is used in oral formulation for treatment of narcolepsy, attention deficit disorder, and obesity. Negative public opinion could significantly restrict the company’s ability to gain regulatory approval.

Unexpected toxicity – Although the company believes the methamphetamine intravenous bolus/infusion will be safe and non-toxic and it has enjoyed safe clinical use for decades, there can be no guarantee that unexpected toxicity will not be encountered in human clinical trials.

Regulatory risk/failure to obtain FDA approval – Although the company’s team has significant experience in gaining FDA approval, there is no guarantee that can be obtained in a timely fashion.

Economic Impacts

Patents applied for or granted

The technology developed has resulted in the filing of two US/international patents applications. It has also resulted in an FDA approved investigational new drug (IND) application. This represents the first drug therapy developed at UM that has moved to clinical trials.

Development of intellectual property

MBRCT support has led to the preclinical development of intellectual property owned by the University of Montana.

New businesses created or expanded

Support of the project has led to the development of a new company, Sinapis Pharma, Inc.

Increase in employment levels

This project has provided employment for Dr. Poulsen (PI), Dr. Rau (post doctoral fellow), Ms. Kothiwol (technician), and Mr. Wohgenhagen (technician).

#09-56 Research and Commercialization of the SepticNET™ Nutrient Removal Technology

Steven Anderson – Water & Environmental Technologies

\$187,038

Final report approved: October 2009

Addendum to Final report approved: April 2010

Summary:

The purpose of this project was to develop, test, and commercialize a full-scale, on-site advanced septic treatment system, called SepticNET™, capable of removing total nitrogen (TN) to below 7.5 mg/L, removing more than 90% of total suspended solids (TSS); and, removing more than 90% of biochemical oxygen demand (BOD).

The research and product development conducted during this project included:

- Design, assemble, and install six (6) full-scale, on-site septic treatment systems.

The systems included 5 below-ground systems and one above-ground system.

- Determine the maximum efficiency of the installed systems. Numerous design and operation options were evaluated including reactor configuration, flow control, bio-film carrier material, and reactor configuration.

- Determine the potential for alternative energy options.

The power usage for the installed systems was logged and different potential alternative energy sources were evaluated. A solar system was designed, but not installed due the high cost and potential for interrupted service during the long, cold winter months in the Butte area.

Commercial Potential:

The commercial potential for SepticNET™ is significant in Montana and numerous other states. The Montana DEQ granted approval for a single SepticNET™ on July 1, 2009, and a more broad approval is expected in fall 2010.

Product description:

The SepticNET™ is a patent-pending superior nutrient removal system for on-site septic systems. Designed for use with new home construction or as an upgrade to existing septic systems, it outperforms all existing competitive systems currently approved by the Montana DEQ or EPA by more than 300%, reducing total nitrogen concentrations below current levels that trigger regulatory action.

Target market including size:

Three major target markets are: land developers seeking permits for large residential developments in rural or suburban areas; individual homeowners installing septic systems during new construction; and, individual homeowners needing or desiring to upgrade existing septic systems.

Marketing strategy:

Initial marketing focus will be within the state of Montana and, eventually, will expand to applications anywhere in the United States. The major topics to be addressed include: developing a complete list of potential customers throughout Montana, beginning with developers; preparing a detailed plan for marketing the system to target markets; constructing a mobile demonstration unit to show potential clients; preparing appropriate marketing materials targeting different market segments; combining personal visits with distributed marketing literature to inform the target markets of the features, capabilities, and benefits of the system; develop product manuals for installation, operation and ownership of the system.

Product Pricing Considerations:

Preliminary cost estimates for manufacturing, installation, and operation show that the SepticNET™ system can be offered in the range of \$16,000 - \$20,000 for an installed system.

Production or manufacturing plan:

Parts and raw materials will be purchased from suppliers already identified. Production and assembly will be completed on site. Electronic controls will be custom-built by a qualified system control manufacturer. The production facility is located in Butte and currently has a total of 5500 square feet of office, storage and warehouse space.

Business risk assessment:

The primary risk involved in the commercialization process will be the ability to gain approval from MDEA to certify the system. A key factor in reducing the initial financial investment will be to produce the systems on an “as needed” basis.

Estimate of sales revenues for five-year period into the future:

Approximately 3,644 septic systems will be installed each year. The first year goal is to install 300 systems, at an estimated cost of \$18,000 each, for a total revenue of \$5,400,000 generated the first year.

Economic Impacts:

A business generating \$5.4 million in revenues and employing 5-10 people would represent a significant contribution to the local Butte economy. A significant portion of the revenue would go to hiring local and state suppliers and contractors. The business has the potential to double or triple revenue in the first three years and to become a major source of economic development in the region.

New businesses created or expanded:

Based on the results of the research, WET is planning to create new businesses designed to manufacture and sell complete systems based on the model systems tested as part of this project.

Increase in employment levels:

Initial employment projects are estimated at up to five full-time positions created in the first year and up to 15 full-time positions after two years. Subcontractors located throughout the state will be required on an as-needed basis to install the systems.

Patents applied for or granted:

Two patents based on the systems tested during this project have been applied for:

- 1) A utility patent application for the SepticNET™ was submitted in August of 2009.
- 2) A patent for a carbon-based bio-film carrier that was evaluated and tested during this project. This carrier has applications in areas other than the SepticNET™ system.

Montana DEQ granted approval for a single SepticNET™ on July 1, 2009, and a more broad approval is expected in the fall of 2010.

#09-59 Enhancement of Montana Coal to Support Future Expansion Sodium Removal Technology Development
Jay McCloskey – Montana Tech - Butte
\$105,000
Final report approved: May 2012

Summary:

Montana has approximately 120 billion tons of coal reserves, more than any other state in the U.S. However, Montana ranks only 6th among the states in coal production. One factor that has historically limited the market for certain Montana coal reserves is the relatively high sodium content, which causes excessive slagging in most power plant boilers. The intent of the project was to identify and physically duplicate selected sodium removal and sodium recovery treatment alternative(s) for laboratory bench-scale evaluations. The overall objectives of the project were to develop and evaluate viable sodium removal and sodium recovery treatment alternatives for the Montana Coal Industry.

An extensive literature review showed that two major technological approaches have been investigated to mitigate the sodium problem during combustion: Solution leaching and addition of metal compounds or mineral phases. This study focused on the characterization and development of a technology to remove a portion of the sodium so that the coal would be suited for use in conventional power plants. The technology chosen for study was to use relatively dilute acid treatment on the coal to lower the sodium content to approximately one-half of the original content.

Four Montana coals were collected for evaluation. The chemical characterization conclusions are that:

- Effective extraction occurs using moderately mild acidic conditions.
- In general, hydrochloric acid is a more effective reagent than sulfuric acid; although acceptable results can be achieved with sulfuric acid.

- The addition of ion exchange reagents are not necessary based on studies on Coal B.
- Sodium removal is from the maceral phase for mild acidic leaching conditions and from the maceral and mineral components for low-pH conditions. This is in agreement with published literature results for other low-rank coals.

Potential Commercialization

It is the investigators belief that several things need to be accomplished before a determination can be made as to the potential commercialization of the studied technology described in this report, including:

- Investigation to determine if multiple leach solution contacts with new coal will allow recycle of the leach solution without detrimentally affecting the leachability of the coals and to produce a concentrated sodium bearing solution in order to limit the amount of leach solution that would have to be treated prior to water recycle or disposal.
- Water cleanup will be required because of the relatively high sodium and chloride or sulfate content. There may also be some dissolved metal species that have to be removed.
- Evaluation of where and how the leachate could be introduced into the coal preparation treatment system.
- Evaluation of possible impact of pretreatment on the subsequent shipping and combustion processes, i.e. the influence of added moisture.
- Anticipated cost of the sodium cleansing treatment and subsequent water treatments

Conclusions and Future Work:

The literature review, modeling, and preliminary test work validates the concept that a mild acidic coal washing technology is appropriate for lowering the sodium content in low-rank coals to acceptable levels.

- Future work should include, but not be limited to:
 - Investigation to determine if multiple leach solution contacts with new coals will allow recycle of the leach solution without detrimentally affecting the leachability of the coals and to produce a concentrated sodium bearing solution in order to limit the amount of leach solution that would have to be treated prior to disposal.
 - Water cleanup will be required because of the relatively high sodium and chloride (or sulfate) content. Techniques to accomplish the cleanup are presently being investigated.
 - Evaluation of where and how the leachate could be introduced into the coal preparation treatment system.
 - Evaluation of the consequences of adding leachate reagents to present coal washing equipment, i.e. would treatment of discharge waters be required.

Test work has not been conducted to evaluate the requirements to produce “Clean” coal to be used for liquefaction or gasification processes. However, if the desire is to produce “Clean” coal from the Montana low-rank coals then aggressive leach studies should be conducted. The approach would be based on the work completed and being presently conducted on Australian “Brown” low-rank coals by Clean Coal Technology, LTD, i.e., very aggressive acidic leach conditions will be used. For example concentrated hydrochloric acid solutions at elevated temperatures will be evaluated using surface-response or two-level factorial experimental design studies to determine the relative importance of a number of variables and to optimize the important variables.

#09-61 Commercialization of Low Vibration Cryocooler Technology

Peter Sellin – S2 Corporation - Bozeman

\$116,075

Final report approved: October 2009

Summary:

S2 Corporation developed low vibration, low thermal fluctuation technology for cryogenic refrigerators for commercialization in industrial and defense markets under prior MBRCT funding and Department of Defense SBIR programs. Cryogenic refrigerators are used for several applications such as superconducting electronics, optical processing and low temperature research. The benefit of using cryogenic refrigerators is that they provide continuous maintenance-free cooling as low as -270 degrees Celsius without requiring the use of liquid helium, which is expensive and difficult to use. Many sensitive applications require that the cooled object also be isolated from the vibrations and thermal fluctuations caused by the cryogenic refrigerator. This low vibration, low thermal fluctuation technology has been a critical enabling innovation for S2 Corporation’s holographic signal processing applications. This project has enabled S2 Corporation to accomplish important development tasks and position the company for commercialization of the technology for industrial and defense related applications.

Commercialization:

Product description:

The intended product is a cryogenic device ready to have a cryocooler device, such as a photodetector or other delicate instrumentation with cryocooler, inserted and connected to RF or optical access points, and be ready for system insertion. Commercial uses include mounting of sensitive optical sensor materials, superconducting electronics, cryogenic photodetectors, or medical imaging equipment. No standardized product is known that integrates the cryocooler and hardware in a stabilized environment regardless of cryocooler choice and device.

Target market including size:

Customers for the technology already exist and are waiting for the product to come available. Academic users are the anticipated early users and initial target markets will be the niche markets of photonic processing and quantum computing. MSU Spectrum Lab, CU Boulder and the Australian National University are centers that will be targeted because of their work in the areas of photonic processing and quantum computing.

Marketing strategy:

S2 will enter the commercial markets by first offering the product to the above potential users. The first 1-50 cryo units could be sold within the first year. This niche will provide a safe environment for product improvement and generation of seed profits. The next market would be the lab cryocooler market, i.e. Cryomech and SHI, followed by medical imaging. SHI currently sells >1,000 cryocoolers per year. Offering a well performing product to the initial customer base will serve as the most effective means of marketing.

Business risk assessment:

One of the risks is that a number of companies may jump in to the market with newly offered competitive products. This risk is being mitigated by a product that specifies <10 nm vibration in x, y, z for all frequencies. In addition, S2 has experience isolating sensitive devices at low temperatures from vibrations, is familiar with design aspects that limit performance of COTS cryocoolers, knows its limited customer base, knows its competition; and, is qualified to act on the opportunity to serve a high tech customer base. A second risk is that another company may reverse engineer the hardware and offer a similar product. A patent has been filed to protect S2 Corporation from this possibility. Licensing options will also continue to be pursued. Therefore, the best ways to mitigate risk are IP protection, licensing, continued innovation and stay ahead of the competition.

Estimate of sales revenues for five-year period into the future:

S2 expects to sell approximately 10 units in 2010 and increase to 50 units per year by 2015, with gross revenues of \$3.5 million.

Economic Impacts:**Sales generated:**

First order was placed with S2 Corporation in April of 2008 to Dr. Jevon Longdell at the University of Otago for the PT-405 COTS cryo-cooler. They are pleased with the system and have recently requested a quote for a second device. A second order was placed with MSU Spectrum Lab February 2009. The vibration isolation retrofit system was custom-tailored to get a lower base temperature on Spectrum Lab's PT 405 cryocooler. Webpage advertising and partnership with JANIS through its website has led to two new interactions. Two quotes for two different needs have been issued. Other quotes include one issued to a Navy contact, which could potentially turn into multiple orders of the lifetime modified SHI does well in Navy tests. An Army contact has expressed interest as well as well as numerous others. Table 3-2, page 54, indicates 11 contacts have been made through 8/05/09. A partnership with Janis, a leading maker of cryocoolers, has begun, and an OEM relationship exists with Cryomech.

Patents applied for or granted:

A provisional U.S. patent was filed on the low vibration cryo-cooler concept on 8/14/08. A provisional U.S. patent was filed on thermal switches for swappable cryo-cooler systems on 8/01/09. Licensing with Janis Research Company is an option being considered to potentially take advantage of an existing international marketing infrastructure to penetrate more markets.

Related Proposals:

Two proposals related to this effort for cryogenic engineering have been submitted. A 2008 Phase II SBIR continuation of the SPAWAR Phase I SBIR program was selected, contracting process begun, and then placed on hold pending resolution of a protracted audit involving Tristan Technologies, Inc., San Diego (the S2 collaborator on the project). A second proposal is a 2009 Phase I SBIR proposal to NASA for the thermal switch for connecting and disconnecting cryocoolers onboard spacecraft. If the funding is obtained, it will be for six months at the \$100,000 level.

#09-62 Commercialization of Clean Coal Production of Methane and Humic Acid:**Stage I****Coal Black Liquids LLC****Paul Gatzemeier/Tom Rossetto****\$415,000*****Final report approved: October 2010*****Summary:**

The original purpose of this project was to research, develop, and commercialize a microbial process for converting Montana coal into methane gas for energy and humic acid (HA) products for agriculture and environmental remediation. This patented process by ArcTech, Inc., of Virginia, appeared to be suited for Montana's coal, agricultural industry, and its focus on the environment.

Coal Black Liquids (CBL) was to develop a 10,000-ton per year plant and needed to complete due diligence research to verify the inventor's claims for the patented conversion process and the efficacy of humic products (Actosol and Humasorb). The plant engineering, design and economics needed to be analyzed to upscale the technology to a commercial size plant for conversion of Montana coal.

Applied research on the effectiveness of ArcTech's Actosol liquid soil amendment

Although results of the research showed some positive benefit, overall there was no significant response for crop growth, remedial land reclamation, or nutrient uptake for Actosol treatments.

Result: Further testing of Actosol was cancelled and the research was redirected toward production and efficacy of humic acid soil amendment products derived from high quality humic rich Montana coal, currently an undeveloped resource.

Applied research on the effectiveness of ArcTech's Humasorb environmental remediation product

The results of the first phase of this research demonstrated that Humasorb was effective in metals removal but had limited effectiveness for organic removal from water. CBL conducted a baseline plant design and costing and determined that the high cost of

production and resulting economics negated Humasorb's commercial viability compared to competing technologies.

Result: Phase two testing of Humasorb was cancelled and research was redirected to testing the effectiveness of an environmental product made from humic rich Montana coal.

Commercial plant engineering and design

The results of bench tests by ArcTech showed yield of biogas was significantly less than the inventor had claimed. Also, humic acid content in the residual coal available for production of Humasorb and Actosol from this process was also lower than anticipated. CBL conducted a preliminary commercial viability analysis, including analysis of plant design and cost factors, and determined the Mic gas patented process was not commercially viable.

Result: Continued research on the patented microbial conversion of coal to methane by ArcTech was terminated.

Because the first phase of research to assess ArcTech's technologies demonstrated that commercialization was not viable, CBL redirected research and commercialization efforts to develop and convert high-quality humic rich Montana coal to humic acid products for agriculture, environmental, and industrial applications.

Redirect project objectives to identify, sample, and analyze potential Montana coal sources.

Conduct crop research with agricultural humic products currently produced in North Dakota (similar to what a Montana coal product would be).

Use humic rich Montana coal samples identified and collected for further environmental product research by MSU's Center for Biofilm Engineering.

Results:

- CBL is conducting crop research on two commercial farms for the 2010 growing season
- Geologic survey for potential sources of a Montana coal source is completed and a source has been sampled, analyzed, and found to be of equal or better quality than North Dakota sources, which are considered to be some of the highest quality in the world.
- Samples of Montana coal are being tested by MSU Center for Biofilm Engineering. Initial results show good effectiveness for metals removals in water treatment. Further testing is required and is ongoing to support product development.

CBL's Assessments:

- CBL’s assessment of the achievement of objectives as presented in the original proposal is that CBL thoroughly evaluated the commercial viability of ArcTech’s patented processes and products as well as alternative humic acid processes and products.
- CBL’s assessment of the commercial potential of the research results is that the project as proposed to build a Montana plant based on ArcTech’s technologies is not economically viable because of:
 - (1) High costs of plant design and construction
 - (2) Low methane production
 - (3) Low cost of alternate humic acid production methods
 - (4) Ineffectiveness of Actosol
 - CBL does consider a commercial plant based on non-patented production of dry and liquid humic acid products, using humic rich Montana coal sources has high potential for commercial development and is pursuing commercialization of this option.

Commercialization:

Key Results:

Research and analysis have identified key results that support commercialization plans for Coal Black Liquids. Upon determination that neither ArcTech’s patented Micgas™ biotechnology nor its patented humic acid technology (Humasorb) were not commercially viable, the project shifted direction to explore the use of Montana’s naturally occurring humic rich resources for the production of high-quality, high-value humic acid products. Highlights of this research include:

Humic acid based soil amendments as an important supplement to conventional fertilizers

- Results of research on Montana’s major wheat and alfalfa crops showed significant protein enrichment in wheat crops, and 2010 harvest results will provide market development data for corn and sugar beet crops.
- Market analysis supports a steady 10% to 15% growth in the worldwide humic acid based soil amendment market. Montana appears to be present a new market.

Humic acid rich coal for metals removals from water

- Initial testing of Montana humic rich coal samples demonstrated promising results for metals removals from water.
- Adsorptive capacity was less than current competing technology ion exchange resins, but the low production cost should provide a competitive advantage. Further research is necessary.

Product description & target market

- **Humic acid soil amendments** – Liquid and dry products will be produced from a Montana humic rich resource. The target market will include agricultural, reclamation, and turf applications. It is believed a solid market can be developed in Montana’s grain market based on research results (current and ongoing).

- **Humic acid product for water treatment** – Derived from a humic rich Montana resource, this treatment product needs substantial additional research to establish its efficacy in the market. However, it is seen as a market growth area and one that will be pursued as solid research development occurs. The competitive advantage is that it can be processed at substantially lower costs than competing technologies.
- **Drilling mud additive** – A well established market currently exists for this product primarily in off shore oil drilling applications. Based on initial baseline testing, CBL believes that a Montana resource will produce a high quality product.
- **Mobile liquid plant** – Although only in the concept phase at this point, a mobile liquid plant is considered to have significant growth potential. CBL will design and construct automated mobile liquid humic acid plants to be located near local agricultural dealers in order to provide low-cost, just-in-time production and distribution of the product near the final market.

Production or manufacturing plan

The primary objective is to identify and develop a one-million ton mining reserve for a high quality humic resource in Montana. After selection of potential reserves, permitting and leasing will be initiated. Permit approval typically takes about 18 to 24 months. The plant will be located near the reserve with easy access to rail and major highways. Mining operation will be an open pit surface operation. Initial staffing will include four fulltime management and professional employees and three plant operators. Plant maintenance will be outsourced. In the interim, CBL will pursue earlier pilot scale production by securing a supply agreement for a humic resource supply at an existing mine.

Business risk assessment

There are many risks, including regulatory approval, permitting, construction, start up, and operation of a project like this. Economic volatility is a significant factor as is potential reduction in the demand for humic acid based products, access to financing sources and capital generation, and the availability of recoverable humic material from initial reserve estimates. CBL's operations are subject to environmental laws and regulations and risks associated with mine and plant operations may have adverse impacts on such a project.

Estimate of sales revenues for five-year period into the future

Initial market analysis for product sales are estimated at \$1.5 to \$2.0 million with an increase in revenue of 10% over the first five years of plant and mining operations.

Economic Impacts

The project will initiate a new industry in Montana that will produce value-added products from a Montana natural mineral resource in an expanding humic acid industry. CBL's organic products will supply Montana's agricultural industry and provide economic benefit by improving crop yields and quality and improve long-term soil

health. CBL's potential environmental products will provide a low-cost option to technologies involved in environmental remediation and water treatment.

Increase in employment levels

CLB will initially employ seven to 10 people. Mining and shipping operations, and testing and analysis functions will provide employment opportunities for local area companies. CBL will require specific professional services on an ongoing basis for product research and development.