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January 29, 2025

Ms. Karlene Fine, Executive Director
North Dakota Industrial Commission
State Capitol – 14th floor
600 East Boulevard Avenue, Dept. 405
Bismarck, ND 58505-0840

Subject: Proposal to the Renewable Energy Program

Dear Ms. Fine:

On behalf of the University of North Dakota, I am pleased to submit Dr. Xiaodong Hou's proposal on "Producing Silicon Anode Materials for Li-ion Batteries," for consideration by the NDIC's Renewable Energy Program. Dr. Hou is a Research Associate Professor in UND's College of Engineering and Mines and is the Principal Investigator for this project. Dr. Hou is proposing an 18-month project with a total requested amount from NDIC of $200,000. The NDIC funding is being requested as a match to the DOE portion of the project, which is currently in the process of being negotiated and awarded for $999,999 under DE-FOA-0003155 as Award Number DE-EE0011725. Additional cost share has been committed by Lattice Materials ($15,000); Leonardite Products ($15,000); Packet Digital ($15,000); and the University of North Dakota ($5000). The total value of the overall project would thus be $1,249,999. We anticipate a start date in approximately April 2025.

Please contact Dr. Hou with any technical questions about the project at (701) 777-6350 or xiaodong.hou@und.edu. If the NDIC selects this proposal for an award, please send any award documents and related communications to Sherry Zeman at sherry.zeman@und.edu for processing on behalf of UND. The $100 application fee is being handled as an electronic payment by UND and should reach your office in a timely manner. Thank you very much for your consideration of this proposal.

Sincerely yours,

DocuSigned by:
Karen Katrinak
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Karen Katrinak, Ph.D.
Proposal Lead, Research & Sponsored Program Development
Karen.katrinak@und.edu 701-777-2505

Application

Project Title: Producing Silicon Anode Materials for Li-ion Batteries

Applicant: University of North Dakota

Principal Investigator: Xiaodong Hou

Date of Application: February 1, 2025

Amount of Request: $200,000

Total Amount of Proposed Project: $1,249,999

Duration of Project: 1.5 years

Point of Contact (POC): Xiaodong Hou

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Renewable Energy Program

North Dakota Industrial Commission

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1 ABSTRACT

Objective: The Center for Process Engineering Research at the University of North Dakota (UND) College of Engineering & Mines, with support from three long-term industry partners (Lattice Materials, Leonardite Products LLC, and Packet Digital LLC), will conduct a prototype demonstration of a proven process for producing low-cost and high-performance silicon monoxide (SiO) with graphene coating (SiO/G) anode materials for lithium-ion batteries (LIBs). The project's success leverages the following: 1) high-purity Si scrap produced from Lattice Materials' semiconductor manufacturing facility; 2) an innovative plasma-based SiO synthetic production technique, and 3) a unique graphene precursor, humic acid, and UND CPER's patented technology for in-situ synthesis of graphene coated SiO anode. The ultimate goal of this project is to prove the technical and economic merits of the technology at a commercially-relevant scale, readying the technology for commercial licensing to build a North Dakota production facility for high-performance SiO anode materials to meet the ever-increasing anode demands in the LIBs industry.

Expected Results: Expected results include: 1) optimization of a high-performance process for producing SiO/G anodes that meet the target level of performance defined later in **Table 1**, 2) prototype demonstration of the process at 10-20 kg/day, 3) techno-economic analysis and environmental lifecycle analysis to prove the technology's economic and environmental feasibility and merits and 4) a market transformation plan to lay out the next development steps to full commercialization in North Dakota. The proposed project directly <u>benefits North Dakota in multiple ways</u>: 1) new markets for ND mineral resources, including Leonardite and silica, 2) partnership that benefits ND private sector companies in both upstream (Leonardite Products) and downstream (Packet Digital) positions in the value chain, 3) demonstration of an innovative new battery anode manufacturing method that could impact multiple sectors of ND's economy, including electric utilities, transportation, and unmanned serial systems (UAS), 4) new markets/demand for ND's renewable energy resources. We expect that this project will ready the technology for immediate commercial licensing.

Duration: 18 months (Suggested: April 1, 2025 – September 30, 2026)

Total Project Cost: NDIC Share: $200,000 | Total Project: $1,249,999

Participants: UND, University of Idaho, Lattice Materials, Leonardite Products, and Packet Digital.

2 PROJECT DESCRIPTION

2.1 Objectives

The primary objective is to conduct a prototype demonstration of a proven process for producing low-cost and high-performance silicon monoxide (SiO) with graphene coating (SiO/G) anode materials for lithium-ion batteries (LIBs). The achievement of this goal leverages the following key components: 1) high-purity Si scrap produced from Lattice Materials' semiconductor manufacturing facility in Bozeman, MT; 2) an innovative plasma-based synthetic SiO production technique, 3) a unique graphene precursor, humic acid produced from Leonardite Products' facility in Williston, ND, and 4) UND's patented technology for in-situ synthesis of graphene coated SiO anode. The ultimate goal of this project is to prove the technical and economic merits of the technology at a commercially-relevant scale, readying the technology for commercial licensing to build a North Dakota production facility for high-performance SiO/G anode materials to meet the ever-increasing anode demands in the LIBs industry.

The proposed project will address key technical gaps identified from prior technology development efforts. Specific goals related to addressing these gaps and targeting specific improvements to the baseline performance and their technical/economic performance are listed in **Table 1.** The baseline for most of the technical objectives is based on the commercial nano-Si/C produced using the ball milling approach, given its competitiveness alongside SiO anodes and the current lack of SiO anode producers in the US.

Table1. Target Level of Performance

Objective/Goal	Metric	Min Target	Stretch Target	Baseline Performance
Reduced water or chemical consumption	% decrease in volume of water or chemical per ton of Si anode produced	50%	90%	Commercial nano-Si/C anodes
Reduced waste	Reduced waste per unit of SiO anode produced	50%	90%	Commercial nano-Si/C anodes
Reduced energy embodiment through energy-efficient processes	% decrease in energy expended per ton of Si-anode produced	20%	30%	Commercial nano-Si/C anodes
SiO as a byproduct in an existing process	% of domestic demand potentially met by sourcing SiO as a byproduct	25%	50%	Projected 2030 Si anode demand in the US
Improved battery performance	Specific capacity (mAh/g)	1000	1600	Commercial nano-Si/C anodes
	Initial Columbic Efficiency (ICE)	80%	85%	
	Cycling life (80% capacity retention)	600	1000	
Cost competitiveness	% decrease in cost per kAh	40%	65%	Commercial nano-Si/C

2.2 Methodology

An overview of the technology methods is provided below (see Appendix 2 for full confidential details). The SiO/G manufacturing technology involves five steps, summarized as follows. **Step 1** – Feedstock selection and pre-treatment: The silicon feedstock will be supplied by Lattice Materials, and Leonardite by Leonardite Products. **Step 2** – The production of SiO via two approaches: 1) through a self-designed and fabricated plasma reactor and 2) through a conventional resistive heating approach. **Step 3** – SiO classification: The SiO solid will be pulverized and then classified into SiO powders with desired particle sizes. **Step 4** – Graphene coating: our patented technology[1] will be used to produce high-purity humic acid as a graphene precursor from Leonardite to produce SiO/G. **Step 5** – Anode functionalization: the obtained SiO/G composite possesses a high reversible capacity but a low ICE, which will be improved to produce a highly competitive LIB anode by leveraging our expertise in relevant techniques.

We propose the following set of tasks to achieve the project objectives.

Task 1 – Project Management and Planning

UND will perform all project management work necessary to manage the project's scope, schedule and budget (see Sections 5, 6, & 7). As a requirement of the associated DOE funding (80% of the project's cost), additional efforts will involve the development and implementation of a Community Benefits Plan (CBP) focusing on DEIA, energy equity, and workforce investment, and development of a market transformation plan (MTP) detailing future plans necessary to bring the technology to full commercialization.

Task 2 – Production of SiO

Subtask 2.1 – Feedstock procurement and characterization: Silicon feedstock will be supplied by Lattice Materials. The feedstock will be comprehensively analyzed to determine properties that need to be tailored for SiO production, including phase structure, impurity content, and particle size. The phase structure will be analyzed with a X-ray diffratometer (XRD). The feedstock impurity content will be measured using an inductively coupled plasma atomic emission spectrometer (ICP-AES). Particle size and morphology will be characterized with Particle size analyzer and scanning electron microscopy (SEM), respectively.

Subtask 2.2 – Reactor design and fabrication: A SiO production reactor using a plasma generator will be fabricated. Key parameters of the reactor will be tested and adjusted to control the plasma parameters to meet the proposed production capacity. Dr. Sarah Wu from University of Idaho will lead the design work and the UND team will fabricate the reactor under her guidance.

Subtask 2.3 – Production of SiO: The feedstock input rate, plasma temperature, and vacuum degree in the furnace will be optimized for SiO production. The structure and composition of the produced SiO will be characterized using XRD and ICP-AES. The results will be compared with commercial reference materials.

Subtask 2.4 –SiO post-treatment: The synthesized SiO in subtask 2.3 will be pulverized and then classified to desired sizes. SiO particle size, surface area, and morphology will be characterized using a particle size analyzer, BET analyzer, and SEM, respectively.

<u>Task 3 – Development of SiO/G Composite Anode</u>

Subtask 3.1 – Bench-scale production of SiO/G composite: This subtask aims to produce SiO/G composite from the SiO produced in Task 2 and humic acid supplied by Leonardite Products, using previously proven technology. The raw humic acid will be purified with UND's patented technology using existing equipment developed as a part of UND's rare earth elements (REE) from lignite extraction technology demonstrations. The carbonization degree will be estimated using the ratio of ordered/disordered carbon atoms through a Raman spectrometer, and the porosity will be tested using a BET surface area analyzer.

Subtask 3.2 – Preparation of SiO/G anode: This subtask aims to make the produced SiO/G in subtask 3.1 practical for use as the anode for LIBs. The SiO/G will be blended with graphite to meet the LIB's different capacity demands. The SiO/G and graphite blend will be used as the active material for electrode fabrication. Additionally, we will investigate pre-lithiation methods via solution or solid reactions to improve the ICE of the SiO/G anodes, if needed.

Subtask 3.3 – Battery performance testing: The battery performance of the synthesized SiO/G anodes will be evaluated against the target performance levels defined in Table 1. CR2032 coin-type cells will be prepared using lithium metal as the counter electrode. A limited number of 18650/pouch-cells will be prepared and tested on battery test systems by charging/discharging at certain currents. Electrochemical performance testing, including initial charge-discharge capacity, ICE, and anode cycle life, will be conducted on a Neware CT-4008 battery testing system (Neware Technology Limited). Cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS) tests will also be conducted on a Gamry potentiostat available at UND.

Task 4 – Prototype Demonstration of SiO/G Anode Production

This task will evaluate the reproducibility of the optimized procedures at a larger, commercially-relevant scale. The production processes developed in Tasks 2 and 3, including feedstock pulverization, classification, humic acid purification, and carbonization, will be scaled up using the existing equipment and facility at UND's REE pilot plant. The SiO/G composite anode production scale will be 10-20 kilograms/day. The aforementioned material characterizations and battery performance testing methods will be applied to this task. In addition, full-size 18650 cylindrical cells using the optimal prototype sample will be fabricated and tested, comparing performance against the target metrics in Table 1.

Task 5 – Techno-Economic Analysis (TEA) and Life Cycle Assessment (LCA)

The technical and economic feasibility of the manufacuring process will be investigated after the major variables that affect capital and operating expenses are thoroughly evaluated. The cost estimates will be considered AACE Class 5. A quantitative LCA will be conducted on the SiO/G anode production process, considering the direct and indirect effects from a cradle-to-grave approach on greenhouse gas emissions, land use effects, and other potential environmental effects. These effects will be compared to those from commercial Si anodes for LIBs. The TEA and LCA will be conducted according to DOE guidelines.

2.3 Anticipated Results

The main result will be proving the technical and economic performance of our innovative manufacturing process for producing SiO/G anode materials at a prototype scale of 10-20 kg/day capacity. The techno-economic and environmental feasibility of full commercialization will be demonstrated via TEA and LCA. A MTP will be developed to lay out the next steps required to achieve full commercialization. At the completion of the project, we anticipate being ready for commercial licensing with the aim of developing commercial manufacturing capacity in North Dakota.

2.4 Facilities & Resources

UND has world-class facilities and resources that will be leveraged in this project, including: 1) battery fabrication and performance testing ranging from coin-cells to full 18650 cells, 2) advanced materials characterization laboratories, 3) bench-scale and pilot-scale facilities associated with UND's development of lignite-based REE technologies, which are directly amenable for use in the production of purified humic acid from Leonardite, 4) wet-chemistry labs, 5) various furnace types and sizes that can be used for production of SiO/G composites, and 6) commercial license to AspenPlus process simulation software and license for SimaPro LCA software. See Appendix 7 for additional details. The project will also leverage the facilities of our industry partners. Lattice Materials will supply silicon byproduct materials and associated analysis information from their Bozeman, MT manufacturing facility. Leonardite Products will supply raw Leonardite and processed humic acids from their Williston, ND mine and process plant

2.5 Techniques to Be Used, Their Availability and Capability

Our prior development of SiO/G anodes is summarized in Section 4**.** The key findings can be found in our recent publication[2], and highlighted in **Figure 1**. Confidential details are in Appendix 2.

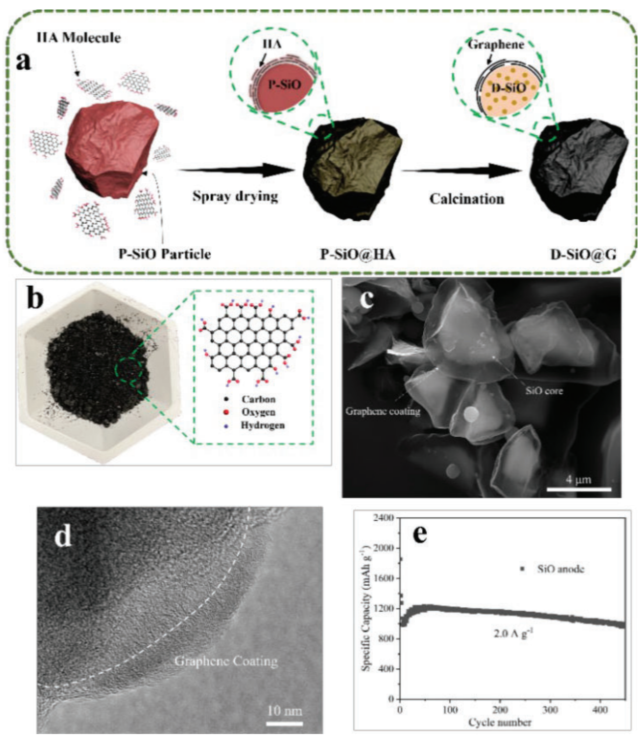


Figure 1. (a) Schematic of the synthesis process for the SiO/G anode. (b) Typical HA molecular model. (c) SEM image of the HF-etched SiO/G particles. (d) HRTEM image of the graphene coating on SiO. (F) Cycling performance of the SiO/G anode.

Humic acid (HA) is an organic material that can be derived from coal or Leonardite, with two-thirds of the carbon atoms sp^2 hybridized, and the rest mainly exist in carboxyl groups or hydroxyl groups (**Fig 1b**).[3] Unlike other graphene precursors, such as graphite and coal tar pitch, that require complex processing, the abundant functional groups make HA soluble in water-based alkaline solutions; therefore, preparing anode materials for graphene coating can be made much simpler using our in-situ aqueous phase approach.

We demonstrated the thin and complete

graphene coating on the SiO particles with HF etching, leaving behind a core of residual SiO encapsulated within intact graphene shells (**Fig 1c**). The TEM image (**Fig 1d**) reveals clear featured graphite lattice fringe corresponding to the graphene coating layer on the surface. The SiO/G (**Fig 1e**) delivered a high initial capacity of 1850 mAh/g, ICE of 79%, and cycling life of 500 cycles with an 85% capacity retention.

2.5.1 Improvements over Competing Technologies

The specific innovations and the advantages over current and emerging technologies are discussed below:

- *Synthetic SiO approach:* Unlike the conventional resistive heating, our technology uses plasma to achieve a higher temperature to produce SiO. This enables practical implementation of continuous feedstock input and SiO production, significantly improving capacity and reducing energy use.
- *In-situ graphene coating*: A unique graphene precursor, humic acid, and UND's patented technology for the in-situ synthesis of graphene-coated SiO anodes significantly simplifies the graphene coating process, lower the coating costs compared to externally adding commercial graphene.
- *SiO vs. nano-Si*: The advantages of SiO over nano-Si are discussed later in Section 2.8. Our technology has a lower environmental impact. Water is mainly used for cooling and can be recycled when the SiO anode is prepared. The process has limited chemical consumption. The feedstocks are environmentally friendly. There is no need for dangerous HF etching commonly used for nano-Si anodes.

2.6 Environmental and Economic Impacts while Project is Underway

The proposed work will involve negligible environmental impacts, as the work involves research-scale demonstrations and desktop engineering work. We will follow all UND permits and procedures for effluent management. Economic impacts during the project will primarily involve employment opportunities for UND faculty, staff and students and the workforce development/ training associated therewith.

2.7 Ultimate Technological and Economic Impacts

Successful commercialization will have broader technological and economic impacts: **1)** Provide significant benefit to our upstream business partners, Lattice Materials and Leonardite Products, by creating a new high-value market for their feedstocks. **2)** Directly benefit the rapidly growing LIB industry, especially the down-stream applications with demands for high-energy and high-power density, such as our industry partner Packet Digital's UAS applications, 3C consumer electronics, EVs, and eventually energy storage. **3)** Contribute to strengthening the security of the domestic supply chain in a critical area: Li-ion battery technology. **4)** Provide the foundation for a ND-based SiO/G anode manufacturing industry, strongly leveraging the unique mineral and renewable energy resources available in the State and region

2.8 Why the Project is Needed

Silicon is one of the most attractive alternatives for replacing state-of-the-art graphite anodes in LIBs primarily because of its high theoretical capacity (**Table 2**) of 4200 mAh g^{-1} (vs. 372 mAh/g for graphite) and low operating voltage (<1V vs. Li/Li^{+});[4] however, it experiences a significant volume change (~300%) during lithiation/delithiation that can cause Si particle fracturing, conductive coating delamination, and solid electrode interface (SEI) instability, causing rapid capacity decay upon cycling.[5-6]

Global silicon anode production is currently limited to two technical routes: nano-Si and SiO. **Table 2** summarizes the state-of-the-art for each. Nano-Si anodes offer enhanced stress resistance, high rate capability and specific capacity, but suffer from low ICE, high costs, and reduced volumetric energy density, limiting their practical use to high-value applications like aviation. In contrast, SiO anodes have a lower capacity but feature reduced volume expansion, better cycling stability, and improved cost-effectiveness, making them more suitable for large-scale applications despite slightly lower performance metrics.

Nano-Si/C and SiO are racing for dominance in the premium LIB market segment within Asia; however, most silicon anode startups favor the nano-Si/C technology. Our project seeks to mitigate the risks associated with the above technology bias, ensuring the stability of the supply chain in anticipation of a potential breakthrough in SiO anode technology. This goal aligns with the US DOE's expectation for domestic critical materials supply chain sustainability, reliability, diversity, security, and resiliency.

Table 2. Properties of graphite, nano-Si, and SiO as anode materials

Parameter	**Graphite**	**Nano-Si**	**SiO**
Capacity	372 mAh g^{-1}	~4200 mAh g^{-1}	~2400 mAh g^{-1}
Cycle life (80% Retention)	>1000	<100	>500
Mechanism	$Li + 6C = LiC_6$	$15Li + 4Si = Li_{15}Si_4$	$(17+x)Li + 5SiO = Li_{15}Si_4 + Li_2O + Li_xSiO_4$
Cost	$5-10/kg	$40-130/kg	~$15-25/kg
Other Key Issues	Poor low-T	Low conductivity & low ICE,	Low conductivity & ICE,

	performance & rate capability	~300% volume change. Severe side reactions with electrolytes	100% volume change

3 STANDARDS OF SUCCESS

The success of this project will be evaluated by following measurable metrics, demonstrated by prototype demonstrations and supplemented by TEA and LCA: **1)** 50% reduced water or chemical consumption, 50% reduced waste, and 20% reduced energy compared with the baseline technology (Table 1); **2)** Improved battery performance with specific capacity 1000 mAh/g and ICE of 80%; **3)** The cost per kAh of SiO/G lowered by 40% compared to the commercial nano-Si/C; and **4)** Successful prototype demonstration at 10-20 kg/day. With success, we anticipate a primary outcome of the proposed work will be readying the technology for licensing to an interested commercial venture/entity.

4 BACKGROUND/QUALIFICIATIONS

4.1 Project Team

The project will be managed through **UND's Center for Process Engineering Research (CPER)**, a team of 100% research focused faculty and staff researchers. Core capabilities include: **1**) technology development and scale-up: through TRL 6-7; **2**) research equipment design and fabrication; **3**) advanced materials characterization; **4**) techno-economic analysis: AACE Class 5 through AACE Class 3; **5**) environmental lifecycle analysis: SimaPro and GREET; **6**) Process engineering simulation, modeling and design: Aspen Plus (commercial license), HSC Chemistry; and **7**) computational fluid dynamics modeling.

The CPER team will be led by the **PI, Dr. Xiaodong Hou**, research associate professor. Dr. Hou is a materials chemist with 20 years of experience synthesizing and characterizing advanced materials. He has over 45 peer-reviewed publications in chemistry materials and holds six patents. Dr. Hou has led multiple projects directly related to developing advanced materials from lignite or Leonardite for LIBs, including the DOE sponsored projects DE-FE0026825, DE-FE0031984, and DE-FE0032139. Dr. Hou will also be supported by UND CPER's REE technology development team, including **Nolan Theaker,** who will assist in prototype-scale production of purified humic acids from Leonardite using the existing REE facilities.

Lattice Materials is a Bozeman, MT-based silicon and germanium parts manufacturer with 30,000 ft^2 of production space. Lattice Materials offers strong support by supplying silicon byproducts generated from their manufacturing processes, alongside relevant technical assistance. Lattice Materials is also extremely interested in the potential new commercial opportunities. **Leonardite Products** is a Williston, ND-based organic fertilizer producer offering their raw humic acid, a proven graphene precursor. We have collaborated previously with Leonardite Products, and they are willing to provide technical support. Leonardite Products is greatly interested in the excellent commercialization potential of using humic acid as a feedstock to prepare graphene for Li-ion battery applications. **Packet Digital** is a Fargo, ND-based Li-ion battery and power systems manufacturer with a particular focus on Unmanned Aerial System (UAS) applications. Packet Digital enthusiastically offers their strong support for this project, aimed at developing high-energy and high-power density silicon anodes. The company is a domestic partner whose goals of meeting their requirements for supply-chain-sensitive UAS applications match our development perfectly. They will provide commercial reference anode materials and technical assistance in electrode formulation and pouch-cell battery fabrication. **Dr. Sarah Wu (University of Idaho**), an associate professor in chemical and biological engineering, will be engaged as a consultant in the proposed work. Dr. Wu has 9 years of research experience in developing plasma-based reactors and processes for wastewater treatment, green chemical and nano material synthesis, CO_2 conversion, microbial inactivation, and food processing. Dr. Wu's research has been funded heavily by USDA NIFA, DoD SERDP, and industry. She holds an international patent application and US patent on liquid-phase plasma discharge reactor and will design and develop a radio-frequency reactor system for plasma-assisted SiO synthesis in this project.

4.2 Technology Development History

Our previous projects discussed below have proven the feasibility of preparing SiO/G at bench-scale. The low-cost feedstocks (silicon scrap and raw humic acid), proposed plasma-assisted synthetic SiO techniques, and continuous production mode will dramatically reduce the final cost of the SiO/G composite.

4.2.1 *UND's in-situ graphene coating battery electrode materials technology development*

Our team was funded by the NDIC-REP in 2018 to prepare graphene-coated lithium iron phosphate cathode materials (LFP/G) for LIBs (R-035-44) at 10 kg/batch in-situ (TRL 5). Major achievements during this project (2018-2020) included the development of a low-cost procedure that can produce high-purity (>99%)

and low ash content (~1%) humic acid from Leonardite. We successfully demonstrated production of LFP/G at 20 kg/day, with a cost reduction of 69% compared to adding external graphene into LFP.

Our team was selected by the DOE NETL UCFER program in 2019 to develop a SiO/G anode for LIBs based on our core technology of in-situ graphene coating (DE-FE0026825/S000045). The SiO/G anode developed (2019-2021) exhibited remarkable overall battery performance, including a 1st-cycle reversible capacity of 1,800 mAh/g, first-cycle efficiency of 79%, and a cycling life of 500 cycles with an 85% capacity retention. This performance is one of the best results for similar anodes reported in the literature. The UND-owned patent based on the above technology "Battery Materials and Fabrication Methods. (U.S. Patent Application No. 62/706,191, August 4, 2020)" was recently granted.

4.2.2 *Plasma-assisted synthetic technology for hydrogen production*

Our team was selected for DOE funding in 2021 to develop plasma-assisted technology (DE-FE0032061) for hydrogen production via catalytic decomposition of methane. During this lab-scale (TRL 4) project (2021-2024), we designed and constructed a cutting-edge reactor with the ability to execute multiple regimes of plasma discharge, enabling an assessment of the potential of electromagnetic energy to enhance efficiency of methane catalytic decomposition reactions. In addition to this plasma reactor experience, our technical consultant Dr. Sarah Wu is a leading expert in plasma technology and holds a patented technology in continuous liquid phase plasma discharge reactor. She will design and develop a radio-frequency (RF) reactor system for plasma-assisted SiO synthesis in this proposed project.

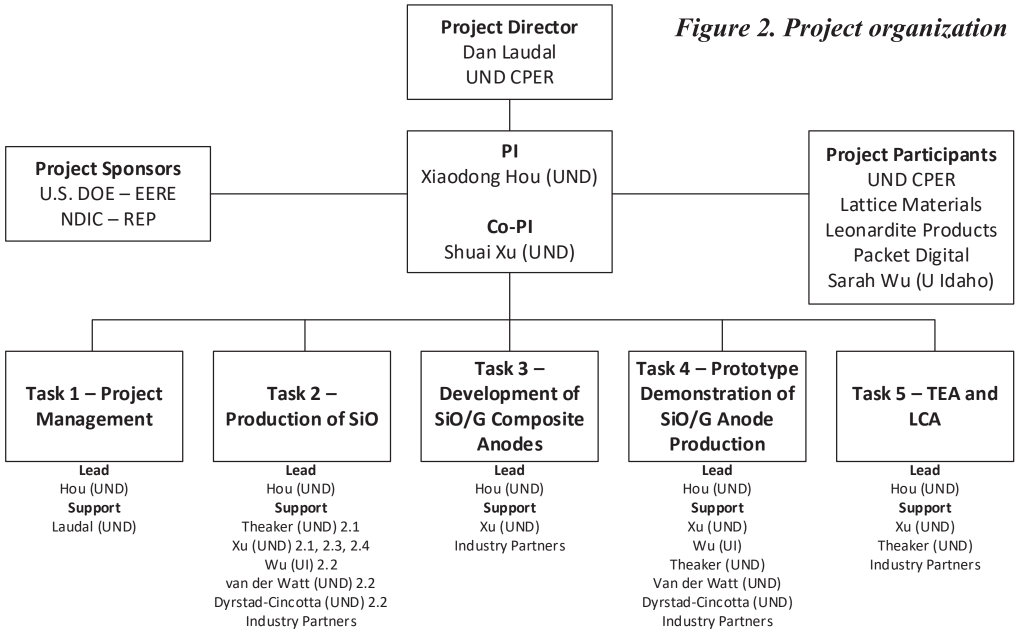
4.2.3 *UND's expertise in REE/CM recovery technologies*

UND CPER is among the top research groups involved in developing REE and critical minerals (REE/CM) technologies for unconventional resources, such as coal and coal byproducts. We are operating a pilot-scale plant (DE-FE0031835) (TRL 6) and are completing a front-end engineering and design and business planning study (DE-FE0032295), and are actively in a commercialization mode. This proposed project will use the REE/CM facility to produce purified humic acid from Leonardite for the prototype demonstration.

5 MANAGEMENT

The project is organized into five tasks, with key personnel leads and key support personnel identified for each task (**Figure 2**). The project's PI, Dr. Hou, reports to the UND CPER Director, Dr. Dan Laudal, who will support project management efforts and serve as a technical advisor. Dr. Hou (PI) and co-PI Dr. Shuai Xu will be responsible for directing technical efforts. The task leads will be responsible for managing the activities within their respective tasks and closely coordinating with the PI. See Appendix 6 for resumes of proposed key personnel.

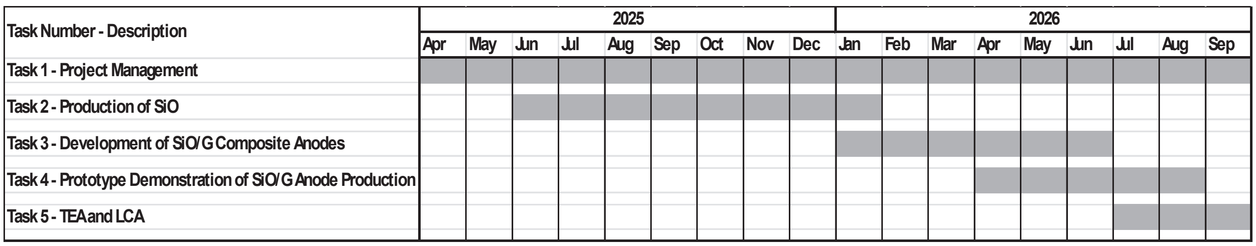
Figure 2. Project organization



UND is the applicant and overall project lead, responsible for overseeing project execution, and will be the point of contact for project sponsors and partners. UND will lead efforts associated with feedstock selection and characterization, reactor design and fabrication, SiO and SiO/G anode production process optimization, battery fabrication and testing, and lead the TEA and LCA. **Dr. Sarah Wu** from the University of Idaho will be a technical consultant, leading the efforts of the design of the plasma-assisted reactor in Task 2.2 and providing guidance on its operation in Task 4. The UND team will closely work with her on the fabrication and testing of the reactor based on her design. **Lattice Materials** is an industry partner, providing cost share support that includes supplying Si scrap and SiO byproduct feedstocks; technical support in analyzing, processing, and handling those materials; and commercial information to UND for the TEA and LCA. **Leonardite Products** is an industry partner, providing cost share support that includes supplying raw humic acid feedstock, technical assistance in handling their feedstock, and access to their operation facility. **Packet Digital** is an industry partner, providing cost support that includes supplying commercial reference anode materials and technical assistance in formulating the electrode and designing and fabricating the pouch cell. The **U.S. Department of Energy,** through the Energy Efficiency and Renewable Energy office, is a project sponsor, providing cash support for 80% of the total project costs.

6 TIMETABLE

The proposed project timeline is 18-months, with an expected start date for the in-negotiation DOE award of April 1, 2025. A simple Gantt chart and milestones table are provided below.



Task No.	Milestone Description (Go/No-Go Decision Criteria)	Milestone Verification Process	Date (Month)
1.1	Project kick-off meeting	Meeting held	2
1.2	Updated Community Benefit Plan (CBP)	Submit to DOE FPM	3
1.3	Market Transformation Plan	Submit to DOE FPM	15
1.4	Final Report	Submit to DOE FPM	18
2.1	The optimal feedstock identified	Quarterly Report	4
2.2	The reactor fabricated	Quarterly Report	5
2.3	SiO production testing completed	Quarterly Report	10
2.4	Bench scale SiO produced	Quarterly Report	10
3.1	Bench scale production of SiO/G completed	Quarterly Report	12
3.2	SiO/G production processes completed	Quarterly Report	14
3.3	Battery performance targets achieved	Quarterly Report	15
4.1	Prototype demonstration of SiO/G anode production succeeds	Quarterly Report	17
5.1	TEA and LCA completed	Submit to DOE FPM	18
1.2	Completed all the objectives in the Community Benefit Plan	Send final report to DOE	18

7 BUDGET

Project Associated Expense	NDIC's Share	Applicant's Share (Cash)	Applicant's Share (in-kind)	DOE Share	Industry Partners' Share
Personnel	105,913	-	-	324,962	-
Fringe Benefits	35,931	-	-	110,241	-
Travel	-	-	-	21,102	-
Equipment	-	-	-	158,753	-
Supplies	-	-	-	22,560	-
Subcontracts	-	-	-	-	45,000
Other Direct Costs	-	-	5,000	127,894	-
Indirect Costs	58,156	-	-	234,487	-
Total	200,000	-	5,000	999,999	45,000

Cost Share Source	Amount	% of Total Project
U.S. Department of Energy	999,999	80%

NDIC - REP	200,000	16%
Lattice Materials	15,000	1.2%
Leonardite Products	15,000	1.2%
Packet Digital	15,000	1.2%
University of North Dakota	5,000	0.40%
TOTAL PROJECT	**1,249,999**	**100%**

The NDIC share will support UND personnel costs, including associated fringe benefits and facilities & administrative costs. ***UND has been selected for award for the 80% cash cost share proposed from the U.S. DOE. This award is currently under negotiation with DOE under DE-FOA-0003155.*** The DOE award selection letter is provided as an attachment in Appendix 5. UND's cost share will take the form of partial tuition support (waivers) for graduate students working on the project. Three industry partners, making up our industry advisory team, will be supporting the project via in-kind and cash cost share. Lattice Materials will provide cash cost share ($5,000) via costs associated with sample collection, analysis, and shipping of silicon materials that will be evaluated in the proposed work. Lattice will provide in-kind support ($10,000) via technical and commercial guidance during project execution. Leonardite Products will provide in-kind cost share ($15,000) through providing samples of processed Leonardite for testing and technical support during project execution. Packet Digital will provide in-kind cost share ($15,000) through providing standard refence materials for battery performance testing and technical support during project execution. UND will also engage with Dr. Sarah Wu, via a consulting contract in the amount of $62,240, to assist with the plasma reactor design and fabrication. Budget notes are in Appendix 4.

8 TAX LIABILITY

The University of North Dakota has no outstanding tax liabilities (see Appendix 8).

9 CONFIDENTIAL INFORMATION

The confidential information is attached as an appendix (Appendix 2).

10 PATENTS AND RIGHTS TO TECHNICAL DATA

The technology for producing HA-derived graphene and SiO/G anode materials for LIBs is currently protected under a patent (U.S. Patent Application No. 62/706,191) solely owned by UND. The additional innovations developed through the proposed work will be considered for patent protection. As we advance our fabrication and testing efforts, any novel devices, procedures or operational designs that emerge will be evaluated for patentability, and we will file domestic and international patent applications as appropriate. In cases involving IP sharing and technology transfer/ licensing, UND will negotiate a comprehensive IP agreement with the participants, in accordance with the university's existing policies.

11 STATE PROGRAMS AND INCENTIVES

UND, as a state-controlled institution of higher education, has been involved in state programs or incentives in the past 5 years, including previous and ongoing research awards through the NDIC grant programs.