

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 4294A 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 50 μ m by 50 μ m 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. 2.5 μ m to

- 14 μ m wavelength (700 - 4,000 cm^{-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 4,000 cm^{-1}
 - Provides s-SNOM imaging in the range of <700->2,000 cm^{-1}
 - Provides AFM-IR spectroscopy and imaging in the range of 700-2,000 cm^{-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 μ m lateral resolution at 633 nm (~500 nm maximum resolution with UV excitation)
 - 80 x 100 mm motorized stage for point by point Raman mapping
 - μ m step size with \pm 1 μ m 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
 - Axiocam 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 μm
 - 15°, 90°, 173° measurement angles
 - Temp. control -5 to 110 C
 - Sample Cells 10 μL – 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 μg to 300 μg
 - 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 μg to 300 μg
 - 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 10n Ω to 100M Ω
 - Synchronized current-pulsed source and measurement times as short as 50 μs

- Delta mode current reversal, resistance measurement technique
- Differential conductance measurement technique
- Current Sourcing:
 - DC: $\pm 10\text{fA} - 100\text{mA}$
 - AC: $4\text{pA p-p} - 200\text{mA p-p}$
- Voltage Measurement:
 - 1nV sensitivity
 - 15nVp-p noise at 1s response time, $40-50\text{nV p-p}$ noise at 60ms
 - Dual channels
 - Built-in thermocouple linearization and cold junction compensation
- BioLogic SP-50 Potentiostat
 - Single channel potentiostat
 - Voltage
 - Control voltage: $\pm 10\text{ V}$
 - Voltage resolution: $5\ \mu\text{V}$ on 200 mV range
 - Compliance: $\pm 10\text{ V}$
 - Current
 - Current ranges: 800 mA to $10\ \mu\text{A}$
 - Maximum current: $\pm 800\text{ mA}$
 - 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 $100/120\text{ Hz}$ notch signal filters
 - Extended dynamic reserve $>100\text{ dB}$
 - Internal or external references
 - Reference channel
 - $1\text{ mHz} - 102\text{ kHz}$ 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 $\pm 0.1^\circ\text{C}$
 - Stability of $\pm 0.04^\circ\text{C}$ for constant ambient
- Keithley 2612B Dual-Source Measurement Unit (qty. 2)
 - Power: 200 W Pulse , 30 W DC / Channel
 - Current Source / Measure: $\pm 100\text{ fA min}$; $\pm 10\text{ A Pulse}$, $\pm 1.5\text{ A DC}$
 - Voltage Source / Measure: $\pm 100\text{ nV min}$; $\pm 200\text{ V max}$
 - 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 $1\ \mu\Omega$ to $100\text{ M}\Omega$

- 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 μ Hz to 30.2 MHz frequency range
 - 1 μ Hz 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/ $\sqrt{\text{Hz}}$ 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