Equipment

EQUIPMENT AVAILABLE THROUGH ANML AT BOISE STATE UNIVERSITY

For more information and/or to learn how to access equipment email Prof. David Estrada at daveestrada@boisestate.edu.

TRANSPORT CHARACTERIZATION LABORATORY

- 3 Advanced DC & sub-RF Electrical Characterization Systems (Computer Controlled)
- Keithley 4200, 100 aA resolution, dual-channel pulse generator pulse I-V (100 ns rise/fall time and 40-150 ns pulse width, duty cycle: 0.01 to 99% 0-5V, quiescent point pulsing), switch matrix, 20Hz-1MHz C-V, built-in 2-channel 750MHz digital o-scope, Quasi-static CV
- Agilent 4156C semiconductor characterization system with switch matrix
- 3 HP 4284A LCR meters (20Hz to 1MHz)
- Probe Stations: 1 closed-cycle cryogenic with actively cooled probes (5.5 to 450 K), 1 high temperature (673K), 2 room temperature
- Low Noise Spectroscopy System
- Agilent 4156C precision impedance analyzer
- 2 SRS SR830 dual phase and SRS SR810 single phase lock-in amplifiers
- 1GHz 4 channel 4GSamples/s Mixed Signal oscilloscope
- ~25 Cascade micromanipulator probes (4 high temperature)

ADVANCED NANOMATERIALS AND MANUFACTURING LABORATORY

Surface Science

- Bruker nanoIR3S AFM
  - Nanoscale IR Spectroscopy
    - s-SNOM providing near field amplitude and phase images and spectra
    - Resonance Enhanced AFM-IR mode
    - Tapping AFM-IR spectroscopy & chemical imaging mode
    - Point Spectroscopy & IR chemical mapping capability
    - HotSPOT enabled selection of any point or series of points within the AFM image to obtain localized nanoIR spectra
    - IR imaging at a fixed wavenumber of interest; ratio spectral images at user defined wavenumbers
    - Export AFM-IR spectra to optional external IR databases for identification of unknown materials
    - Analysis Studio software package for acquisition, control, analysis & export
  - Atomic Force Microscopy
    - X,Y scanner with range of 50μm by 50μm using closed loop linearization for precise positioning performance
    - Standard AFM modes supported: Tapping, Phase Imaging, Contact, Lateral Force, Force Curves, Force Modulation, EFM/MFM mode
    - Integrated bright-field optical microscope with a 10X objective for viewing the sample and probe with a resolution of 1.5 microns
    - Computer controlled XY sample positioning stage, 8.0 mm travel in X, 8.0mm travel in Y
    - Analysis Studio software package for acquisition, control, and analysis
  - Mid-IR Laser Source for s-SNOM and AFM-IR Broadband Spectroscopy
    - Femtosecond based laser source with a spectral range of approx. 2.5μm to
14μm wavelength (700 - 4,000cm⁻¹) for use with s-SNOM & AFM-IR technique. Configuration includes:
- Includes additional nanoIR laser integration module & associated optics for broadband spectroscopy operation for complete operation
- Provides s-SNOM spectroscopy across a spectral range of 700 to 4,000cm⁻¹
- Provides s-SNOM imaging in the range of <700->2,000cm⁻¹
- Provides AFM-IR spectroscopy and imaging in the range of 700-2,000cm⁻¹

- AM-nIR-TA Thermal Analysis
  - Transition Temperature Microscopy (TTM)
  - Relative thermal conductivity/temperature mapping (SThm)

- Horiba Scientific LabRAM HR Evolution Raman Microscope
  - 442 nm, 532 nm, and 633 nm (visible) excitation wavelengths available
  - 325 nm (UV) excitation wavelength possible with additional laser line filter
  - 10x, 20x, 50x, and 100x bright field objectives
  - LWD 20x objective also compatible with DIC, fluorescence, and polarized light
  - 600 and 1800 line/mm holographic diffraction gratings blazed for 500-600 nm
  - 0.8 m monochromator equipped with confocal pinhole
  - Thermoelectrically cooled Si CCD array (256 x 1024) detector
  - ~1 μm lateral resolution at 633 nm (~500 nm maximum resolution with UV excitation)
  - 80 x 100 mm motorized stage for point by point Raman mapping
  - μm step size with ± 1 μm repeatability and accuracy
  - DuoScan optics for high speed, high resolution mapping

- PHI VersaProbe II Scanning XPS Microprobe
  - Scanned, micro-focused, monochromatic x-ray beam
  - X-ray beam induced secondary electron imaging
  - Dual beam charge neutralization
  - Large area XPS
  - Micro-area XPS
  - Chemical state imaging with 128 data channels
  - Sputter depth profiling
  - Floating column argon ion gun
  - Compucentric Zalar rotation
  - Angle dependent XPS
  - Five axis automated sample manipulator
  - 25 mm and 60 mm diameter sample holders

- Zeiss Axio Imager M2m Materials Microscope
  - Transmitted Light
  - Reflected Light
  - DIC imaging
  - Phase contrast imaging
  - Polarization imaging
  - Automated X-Y-Z mechanical stage
  - Colibri fluorescence imaging
  - Axioscam 105 Color Camera
  - 10X thru 100X objectives
  - ZenCore Analysis Software

- Biolin Scientific T200-Auto3 Attension Theta Optical Tensiometer with Automatic XYZ stage and Pipette Dispenser
  - Sessile Drop Contact Angle Measurements
  - Dynamic Contact Angle
Surface Free Energy Calculations
Surface and Interfacial Tension Measurements
Topography Attachment for Surface Roughness Analysis

- Biolin Scientific Attension Theta Lite Tensiometer
  - Sessile Drop Contact Angle Measurements
  - Dynamic Contact Angle
  - Surface Free Energy Calculations
  - Surface and Interfacial Tension Measurements
- QEA PIAS-II Image Analysis System with Field Verification Target.

2-dimensional Materials Synthesis
- Aixtron 2D Cold Coupled Showerhead Metalorganic Vapor Phase Epitaxy (MOVPE) System
  - 12 metalorganic sources with 12 Epison 5 controllers
  - 5 process gasses (H₂S, H₂Se, NH₃, CH₄, H₂)
  - N₂ and Ar carrier gasses
  - 1400 C 3” x 2” CCS Tungsten 3-zone furnace with Graphite Reactor
    - Full flow and stop flow modes
  - Argus top-side temperature control and Laytec EpiTT® 3W In-situ process monitoring
- PlanarTech planarGROW-3S-TMD 3-zone Thermal Chemical Vapor Deposition (CVD) System
  - 3” (75mm) OD Quartz Tube
  - One (1) x 3-Zone Fixed Furnace
    - Max. 1,100°C
    - 100/300/100mm Heating Zones
  - Three (3) MFCs for Ar, H₂ & CH₄
  - LN2 Cold Trap & H₂ Dilution Kit
  - 250l/m Dry Scroll Pump
  - Auto-Pressure Control
  - 1000 Torr Capacitance Manometer
  - Motorized Throttle Valve
  - Fully Automated PC Control w/ LabVIEW Front End
  - 2 solid source heating kits
- Custom built quartz tube variable pressure chemical vapor deposition system with 4 inlet gases and up to two solid-source precursors.
- MTI 2” Alumina Tube furnace with inert gas inlet and vacuum compatible (qty. 2)
  - Vacuum or inert gas environment
  - 5 - 10°C/min heating rate
  - 23°C - 1500°C capability

High Performance Computing
- COMSOL Multiphysics FEM software
  - Floating Network License (FNL) for one (1) concurrent user (qty. 3)
  - AC/DC Module for use with COMSOL Multiphysics, (FNL qty. 1)
  - Acoustics Module for use with COMSOL Multiphysics, (FNL qty. 1)
  - CAD Import Module for use with COMSOL Multiphysics (FNL qty. 1)
  - CFD Module for use with COMSOL Multiphysics (FNL qty. 1)
  - Chemical Reaction Engineering Module for use with COMSOL Multiphysics (FNL qty. 1)
  - Electrochemistry Module for use with COMSOL Multiphysics (FNL qty. 1)
  - Heat Transfer Module for use with COMSOL Multiphysics (FNL qty. 1)
  - Material Library for use with COMSOL Multiphysics (FNL qty. 1)
MEMS Module for use with COMSOL Multiphysics (FNL qty. 1)
Microfluidics Module for use with COMSOL Multiphysics (FNL qty. 1)
Porous Media Flow Module for use with COMSOL Multiphysics (FNL qty. 1)
RF Module for use with COMSOL Multiphysics (FNL qty. 1)
Semiconductor Module for use with COMSOL Multiphysics (FNL qty. 1)
Structural Mechanics Module for use with COMSOL Multiphysics (FNL qty. 1)
Wave Optics Module for use with COMSOL Multiphysics (FNL qty. 1)

Nanoink/Nanofluid Synthesis

- 4 fume hoods equipped with hot plates, mixers, and various glassware for nanomaterials synthesis through chemical reactions.
- 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
- Heraeus Megafuge 8 with TX-150 Cell Cult Pkg (8 x 50 ml)
- Thermo Scientific Heratherm Programmable Gravity Convection Oven
- Beckman/Coulter Optima XE-90 Ultracentrifuge
  - 90,000 maximum RPM
  - 694,000g
  - 0 – 40 °C temperature range
  - SW41-Ti swing bucket rotor with 90 mL capacity
- Retsch EMAX High Energy Ball Mill System (qty. 2)
  - Max 2000 RPM
  - Water cooled for temperature controlled grinding
  - Operation with 2 grinding jars
  - Stainless steel, chrome steel, and zirconia jars and media
- Silverson L5MA Stand Mixer (qty. 2)
  - High shear mixer for particle dispersion
  - Capacity from 1 ml to 12 liters
  - Maximum speed of 6000 rpm under full load
  - Multiple workheads for different application including: disintegrating head, emulsor screens, particle size reduction, and axial flow heads.
- Biocomp Instruments Nano Gradient Fractionator/Former
- QSonica Q125 probe-tip ultra-sonicator
- QSonica Q700 probe-tip ultra-sonicator
- Buchi Corporation Rotavapor R-100 Rotary Evaporator with I-100 Controller
- Labconco FreeZone 4.5L Benchtop Freeze Dryer w/PTFE Coated SS 12 Port Drying Chamber (-105 °C)
- KrosFlo KR2i Fully Automated Tangential Flow Filtration System
  - 10 mL – 15 L volume capacity
  - 100 cm² to 5000 cm² filtration area
- MBraun UniLab Pro PS Glovebox System
  - 3 glove system
  - Copper catalyst and carbon filter work together to provide an in-box atmosphere of O₂ and H₂O <1ppm
  - Equipped with scale and hot plate
  - Capable of air sensitive chemical reactions, with top purge valve to snorkel hood for easy
environmental purge and generated gas removal

**Nanoink/Nanofluid/Nanomaterial Characterization**
- Brookfield Engineers Lab DV3TLV Rheometer
- Rheosense microVISC and Temperature Controlled Rheometer
- Brookfield Engineers Lab DVNext Cone/Plate Rheometer
- Brookhaven NanoBrook Omni Submicron Particle Sizer (DLS) and Zeta Potential Analyzer (PALS)
  - < 0.3 nm to 10 um
  - 15°, 90°, 173° measurement angles
  - Temp. control -5 to 110°C
  - Sample Cells 10 uL – 3 mL
  - Concentration Range 0.1 ppm to 50 mg/mL (sample dependent)
- Netzsch STA 449 F5 Jupiter Simultaneous Thermal Analyzer
  - RT to 1600°C
  - TGA resolution: 0.025 µg
  - Heating and Cooling Rate: 0.001 K/min to 50 K/min
  - DSC resolution: < 1 µW
  - Mass Range: 1 u to 300 u
  - Atmospheres: inert, oxidizing, static, dynamic, vacuum
- Netzsch STA 449 F1 Jupiter Simultaneous Thermal Analyzer Coupled to Netzsch QMS 403C and Bruker Tensor 27 FTIR
  - RT to 2000°C
  - TGA resolution: 0.025 µg
  - Heating and Cooling Rate: 0.001 K/min to 50 K/min
  - DSC resolution: < 1 µW
  - Atmospheres: inert, oxidizing, static, dynamic, vacuum
  - Mass Range: 1 u to 300 u
  - Electron Impact Ion Source
  - Quartz-glass Capillary 75 µm diameter, in metal tube, with supply coil, easily exchangeable
  - mid-IR source 4000 to 400 cm⁻¹
  - Resolution: <1 cm⁻¹
  - KBr pellet holder and press

**Physical/Chemical Property Characterization**
- Quantum Design Physical Property Measurement System
  - DC Resistivity, AC Transport (AC Resistivity, Hall Coefficient, I-V Curve, & Critical Current for superconductors) under user controlled magnetic field, pressure, gas composition, and temperature.
  - Magnetic field may be programmed anywhere from 0 to +/- 70,000 Oersted and the sample’s temperature can be programmed from 1.9 to 400 K.
- Janis CCS-400H/204N high temperature, optical cryostat system with sample in vacuum (10 K to 800 K)
  - 19 pin electrical feed-through
  - LakeShore Model 335 temperature controller
  - Model TS-75-D turbo-pumping station
  - OFHC copper optical sample holder
- Keithley 6221/2182A Current Source and Nanovoltmeter Combo
  - Measure resistances from 10nΩ to 100MΩ
  - Synchronized current-pulsed source and measurement times as short as 50µs
- Delta mode current reversal, resistance measurement technique
- Differential conductance measurement technique
- Current Sourcing:
  - DC: ±10 fA – 100 mA
- Voltage Measurement:
  - 1 nV sensitivity
  - 15 nV p-p noise at 1 s response time, 40–50 nV p-p noise at 60 ms
  - Dual channels
  - Built-in thermocouple linearization and cold junction compensation
- BioLogic SP-50 Potentiostat
  - Single channel potentiostat
    - Voltage
      - Control voltage: ±10 V
      - Voltage resolution: 5 µV on 200 mV range
      - Compliance: ±10 V
    - Current
      - Current ranges: 800 mA to 10 µA
      - Maximum current: ±800 mA
      - Current resolution: 0.760 nA
- EC Lab Software
- SRS 830 SDP Lock-in Amplifier (qty. 3)
  - 2 nV minimum voltage sensitivity
  - Single-ended or differential voltage input
  - Digital signal processing
  - 50/60 and 100/120 Hz notch signal filters
  - Extended dynamic reserve >100 dB
  - Internal or external references
  - Reference channel
    - 1 mHz – 102 kHz frequency range
    - TTL (rising or falling edge) or sine wave input
    - 0.01° phase resolution
- Omega Ice Point Calibrator High Precision Base Model TRCIII
  - On-site calibration of temperature sensors
  - Uniform thermocouple junction temperatures
  - Compensate for thermocouple effect
  - Up to 6 probes
  - Six reference wells at precisely 0°C
  - Alternates freezing and thawing of the ice accurately maintains a 0°C
    - Automated (sensed by expansion of bellows)
    - Maintained at ±0.1°C
    - Stability of ±0.04°C for constant ambient
- Keithley 2612B Dual-Source Measurement Unit (qty. 2)
  - Power: 200 W Pulse, 30 W DC / Channel
  - Current Source / Measure: ±100 fA min; ±10 A Pulse, ±1.5 A DC
  - Voltage Source / Measure: ±100 nV min; ±200 V max
  - Comms: IEEE-488; USB 2.0, LAN/LXI-C; RS-232
- Keithley 6500 Digital Multimeter
  - 15 measurement functions including capacitance, temperature, and digitizing
  - Expanded measurement ranges include 10 pA to 10 A and 1 µΩ to 100 MΩ
- Large 5-inch (12.7 cm) multi-touch capacitive touchscreen with graphical display
- Large internal memory; store up to 7 million readings

**SRS-DS345 – 30 MHz Function/ARB Generator**
- 1 µHz to 30.2 MHz frequency range
- 1 µHz frequency resolution
- Sine, square, ramp, triangle & noise
- Phase continuous sweeps
- AM, FM, PM & burst
- 16,300 point arbitrary waveforms
- 10 MHz reference input
- RS-232 and GPIB

**SRS-560 Low-noise voltage preamplifier**
- 4 nV/√Hz input noise
- 1 MHz bandwidth
- Variable gain from 1 to 50,000
- AC or DC coupled
- Two configurable signal filters
- Differential and single-ended inputs
- Line or battery operation
- RS-232 interface

**Krohn-Hite Model 3382 0.1 Hz to 200 kHz Dual Channel 8-Pole Filter**
- Two Independent Filter Channels
- One Band-Pass Channel
- Attenuation: 48dB/Octave
- Filter Modes: Low-Pass and High-Pass
- Response: Butterworth and Bessel
- Input: Differential and Single-Ended
- Input Gain: 0dB to 50dB in 10dB steps
- Output Gain: 0dB to 20dB in 0.1dB steps
- Battery Operation Option

**NI PXIe-1071 3 slot Chassis**
- 2.2 GHz Celeron 1020E Dual Core Processor and Control Board
- X Series Data Acquisition: 2 MS/s, 16 AI, 24 DIO, 2 AO
- 25 kS/s, 24-Bit, 8-Channel PXI Strain/Bridge Input Module

**TDK Lambda Programmable Power Supply**
- 750 W
- 85 – 265 Vac Continuous
- Max Voltage Output: 600V
- Max Current Output: 100A
- Built in RS-232/RS-485 I/O Board

**Tempos Thermal Properties Analyzer (-50°C to 150°C)**
**Hukseflux TP02 Thermal Properties Analyzer (-55°C to 180°C)**
**Kurt J Lesker Thin Film Sputter Machine**
- Physical Vapor Deposition system with RF and DC target sputtering capability. 100mm tooling, heated substrate, load lock, film thickness monitor, substrate biasing.

**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