Request for Proposals

EDITABLE COVER PAGE

Idaho State Board of Education
Higher Education Research Council
Idaho Incubation Fund Program
FY 2022

COVER SHEET FOR HERC INCUBATION FUND GRANT PROPOSALS

State Board of Education

PROPOSAL NUMBER: (to be assigned by HERC)	AMOUNT REQUESTED: 100,000

TITLE OF PROPOSED PROJECT:
Multiphysics Characterization of Printed Smart Materials and Systems

SPECIFIC PROJECT FOCUS:

Smart materials are a class of materials whose properties vary controllably with respect to external stimuli. Since joined Boise State University in fall 2018, the PI has additively manufactured, characterized, and modeled three types of smart materials: piezoelectric materials that build up surface electrical charges when stressed, magnetostrictive materials that demonstrate magnetic property variation when subjected to mechanical loadings, and shape memory polymers that exhibit visible and repeatable deformation during heating. In collaboration with local companies (American Semiconductor, Inflex Lab), National Laboratories (Idaho National Lab, Oak Ridge National Lab), and NASA Ames, the PI has successfully designed, fabricated, and tested Technology Readiness Level 3 (TRL-3) smart-material-based prototypes (also known as smart systems), including acoustic transducers, tactile sensors, morphing structures, and energy harvesters. These disruptive technologies provided unprecedented solutions to challenges in geosciences, biomedical, electrical, materials, and mechanical engineering. However, commercialization of the aforementioned smart systems relies on a fundamental understanding of smart materials, especially their mechanical properties. Smart materials are multiphysics in nature. Therefore, the material characterization instrument should include traditional load frames as well as customized setups that can simultaneously control the magnetic, electrical, and thermal stimuli. Existing instruments at Boise State University and other Idaho institutions either provide load capacities that are beyond the operation range of smart materials (100 N – 10 kN) or lack flexibility for system customization. The ultimate goal of this project is to establish new multiphysics characterization infrastructure for smart materials and build expertise in smart system development within the State of Idaho. Towards this goal, we will first acquire an MTS Criterion Series 40 Electromechanical Universal Test System and complete system customization so that we can achieve accurate stress-strain measurement while enabling real-time temperature, electrical field, and magnetic field control. The new research infrastructure will reinforce Idaho's research strength in novel materials, stimulate collaboration between Boise State University and local private companies, and speed up the commercialization of existing smart systems developed in PI's lab. The proposed research will also provide students state-of-the-art material characterization experience and train next generation engineers to support the sustainable economic growth of Idaho.

PROJECT START DATE: 7/1/2021	PROJECT END DATE: 6/31/2022
NAME OF INSTITUTION: Boise State University	DEPARTMENT: Mechanical and Biological Engineering
ADDRESS: 1910 University Drive, Boise, ID 83725-1135	
E-MAIL ADDRESS: osp@boisestate.edu	PHONE NUMBER: 208-426-4420

	NAME:	TITLE:	SIGNATURE:
PROJECT DIRECTOR/PRINCIPAL INVESTIGATOR	Zhangxian Deng	Assistant Professor	Zhangxian Deng Digitally signed by Zhangxian Deng Date: 2021.04.01 12:10:46 -06'00'
CO-PRINCIPAL INVESTIGATOR			

NAME OF PARTNERING COMPANY: InFlex Labs, INC	COMPANY REPRESENTATIVE NAME: David Estrada
NAME OF PARTNERING COMPANY: American Semiconductor	COMPANY REPRESENTATIVE NAME: Dale G. Wilson

Authorized Organizational Representative	Matt Smith	Digitally signed by Matt G. Smith Date: 2021.04.01 14:39:40 -06'00'

SUMMARY HERC INCUBATION FUND PROPOSAL BUDGET

Name of Institution: Boise State University

Name of Project Director: Zhangxian Deng

A. PERSONNEL COST (Faculty, Staff, Visiting Professors, Post-Doctoral Associates, Graduate/Undergraduate Students, Other)

Name/ Title	Salary/Rate of Pay	Fringe	Dollar Amount Requested
Amanda White, Graduate Student	$24,000	$4,200	$14,500

% OF TOTAL BUDGET:	14.5%	**SUBTOTAL:**	14,500

B. EQUIPMENT: (List each item with a cost in excess of $1000.00.)

Item/Description	Dollar Amount Requested
MTS Criterion Series 40 Electromechanical Universal Test System	$85,500
SUBTOTAL:	$85,500

C. TRAVEL:

Dates of Travel (from/to)	No. of Persons	Total Days	Transportation	Lodging	Per Diem	Dollar Amount Requested
					SUBTOTAL:	$0

D. Participant Support Costs:	Dollar Amount Requested
1. Stipends	
2. Other	
SUBTOTAL:	$0

E. Other Direct Costs:	llar Am unt Requested
1. Materials and Supplies	
2. Publication Costs/Page Charges	
3. Consultant Services (Include Travel Expenses)	
4. Computer Services	
5. Subcontracts	
6. Other (specify nature & breakdown if over $1000)	
SUBTOTAL:	$0
F.. Total Costs: (Add subtotals, sections A through E) TOTAL:	
G.. Amount Requested: TOTAL:	$100,000

Project Director's Signature: Zhangxian Deng Digitally signed by Zhangxian Deng Date: 2021.04.01 09:41:13 -06'00'	Date:

INSTITUTIONAL AND OTHER SECTOR SUPPORT FOR HERC INCUBATION FUND PROPOSAL
(add additional pages as necessary)

A. INSTITUTIONAL / OTHER SECTOR DOLLARS

Source / Description	Amount

B. FACULTY / STAFF POSITIONS

Description

C. CAPITAL EQUIPMENT

Description

D. FACILITIES & INSTRUMENTATION (Description)

1. **Name of Idaho Public Institution:** Boise State University
2. **Name of Principal Investigator directing the project:** Zhangxian Deng
3. **Prior Proposal:** No
4. **Executive Summary:** Smart materials are a class of materials whose properties vary controllably with respect to external stimuli. Since joining Boise State University in fall 2018, the PI has additively manufactured, characterized, and modeled three types of smart materials: piezoelectric materials that build up surface electrical charges when stressed, magnetostrictive materials that demonstrate magnetic property variation when subjected to mechanical loadings, and shape memory polymers that exhibit visible and repeatable deformation during heating. In collaboration with local companies (American Semiconductor, Inflex Lab), National Laboratories (Idaho National Lab, Oak Ridge National Lab), and NASA Ames, the PI has successfully designed, fabricated, and tested Technology Readiness Level 3 (TRL-3) smart-material-based prototypes (also known as smart systems), including acoustic transducers, tactile sensors, morphing structures, and energy harvesters. These disruptive technologies provided unprecedented solutions to challenges in geosciences, biomedical, electrical, materials, and mechanical engineering. However, commercialization of the aforementioned smart systems relies on a fundamental understanding of smart materials, especially their mechanical properties. Smart materials are multiphysics in nature. Therefore, the material characterization instrument should include traditional load frames as well as customized setups that can simultaneously control the magnetic, electrical, and/or thermal stimuli. Existing instruments at Boise State University and other Idaho institutions either provide load capacities that are beyond the operation range of smart materials (100 N – 10 kN) or lack flexibility for system customization. The ultimate goal of this project is to

establish new multiphysics characterization infrastructure for smart materials and build expertise in smart system development within the State of Idaho. Towards this goal, we will first acquire an MTS Criterion Series 40 Electromechanical Universal Test System and complete system customization so that we can achieve accurate stress-strain measurement while enabling real-time temperature, electrical field, and magnetic field control. The new research infrastructure will reinforce Idaho's research strength in novel materials, stimulate collaboration between Boise State University and local private companies, and speed up the commercialization of existing smart systems developed in PI's lab. The proposed research will also provide students state-of-the-art material characterization experience and train next generation engineers to support the sustainable economic growth of Idaho.

5. **Project Objective and Total Amount Requested:** Objective 1: Acquire an MTS Criterion Series 40 Electromechanical Universal Test System. The requested instrument consists of a load frame (100 N-25 kN capability), environmental chamber (-129 ℃-350 ℃ range), and other testing accessories (e.g., fixtures and calibration kits). This objective well supports the Goal 1 in the Idaho Higher Education Research Strategic Plan (2017-2022). Objective 2: Train students and other researchers on the proposed instrument. MTS engineers will offer an on-site training session for potential users of the proposed instrument. The PI will also develop training materials, manuals, and standard test procedures for future users. This objective aligns with the Goal 4 in the Idaho Higher Education Research Strategic Plan. Objective 3: Characterize Smart Materials and Systems. Taking advantage of new capabilities enabled by the proposed instrument, the PI will collaborate with local companies, national labs, and NASA centers to characterize smart materials and prototypes developed in previous projects and investigate product commercialization plans. This objective aligns with

the Goal 4 in the Idaho Higher Education Research Strategic Plan. Objective 4: Seek for long-term funding to support the sustainability of smart materials research and smart system commercialization. Again, this objective aligns with the Goal 1 and Goal 2 in the Idaho Higher Education Research Strategic Plan.

The amount requested through IGEM is $100,000, including $85,534 of an MTS test system. The remainder $14,466 will be used to support 6 months of stipend and fringes for a graduate student. If funded, the PI will support the graduate student for another 6 months using a GA line from his startup package.

6. **Market Opportunity:** According to a MarketWatch report, the market share of global smart materials is projected to reach $48.48 billion by 2024. This corresponds to a CAGR of 14% between 2020 and 2024. Potential applications of smart materials include sensing, actuation, and energy harvesting. The major industries interested in these technologies are aerospace, defense industry, nuclear, space, construction, and biomedicine. The predominant barrier for market entry is the lack of accurate and reliable characterization data identifying the capabilities and limitations of smart systems, especially under harsh operation conditions (e.g., large temperature variation), because most of the aforementioned industries have a critical need and strict requirements on device reliability and safety. In order to fill the current gap between lab prototypes and product commercialization, this project will establish new multiphysics material characterization infrastructure and train next generation engineers in smart system characterization.

7. **The Technology and Path to Commercialization:** ***Figure 1*** shows piezoelectric tactile sensors printed by the nScrypt SmartPump available at the Idaho Microfabrication Laboratory. An electrical voltage builds up across the electrodes when the piezoelectric layer

is stressed. In collaboration with Dr. Johnson from the Electrical and Computer Engineering and Mr. Dale Wilson from American Semiconductor Inc. (ASI), the PI's group has

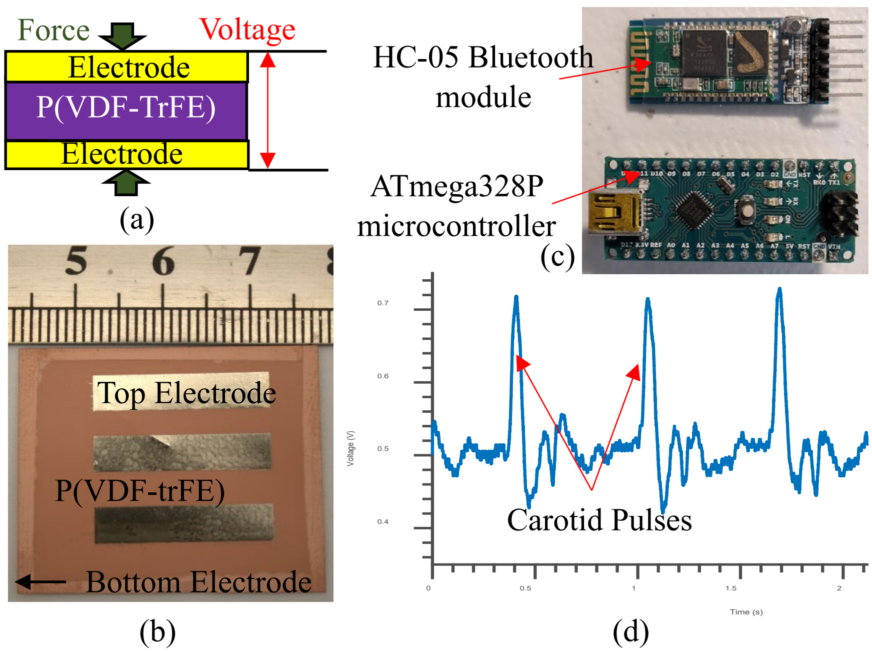

Figure 1 (a) Configuration of piezoelectric tactile sensors; (b) Piezo force sensors printed by nScrypt SmartPump; (c) Wireless communication circuits for PVDF-trFe sensors; and (d) Carotid pulses measured by wireless piezoelectric sensors.

developed wireless data transmission circuit and collected human carotid pulses data. Magnetostrictive wire exhibit significant axial deformation when driven by an electromagnet or vice versa. ***Figure 2*** shows a magnetostrictive waveguide thermometer for next-generation nuclear reactors. Sponsored by INL, the PI's group has preliminarily validated its performance up to 110 °C. Collaborating with NASA Ames, the PI's group used our nScrypt SmartPump to print a magnetostrictive cantilever beam that is able to output micron-scale tip

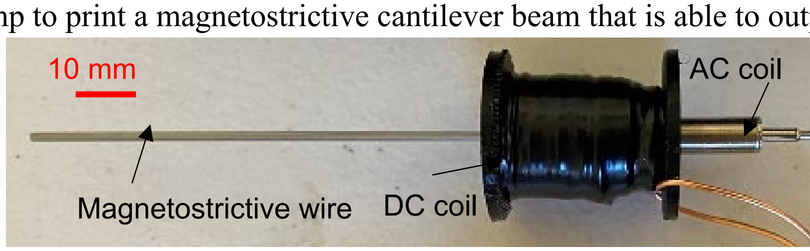

Figure 2 Magnetostrictive waveguide thermometer developed for INL.

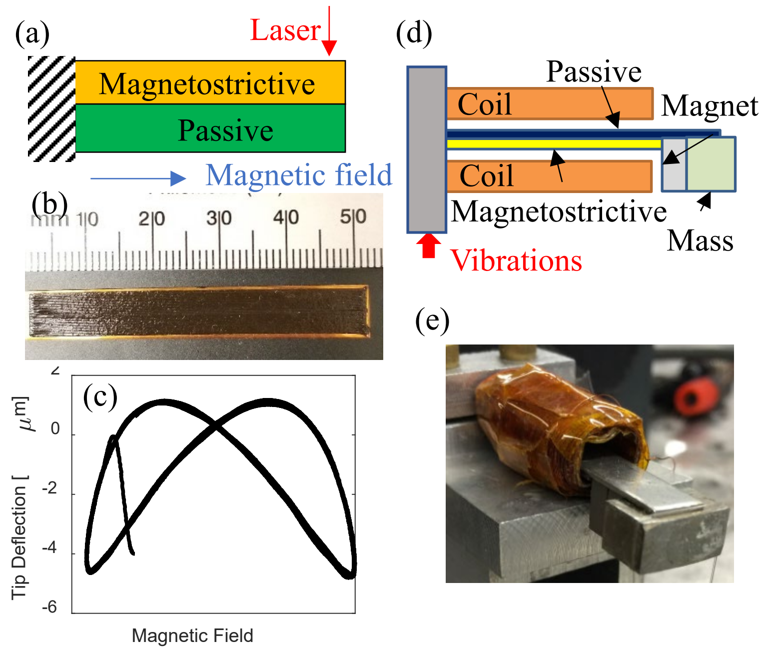

Figure 3 (a) Configuration of a magnetostrictive beam actuator; (b) magnetostrictive cobalt-ferrite beam printed by nScrypt SmartPump; (c) Tip deflection of the cobalt ferrite beam under varying magnetic field; (d) configuration of magnetostrictive energy harvester; and (e) actual assembly of a magnetostrictive energy harvester.

deflections, as shown in ***Figure 3 (a)-(c)***. Such a device could potentially be used for accurate drug delivery or precise optical instrument. Using a similar magnetostrictive cantilever beam, as shown in ***Figure 3 (d)-(e)***, the PI's group has developed energy harvesters that can recover over 100 mW electrical power from ambient structural vibrations. This device can potentially replace batteries and support self-sustaining sensor networks. Moreover, sponsored by discretionary funds, the PI has recently printed shape memory morphing structures driven by printed electrodes, as shown in ***Figure 4***. This technology, also known as 4-dimensional printing, is able to convert 2D electronics developed by InFlex Lab, llc. to complicated 3D circuits. One potential application is to print conformal antennas for aerospace or defense industries that would otherwise be very difficult, labor intensive, or expensive to produce.

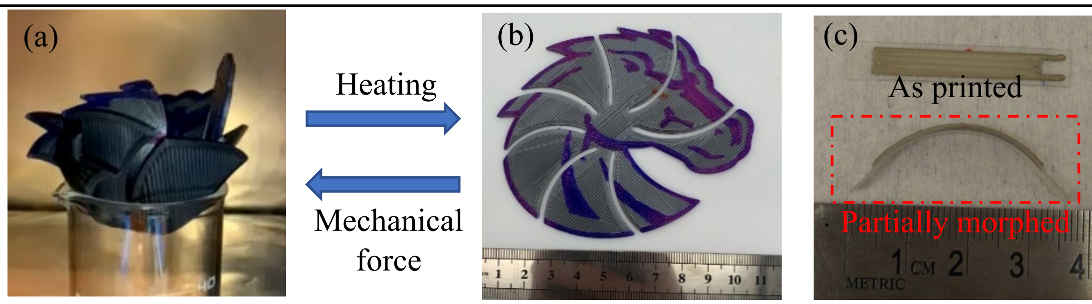

Figure 4 (a) PLA/TPU shape memory polymer in folded in a rose shape; (b) the rose-shaped shape memory polymer morphs into a Bronco logo at 70 C; and (c) electrodes printed on commercial polystyrene shape memory polymer using nScrypt SmartPump.

All these smart systems are at TRL 2-3 stage. In order to reach TRL 6-8 and realize device production and commercialization, we will need to complete a comprehensive and reliable characterization of these prototypes. The measurement data will identify the reliability and survivability of smart systems under harsh environment, guide smart system selection for engineers from NASA and National Labs, and facilitate ink development and system integration efforts in InFlex Lab and ASI.

8. **Institutional Support:** 1) Boise State University will provide access to shared facilities (e.g., Idaho Microfabrication Lab and student innovation studio) to facilitate sample preparation and device fabrication. 2) Boise State University will provide an appropriate lab space to house the proposed system. 3) The Office of Sponsor Program at Boise State will support the development of future proposals using the requested system and the preliminary results collected by the instrument in order to ensure research sustainability.

9. **Commercialization Partners (Public or Private):** The commercialization partners identified are INFlex Labs, and ASI. INFlex Labs LLC (IFL) is a small business, located in Boise, ID, which spun out of research at Boise State University in 2018. The primary focus of the company is in the area of printed and flexible hybrid electronics, providing consulting, design, manufacturing, and printed ink solutions to customers in healthcare, energy, and

defense sectors. INFlex labs conducts its business primarily within US and Canada, through its distribution partner NTVUSA, LLC. Through the successful development and commercialization of platinum, nickel, and molybdenum ink, the company is well-poised to capturing the specialty nanomaterial ink market share within the next couple of years. INFlex Labs is already delivering these nanomaterials-based inks for a rapidly growing additive manufacturing market and will work with BSU in scalable development and commercialization of new smart-material-based inks for multi-jet printer technologies.

ASI serves the semiconductor and related industries as the leading developer and manufacturer of ultra-thin chip technology and manufacturing. Headquartered in Boise, Idaho, ASI operates a 9,000 square foot facility housing wafer level chip scale packaging, assembly and test operations. The multiphysics material characterization capabilities established in this project will facilitate the development of innovative smart material systems, including sensors, energy harvesters, and morphing antennas, that can be integrated with Flex-ICs commercially available at ASI. ASI has been supporting Boise State University in numerous research grants with Boeing, NASA, and Army.

10. **Specific Project Plan:** The ultimate goal of this project is to establish new multiphysics characterization infrastructure for smart materials and build expertise in smart system development within the State of Idaho. We have identified the following tasks:

<u>Task 1: Acquire and install the MTS test system.</u> We will purchase an MTS Criterion Series 40 Electromechanical Universal Test System, including an MTS Criterion C43.104 load frame, MTS Advantage Environmental Chamber, and other testing accessories.

<u>Task 2: Provide instrument training and increase visibility.</u> We will invite students and all potential users on campus to participate the onsite training provided by MTS engineers. We

will add the new MTS test system to Boise State University website and CAES website in order to attract collaborators from other state institutions and across the nation. We will prepare training videos and standard testing templates for future users.

<u>Task 3: Characterize thermomechanical loops of printed shape memory polymers.</u> We will integrate the environmental chamber setup with the MTS load frame to measure the stress-strain curves of PLA/TPU shape memory polymers from room temperature to 70 Celsius.

<u>Task 4: Characterize the Young's modulus of magnetostrictive iron-gallium alloys</u>. We will measure the stress-strain curves of iron-gallium alloys under controlled magnetic fields up to 180 Celsius. This material characterization will directly benefit ongoing development effort of ultrasonic waveguides sponsored by INL.

<u>Task 5: Seek for long-term funding sources to support sustainable research and product commercialization.</u> Based on the preliminary data collected in this project, we will develop full proposals targeting DOE, NASA, or NSF funding.

11. Criteria for measuring success:

Task No. and Deliverables	**Schedule**											
	Q1			Q2			Q3			Q4		
1: Procurement & installation of the system												
2: Training videos & standard test procedures												
3: Thermomechanical cycles of PLA/TPU												
4. Young's modulus data of Galfenol												
5. A full proposal ready for submission												

SUMMARY HERC INCUBATION FUND PROPOSAL BUDGET

Name of Institution: Boise State University

Name of Project Director: Zhangxian Deng

A. PERSONNEL COST (Faculty, Staff, Visiting Professors, Post-Doctoral Associates, Graduate/Undergraduate Students, Other)

Name/ Title	Salary/Rate of Pay	Fringe	Dollar Amount Requested
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					SUBTOTAL:	$0

D. Participant Support Costs:	Dollar Amount Requested
1. Stipends	
2. Other	
SUBTOTAL:	$0

E. Other Direct Costs:	Dollar Amount Requested
1. Materials and Supplies	
2. Publication Costs/Page Charges	
3. Consultant Services (Include Travel Expenses)	
4. Computer Services	
5. Subcontracts	
6. Other (specify nature & breakdown if over $1000)	
SUBTOTAL:	$0
F.. Total Costs: (Add subtotals, sections A through E) TOTAL:	
G.. Amount Requested: TOTAL:	$100,000

Project Director's Signature: Zhangxian Deng Digitally signed by Zhangxian Deng Date: 2021.04.01 09:41:13 -06'00'	Date:

INSTITUTIONAL AND OTHER SECTOR SUPPORT FOR HERC INCUBATION FUND PROPOSAL

(add additional pages as necessary)

A. INSTITUTIONAL / OTHER SECTOR DOLLARS

Source / Description	Amount

B. FACULTY / STAFF POSITIONS

Description

C. CAPITAL EQUIPMENT

Description

D. FACILITIES & INSTRUMENTATION (Description)

Dr. Zhangxian Deng is the director of the Smart Materials and Systems Laboratory (SMSL) at Boise State University. The SMSL has implemented COMSOL Multiphysics to model systems coupling magnetic, mechanical, thermal, and electrical dynamics. The SMSL also has established hardware capabilities for mechanical, electrical, and magnetic property characterization. The PI is also an affiliated faculty member of the Boise State Advanced Nanomaterials and Manufacturing Laboratory (ANML). The ANML possesses state-of-the-art research facilities for nanoparticle synthesis, ink preparation and characterization, and 2D film analysis.

Other research resources are available to the PI of this grant through core facilities at Boise State University. These include the Idaho Microfabrication Laboratory (IMFL) and the College of Engineering machine shop. The IMFL is a resource dedicated to the research and advancement of materials and processes used in micro & nanoelectronics design and fabrication. The 3D printing capabilities in IMFL, including Space Foundry Plasma Jet Printer, Dimatix 2800 Inkjet Materials Printer, Optomec 200 Aerosol Jet Printer, and nScrypt 3DN Microdispense Printer, will enable additive manufacturing of smart systems. All instruments are available to qualified users, and two full-time research technicians support equipment training and maintenance. The university and the state of Idaho have invested heavily to upgrade the facility and add capabilities for additive manufacturing of printed and flexible electronics.

Idaho Microfabrication Laboratory (IMFL)

The Idaho Microfabrication Laboratory (IMFL) consists of a small gowning room, a 900 ft^2 Class 1000 cleanroom, a 1500 ft^2 process lab, and a 900 ft^2 metrology lab. The laboratory is equipped to fabricate microelectronic devices using various thin film deposition techniques, chemical processing, photolithography, and plasma etching. The university and the state of Idaho have invested heavily to upgrade the facility and add capabilities for additive manufacturing of printed and flexible electronics. The following instruments are available in IMFL for fabrication and characterization of devices.

MATERIALS PRINTING INSIDE THE IDAHO ADDITIVE MANUFACTURING LAB (IAML)

- Space Foundry Plasma Jet Printer
- Dimatix 2800 Inkjet Materials Printer
- Optomec 200 Aerosol Jet Printer
- nScrypt 3DN Microdispense Printer
- Xenon Sinteron2010 Photonic Sintering

DEPOSITION

- AJA Orion 5 Sputtering Machine
- Torr CrC-150 Benchtop Sputterer
- CHA 600 Thermal Evaporator

CHARACTERIZATION AND METROLOGY

- J.A. Woollam M-2000 Spectroscopic Ellipsometer
- Nanometrics NanoSpec 212
- Bruker Dektax XT-A Stylus Profilometer
- Wyko/Veeco NT1100 Optical Profiler
- Superior Electronics Automatic 4-Point Probe

PLASMA ETCH

- Oxford PlasmaLab 180 ICP with Bosch Etch (fluorine-based)
- Branson 3000 Series RIE/Asher
- Veeco ME-1001 Ion Mill
- Surface Chemistry/Wet Processing
- JST Manufacturing Acid Station with RCA clean
- JST Manufacturing General Base Station
- JST Manufacturing Solvent Processing Station
- SemiTool ST-460 Spin Rinse Dryer

PHOTOLITHOGRAPHY

- Quintel Q-4000 Contact Aligner
- OAI 5000 Contact Aligner
- CEE Model 200X-F Spin Coater (Integrated with JST Solvent Processing Station)

THERMAL PROCESSING

- MiniBrute MB-80 Thermal Oxidation/Diffusion Furnace
- Modular Process Technology RTP-600s Rapid Thermal Annealer
- Blue Electric SV-57A Vacuum Oven
- Programmable Hot Plates (Integrated With Each of Three JST Chemical Processing Stations)
- Systems Integration 7200-1453 Hot Plate

BACK-END PROCESSING

- WestBond Model 7476 Wire Bonding System
- K&S Model 4526 Wedge Bonding System

- ADT982-6 Wafer Dicer

College of Engineering (COEN) Student Shop

The student shop is located in the Harry Morrison Civil Engineering (HML) building and supports parts fabrication, machining (including Computer Numerical Control, CNC), welding and painting. The shop is open to students, faculty and staff to work on school-related projects. The state-of-the-art shop has the following machines and capabilities:

- CNC Mill
- CNC Lathe
- Manual Lathe
- Manual Mill
- CNC plasma cutter
- MIG/TIG/ and stick welding capabilities of steel and aluminum.
- Wire EDM
- Solidworks and other CAD/ CAM software
- Capabilities to design and fabricate complex systems.
- 3 Delta style 3D printers with larger print envelope.
- 1 Cube Trio 3D printer

Smart Materials And Systems Laboratory

Dr. Zhangxian Deng is the director of the Smart Materials and Systems Laboratory (SMSL) at Boise State University. The SMSL has been establishing software capabilities of finite element modeling, as well as hardware capabilities of vibration and magnetism measurements. A detailed list of hardware and software in SMS laboratory is presented as follows.

- COMSOL Multiphysics
- Labworks ET-126-1 electrodynamic shaker
- Lakeshore cryotronics fluxmeter (Model 480)
- PCB 352C33 accelerometer
- PCB 356B18 accelerometer
- PCB 208C02 load cell
- AE Techron linear amplifier (Model 7224)
- Newport optical table
- B&K precision 4052 function generator
- B&K precision 1672 power supply
- Tektronix TBS1052B Oscilloscope
- Keysight E4990A (120 MHz) precision impedance analyzer
- Omega LCM703-50lbf load cell
- Omega DMD4059 amplifier
- PI E505.00 high voltage amplifier with a voltage monitor unit
- Trek 610E high voltage amplifier
- Data Physics Quattro 240 analyzer
- PI 352C33 ICP signal conditioner
- Geeetech A30M mix-color 3D printer
- LakeShore 7300 VSM system
- 0.6CF Lab Drying Oven

- Cimatrec Basic stirring hotplate
- Keysight B2985A electrometer
- Torrey Hills T50 three roll mill
- Fisher Scientific vortex mixer
- Keyence LK-G32 laser displacement sensor
- Thermo Scientific Thermolyne
- Fluke 11y electricians True RMS multimeter
- Happybuy CNC coil winder
- ThorLab discrete piezo stack
- Scienceware Dry-Keeper
- Cole-Parmer 3L ultrasonic cleaner
- Thermo Scientific Heratherm 51028121 GP Mechanical Oven
- NI 9944 and NI 9945 high accuracy, quarter bridge completion accessory
- IET Labs RS-201W-2W resistance decade box
- CS-301L capacitance decade box
- LS-400L capacitance decade box
- CS-300H high range capacitance decade box
- Mettler Toledo MS303TS Newclassic MS-TS Toploading Balance with Shield
- Eppendorf Research Pipettors
- PCB P-010.00H piezo actuator
- Rigol DP832A Programmable DC Power Supply
- Copper Mountain TR1300/1 vector network analyzer
- National Instruments (NI) CompactRIO chassis (cRIO-9035)

- NI-9237 bridge analog input module
- NI-9234 sound and vibration input module
- NI-9269 voltage output
- NI-9265 current output
- NI-9239 analog input module
- NI CompactDAQ chassis (cDAQ-9174)

Advanced Nanomaterials and Manufacturing Laboratory (ANML)

Dr. Subbaraman and Dr. Estrada co-direct the Advanced Nanomaterials and Manufacturing Laboratory (ANML) laboratory. Dr. Zhangxian Deng is affiliated with the ANML. The ANML houses a custom-built variable pressure chemical deposition system and equipment for liquid exfoliation of 2-dimensional nanomaterials. In addition, a recent infrastructure award from the Department of Energy has allowed Drs. Estrada and Subbaraman to purchase a suite of instruments for nanomaterials ink development. This suite of instruments includes tools for creating nanoparticles and 2D nanoflakes using top-down physical methods, which complement the bottom-up wet chemical nanoparticle synthesis capabilities of the ANML. The addition of a glove box and ultracentrifuge further amplify 2D materials ink synthesis capabilities. A suite of characterization tools will allow for particle size analysis through dynamic light scattering (DLS), and thermophysical properties characterization through thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). A state-of-the-art tensiometer will also allow for characterization of ink-substrate interactions, e.g., wettability and surface tension.

A detailed list of equipment available at ANML for material synthesis and material solution formulation is provided below:

- Axon MultiClamp 700B patch clamp amplifier on a vibration isolation table
- Axon Digidata 1550 low-noise data acquisition system
- pClamp 10 electrophysiology data acquisition and analysis software
- Custom built quartz tube variable pressure chemical vapor deposition system with 4 inlet gases and up to two solid-source precursors.
- QSonica Q125 probe-tip ultra-sonicator
- QSonica Q700 probe-tip ultra-sonicator
- Branson 2800 variable temperature ultra-sonicator
- 6 Eppendorf adjustable volume pipettes
- 6 Fisherbrand mini-centrifuges
- Mettler Toledo Analytical Balance
- Thermo Scientific Legend Micro 21 Microcentrifuge
- Think Planetary Centrifuge
- Thermo Scientific Heratherm Programmable Gravity Convection Oven
- Heraeus Megafuge 8 with TX-150 Cell Cult Pkg (8 x 50 ml)
- MTI 2” Quartz Tube furnace with inert gas inlet and vacuum compatible
- Agilent and Varian Eclipse Fluorescence Spectrophotometers
- Agilent Cary 5000 UV-Vis-nIR spectrophotometer
- COMSOL Multiphysics FEM software
- MBraun UniLab Pro PS Glovebox System
- Retsch EMAX High Energy Ball Mill System
- Beckman/Coulter Optima XE-90 Ultracentrifuge w/SW41 Rotor

- Labconco FreeZone 4.5L Benchtop Freeze Dryer w/PTFE Coated SS 12 Port Drying Chamber (-105 °C)
- Biolin Scientific T200-Auto3 Attension Theta Optical Tensiometer with Automatic XYZ stage and Pipette Dispenser
- Brookhaven NanoBrook Omni Submicron Particle Sizer (DLS) and Zeta Potential Analyzer (PALS)
- Netzsch STA 449 F5 Jupiter Simultaneous Thermal Analyzer (TG-DSC/DTA; RT to 1600 °C)
- Zeiss Axio Imager M2m Materials Microscope
    - Transmitted Light
    - Reflected Light
    - DIC imaging
    - Phase Contrast Imaging
    - Automated X-Y-Z mechanical Stage
    - Axiocam 105 Colar Camera
    - 10X thru 100X objectives
- Brookfield Engineers Lab DV3TLV Rheometer
- Biocomp Instruments Nano Gradient Fractionator/Former
- Buchi Corporation Rotavapor R-100 Rotary Evaporator with I-100 Controller

NSF BIOGRAPHICAL SKETCH

NAME: Deng, Zhangxian

ORCID: 0000-0003-1084-1738

POSITION TITLE & INSTITUTION: Assistant Professor, Boise State University

(a) PROFESSIONAL PREPARATION

INSTITUTION	LOCATION	MAJOR / AREA OF STUDY	DEGREE (if applicable)	YEAR YYYY
Zhejiang University	Hangzhou, Zhejiang	Mechatronics Engineering	BENG	2010
The Ohio State University	Columbus, OH	Mechanical and Aerospace Engineering	PHD	2015
The Ohio State University	Columbus, Ohio	Postdoctoral researcher at the NSF IUCRC Smart Vehicle Concepts Center	Postdoctoral Fellow	2015 - 2018

(b) APPOINTMENTS

2018 - present Assistant Professor, Boise State University, Mechanical and Biomedical Engineering, Boise, Idaho

2015 - 2018 Postdoctoral Researcher, The Ohio State University, Mechanical and Aerospace Engineering, Columbus, OH

(c) PRODUCTS

Products Most Closely Related to the Proposed Project

1. Deng Z, Gingerich M, Han T, Dapino M. Yttria-stabilized zirconia-aluminum matrix composites via ultrasonic additive manufacturing. Composites Part B: Engineering. 2018 October; 151:215-221. Available from: https://linkinghub.elsevier.com/retrieve/pii/S1359836818309089 DOI: 10.1016/j.compositesb.2018.06.001
2. Deng Z, Scheidler J, Asnani V, Dapino M. Shunted magnetostrictive devices in vibration control. Smart Materials and Structures. 2020 October 01; 29(10):105007-. Available from: https://iopscience.iop.org/article/10.1088/1361-665X/ab9e07 DOI: 10.1088/1361-665X/ab9e07
3. Deng Z, Dapino M. Magnetic flux biasing of magnetostrictive sensors. Smart Materials and Structures. 2017 May 01; 26(5):055027-. Available from: https://iopscience.iop.org/article/10.1088/1361-665X/aa688b DOI: 10.1088/1361-665X/aa688b
4. Deng Z, Scheidler J, Asnani V, Dapino M. Quasi-static major and minor strain-stress loops in textured polycrystalline $Fe_{81.6}Ga_{18.4}$ Galfenol. Journal of Applied Physics. 2016 December 28; 120(24):243901-. Available from: http://aip.scitation.org/doi/10.1063/1.4972479 DOI: 10.1063/1.4972479
5. Deng Z, Dapino M. Characterization and finite element modeling of Galfenol minor flux density loops. In:Goulbourne N, Naguib H, editors. SPIE Smart Structures and Materials + Nondestructive Evaluation and Health Monitoring; Sund 0 ; San Diego, California, USA. Available from: http://proceedings.spiedigitallibrary.org/proceeding.aspx?doi=10.1117/12.2012511 DOI: 10.1117/12.2012511

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

1. Fujimoto K, Watkins J, Phero T, Litteken D, Tsai K, Bingham T, Ranganatha K, Johnson B, Deng Z, Jaques B, Estrada D. Aerosol jet printed capacitive strain gauge for soft structural materials. npj Flexible Electronics. 2020 November 23; 4(1):-. Available from: http://www.nature.com/articles/s41528-020-00095-4 DOI: 10.1038/s41528-020-00095-4
2. Deng Z, Dapino M. Modeling and design of Galfenol unimorph energy harvesters. Smart Materials and Structures. 2015 December 01; 24(12):125019-. Available from: https://iopscience.iop.org/article/10.1088/0964-1726/24/12/125019 DOI: 10.1088/0964-1726/24/12/125019
3. Palmer S, Deng Z. Additive manufacturing of magnetostrictive thin film sensors. In:Zonta D, Huang H, editors. Sensors and Smart Structures Technologies for Civil, Mechanical, and Aerospace Systems 2020. Sensors and Smart Structures Technologies for Civil, Mechanical, and Aerospace Systems; ; Online Only, United States. SPIE; c2020. Available from: https://www.spiedigitallibrary.org/conference-proceedings-of-spie/11379/2557926/Additive-manufacturing-of-magnetostrictive-thin-film-sensors/10.1117/12.2557926.full DOI: 10.1117/12.2557926
4. Choi L, Deng Z. 3D-printed and wireless piezoelectric tactile sensors (Conference Presentation). In:Bar-Cohen Y, Anderson I, Shea H, editors. Electroactive Polymer Actuators and Devices (EAPAD) XXII. Electroactive Polymer Actuators and Devices (EAPAD) XXII; ; Online Only, United States. SPIE; c2020. Available from: https://www.spiedigitallibrary.org/conference-proceedings-of-spie/11375/2558222/3D-printed-and-wireless-piezoelectric-tactile-sensors-Conference-Presentation/10.1117/12.2558222.full DOI: 10.1117/12.2558222
5. Harne R, Deng Z, Dapino M. Characterization of Adaptive Magnetoelastic Metamaterials Under Applied Magnetic Fields. Volume 1: Multifunctional Materials; Mechanics and Behavior of Active Materials; Integrated System Design and Implementation; Structural Health Monitoring. ASME 2016 Conference on Smart Materials, Adaptive Structures and Intelligent Systems; Sept -; Stowe, Vermont, USA. American Society of Mechanical Engineers; c2016. Available from: https://asmedigitalcollection.asme.org/SMASIS/proceedings/SMASIS2016/50480/Stowe,%20Verm DOI: 10.1115/SMASIS2016-9252

(d) SYNERGISTIC ACTIVITIES

1. Mentor (05/2019-present), NSF Research Experiences for Undergraduates (REU) in Materials for Society
2. Member of IEEE (06/2019-present)
3. Student Member of SPIE (03/2013-03/2015)
4. Journal reviewers, Smart Materials and Structures, IEEE Transactions on Mechatronics, Journal of Applied Physics, etc.

American Semiconductor
Reliably Thin Electronics

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Boise, ID 83709
208.336.2773

March 23, 2021

Zhangxian Deng, Assistant Professor
Department of Mechanical and Biomedical Engineering
Boise State University

Dear Dr. Deng,

I am pleased to support your multiphysics characterization infrastructure for smart materials research proposal for submission to the IGEM program. The multiphysics material characterization capabilities established in this project will facilitate the development of innovative smart material systems, including sensors, energy harvesters, and morphing antennas, that can be integrated with Flex-ICs commercially available at ASI. American Semiconductor is a world leader in flexible integrated circuits and flexible hybrid electronics (FHE) development. Our ultra-thin, physically flexible, high-performance FleX™ Semiconductor-on-Polymer™ integrated circuits (FleX-ICs) are well suited to use in smart materials and sensor systems. With a total thickness of less than 35um and a proven ability to bend to radii less than 5mm and flex for 10K+ cycles, our FleX-ICs are already beginning to be employed in multiphysical devices that support motion, electronics signal processing and heat generation in a single device. This FleX-IC technology has been recognized with several national awards in flexible hybrid electronics over the past few years.

Throughout our 20-year history, we have worked closely with Idaho universities. Working with Idaho universities is consistent with American Semiconductor goals of (1) advancing US-based FHE technology design and manufacturing, (2) demonstrating new applications for FHE and FleX-ICs, (3) supporting STEM education, and (3) identifying and recruiting highly capable engineers to join our team. About 25% of our engineering and management staff attended Boise Statue University with several of them transitioning from internships to full-time employment. This effort will support the continued collaboration between ASI and BSU that has included programs for NASA, Flextech, US Army, and Boeing.

In conclusion, we fully support the research goals you have established to expand the local infrastructure for multiphysics material characterization.

Sincerely,

Dale G. Wilson
Director of Engineering

INFlex Labs, LLC.

Materials and Technology for a Flexible World

May 20th, 2019

Zhangxian Deng
Assistant Professor
Mechanical and Biomedical Engineering
Boise State University
1910 University Dr
Boise, ID 83725

Dear Dr. Deng,

INFlex Labs, LLC is excited to support your proposal to the Idaho Higher Education Research Council IGEM Incubation Fund program entitled *Multiphysics Characterization of Printed Smart Materials and Systems*. The global printed and flexible electronics industry is rapidly growing and projected to reach $250B by 2025. A major bottleneck in this industry is the availability of high-quality material characterization data to guide the development and optimization of printed electronics.

We are excited about the work ongoing in the Smart Materials Laboratory at Boise State University and look forward to working with you and the university as a commercial partner to scale up production of your smart material based inks. One of the major foci of INFlex Labs, LLC is in providing novel materials to the printed and flexible electronics industry, and this partnership is a natural fit for our commercialization goals.

Yours sincerely,

David Estrada

David Estrada, Ph.D.
Co-Founder & President

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