MICROBEAM TECHNOLOGIES, INC.

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October 1, 2024

Mr. Reice Haase
Executive Director
ATTN: Lignite Research, Development and Marketing Program
North Dakota Industrial Commission
State Capitol, 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Mr. Haase:

Subject: Proposed Project entitled "Bipartisan Infrastructure Law (BIL) – Production of Germanium and Gallium Concentrates for Industrial Processes" for consideration for funding as part of the October 1, 2024 Grant Round.

We are pleased to submit this proposal for co-funding. The proposal was submitted in response to US Department of Energy (DOE) funding opportunity announcement (FOA) DE-FOA-0002619 "Bipartisan Infrastructure Law (BIL) Advanced Processing of Rare Earth Elements and Critical Minerals for Industrial and Manufacturing Applications," Area of Interest (AOI-2) Production of Critical Minerals and Materials Excluding Materials Containing Rare Earth Elements from Coal-Based Resources." The project was selected by the DOE for an award (Award No. is DE-FE0032522) with a start date of September 1, 2024, and a period of performance of thirty-six months. In addition to the request for co-funding from the North Dakota Industrial Commission (NDIC), other project members providing cost share include North American Coal Corporation, 5N Plus Semiconductors LLC, University of North Dakota, Barr Engineering. Lattice Materials, BNI Energy, and Microbeam Technologies Inc.

This project team includes key member of the supply chain for the production Ge and Ga metal that includes carbon-ore producers (NACC), pilot-scale mixed rare earth oxide/salt (MREO/MRES) operator (UND), advanced separation/purification/reduction to metal process developers (Microbeam and 5N Plus), and industrial partners (Lattice Materials and 5N Plus). This effort is aimed at achieving major (>50%) domestic production of these energy-critical elements utilizing easily accessible (usable within 4-5 years) carbon-ore resources.

Please let me know if you have any questions or comments. We will send a check for $100 for the application fee.

Sincerely,

Steven A. Benson, PhD
President

c/enc. Mike Holmes, LEC

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Bipartisan Infrastructure Law (BIL) – Production of Germanium and Gallium Concentrates for Industrial Processes – Phase II

Submitted to:

Mr. Reice Haase
Deputy Executive Director
North Dakota Industrial Commission
ATTN: Lignite Research, Development and Marketing Program
State Capitol, 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Submitted by:

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10/01/2024

Total Project Costs: $3,134,978

NDIC Amount Requested: $376,000

Contents

1.0 ABSTRACT

Microbeam Technologies Incorporated (MTI) has teamed with the University of North Dakota (UND) and Barr Engineering with support from the US DOE National Energy Technology Laboratory (NETL), North American Coal Corporation (NACC), BNI Energy, Lattice Materials, and 5N Plus Semiconductors to conduct a Phase II project to demonstrate at a bench-scale the production of Ge and Ga metal utilizing abundant lignite-based carbon-ore resources. Phase II builds on the Phase I conducted by MTI, UND, and Dennis James funded by NETL, NDIC, and NACC to develop a conceptual design to extract, separate, recover and purify germanium and gallium from lignite carbon ore-derived mixed rare earth element concentrates (MREC) at lower costs than current conventional methods. The technology involves a combination of pyrometallurgical and hydrometallurgical processes to produce high purity Ge and Ga metals and intermediate forms from the MREC derived from UND's pilot-scale production facility. Ge and Ga are used in a variety of applications that include advanced electronics, optoelectronics, fiber optics, solar cells, and computer chips. Currently, the Ge and Ga supply in terms of price, delivery schedule and availability are largely controlled by foreign entities. The US dependency on imports for 100% Ga and >50% of Ge creates significant risks that weakens national defense capabilities, limits economic output, hinders technological advancement, and creates geopolitical tensions.

The technical and economic feasibility of the concept was derived from the results of modeling, testing, and analysis conducted as part the Phase I project, and the results from past projects conducted by MTI that were supported by the National Science Foundation (NSF) and industry. The technology involves separation of Ge/Ga from MREC via vaporization and recovered via condensation followed by refining of Ge/Ga into usable materials. Preliminary estimates of the production of Ge and Ga from a 0.5 to 1 mtpd MREC is 8 to 25 metric tons of Ge and 6 to 20 metric tons of Ga concentrate per year.

The duration of the Phase II project is expected to be 36 months, and the total project is $3,135,483 that includes $635,505 of cost share. The cost share received from other project partners is $259,505. The NDIC share of the proposed project is $376,000. The remaining budget, $2,499,978, will be funded by the DOE through Award No. DE-FE0032522.

2.0 PROJECT SUMMARY

This Phase II project will conduct testing to demonstrate the ability of the technology to achieve major (>50%) domestic production of these energy-critical Ge and Ga elements utilizing easily accessible (usable within 4-5 years) resources. The patented technology[1] is based on an innovative process that recovers, separates, and refines Ge and Ga to produce high value high purity metals for use by industry at lower costs.

The concept developed as part of Phase I involves a combination of pyrometallurgical and hydrometallurgy methods to recover and refine Ge and Ga from UND's pilot MREC. The MREC has unique properties in that it does not contain some of the challenging impurities found in fly ash, zinc ore refining waste, and bauxite refining residues used in the production of Ge and Ga metals. The MREC has very low levels of zinc, arsenic, lead, and other intermediate volatility elements that will vaporize and condense at similar temperatures. The first step in the recovery process is the vaporization and selective condensation to produce relatively pure Ge and Ga concentrates. For Ge concentrate, the steps include extraction to form $GeCl_4$, hydrolysis to form GeO_2, metallization to form Ge metal, and zone refining to produce high purity Ge metal (99.999+%). For Ga, the processes involve the formation of $GaCl_3$, electrowinning to produce Ga metal, and zone refining to produce high purity Ga metal (99.999+%).

3.0 PROJECT DESCRIPTION

3.1 Overview of Project Scope

The goal of the project is to demonstrate, at a bench-scale, an environmentally benign process to produce Ge and Ga that is fully integrated with downstream uses and with the properties of UND's MREC which is a Mixed Rare Earth Oxide/Mixed Rare Earth Salt (MREO/MRES). The first task is project management and planning that will involve the coordination of the project to attain all project objectives and provide deliverables on time and within budget. The second task will involve the design and

[1] Benson, S. and Benson, A. (2024) System and Method for Producing Critical Minerals. (U.S. Patent No. 12,031,195 B2). U.S. Patent and Trademark Office.

construction of a bench-scale system that is capable of processing MREO/MRES to produce high purity Ge and Ga metals. The third task will be aimed at performing shakedown and parametric testing of the system to determine the optimum conditions required to produce Ge and Ga metals from MREC. The fourth task will involve production of Ge and Ga metal under optimized conditions using a MREC derived from a Ge- and Ga-rich lignite. The fifth task will be aimed at determining the economic viability and the commercialization potential of the technology that would utilize products from a MREC production facility.

3.2 Project Objectives

In order to meet the goal described in section 3.1, the following specific objectives will involve: 1) design and construct a bench-scale pyrometallurgical system that has the capability to demonstrate the ability to vaporize Ge and Ga from the MREC, selectively condense, and concentrate Ge and Ga in oxides and metal forms of purity >90% oxide basis, 2) perform shakedown and parametric testing of the system to identify the optimum conditions temperatures and gas compositions necessary to produce Ge and Ga concentrates from pilot-scale MREC, 3) conduct analysis of the concentrates produced under a range of conditions to determine form and abundance of Ge and Ga as a function pyrometallurgical system conditions, 4) perform bench-scale production testing to produce high purity Ge and Ga metals (99.999%+) under optimum conditions for end user evaluation using MREC from Ge and Ga-rich lignite, analyze the purity of Ge and Ga concentrates, and test the ability to refine to metal using conventional technologies, and 5) perform a technical and economic analysis of the commercialization potential of the process. Completion of these objectives will provide a foundation for development of an economically viable, sustainable, and responsible critical mineral supply chain in the United States.

3.3 Methodology

Task 1.0 – Project Management and Reporting

Subtask 1.1 – Project Management Plan

The project team will manage and direct the project in accordance with a Project Management Plan to meet all technical, schedule and budget objectives and requirements. The project manager will coordinate activities in order to effectively accomplish the work and will ensure that project plans, results, and decisions are appropriately documented, and project reporting and briefing requirements are satisfied.

Management of project risks will occur in accordance with the risk management methodology delineated in the Project Management Plan in order to identify, assess, monitor and mitigate technical uncertainties as well as schedule, budgetary and environmental risks associated with all aspects of the project. The results and status of the risk management process will be presented during project reviews and in quarterly progress reports with emphasis placed on the medium- and high-risk items.

Subtask 1.2 – Technology Maturation Plan

The project team will develop a Technology Maturation Plan (TMP) that describes the current technology readiness level (TRL) of the proposed technology/technologies, relates the proposed project work to maturation of the proposed technology, describes the expected TRL at the end of the project, and describes any known post-project research and development necessary to further mature the technology.

Task 2.0 – Bench Scale System Design and Construction

This task will involve finalizing a modular bench-scale system design based on the conceptual design process flow diagrams, procuring all materials and supplies for construction, and constructing the system that can process MREC from a pilot-scale production facility to produce high purity Ge and Ga metals. The assembled bench-scale system will consist of 1) a high temperature furnace system designed to vaporize Ge and Ga from the MREC, 2) a condenser system to recover Ge and Ga concentrates separately, and 3) a particulate control (capture) system. The materials collected will be subjected to analysis to determine

chemical composition using the materials analysis system, along with Ge and Ga condensate processing to produce high purity metal.

Subtask 2.1 Furnace System

This subtask will focus on the design of the bench scale system furnace to provide sufficient temperature, gas composition, and residence time to vaporize the Ge/Ga from the MREO/MRES concentrate. This work will be based on the conceptual design information derived from past experimental data combined with modeling using tools such as FactSage and Aspen. The main furnace system is expected to be commercially available and is planned to be fitted with a feed system, reducing gas purge, and high temperature transport lines to the condensation system.

Subtask 2.2 Condensation Capture System

This subtask will be aimed at designing, procuring materials, and constructing a heat exchange system to cool the gas stream to allow for the condensation and recovery of Ge and Ga in the bench scale system.

Subtask 2.3 Particulate Control System

This subtask involves the design and installation of a cyclone and baghouse integrated into the bench scale system that can capture sub-micrometer particles that are rich in Ge and Ga.

Subtask 2.4 Materials Analysis System

The Ge and Ga condensation products will be analyzed to determine the abundance of Ge and Ga and levels of other elements that can be considered impurities that can impact purification processing. Techniques such as X-ray fluorescence (XRF) will be used to determine the bulk composition of the materials, while techniques such as scanning electron microscopy (SEM) and X-ray microanalysis will be performed to examine microstructure and determine the composition of selected features to ascertain associations of elements. Of specific interest is determining the form(s) of condensed Ge and Ga, whether metallic, oxide, sulfide, or other form(s). Selected samples will be characterized using techniques such as Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) to determine the abundance of impurities and the abundance of critical minerals such as rare earth elements (REE), Ge, Ga, Sc, and Y.

Subtask 2.5 Ge Condensate Processing

The potential for direct metallization of Ge condensate will be evaluated using a high temperature melting furnace that can be operated in reducing conditions (such as hydrogen atmosphere) to convert germanium oxide into elemental germanium, in forms such as metal ingots or liquid droplets. The purity of the germanium metal will be determined using techniques such as ICP-MS.

If the direct metallization of Ge condensate is determined not be feasible because of factors such as impurity levels, the Ge condensate will be processed using an industry standard method to produce Ge products, including $GeCl_4$, GeO_2 and Ge metal. The process involves reacting the Ge concentrate in a heated vessel to produce $GeCl_4$ gas, which is condensed to produce a liquid. The team will produce gram sized samples of this material for analysis. The team will hydrolyze samples of the $GeCl_4$ to produce GeO_2 and subsequently reduce the GeO_2 to form Ge metal, with a target purity of 99.9%.

Subtask 2.6 Ga Condensate Processing

For the Ga concentrate, a direct chlorination of the Ga pre-concentrate with Cl_2 gas at elevated temperatures will be utilized, followed by selective condensation and subsequent gas cleanup. The condensed $GaCl_3$ will be electrolyzed using a low-temperature, molten-salt cell.

Subtask 2.7 Zone refining of Ge and Ga

When enough Ge and Ga unrefined metals are available from prior subtasks, supporting team members will subject the materials to further purification via zone refining. The objective of this subtask is to produce materials that are of high purity (target purity of 99.999%). The resulting materials will be analyzed using techniques such as SEM, ICP-MS, and XRF analysis.

Task 3.0 – Shakedown and Parametric Testing

The pyrometallurgical system to vaporize Ge and Ga from the MREC followed by selective condensation to produce Ge and Ga concentrates is the unique feature of the technology and requires parametric testing. The shakedown and parametric testing will be conducted using MREC produced by a subrecipient's pilot system.

Subtask 3.1 Shakedown Testing

The project team will test all electrical and mechanical systems associated with the vaporization, condensation, and particulate control systems. Initial operation shakedown of the system will be conducted with the flow of materials such as silica sand or clay materials to measure feed rates, flow through the furnace system, heat exchangers, and particulate control. The team will conduct an initial test (or tests) of the systems with a preference to use the more abundant Stage 2 MREC from the UND process for this Subtask. Sampling protocols will be developed and samples of the Ge/Ga extracted material, condenser hopper samples, heat transfer surface accumulation, cyclone and baghouse will be gathered and analyzed using methods such as SEM, ICP-MS, and XRF analysis. In addition, the particulate exiting the heat exchange system will be collected using a 4-stage particle impactor (including backup filter) to measure the presence of particles of various diameters. The team will measure the mass in each stage of the impactor and analyze the composition of materials collected on each stage of the impactor using techniques such as SEM and X-ray microanalysis.

Subtask 3.2 Parametric Testing

Based on the shakedown testing of the pyrometallurgical system, the team will have developed the key initial operating conditions that will be used for Ge and Ga production runs. All testing of the pyrometallurgical system will be performed using Stage 1 and Stage 2 MREC sourced from a subrecipient's pilot facility.

Sampling and analysis protocols will be the same as developed in Subtask 3.1.

Task 4.0 – Production Testing

The goal of the production testing is to produce Ge and Ga metal samples for evaluation by commercial project team members who are interested in utilizing the produced materials in their processes.

Subtask 4.1 Ge and Ga-rich feedstock selection

The team will review data from recent mine sampling and analysis efforts to identify a region in one or more project partner's active mine(s) suitable to selectively recover 30 to 50 tonnes of Ge and Ga-rich

lignite carbon ore. The material will be processed through a MREC pilot facility to produce approximately 150 kg of MREC to contain higher levels of Ge and Ga. The estimated quantity of Ge and Ga metal produced from the MREC is estimated to be on the order of 0.5 to 1.0 gram per 1 kg of concentrate. This estimate is based on production of a MREC with 16 ppm levels of each of Ge and Ga in the original lignite feedstock material. The amount of Ge and Ga metal to be produced under this Subtask is expected to be approximately 50 grams of each material, which is expected to be sufficient for project support team members to perform subsequent quality/purity testing.

Subtask 4.2 Production of Ge and Ga Concentrates

The team will leverage the optimum process conditions determined in the parametric testing (Subtask 3.2) to produce Ge and Ga concentrates. It is anticipated that at a feed rate of about 5 to 10 kg/hr of MREC and run campaigns of 4 hours per day will produce sufficient quantities of the Ge and Ga concentrates for recovery for subsequent refining. The samples will be analyzed using methods such as SEM, ICP-MS, and XRF analysis.

Subtask 4.3 Refining of Ge and Ga Concentrates to Metals

The project team will refine Ge and Ga concentrates to metals following the refining process descriptions in Subtasks 2.5 to 2.7.

Subtask 4.4 Ge and Ga Metal Quality Evaluation

Commercial project team members who have an interest in using Ge and Ga in their process(es) will evaluate the purity of the produced materials using methods such as SEM, ICP-MS, and XRF analysis.

Task 5.0 – Techno-economic Analysis and Commercialization

Subtask 5.1 Review Overall Process Performance

The project team will conduct the following work under this subtask:

1) Compile and review all analysis and analytical data.
2) Review and update the process design and operating parameters, as necessary, based on the results of testing.

3) Update the process flow diagrams and the heat and materials balances, as needed, when updates that improve process operation, performance, and product purity/consistency are identified.
4) Obtain feedback from potential product end users on the properties of the product material(s).

Subtask 5.2 Techno-economic Analysis

The project team will complete a techno-economic analysis (TEA) of the overall Ge and Ga separation technology based upon the bench-scale experimental testing results. The TEA may build upon past modeling efforts and preliminary TEA conducted as part of an earlier related project. Specifically, the TEA will include a projected cost comparison for the advanced systems/processes relative to a similarly sized system(s) that utilizes conventional technologies. Environmental life cycle analyses (LCA) will also be addressed as a part of the TEA.

Task 6.0 – Critical Materials Collaborative (CMC) Research Development and Demonstration (RD&D) Coordination

The Principal Investigator (PI) or designee will participate in an in-person Annual CMC Meeting, most likely in Washington D.C., where they will give a presentation on research progress. The coordination meeting is intended to build an innovative ecosystem and facilitate rich scientific and technical exchange and discussion. The attendees will include PIs selected from the DE-FOA-0002619, the Critical Materials Collaborative, DOE Program Offices and Federal agencies that fund relevant and related critical materials/minerals projects, and stakeholders working on critical materials projects. Additionally, project teams will attend and participate, either virtually or physically, in other critical materials RD&D related meetings convened by DOE or the CMC when relevant.

3.4 Anticipated Results

This project is expected to design, construct and demonstrate the pyrometallurgical process to separate Ge and Ga from a MREC through vaporization combined with selective condensation to produce Ge and Ga concentrates at a TRL of 4 or 5.

3.5 Facilities and Resources

Current Facilities and Resources

Microbeam has two locations, one in Grand Forks, ND and one in Minnetonka, MN. Both locations have offices and laboratory space. The Grand Forks location houses high temperature furnaces, two advanced computer-controlled scanning electron microscopes equipped with x-ray microanalysis (CCSEM), chemical fractionation equipment, and associated sample preparation equipment. The Minnetonka location is about 7000 square feet of office, shop, and laboratory area for testing. The shop/laboratory testing area has a shop area for construction and modification of testing equipment, a fluidized bed reactor, metals recovery system, sample preparation and field test staging area. The metals recovery system was designed to be used to study the vaporization, condensation, and capture of critical minerals such as Ge and Ga that was developed through National Science Foundation projects.

UND lab and Pilot scale facilities

Advanced Materials Characterization Lab (UND) -- The AMCL has experienced technicians and analytical chemists and has a vast array of analytical equipment and capabilities, including SEM-EDS, XRF, XRD, ICP-OES and thermal gravimetric analysis. Pilot-Scale REE Extraction Facility (UND) -- UND pilot facility is capable of processing 500 kg/hr of cleaned coal through the REE extraction and recovery process with low rank coals. The facility operates in a continuous mode in producing a pre-concentrate at a rate of roughly 8-10 kg (pure REE basis, despite a concentration near 60-70%) per week of a 300-ppm feedstock.

New Equipment

New bench-scale equipment will be purchased as part of the project. The bench-scale system will be installed at Microbeam's Minnetonka location in the shop laboratory area. The design of the system is based on the conceptual design developed during Phase I. The system will separate Ge and Ga through vaporization from the MREC and selectively condense the Ge and Ga as oxides or metals. The condensed materials will be recovered at carefully controlled temperatures and atmospheres. The equipment that will

be purchased or constructed includes: 1) a high temperature furnace system that will process MREC at a rate of 5 lb/hr to vaporize Ge and Ga, 2) a gas solid separation unit will be designed to produce a Ge and Ga free MREC, 3) a condensation system to selectively condense Ga and Ge producing concentrates, 4) a bench-top x-ray fluorescence analyzer to measure the composition of the concentrates quickly allowing for rapid feedback, 5) a cyclone and filter system to capture the particles and condensed phase materials for recycling, and 6) auxiliary equipment including fans to maintain gas flow, ventilation, sensors (temperature, flow rates, gas composition), and a lab view control system. This system is essential to be able to demonstrate the feasibility of the conceptual design. The approximate footprint of the Ge/Ga system will be about 600 ft^2. Microbeam's Minnetonka facility has adequate utilities (power, ventilation), safety, and access (loading dock).

3.6 Environmental and Economic Impacts

The technology proposed is an environmentally benign process to produce 90 to 99% pure germanium and gallium oxides, salts, or metals from REE concentrates derived from coal, following which refining to >99% is achievable. The technology is consistent with the objectives of the DOE FOA to develop domestic sources of critical materials that includes germanium and gallium. International production rates of the two critical elements (minerals) are estimated at 130 tonnes and 300 tonnes per year for Ge and Ga, respectively. US consumption of each mineral totaled 23% and 5%, respectively, and the US was 50 to 100% import reliant[2,3]. For example, a single 1-3 MTPD REE concentrate plant would be able to mitigate up to 23% and 42% of the US demand for each of the Ge and Ga, and this while utilizing a lignite more enriched in the REE than Ge and Ga specifically. The UND process for REE recovery simultaneously concentrates these critical minerals from the lignite sources, resulting in a major opportunity for domestic production (potentially past current consumption rates) of these two critical minerals with minimal additional cost over REE production.

[2] Jaskula, B. W. "Mineral Commodity Summaries: Gallium." United States Geologic Survey, p62, 2021.
[3] Tolcin, A. C. "Mineral Commodity Summaries: Germanium." United States Geologic Survey, p68, 2021

3.7 Relevance and Outcomes/Impacts

The benefit of the project is the development of a domestic source of Ge and Ga from the abundant lignite resources. The elements are extensively used in military and domestic applications and demand for these elements is expected to increase. The elements are used in advanced electronics, optoelectronics, fiber optics, solar cells, computer chips, and other applications. Lignites with concentrations in excess of 25 ppm on a dry whole-coal basis for each critical mineral have been identified inside and outside of active mines, making these elements easily recoverable from lignite in quantities to significantly offset US import demands.

4.0 STANDARDS OF SUCCESS

Critical Success Factors include: 1) availability of lignite-derived MREC from the UND facility that contains Ge and Ga and 2) ability to produce 90 to 99% pure Ge and Ga concentrates resulting in 20 % lower costs by decreasing processing steps and in lowering environmental impact as compared to currently available refining and purification processes.

5.0 BACKGROUND

Germanium and gallium are very important elements used in advanced electronics, optoelectronics, fiber optics, solar cells, computer chips, and other applications. The elements are of great economic importance to the US and pose a supply security risk and thus are classified as critical. The US is dependent upon imports for 100 % gallium and >50% of germanium. Figure 1 shows the countries that the United States imports these elements from. Ge and Ga have been receiving media attention due to China's plans to implement export controls. Selected news media articles include: 1) ***Pentagon Seeks Supply of Chip-Mineral Gallium After China Curbs Exports***[4], "The Pentagon plans to issue a first-time contract to US or Canadian companies by year-end to recover gallium, a mineral used in semiconductors and military radar

[4] Financial Post, financialpost.com/pmn/business-pmn/pentagon-seeks-supply-of-chip-mineral-gallium-after-china-curbs-exports, Jul 26, 2023

systems, after China curbed exports this month.", 2) ***China turning the screws on US military, taking away key material***[5], "This is just the beginning of China's countermeasures, and China's toolbox has many more types of measures available." 3) ***"China Restricts Export of Chipmaking Metals in Clash With US"***[6] China on August 1, 2023, will apply export controls on germanium and gallium to protect national security. 4) **China restricts exports of chip-making metals gallium and germanium**[7].

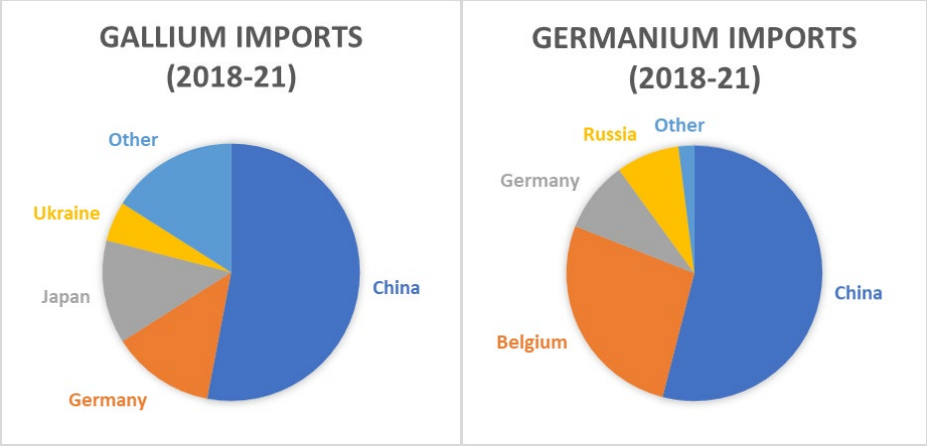


Figure 1. Gallium[8] and Germanium[9] imports.

Currently, the primary global germanium resource is in Zn-refinery residue and coal fly ash. Secondary sources are from recycling and coal directly. The estimated minimum recoverable Ge in zinc ores and coals using existing recovery technologies is about 119 ktonnes[10] total, globally. The expected recovery of quantities of Ge is ~7 kt for zinc ore and ~112 kt for coal. With improved technologies, the estimated recovery potential of up to 440 kt (~50 kt from zinc or/and ~390 kt from coal) could be made available. Low levels of production from coal fly ash are thought to be due to the limitations in technology available

[5] American Military News, americanmilitarynews.com/2023/07/china-turning-the-screws-on-us-military-taking-away-key-material/, July 7, 2023.
[6] Bloomberg,bloomberg.com/news/articles/2023-07-03/china-to-restrict-exports-of-metals-critical-to-chip-production?utm_source=website&utm_medium=share&utm_campaign=email, July 3, 2023.
[7] Dow Jones Newswire, .marketwatch.com/story/china-imposes-export-control-on-gallium-germanium-related-item-c94a4867?reflink=mw_share_email, July 3, 2023.
[8] U.S. Geological Survey, (2023, January). Gallium - USGS Publications Warehouse. Gallium, Mineral Commodity Summaries. https://pubs.usgs.gov/periodicals/mcs2023/mcs2023-gallium.pdf.
[9] U.S. Geological Survey, (2023, January). Germanium - USGS Publications Warehouse. Germanium, Mineral Commodity Summaries, January 2023. https://pubs.usgs.gov/periodicals/mcs2023/mcs2023-germanium.pdf
[10] Frenzel, M., Ketris, M., & Gutzmer, J. (2013). On the geological availability of germanium. Mineralium Deposita, 49(4), 471-486.

to extract and refine Ge from coal ash[9]. Currently, lignite is a significant source of Ge in China with 16 metric tons being produced annually at the Lincang lignite mine[11]. The primary sources of Ge in the US are believed to be similar to the sources of China. It is estimated that the US reserves of Zn may contain more than 2500 tonnes of recoverable Ge and the coal deposits may contain over 1.7 million tonnes of recoverable Ge[12].

Gallium is a byproduct of bauxite and Zn-ore processing. Ga-bearing zinc ore is extracted with sulfuric acid and goes through a multistep complex process to form a $GaCl_3$ solution that goes through electrolysis to produce Ga metal. The Ga metal is further refined by Zone refining[13]. Gallium has been identified in coals around the world, as referenced by Seredin and Finkelman (2008)[14] and Qin, et. al. (2015)[15]. However, gallium has not been widely studied as many other trace elements, likely due to its low environmental toxicity. Thus, while data shows gallium is present in many coals, there is not enough data to support its mode of occurrence.

In North Dakota lignite, gallium occurs in relatively consistent concentrations ranging from low single digit parts per million (ppm) up to 48 ppm on a dry whole coal basis. Vertical incremental sampling has not shown any relationships in the seam, such as germanium's tendency to be concentrated at the top of the seam. Aerially, gallium does not show any patterns other than an apparent regional consistency; however, this could be due to the scarcity of data.

Statistical analyses of conventional trace element analyses do show a number of strong correlations between gallium and other elements. Silica, alumina, potassium, titanium, and the rare earth elements all have a correlation coefficient exceeding 0.9. Selenium, vanadium, cobalt, rubidium, magnesium, and

[11] Hu, Rui-Zhong, Hua-Wen Qi, Mei-Fu Zhou, Wen-Chao Su, Xian-Wu Bi, Jian-Tang Peng, Hong Zhong, and. "Geological and geochemical constraints on the origin of the giant Lincang coal seam-hosted germanium deposit, Yunnan, SW China: A review." Ore Geology Reviews 36.1-3 (2009): 221-234.
[12] Ruiz, A. G., Sola, P. C., and Palmerola, N. M. (2018). Germanium: Current and novel Recovery Processes. Advanced Material and Device Applications with Germanium. https://doi.org/10.5772/intechopen.77997
[13] Butcher, T., Brown, T., & , (2013). Gallium. Critical Metals Handbook, 150-176.
[14] Seredin, Vladimir V. and Finkelman, Robert B., 2008, Metalliferous coals: A review of the main genetic and geochemical types. International Journal of Coal Geology, v. 76, p. 253-289
[15] Qin, Shenjun, Sun, Yuzhuang, Li, Yanheng, Wang, Jinxi, Zhoa, Cunliang, and Geo, Kang, November 2015, Coal deposits as promising alternative sources for gallium. Elsevier Earth Science Reviews, Volume 10, p. 95-101.

thorium all have high coefficients as well. SEM analyses of coal samples support the alumina-silicate correlation.

The Phase 1 project goal was to develop a concept to extract, separate, recover and purify germanium and gallium from lignite carbon ore-derived rare earth element concentrates. This effort was aimed at achieving major (>50%) domestic production of these energy-critical elements utilizing easily accessible (usable within 4-5 years) resources. As part of the Phase I effort, this technical research plan was developed to perform bench scale proof-of-concept testing to determine the viability to produce high purity germanium and gallium metal materials from the University of North Dakota's pilot-scale MREC. The goal is an advanced innovative process that recovers, separates, and refines Ge and Ga to produce high value high purity metals for use by industry at lower costs.

The concept developed as part of Phase I involves a combination of pyrometallurgical and hydrometallurgy methods to recover the germanium and gallium from the UND's pilot MREC. The MREC concentrate has unique properties in that it does not contain some of the challenging impurities found in fly ash and other materials used in the production of Ge and Ga metals[16]. The MREC concentrate has very low levels of zinc, arsenic, lead, and other intermediate volatility elements that will vaporize and condense at similar temperatures. The first step in the recovery process is the vaporization and selective condensation to produce relatively pure Ge and Ga concentrates. For Ge concentrate, the steps include extraction to form $GeCl_4$, hydrolysis to form GeO_2, metallization to form Ge metal, and zone refining to produce high purity Ge metal (99.999+%). For Ga, the processes involve the formation of $GaCl_3$, electrowinning to produce Ga metal, and zone refining to produce high purity Ga metal (99.999+%).

6.0 QUALIFICATIONS

The personnel who are part of the project team are uniquely qualified to perform the project. The personnel include fuel scientists who have knowledge of the forms and abundance of critical mineral in the

[16] James R. Piedmont, Richard J. Riordan, "The Supply of Germanium For Future World Demands," Proc. SPIE 0164, 4th European Electro-Optics Conf, (25 July 1979); doi: 10.1117/12.965520

lignite feedstocks and understand the behavior of critical minerals during processing, chemical and mechanical engineers who have direct experience with the recovery of critical minerals and designing and constructing pilot scale processes, and chemists who can analyze the materials. The project team will work together to develop the overall concept for the recovery of Ge/Ga that is consistent with refining and end use requirements.

Dr. Steve Benson, Dr. Benson will be the technical lead and Principal investigator for this proposed project. Dr. Benson, Microbeam President, has a BS in Chemistry from Minnesota State University and a Ph.D. in Fuel Science from Pennsylvania State University. Prior to joining Microbeam full time in 2017 he held faculty and research positions at the UND. He was PI on the DOE and industry funded project (FOA 1202, DE-FE0027006) to develop technologies to recover REE from coal and coal byproducts. He has 45 years of experience in fuel analysis, fuel properties, combustion, gasification, ash transformations, pollution control, and critical mineral recovery. In addition, Dr. Benson has developed and managed numerous complex multidisciplinary research, development and commercialization projects associated with the utilization of coal funded by US DOE and industry. Dr. Benson is one of the inventors on a US patent held by UND for the extraction of REE/CM from lignite and associated materials, one of the inventors on a US patent held by MTI for algorithms used with handheld XRF and PGNAA-DGA for measuring REE-CM, and one of the inventors of a patent for the process of producing separated Ge and Ga concentrates from ash materials and mixed rare earth element concentrates.

Alex Benson, Mr. Benson will be Project Manager for this project and will be responsible for the day-to-day coordination of the efforts. Mr. Benson is currently a Senior Project Manager at Microbeam. He has a B.S. degree in Mechanical Engineering from University of St. Thomas. Mr. Benson has over 5 years of experience conducting projects associated with critical minerals. Currently he leads multiple commercial projects associated with REE/CM resource evaluation, detection, measurement, and extraction from carbon-ore and associated waste materials. He was the project PI (DE-SC0021837) and is one of the inventors on a US patent held by Microbeam for algorithms used with handheld XRF and PGNAA-DGA for REE/CM measurements and of a US patent for Ge and Ga separation from ash materials and mixed rare

earth element concentrates. Mr. Benson has over seven years of manufacturing engineering, project management and commercialization in the medical device manufacturing industry. He led engineering activities for new product launches and capacity expansion projects.

Eric Kolb, Mr. Kolb, Research Engineer, has a B.S. degree from UND in Mechanical Engineering. Mr. Kolb worked with UND on the design, construction, and operation of UND's pilot-scale REE and CM processing plant (DE-FE0031835). His experience associated with the UND system will provide important information that will facilitate integrating the Ge and Ga recovery process into the UND MREC production process. Mr. Kolb has experience in performing analysis using electron microscopes as well as performing tests using the metals recovery unit and other high temperature equipment at Microbeam. Mr. Kolb will coordinate the assembly, shakedown, and testing efforts associated with the Ge/Ga separation and capture system. He will work closely with UND to develop the process control system.

UND is the technology developer IP holder for REE and CM extraction from coal resource technology that will produce the MREC for this proposed project. In 2016, UND was among the first teams to be awarded funds from the DOE (FOA 1202, DE-FE0027006) to develop technologies to recover REE from coal and coal byproducts. The UND team that included Microbeam successfully advanced the technology from the lab-scale to a pilot-scale system under DE-FE0031835 (500 kg/hour of mine waste feed). UND also previously led a successful project to perform a conceptual design and feasibility study (AACE Class 4) to produce 1 mtpd of REE concentrate using UND's technology (contract 89243320RFE000032). The key people from UND will be Dan Laudal and Nolan Theaker.

Dr. Daniel Laudal, Research Professor in Chemical Engineering and Executive Director of the Energy and Mines Research Institute. Dr. Laudal holds a B.S. and Ph.D. in Chemical Engineering from UND. He will support the project as a technical advisor. Dr. Laudal was the technical lead for UND's original lab-scale project and the original PI for the bench-scale project (DE-FE0027006). His Ph.D. research/dissertation was the foundation for the proposed technology/project. Dr. Laudal has been PI, Co-PI, or key personnel on numerous DOE, State, and Industry-funded projects, primarily focusing on technology development and scale-up, including several efforts related to REE/CM. In addition, Dr. Laudal was the Environmental

Manager for Minnkota Power Cooperative, an electric generation and transmission cooperative that operates in ND and MN.

Nolan Theaker, Technical Group Manager – Critical Minerals at UND's Energy and Mines Research Institute, has B.S. and M.S. degrees in Chemical Engineering from the University of Louisville, Kentucky. He will be the principal investigator (PI) for the UND portion of the proposed project. Mr. Theaker has been the technical driver for UND's technology development and resource characterization efforts related to REE/CM since he joined IES in 2018. He is widely recognized within the DOE and the research community as a leading expert on REE/CM technologies. Mr. Theaker was the Co-PI/technical lead on UND's bench-scale demonstration (DE-FE0027006), the PI on the ongoing pilot-scale project (DE-FE0031835), and the Co-PI/technical lead on the conceptual design and feasibility study (89243320RFE000032).

Barr Engineering is a comprehensive engineering and environmental firm, providing consulting services to clients globally. Barr works with clients on large and complex engineering and environmental projects, providing services that range from initial permitting and siting assistance through process and facility design to construction management, operations support, and closure planning. Barr's services and staff have grown to meet client needs for over 50 years, with offices in seven states and Canada. Barr has collaborated with UND and Microbeam on technology development since efforts began in 2016 and was the engineering lead on the team's successful AACE Class 4 pre-FEED study. The project manager from Barr Engineering is Chad Haugen.

Chad Haugen**,** Senior Process Engineer, has a BS degree in Chemical Engineering from UND and is a professional engineer. He will be the project manager from Barr on this proposed project. Mr. Haugen has 15 years of process engineering and project management experience providing process engineering support for projects related to critical minerals. These projects included leaching rare earth elements from coal for a domestic source. The project included pre-feasibility design evaluations, techno-economic analysis, and a review of the design and implementation of a lab/pilot testing system. He also provided preliminary engineering support and completed a techno-economic analysis for extracting rare earth elements from

geothermal brines in Southern California near the Salton Sea. On this project he will assist in the system design and review the efforts associated with the construction of the system. In addition, he will be the lead on the Technical and Economic Assessment for the project.

7.0 VALUE TO NORTH DAKOTA

This project has the potential to demonstrate a technology that can utilize the abundant lignite resource to produce critical minerals. The technology would be implemented in North Dakota and would provide high paying jobs associated with the extraction, concentrating, separation and refining to produce a high value product. In addition, ND will facilitate in the development of a domestic source of Ge and Ga from the abundant lignite resources. The elements are extensively used in military and domestic applications and demand for these elements is expected to increase.

8.0 MANAGEMENT

The management structure for the project is shown in Figure 2, which is designed on a task-by-task basis with the task leaders and key/essential personnel for each task identified. The team brings together the unique expertise required. The organization of the project, illustrated in Figure 1, shows the breakdown of the project by task and the personnel who will be contributing to the effort.

Dr. Steve Benson is the principal investigator and will manage the overall effort. He has managed numerous DOE and industry projects similar in complexity and size to this proposed project. He was the principal investigator of Phase I of this effort.

Mr. Alex Benson will be the project manager for this project. Due to the size and scope of this project, it is important to split principal investigator and project management responsibilities to ensure successful completion of the project. Mr. Benson will be responsible for day-to-day coordination efforts including tracking project deliverables, due dates, budgets, and overall progress in meeting project objectives. Mr. Benson has led multiple DOE and NDIC funded projects ranging from $250,000 to $2.5 million.

Microbeam utilizes several project management tools that include Smartsheet and Jira. Jira is used to track personnel time and Smartsheet is used to track project schedule. Smartsheet is software used to track project progression, assignment of tasks, allocation of resources, and adherence to project timeline. Smartsheet can also be used to notify individuals of upcoming action items, provide Gantt charts for reporting, and as a location for notes and comments regarding progress updates. Information from Jira on personnel time for each project is utilized by Quickbooks to track spending and is used for invoicing.

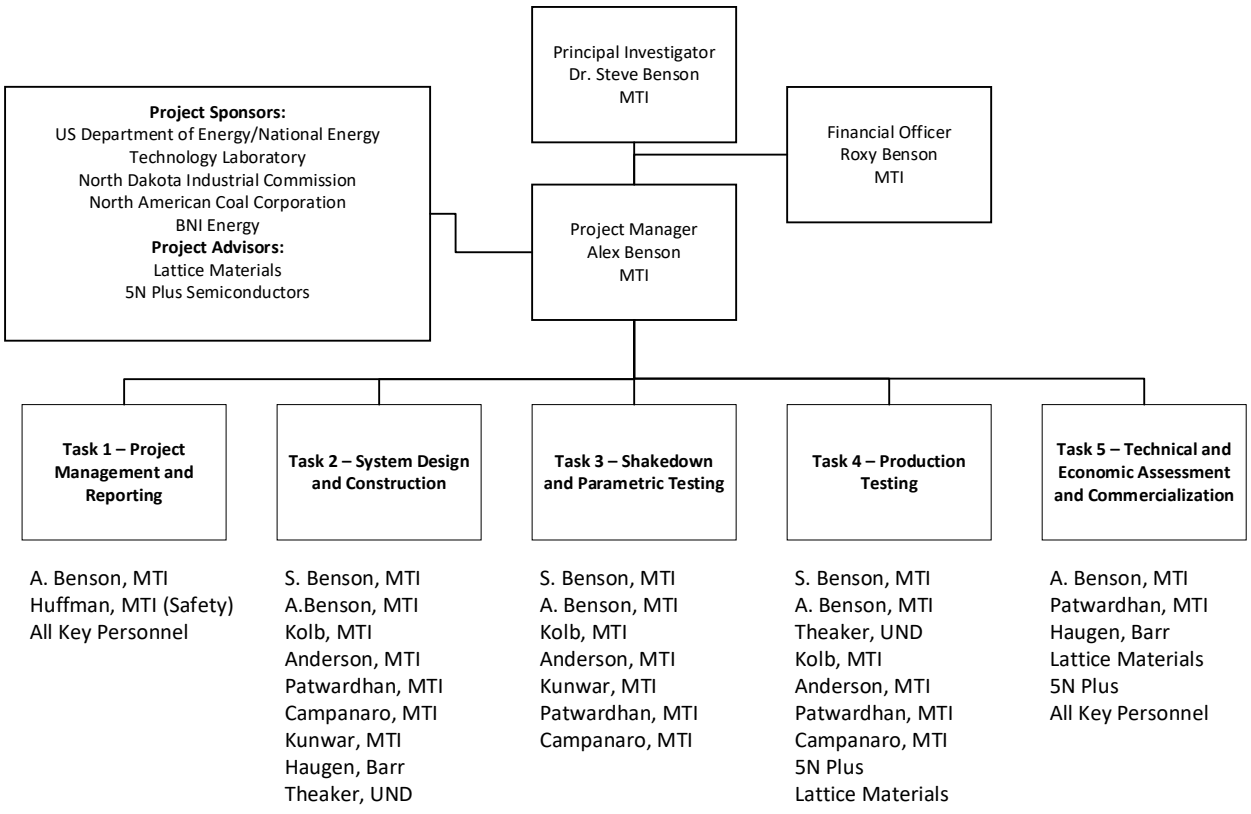


Figure 2. Project organizational chart.

9.0 TIMETABLE

The project is expected to take 36 months to complete. The timeline is shown in Figure 3.

Task Name	Duration	Start	Finish
Task 1. Project Management and Reporting	781 d	09/02/24	08/30/27
Subtask 1.1 Project Management Plan	23d	09/02/24	10/02/24
Subtask 1.2 Technology Maturation Plan	67d	09/02/24	12/03/24
Subtask 1.3 Community Benefits Plan	781 d	09/02/24	08/30/27
Assessment of and Execution of Community Benefits Plan	781 d	09/02/24	08/30/27
Initiate Annual Stakeholder Meetings	~0	08/29/25	08/29/25
Update Company Diversity Plan	~0	08/29/25	08/29/25
Final Report	106d	04/05/27	08/30/27
Task 2. System Design and Construction	330d	10/07/24	01/09/26
Subtask 2.1 Furnace System	200d	10/07/24	07/11/25
Subtask 2.2 Condensation Capture System	200d	11/04/24	08/08/25
Subtask 2.3 Particulate Control System	200d	12/02/24	09/05/25
Subtask 2.4 Materials Analysis System	200d	01/06/25	10/10/25
Subtask 2.5 Ge Condensate Processing	200d	02/03/25	11/07/25
Subtask 2.6 Ga Condensate Processing	200d	03/03/25	12/05/25
Subtask 2.7 Zone Refining of Ge and Ga	200d	04/07/25	01/09/26
Task 3. Shakedown and Parametric Testing	290d	07/14/25	08/21/26
Subtask 3.1 Shakedown Testing	170d	07/14/25	03/06/26
Subtask 3.2 Parametric Testing	120d	03/09/26	08/21/26
Task 4. Production Testing	645d	01/06/25	06/25/27
Subtask 4.1 Ge and Ga Rich Feedstock Selection	300d	01/06/25	02/27/26
Subtask 4.2 Production of Ge and Ga Concentrates	60d	08/24/26	11/13/26
Subtask 4.3 Refining to Ge and Ga Metal	120d	11/16/26	04/30/27
Subtask 4.4 Ge and Ga Metal Quality Evaluation	140d	12/14/26	06/25/27
Task 5. Technical and Economic Assessment and Commercialization	206d	11/16/26	08/30/27
Subtask 5.1 Review Overall Process Performance	60d	11/16/26	02/05/27
Subtask 5.2 Technical and Economic Assessment	120d	11/16/26	04/30/27
Subtask 5.3 Commercialization Planning	146d	02/08/27	08/30/27

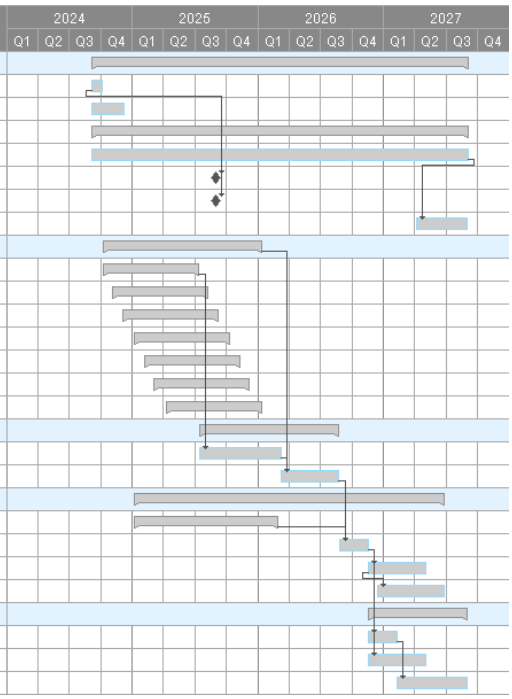


Figure 3. Proposed project timeline.

10.0 BUDGET

The overall project and subrecipient budgets are summarized in Table 2. The total budget for the project is $3,135,483. The costs are shared by the DOE for a total of $2,499,978 that covers the cost of personnel, travel, equipment, supplies, analysis, indirect, and general and administrative (G&A). Note that the indirect and G&A rates are approved by the US Department of Energy. The NDIC share of the overall budget is $376,000 that covers personnel, indirect, and G&A costs.

Table 1. Overall Project Budget.

Budget Category:	Total Budget incl. Cost Share	DOE Share	NDIC Cash Cost Share	NACC Cash Cost Share	MTI Cash Cost Share	Inkind Cost Share	Total Budget
Personnel	$ 672,657.00	$ 486,221.00	$ 166,508.00	$ 19,928.00			$ 672,657.00
Fringe	$ 242,157.00	$ 175,040.00	$ 59,943.00	$ 7,174.00			$ 242,157.00
Total Personnel	$ 914,814.00	$ 661,261.00	$ 226,451.00	$ 27,102.00			$ 914,814.00
Travel	$ 24,238.00	$ 24,238.00					$ 24,238.00
Equipment	$ 594,419.00	$ 594,419.00					$ 594,419.00
Supplies	$ 39,479.00	$ 39,479.00					$ 39,479.00
Subrecipient - UND	$ 415,000.00	$ 380,000.00				$ 35,000.00	$ 415,000.00
Subrecipient - Barr Eng.	$ 290,880.00	$ 280,880.00				$ 10,000.00	$ 290,880.00
Subrecipient - Inkind - NACC	$ 75,420.00					$ 75,420.00	$ 75,420.00
Subrecipient - Inkind - BNI Energy	$ 20,000.00					$ 20,000.00	$ 20,000.00
Subrecipient - Inkind - Lattice Materials	$ 10,000.00					$ 10,000.00	$ 10,000.00
Subrecipient - Inkind - 5N Plus	$ 56,085.00					$ 56,085.00	$ 56,085.00
Ventilation Contractor - Inkind - MTI	$ 8,000.00				$ 8,000.00		$ 8,000.00
Analysis	$ 48,430.00	$ 48,430.00	$ -	$ -			$ 48,430.00
Total Direct Costs	$ 2,496,765.00	$ 2,028,707.00	$ 226,451.00	$ 27,102.00	$ 8,000.00	$ 206,505.00	$ 2,496,765.00
Indirect Costs	$ 322,106.00	$ 232,829.00	$ 79,734.00	$ 9,543.00			$ 322,106.00
G&A Costs	$ 316,612.00	$ 238,442.00	$ 69,815.00	$ 8,355.00			$ 316,612.00
Total Indirect Costs	$ 638,718.00	$ 471,271.00	$ 149,549.00	$ 17,898.00	$ -	$ -	$ 638,718.00
Total Direct & Indirect Costs	**$ 3,135,483.00**	**$ 2,499,978.00**	**$ 376,000.00**	**$ 45,000.00**	**$ 8,000.00**	**$ 206,505.00**	**$ 3,135,483.00**

11.0 MATCHING FUNDS

Approximately 80% of the project costs are covered by the US DOE. There remaining 20% of the costs NDIC ($376,000), 5N Plus ($56,085), Barr Engineering ($10,000), BNI Coal ($20,000), Lattice Materials ($10,000), Microbeam Technologies Inc ($8,000), North American Coal Corporation ($120,420), and University of North Dakota ($35,000). The cost share is described as follows:

- NACC is providing $120,420 in the form of cash that will cover personnel, indirect, and G&A and inkind support to identify and provide coal for testing.
- Microbeam will provide $8,000 in cash that covers the installation of ventilation equipment.
- UND will provide inkind support of $35,000 to produce MREC.
- Barr Engineering will provide inkind support of $10,000 for engineer design and support.
- BNI Energy will provide inkind support of $20,000 for use in identifying potential optimum lignite properties for testing.

- Lattice Materials will provide inkind support of $10,000 for consultation on the quality of germanium metal produced required for the manufacture of products for defense and commercial applications.
- 5 NPlus semiconductors will provide inkind support of $56,085 to perform refining tests on the germanium and gallium rich concentrates to produce metals.

12.0 TAX LIABILITY

None – See statement in Appendix

13.0 CONFIDENTIAL INFORMATION

None

14.0 APPENDICES

14.1 Resumes

14.2 Project Letters of Commitment

14.3 DOE Award Letter

14.4 Tax Liability Statement

IDENTIFYING INFORMATION:

NAME: Benson, Steven

POSITION TITLE: President

PRIMARY ORGANIZATION AND LOCATION: Microbeam Technologies Incorporated, Grand Forks, North Dakota, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
Pennsylvania State University, University Park, Pennsylvania, United States	PHD	05/1987	Fuel Science
Minnesota State University, Moorhead, Minnesota, United States	BS	07/1977	Chemistry

Appointments and Positions

1991 - present	President, Microbeam Technologies Incorporated, Grand Forks, North Dakota, United States
2015 - 2017	Associate Vice President for Research, Energy & Environmental Research Center, University of North Dakota, Grand Forks, North Dakota, United States
2010 - 2014	Chair Petroleum Engineer Department and Director Institute for Energy Studies, University of North Dakota, Grand Forks, North Dakota, United States
2008 - 2010	Professor, Chemical Engineering, University of North Dakota, Grand Forks, North Dakota, United States
1994 - 2008	Associate Director for Research/Senior Research Manager, Energy & Environmental Research Center, University of North Dakota, Grand Forks, North Dakota, United States
1986 - 1994	Senior Research Manager, Energy & Environmental Research Center, University of North Dakota, Grand Forks, North Dakota, United States
1984 - 1987	Graduate Research Assistant, Pennsylvania State University, University Park, Pennsylvania, United States
1983 - 1984	Research Supervisor, UND Energy Research Center, Grand Forks, North Dakota, United States
1977 - 1983	Research Chemist, ERDA and US DOE, Grand Forks Energy Technology Center, Grand Forks, North Dakota, United States

Products

Products Most Closely Related to the Proposed Project

1. Laudal DA, Benson SA, Addleman RS, Palo D. Leaching behavior of rare earth elements in Fort Union lignite coals of North America. International Journal of Coal Geology. 2018 April 15; 191:112.
2. Daniel LA, Benson SA, Palo D, Addleman AS. Rare Earth Elements in North Dakota Lignite Coal and Lignite-Related Materials. ASME, J. Energy Resour. Technology. 2018 April 09;

140(6):062205.

3. James DW, Krishnamoorthy G, Benson SA. Modeling trace element partitioning during coal combustion. Fuel Processing Technology. 2014; 126:284.
4. Fuka M, Kolb E, Benson A, Benson S. System and Method for Predicting the Presence of Rare Earth Elements. Patent No. US 11,733,184 B2. 2023 August 22.
5. Laudal D, Benson S. Rare Earth Extraction from Coal. US Patent US 10,669,610 B2. 2020 June 02.

Other Significant Products, Whether or Not Related to the Proposed Project

1. Benson S, Patwardhan S, Stadem D, Langfeld J. Energy System Performance Manager. US Patent Application 63/159762. 2021 March 11.
2. Mota R, Krishnamoorthy G, Dada O, Benson S. Hydrogen rich syngas production from oxy-steam gasification of a lignite coal – A design and optimization study. Applied thermal engineering. 2015 November 01; 90:13.
3. Benson SA., Laumb M. The Path to Higher Availability Through Reduced Syngas Cooler Fouling. Gasification Technologies Conference. 2007 October 14.
4. Van Dyk JC, Waanders FB, Benson SA, Laumb M. Viscosity Predictions of the slag composition of gasified coal, utilizing FactSage equilibrium modeling. Fuel. 2009; 88:67.
5. Patwardhan S, Stadem D, Benson S, Krishnamoorthy G. Modeling Ash Partitioning in Slagging Energy Conversion Systems. Pittsburgh Coal Conference. 2022 September 19.

Synergistic Activities

1. College of Earth and Mineral Science Alumni Achievement Award, Pennsylvania State University, 2002;
2. Science and Technology Award, Impacts of Fuel Impurities Conference, 2014.
3. UND Spirit Award for Teaching and Research, 2013

Certification:

When the individual signs the certification on behalf of themselves, they are certifying that the information is current, accurate, and complete. This includes, but is not limited to, information related to domestic and foreign appointments and positions. Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Benson, Steven in SciENcv on 2023-10-12 16:14:26

IDENTIFYING INFORMATION:

NAME: Benson, Alexander

POSITION TITLE: Sr. Project Manager

PRIMARY ORGANIZATION AND LOCATION: Microbeam Technologies Inc., Minnetonka, Minnesota, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
University of St Thomas., St. Paul, Minnesota, United States	BS	12/2011	Mechanical Engineering

Appointments and Positions

2019 - present Sr. Project Manager, Microbeam Technologies Inc., Minnetonka, Minnesota, United States

2017 - 2019 Sr. Research Engineer (part-time), Microbeam Technologies Inc., Denver, Colorado, United States

2017 - 2019 Manufacturing Manager, Medtronic - Minimally Invasive Technology Group, Boulder, Colorado, United States

2016 - 2017 Sr. Product Engineer, Medtronic - Minimally Invasive Technology Group, Boulder, Colorado, United States

2015 - 2016 Sr. Manufacturing Engineer, Medtronic Energy and Component Center, Minneapolis, Minnesota, United States

2012 - 2015 Manufacturing Engineer, American Medical Systems, Minnetonka, Minnesota, United States

2007 - 2012 Lab Assistant (part-time), Microbeam Technologies Inc, Grand Forks, North Dakota, United States

Products

Products Most Closely Related to the Proposed Project

1. Fuka M, Kolb E, Benson A, Benson S., inventors. Microbeam Technologies, Inc., assignee. System And Method For Predicting Abundance Of Rare Earth Elements. United States of America 11,733,184. 2022 February 11.
2. Benson A, Benson S, Kolb E, Fuka M. Development of Low-Cost Rare Earth Element Analysis and Sorting Methods. [revised 2021 January]. [Print]. 2017 July. Other: Contract No. FY18-LXXXIII-213

Other Significant Products, Whether or Not Related to the Proposed Project

1. Benson S, Patwardhan S, Stadem D, Langfeld J, Benson A, Desell T. Application of Condition Based Monitoring and Neural Networks to Predict the Impact of Ash Deposition on Plant Performance. Accepted for presentation at 28th International Conference on the Impact of Fuel Quality on Power Production and the Environment, 2022.; 2022.

Synergistic Activities

1. "Development of Low-Cost Rare Earth Element Analysis and Sorting Method" - North Dakota Industrial Commission funded research project. Developing an REE predictive algorithm to be used with pXRF and PGNAA to assist in the exploration, identification, and sorting of REE in coal.
2. "Recovery of Lanthanides from Coal - chapter in DOE Rare Earth Elements in Coal and Coal Byproducts book. Submitted for review.
3. "Investigation of Rare Earth Element Extraction From North Dakota Coal-Related Feedstocks" (DE-FOA-0001202). Subcontract to University of North Dakota.
4. "Conceptual Design of a One Ton Per Day Rare Earth Oxide Extraction and Concentration Plant from Low-Rank Coal Resources" (89243320RFE000032). Subcontract to University of North Dakota.

Certification:

When the individual signs the certification on behalf of themselves, they are certifying that the information is current, accurate, and complete. This includes, but is not limited to, information related to domestic and foreign appointments and positions. Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Benson, Alexander in SciENcv on 2023-10-07 16:35:38

IDENTIFYING INFORMATION:

NAME: Kolb, Eric

POSITION TITLE: Research Engineer

PRIMARY ORGANIZATION AND LOCATION: Microbeam Technologies Inc., Minnetonka , Minnesota, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
University of North Dakota , Grand Forks , North Dakota, United States	BS	12/2020	Mechanical Engineering

Appointments and Positions

2021 - present Research Engineer , Microbeam Technologies Inc., Minnetonka , Minnesota, United States

2020 - 2021 Associate Research Engineer , Microbeam Technologies Inc., Grand Forks , North Dakota, United States

2019 - 2020 Intern, Microbeam Technologies Inc , Grand Forks , North Dakota, United States

Products

Products Most Closely Related to the Proposed Project

1. Benson A, Benson S, Fuka M, Kolb E. Development of Low-Cost Rare Earth Element Analysis and Sorting Methods. [revised 2021 January]. [Print]. 2017 July. Other: Contract No. FY18-LXXXIII-213
2. Benson A, Benson S, Fuka M, Kolb E., inventors. Microbeam Technologies Inc., assignee. System And Method For Predicting Abundance Of Rare Earth Elements With Handheld X-Ray Fluorescence. United States of America 11,733,184. 2021 February 11.

Other Significant Products, Whether or Not Related to the Proposed Project

Synergistic Activities

1. "Rare Earth Element Extraction and Concentration at Pilot-Scale from North Dakota Coal-Related Feedstocks"(DE-FE0031835). Subcontract to the University of North Dakota. Assisting the University with design, construction, and operation of the pilot- scale facility.
2. "Conceptual Design of a One Ton Per Day Rare Earth Oxide Extraction and Concentration Plant from Low-Rank Coal Resources" (89243320RFE000032). Subcontract to University of North Dakota. Assisting the University of North Dakota in writing a National Instrument (NI) 43-101 technical report on the extraction and concentration plant.
3. "Development of of Low-Cost Rare Earth Element Analysis and Sorting Method" - North Dakota Industrial Commission funded research project. Developing an REE predictive algorithm to be used with pXRF and PGNAA to assist in the exploration, identification, and sorting of REE in coal
4. Fundamentals of Mineral and Metallurgical Processing Short Course. This class was studying common theory's and practices of mineral and metallurgical processing hosted by the Society of

Mining Engineering.

Certification:

When the individual signs the certification on behalf of themselves, they are certifying that the information is current, accurate, and complete. This includes, but is not limited to, information related to domestic and foreign appointments and positions. Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Kolb, Eric in SciENcv on 2023-10-10 09:15:55

Dr. Daniel A. Laudal, Research Professor and Executive Director, University of North Dakota
daniel.laudal@und.edu | 701-777-5745

Education and Training

University of North Dakota	Chemical Engineering	B.S. 2006
University of North Dakota	Chemical Engineering	Ph.D. 2017

Research and Professional Experience

2022-Present Executive Director, UND College of Engineering & Mines Research Institute
Leading the research division of the College of Engineering & Mines.

2021-Present Research Professor and Director, UND Energy & Minerals Innovation Center (EMIC)
Leading the research programs in Energy and Minerals at the College of Engineering & Mines. Help realize the EMIC goal of developing UND into a premier "Energy University" that "inspires the creation of new knowledge to enable the development of revolutionary energy technologies, train the next generation of energy experts, and establish advanced industries required to make affordable emissions free energy technologies a reality". Responsibilities include identifying key technical and economic barriers to the development of secure, affordable, and reliable energy production technologies; identifying proposal opportunities and develop new relationships with potential partners; and drawing from resources across campus building teams to deliver the research, education, and outreach required to meet the needs of public and private partners.

2019-2021 Environmental Manager / Project Tundra Project Manager, Minnkota Power Coop.
Led the environmental regulatory compliance and environmental planning efforts for a generation & transmission cooperative serving eastern ND and northwestern MN. As Project Tundra Project Manager, led Minnkota's development of a $1.5B world-scale carbon capture and storage project for the Milton R. Young Station, a lignite coal fired power plant in ND. Responsibilities included leading development of the design, permitting and financing of the carbon capture plant and geologic storage facility.

2016-2018 Manager: Major Projects, UND Institute for Energy Studies (IES).
Primary roles included developing and writing funding proposals, managing research projects, coordinating IES research staff and students, and process design/development of innovative solutions to challenges in the energy industry. Principal Investigator or Project Manager or several DOE, State and industry funded projects. Research focused on the following major areas: carbon management for the power industry, production of co-products from coal and associated materials, value-added opportunities/technology development for North Dakota's energy industries.

2012-2015 Research Engineer, UND Institute for Energy Studies.
Lead researcher or principal investigator on several federal, state and industry funded projects. Work involved early-stage R&D of novel processes and technologies, primarily focusing on laboratory- and bench-scale demonstrations. Areas of focus included chemical looping combustion and post combustion carbon dioxide capture.

2008-2012 Research Engineer, UND Energy & Environmental Research Center.
Research involved design and operation of various lab and pilot-scale gasification, combustion and advanced power systems. Gained invaluable experience with high pressure and high temperature systems and fluidized beds.

2006-2008 Field Engineer, Schlumberger Oilfield Services.
Design, execution and evaluation of well cementing operations in the Williston Basin.

Selected Publications/Patents

Laudal, D., Benson, S. "Rare earth element extraction from coal." U.S. Patent No. 10,669,610. March 2017

Theaker, N., **Laudal, D.,** Lucky, C. "Generation of rare earth elements from organically associated leach solutions." U.S. Patent Application No. 17/519,346. Filed May 2022.

Theaker, N., **Laudal, D.** "Method for leaching rare earth elements and critical minerals from organically associated materials." U.S. Patent Application No. 17/519,341. Filed May 2022.

Laudal, D., Benson, S., Addleman, S., Palo, D. "Leaching behavior of rare earth elements in Fort Union lignite coals of North America." International Journal of Coal Geology 191 (2018) 112-124.

Laudal, D., Benson, S., Addleman, S., Palo, D. "Rare earth elements in North Dakota lignite coal and lignite-related materials." ASME Journal of Energy Resources and Technology 140 (2018).

Park, D., Middleton, A., Smith, R., Deblonde, G., **Laudal, D.,** Theaker, N., Hsu-Kim, H., Jia, Y. "A biosorption-based approach for selective extraction of rare earth elements from coal byproducts." Separation and Purification Technology. Volume 241:116726. June 2020.

Van der Watt, J.G., **Laudal, D**., Krishnamoorthy, G., Feilen, H., Mann, M., Shallbetter, R., Nelson, T., Srinivasachar, S. "Development of a spouted bed reactor for chemical looping combustion." Journal of Energy Resources and Technology. 140(11), 112002 (8 pages), November 2018.

Nelson, T., van der Watt, J.G., **Laudal, D**., Feilen, H., Mann, H., Srinivasachar, S. "Reactive jet and cyclonic attrition analysis of ilmenite in chemical looping combustion systems." International Journal of Greenhouse Gas Control. Volume 91, December 2019, 102837.

Nasah, J., Jensen, B., Dyrstad-Cincotta, N., Gerber, J., **Laudal, D**., Mann, M., Srinivasachar, S. "Method for separation of coal conversion products from oxygen carriers." International Journal of Greenhouse Gas Control. Volume 88, September 2019, pages 361-370.

Emerson, S., Zhu, T., Davis, T. Peles, A., She, Y., Willigan, R., Vanderspurt, T., Swanson, M., **Laudal**, **D**. "Liquid Phase Reforming of Woody Biomass to Hydrogen". International Journal of Hydrogen Energy, August 2013.

Synergistic Activities

Dr. Laudal's technical areas of expertise include carbon capture, utilization and storage, critical mineral and rare earth processing technologies, coal utilization, and carbon-based products. His PhD research involved evaluation of lignite coals as a resource of critical minerals, including the development of a new processing technology that led to one patent issued, two patents pending, and a series of DOE-, state- and industry-funded R&D projects to continue research in this area. Dr. Laudal is currently leading UND's Phase 1 project under DE-FE0032295 (DE-FOA-0002618) that is performing a front-end engineering & design and business plan to commercialize the patented technology.

Nolan L. Theaker

Technical Group Manager – Critical Minerals, Institute for Energy Studies
University of North Dakota, Grand Forks, ND 58202

Education and Training

University of Louisville	Chemical Engineering	B.S. 2016
University of Louisville	Chemical Engineering	M.Eng. 2017
University of North Dakota	Chemical Engineering	Pursuing PhD

Research and Professional Experience

2017-Present Technical Group Manager, UND Institute for Energy Studies.

Responsibilities include high-level innovative research and development of novel concepts for submission of funding proposals. Coordinated and led efforts associated with downstream rare earth element concentration operations that have resulted in the development of final process flow diagrams and process designs. Principle Investigator to $6.5M pilot-scale REE extraction and concentration project, as well as PI/Co-PI on 7 other proposals, managing up to $10M in total project funds involving pilot-scale design, construction, and operation; resource identification and quantification; engineering-scale economic and engineering analyses; and novel process development and commercialization. Key contributor/PI to multiple proposals involving REE/CM extraction and/or concentration from multiple, conventional and unconventional feedstocks. Proposed efforts associated with coal conversion and value improvement using chemical/thermal methods. Co-PI for project involving CO_2 utilization from coal-derived flue gases.

2016-2017 Research Assistant, University of Louisville Conn Center.

Research involved design and operation of multi-stage electrochemical reactor scheme for efficient production of fuels from CO_2. Developed nano-functionalized electrocatalysts for improvements in activity and selectivity for targeted reactions in two phase reaction systems. Implemented phase-segregation devices for multi-step electrochemical reaction system, with planned production cost below research benchmarks to date.

2014-2015 Co-op Engineer, University of Kentucky CAER.

Research involved improvement and operation of a DOE bench-scale CO_2 capture unit in multiple reaction conditions, including enzymatic and amine-based systems. Evaluation and comparison of catalyst performance in a holistic view for CO_2 capture was conducted, including novel organic and enzymatic catalysts. Implemented system changes for improved user functionality of the system, including development of control systems and equipment selection for easy manual usage.

Publications/Presentations

1. **Theaker, N.**, Strain, J. M., Kumar, B., Brian, J. P., Kumari, S., & Spurgeon, J. M. (2018). Heterogeneously Catalyzed Two-Ctep Cascade Electrochemical Reduction of CO_2 to Ethanol. *Electrochimica Acta, 274*, 1-8. doi:10.1016/j.electacta.

2. Park, D., Middleton, A., Smith, R., Laudal, D., **Theaker, N.**, Hsu-Kim, H., Jiao, Y. A Biosorption-based approach for the selective extraction of REEs from coal byproducts. *Separation and Purification Technology*. 2020.

3. Dong, Z; Deblonde, G; Middleton, A; Hu, D; Dohnalkova, A; Kovarik, L; Qafoku, O; Shutthanandan, S; Jin, H; Hsu-Kim, H; **Theaker, N**; Jiao, Y; Park, D. "Microbe Encapsulated Silica Gel Biosorbent for Selective Extraction of Scandium from Coal Byproducts." *Environmental Science and Technology.* 2021.
4. Mann, M; **Theaker, N**; Benson, S; Palo, D. "Investigation of Rare Earth Element Extraction from North Dakota Coal-Related Feedstocks – Final Report". Submitted March 31, 2020.
5. Mann, M., **Theaker, N.**, Ling, A., Haugen, C., Winburn, R., Brewer, J., Benson, S., Benson, A., James, D., Goven, G., Koenig, A, Srinivasachar, S. "Feasibility Study of a One Tonne per day Rare Earth Extraction and Concentration Plant from Low-Rank Coal Resources." Submitted January 28, 2022.
6. **Theaker, N.**, Rew, B., Laudal, D., Mann, M. Investigation of rare earth element extraction from North Dakota Coal-Related Feed Stocks. 2019 NETL Annual Crosscutting Projects Review Meeting. April 9th, 2019. Pittsburgh, PA.
7. **Theaker, N.** "Extraction of Rare Earth Elements from Lignite Coal – Kinetics of Extraction and Bench-Scale Updates." 2019 Annual Society of Mining Engineering" Presented February 2, 2019.
8. Zygarlicke, C; Folkedahl, B; Feole, I; Kurz, B; **Theaker, N**; Benson, S; Hower, J; Eble, C. "Rare-Earth Elements (REEs) in U.S. Coal-Based Resources: Sampling, Characterization, and Round-Robin Interlaboratory Study – Final Report". Submitted September 30th, 2019.
9. Gautam, M; Hofsommer, D. T; **Theaker, N**; Paxton, W. F; Grapperhaus, C. A; Spurgeon, J. M. "The effect of flue gas contaminants on electrochemical reduction of CO2 to methyl formate in a dual methanol/water electrolysis system." Chem Catalysis, 2022.
10. Spurgeon, J; **Theaker, N**; Phipps, C; Uttarwar, S; Grapperhaus, C. A. "A Comparative Technoeconomic Reduction of CO2 with Methanol to Produce Methyl Formate." ACS Sustainable Chemistry & Engineering, 2022.

Patents/Applications:

1. Theaker, Nolan; Laudal, Dan. 2020. Method for Leaching Rare Earth Elements and Critical Minerals from Organically Associated Materials. USA. 63/112,846A, filed Nov. 12, 2020.
2. Theaker, Nolan; Laudal, Dan; Lucky, Christine. 2020. Generation of Rare Earth Elements from Organically-Associated Leach Solutions. USA. 63/112,842A, filed Nov. 12, 2020.

Synergistic Activities

Mr. Theaker's principal area of research interest include energy, fuels, and alternative critical material research. These include developing alternative uses and sources of fuels and valuable materials, both carbon and mineral based, as well as developing new and unconventional sources of energy-critical materials.

*NAME Haugen, Chad *Required fields

ORCID ID (Optional)

*POSITION TITLE Senior Process Engineer

*PRIMARY ORGANIZATION & LOCATION Barr Engineering Co., Minneapolis, Minnesota, U.S.

***PROFESSIONAL PREPARATION - (see PAPPG Chapter II.D.2.h.i.a.3)**

PREVIOUS ORGANIZATION(S) & LOCATION(S)	DEGREE (if applicable)	RECEIPT DATE* (MM/YYYY)	FIELD OF STUDY
University of North Dakota, Grand Forks, North Dakota, United States	BS	05/2008	Chemical Engineering

Note - For Fellowship applicants only, please include the start date of the Fellowship.

***APPOINTMENTS AND POSITIONS - (see PAPPG Chapter II.D.2.h.i.a.4)**

Start Date - End Date	Appointment or Position Title, Organization, and Location
2018 - present	Senior Process Engineer, Barr Engineering Co., Minneapolis, Minnesota, United States
2012 - 2018	Process Engineer, Barr Engineering Co., Minneapolis, Minnesota, United States
2008 - 2012	Production Engineer and Shift Supervisor, Archer Daniels Midland, Corn Processing Division, Marshall, Minnesota, United States

***Synergistic Activities - (see PAPPG Chapter II.D.2.h.(i)(a)(6))**

1. Professional Engineer registration in Minnesota and Illinois.
2. Member of American Institute of Chemical Engineers (AIChE) from 2023 to the present.

***Certification**:

When the individual signs the certification on behalf of themselves, they are certifying that the information is current, accurate, and complete. This includes, but is not limited to, information related to domestic and foreign appointments and positions. Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§287, 1001, 1031 and 31 U.S.C. §§3729-3733 and 3802.

Signature
(Please type out full name): Chad Andrew Haugen Date: 10/12/2023

UNIVERSITY OF NORTH DAKOTA

UND.edu

COLLEGE OF ENGINEERING & MINES

Office of the Dean
Upson II, Room 165
243 Centennial Dr Stop 8155
Grand Forks, ND 58202-8155
Phone: 701.777.3411
Fax: 701.777.4838
Website: engineering.UND.edu

October 20, 2023

Alexander Benson
Sr. Project Manager
Microbeam Technologies Inc.
4200 James Ray Drive, Ste 193
Grand Forks, ND 58202

Re: Support of the proposal entitled "Production of Germanium and Gallium Concentrates for Industrial Processes" submitted in response to DE-FOA-0002619 "Bipartisan Infrastructure Law (BIL) – Advanced Processing of Critical Minerals and Materials for Industrial and Manufacturing Applications".

Dear Mr. Benson:

The University of North Dakota, College of Engineering & Mines (UND) is pleased to team with Microbeam Technologies Inc. to design, construct, and operate a bench-scale unit to produce germanium and gallium from mixed rare earth element (MREE) concentrates.

UND will work with Microbeam to test the Ge concentrates that are produced from the bench-scale for use in further purification and refinement processes. UND will produce the MREE that will be used as a feedstock in this project through our existing pilot-scale REE extraction facility. In addition to providing the feedstock for the project, UND will assist in the process design, techno-economic assessment, and commercialization efforts. The proposed technology can be integrated at the commercial scale with UND's REE processing plant, so it is critical that UND be involved in discussions related to the supply chain development of the Ge/Ga production process.

The total cost of UND's work in this project is $415,000. Of this, UND commits to providing up to $35,000 as in-kind cost share in the form of salary, fringe benefits, and indirect costs associated with the effort of faculty and senior researchers at UND (Dr. Daniel Laudal and Mr. Kevan Rusk) who will contribute to the techno-economic analysis and commercialization planning efforts. Our attached budget justification provides full details. If you have any question or require additional information, please contact UND's project manager, Nolan Theaker at nolan.theaker@und.edu.

We look forward to continuing our collaborations with the Microbeam team.

Sincerely

DocuSigned by:
Daniel Laudal
9CFF8579D0B9464...

Daniel Laudal, Ph.D.
Executive Director
College of Engineering & Mines Research Institute
University of North Dakota
daniel.laudal@und.edu

DocuSigned by:
Karen Katrinak
DD9BE15BC81D4AA...

Karen Katrinak, Ph.D.
Proposal Development Officer
Research and Sponsored Programs Development
University of North Dakota
karen.katrinak@und.edu

resourceful. naturally.
engineering and environmental consultants

BARR

October 20, 2023

Mr. Alexander Benson
Sr. Project Manager
Microbeam Technologies Inc.
4200 James Ray Drive, Ste 193
Grand Forks, ND 58202

Re: Support of the proposal entitled "Production of Germanium and Gallium Concentrates for Industrial Processes" submitted in response to DE-FOA-0002619 "Bipartisan Infrastructure Law (BIL) – Advanced Processing of Critical Minerals and Materials for Industrial and Manufacturing Applications"

Dear Mr. Benson:

Barr Engineering Co. is pleased to team with Microbeam Technologies Inc. to design, construct, and operate a bench-scale unit to produce germanium and gallium from mixed rare earth element (MREE) concentrates. Having worked with Microbeam on previous DOE-funded projects along with others, Barr has the experience to assist Microbeam in successfully executing this project.

Barr will work with the Microbeam team to assist in the project's subsystem designs, technical and economic assessment (TEA), and commercialization planning tasks. With our extensive experience in process development, process modeling, and engineering related to mineral processing, Barr will provide Microbeam with the required tools and insights to evaluate and scale the proposed technology fully.

The DOE-funded share of Barr's participation in this 36-month project is $280,880. These costs cover Barr's contributions to Task 1: Project Management and Reporting, Task 2: System Design and Construction/Setup, and Task 5: Technical and Economic Assessment and Commercialization. In conducting these tasks, Barr proposes to provide up to $10,000 of in-kind cost share through a combination of software fees, staff labor, and travel expenses. If you have questions or require additional information, please contact Chad Haugen by phone at 218-779-9776 or by email at chaugen@barr.com.

Sincerely,

Chad Haugen, PE
Senior Process Engineer
Project Manager

Daniel R. Palo, PhD, P.Eng., PE
Vice President and Senior Process Engineer
Principal in Charge

North American COAL

October 27, 2023

Alexander Benson
Sr. Project Manager
Microbeam Technologies Inc.
4200 James Ray Drive, Ste 193
Grand Forks, ND 58202

Re: Support of the proposal entitled “Production of Germanium and Gallium Concentrates for Industrial Processes” submitted in response to DE-FOA-0002619 “Bipartisan Infrastructure Law (BIL) – Advanced Processing of Critical Minerals and Materials for Industrial and Manufacturing Applications”.

Dear Mr. Benson:

North American Coal Corporation (NACC) is pleased to team with Microbeam Technologies Inc. to design, construct, and operate a bench-scale unit to produce germanium and gallium from mixed rare earth element (MREE) concentrates.

NACC will work with Microbeam to select and procure a lignite resource with high germanium and gallium to be used for testing and to participate in the technical and economical assessments. It is estimated that 30-60 tons of lignite will be required for the testing efforts in this project. The ability to domestically produce Ge and Ga for industrial applications is important to the US economy. This technology could produce a valuable opportunity to current mine wastes.

NACC will provide up to $120,000 in the form of cash and in-kind cost share. NACC will provide $15,000 in cash per year, totaling $45,000 for the entirety of the project. The $75,000 of in-kind cost share will be a result of the costs from personnel time related to selection of a resource and participation in TEA development and the costs of collecting 30-60 tons of lignite.

If you have questions and require additional information, please contact me or Gerard Goven at (701) 250-2604, gerard.goven@nacoal.com.

Sincerely,
THE NORTH AMERICAN COAL CORPORATION

Carroll L. Dewing
Senior Vice President and Chief Operating Officer

North American Coal
5340 Legacy Drive, Suite #300
Plano, TX 75024
972.448.5400 | Direct 701.323.3392
NACoal.com | carroll.dewing@nacco.com

PHONE (701) 355-5588

FAX (701) 794-3125

BNI coal

A BNI ENERGY COMPANY

October 20, 2023

Alexander Benson
Sr. Project Manager
Microbeam Technologies Inc.
4200 James Ray Drive, Ste 193
Grand Forks, ND 58202

Re: Support of the proposal entitled "Production of Germanium and Gallium Concentrates for Industrial Processes" submitted in response to DE-FOA-0002619 "Bipartisan Infrastructure Law (BIL) – Advanced Processing of Critical Minerals and Materials for Industrial and Manufacturing Applications".

Dear Mr. Benson:

BNI Coal is pleased to team with Microbeam Technologies Inc. to design, construct, and operate a bench-scale unit to produce germanium and gallium from mixed rare earth element (MREE) concentrates.

BNI will work with Microbeam to select and procure a lignite resource with high germanium and gallium to be used for testing and to participate in the technical and economical assessments. It is estimated that 30 tons of lignite will be required for the testing efforts in this project. The ability to domestically produce Ge and Ga for industrial applications is important to the US economy. This technology could produce a valuable opportunity to current mine wastes.

BNI will provide $20,000 in the form of in-kind cost share. The cost share will be a result of the costs from personnel time related to selection of a resource and participation in TEA development and the costs of collecting approximately 30 tons of lignite. If you have questions and require additional information, please contact Jon Rudnick by phone at 701-355-5530 or by email at jrudnick@bnicoal.com.

Sincerely,

Mike Heger
General Manager

BNI COAL, LTD.
2360 35TH AVENUE SW, CENTER, ND 58530-9499

October 20, 2023

Alexander Benson
Sr. Project Manager
Microbeam Technologies Inc.
4200 James Ray Drive, Ste 193
Grand Forks, ND 58202

Re: Support of the proposal entitled "Production of Germanium and Gallium Concentrates for Industrial Processes" submitted in response to DE-FOA-0002619 "Bipartisan Infrastructure Law (BIL) – Advanced Processing of Critical Minerals and Materials for Industrial and Manufacturing Applications".

Dear Mr. Benson:

5N Plus is pleased to team with Microbeam Technologies Inc. to design, construct, and operate a bench-scale unit to produce germanium and gallium from mixed rare earth element (MREE) concentrates.

5N Plus will work with Microbeam to test the Ge concentrates that are produced from the bench-scale for use in further purification and refinement processes. 5N Plus operates a commercial level Ge recycling facility in Utah but also has laboratory-scale equipment that will be able to simulate a commercial application for dechlorination, hydrolysis, reduction, and zone refining. The ability to domestically produce Ge and Ga for industrial applications is important to the US economy. In addition to the testing of Microbeam's Ge concentrates, 5N Plus will provide input on technical and economic evaluations and commercialization opportunities.

5N Plus will conduct testing and advisory services as part of in-kind cost share for a total of $56,000 for the project. If you have questions and require additional information, please contact Jason Merrell by phone at 801-808-5938 or by email at Jason.Merrell@5nplus.com.

Sincerely,

Jason Merrell, PhD
Director of Engineering
& Technology Development

LATTICE MATERIALS
A TPC COMPANY

October 12, 2023

Alexander Benson
Sr. Project Manager
Microbeam Technologies Inc.
4200 James Ray Drive, Ste 193
Grand Forks, ND 58202

Re: Support of the proposal entitled "Production of Germanium and Gallium Concentrates for Industrial Processes" submitted in response to DE-FOA-0002619 "Bipartisan Infrastructure Law (BIL) – Advanced Processing of Critical Minerals and Materials for Industrial and Manufacturing Applications".

Dear Mr. Benson:

Lattice Materials is pleased to team with Microbeam Technologies Inc. to design, construct, and operate a bench-scale unit to produce germanium and gallium from mixed rare earth element (MREE) concentrates.

Lattice Materials will work with Microbeam to test the Ge concentrates that are produced from the bench-scale for use in further purification and refinement processes. Lattice Materials has laboratory-scale equipment that will be able to assist in evaluating the feasibility of the Ge produced from this technology. The ability to domestically produce Ge and Ga for industrial applications is important to the US economy. In addition to the testing of Microbeam's Ge concentrates, Lattice Materials will provide input on technical and economic evaluations and commercialization opportunities.

Lattice Materials will conduct testing and advisory services as part of in-kind cost share for an estimated total of $10,000 for the project. If you have questions and require additional information, please contact Travis Wood by phone at (406) 556-5754 or by email at travisw@latticematerials.com.

Sincerely,

Travis Wood
General Manager
Lattice Materials

ASSISTANCE AGREEMENT

1. Award No.	2. Modification No.	3. Effective Date	4. CFDA No.
DE-FE0032522		09/01/2024	81.089

5. Awarded To	6. Sponsoring Office	7. Period of Performance
MICROBEAM TECHNOLOGIES INCORPORATED Attn: ROXANNE BENSON P.O. BOX 5 Victoria MN 553860005	Fossil Energy and Carbon Management FECM-1 U.S. Department of Energy 1000 Independence Avenue, S.W. Washington DC 20585	09/01/2024 through 08/31/2027

8. Type of Agreement	9. Authority	10. Purchase Request or Funding Document No.
☐ Grant ☒ Cooperative Agreement ☐ Other	See Page 2	24FE003329

11. Remittance Address	12. Total Amount	13. Funds Obligated
MICROBEAM TECHNOLOGIES INCORPORATED Attn: Roxanne Benson P.O. BOX 5 Victoria MN 553860005	Govt. Share: $2,499,978.00 Cost Share : $635,505.00 Total : $3,135,483.00	This action: $2,499,978.00 Total : $2,499,978.00

14. Principal Investigator	15. Program Manager	16. Administrator
	Brett Michael Hakey Phone: 304-285-0262	U.S. DOE/NETL NATIONAL ENERGY TECH LAB 3610 Collins Ferry Road Morgantown WV 26505-2353

17. Submit Payment Requests To	18. Paying Office	19. Submit Reports To
VIPERS https://vipers.doe.gov Any questions, please contact by call/email 855-384-7377 or VipersSupport@hq.doe.gov	VIPERS https://vipers.doe.gov Any questions, please contact by call/email 855-384-7377 or VipersSupport@hq.doe.gov	See Attachment 3 - Reporting Requirements Checklist

20. Accounting and Appropriation Data

00174-2023-31-232413-25500-1611475-0000000-0000000-0000000

21. Research Title and/or Description of Project

Bipartisan Infrastructure Law (BIL) - Production of Germanium and Gallium Concentrates for Industrial Processes.

For the Recipient		For the United States of America	
22. Signature of Person Authorized to Sign		25. Signature of Grants/Agreements Officer	
23. Name and Title	24. Date Signed	26. Name of Officer	27. Date Signed
Steven A. Benson, President	09/10/2024	Kelly A. Haught	09/10/2024

ITEM NO. (A)	SUPPLIES/SERVICES (B)	QUANTITY (C)	UNIT (D)	UNIT PRICE (E)	AMOUNT (F)
	UEI: X7LDM8GNRVF1 Block 9 Authority: Public Law (P.L.) 95-91, DOE Organization Act, as amended; • P.L. 116-260, Div. Z, Energy Act of 2020, Title VII, Sec. 7001, as amended, codified at 42 U.S.C. 13344; and • P.L. 117-58, Infrastructure Investment and Jobs Act (IIJA), Sec. 41003(b), which authorized appropriations for 42 U.S.C. 13344(a). Project Period: 09/01/2024 - 08/31/2027 Budget Period 1: 09/01/2024 - 08/31/2027 Recipient Business Point of Contact: Roxanne Benson rbenson@microbeam.com 701-739-6909 Recipient Principal Investigator Dr. Steven A. Benson sbenson@microbeam.com 701-213-7070 DOE Project Officer: Brett Hakey Brett.Hakey@netl.doe.gov 304-285-0262 DOE Award Administrator: Sheldon Funk Sheldon.Funk@netl.doe.gov 304-285-0204 ASAP: NO: STD IMMEDIATE Extent Competed: COMPETED Davis-Bacon Act: YES PI: Steven A. Benson Fund: 00174 Appr Year: 2023 Allottee: 31 Report Entity: 232413 Object Class: 25500 Program: 1611475 Project: 0000000 WFO: 0000000 Local Use: 0000000				

Industrial Commission

Tax Liability Statement

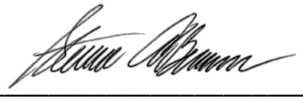
Applicant:
Microbeam Technologies Incorporated
4200 James Ray Drive, Ste. 193
Grand Forks, ND 58202-6090

Application Title:
Bipartisan Infrastructure Law (BIL) – Production of Germanium and Gallium Concentrates for Industrial Processes – Phase II

Program:

- ☑ Lignite Research, Development and Marketing Program
- ☐ Renewable Energy Program
- ☐ Oil & Gas Research Program
- ☐ Clean Sustainable Energy Authority

Certification:
I hereby certify that the applicant listed above does not have any outstanding tax liability owed to the State of North Dakota or any of its political subdivisions.



Signature

President

Title

9/30/2024

Date