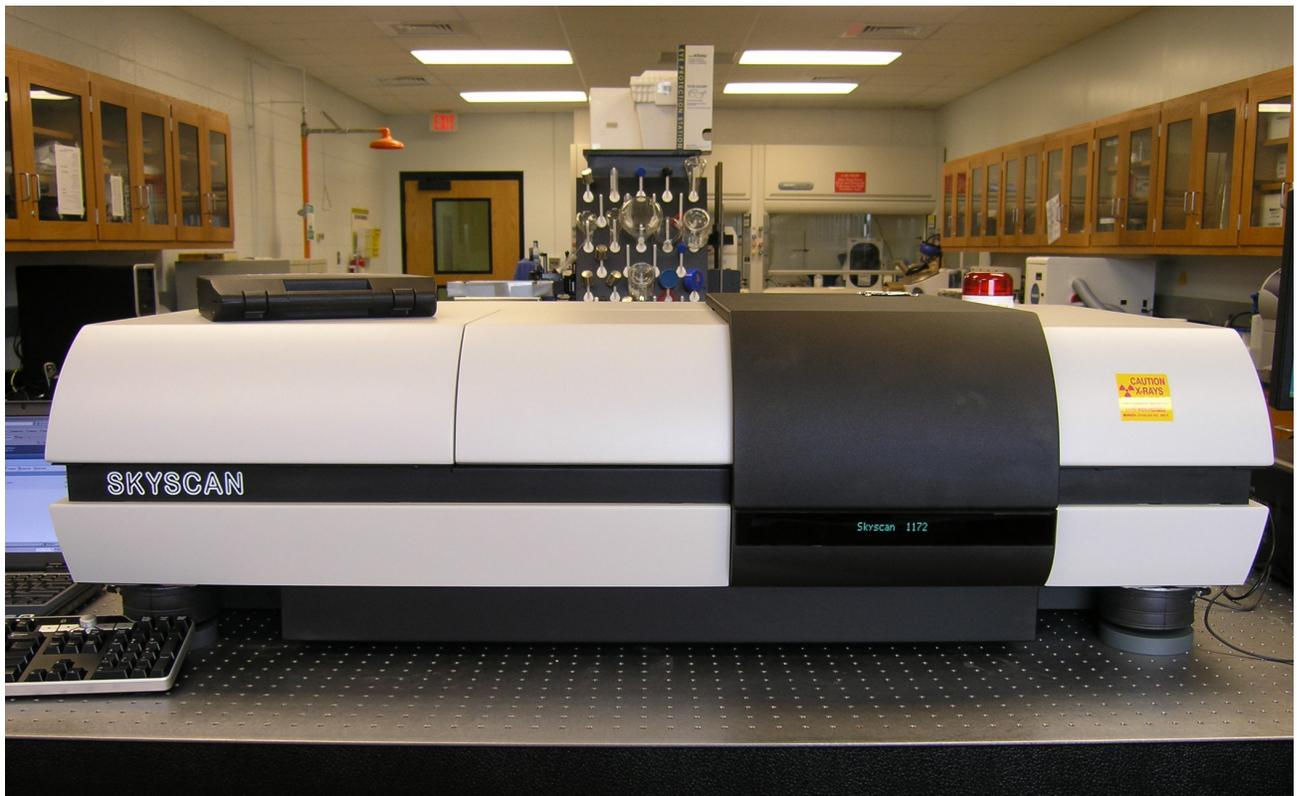




THE UNIVERSITY OF MISSISSIPPI  
**MEDICAL CENTER**  
School of Dentistry

# Biomedical Materials Science Shared Equipment Facility



**Advanced Materials Characterization Equipment  
For Materials Testing, Physical & Chemical  
Characterization, and Failure Analysis**

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## ABOUT THE FACILITY

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The Department of Biomedical Materials Science at the University of Mississippi Medical Center (UMMC) was formed in July 2004 but has existed as a division within another department for approximately 35 years. As a part of the academic program of the School of Graduate Studies in the Health Sciences and the School of Dentistry, efforts are dedicated to research, development, and characterization of materials, and the interfacial and biological phenomena that govern the outcome of biomedical implants and devices.

In light of the fact that the equipment available in our laboratories represents the state of the art in material testing and characterization, and requests from a variety of industries and other universities for access to this equipment, the department has formalized a shared equipment facility.

This facility provides access to equipment used to perform materials processing, characterization, and certification. These services are now available to users within and outside the academic community on a fee-for-service basis.

Users may become trained in the use of the equipment and be allowed independent



Operation, or testing may be performed by departmental personnel at an additional cost.

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Department of Biomedical Materials Science

School of Dentistry

University of Mississippi Medical Center

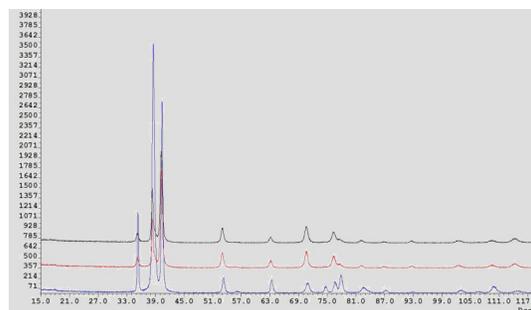
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## High Resolution X-Ray Diffraction System



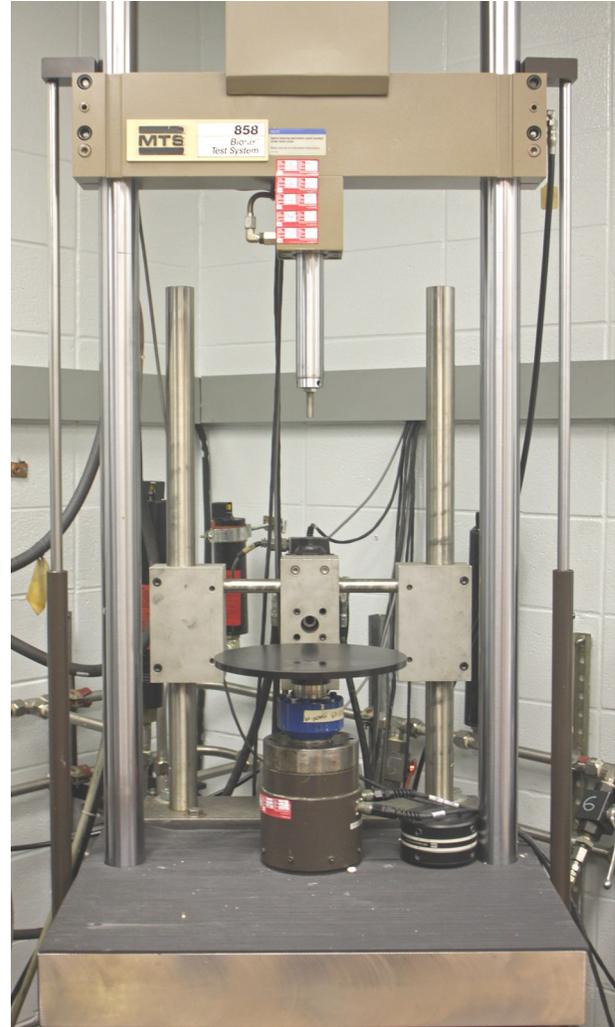
X-ray diffraction is a non-destructive analytical technique which reveals information about the crystallographic structure, chemical composition, and physical properties of materials and thin films.

Our x-ray diffraction system is a four axis Scintag system with a copper or chromium x-ray source. The analyses are performed with an automated diffractometer controlled by JADE software. The data are analyzed with a computerized match procedure compared to NIST ICSD.

- X-Ray Sources: Copper (2.2 kW, 60 kV max) & Chromium (1.7 kW, 60 kV max)
- Goniometer: theta/3-theta (theta/2-theta and theta/theta), Theta Range: 0 to 180 degrees, Omega Range: -2 to 90 degrees
- Scan Rate: 0.1 to 120 degrees at 2-theta per minute (continuous scan mode)
- Sample holder with variable rotation speed
- Crystallographic structure identification
- Chemical composition
- Grain alignment (texture) of polycrystalline materials
- Determination of residual stresses
- Determination of crystal lattice parameters
- Capability of testing metals, ceramics, powders, minerals, thin films, and coatings
- NIST ICSD database search with over 70,000 inorganic crystal structures

## Three-Axis Mechanical Testing System

The MTS 858 Bionix system is a three-axis hydraulic load frame connected to an MTS Flex-Test GT controller. The Bionix system is equipped with a lateral actuator and a vertical actuator capable of simultaneous vertical and rotational control. The vertical control channel has a load capacity of 25 kN, displacement capacity of 100 mm, rotation range from 0 to 60 degrees, and a torsion range from 0 to 250 Nm. The lateral channel has a load capacity of 2.25 kN and displacement range from 10 to 100 mm. The vertical actuator can be controlled in load, displacement, or strain and torsion or rotation while acquiring data from any and all of the other modes. This allows for a multitude of test configurations including biomechanics, stress corrosion cracking, corrosion fatigue, and torsion. The controller is connected to a computer with MTS Testworks software for data acquisition.



- Three-axis hydraulic load frame
- MTS Flex-test GT controller
- MTS TestWorks software for test setup and data acquisition
- Equipped with an vertical actuator and a lateral actuator capable of simultaneous vertical and rotational control
- Vertical actuator:
  - Load range up to 25 kN
  - Displacement capacity of 100 mm
- Rotation range from 0 to 60 degrees,
- Torsion range from 0 to 250 Nm
- Vertical actuator can be controlled in load, displacement, or strain as well as torsion or rotation while acquiring data from any and all of the other modes
- Lateral actuator:
  - Load range up to 2.25 kN
  - Displacement range from 10 to 100 mm

## Uniaxial Mechanical Testing Systems



The MTS 810 and 812 testing systems deliver a broad array of testing capabilities for both low and high force static and dynamic testing. A range of test modes, load capacities, and control modes can be used for your testing needs. Both the 810 and 812 models can be operated in either displacement, load or strain control while simultaneously capturing data from the other two channels.

The 810 and 812 testing systems are hydraulic driven load frames equipped with fatigue rated servo-valves capable of both monotonic and cyclic loading. For all systems, tests are programmed and monitored using MTS TestWorks software, which includes real time data observations. Test fixtures are available for axial tension, compression, bending, fatigue and shear tests. A test space maximum daylight of 30 inches (~75 cm) is available for both systems.

- Low and high force static and dynamic testing
- Range of test mode operations including load, displacement, and strain
- Load ranges from 100 N (.02 kip) to 450 kN

- Displacement range up to 100 mm
- Strain ranges from 2 to 20%
- Hydraulic driven load frames equipped with fatigue rated servo-valves for low displacement high frequency tests
- Tests are programmed and monitored using MTS TestWorks software
- Axial tension, compressive, shear, three- and four-point bend test fixtures are available for a variety of material sizes and geometries
- The ability to test materials ranging in strength from polymers to composites and ceramics, to metals.
- A large test space (maximum daylight of 30 inches) to accommodate standard, medium and large size specimens
- Hydraulic grips with inserts to accommodate rounds, flats, and fine wire specimens (MTS 810 and 812)
- The capacity to perform a wide variety of test types from tensile to high cycle fatigue, fracture mechanics, compressive bending, and durability of components



## Multi-Frame Flex Test System

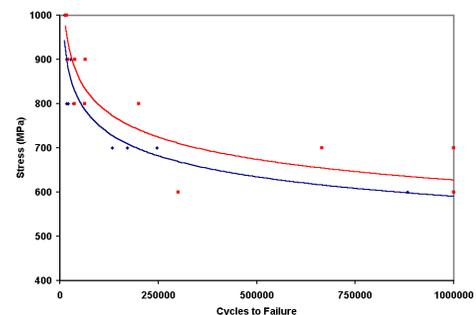
The Multi-Frame FlexTest System is a hydraulic mechanical test system consisting of five independently controlled load frames with the capability of performing dynamic and monotonic testing in air or fluid environment under thermal control. Each load frame is capable of being programmed in either load or displacement control with one frame also having strain control capability. All load frames have a load range of 25 kN and displacement range of 100 mm. The load frame with strain control capability has a range of 2-20%.

The test system is connected to a computer with independent data acquisition using MTS TestWorks software. A variety of tests, along with appropriate test fixtures, can be performed including stress corrosion cracking, high and low cycle corrosion fatigue, and compression testing.

Each load frame is equipped with independent strain gauge alignment fixtures for precise sample alignment. A test space maximum daylight of 24 inches (~60 cm) is available for all four load frames.

- Hydraulic mechanical test system consisting of five independently controlled load frames
- Capability of performing dynamic and monotonic testing in air or fluid environment under thermal control
- Each load frame is capable of being operated in either load or displacement control with one frame also having strain control capability

- All four load frames have a load range up to 25 kN
- Displacement range to 100 mm Strain control for one frame with range of 2-20%
- Independent data acquisition using MTS TestWorks software
- A variety of tests can be performed including stress corrosion cracking, high and low cycle corrosion fatigue, and compression testing
- Each load frame is equipped with independent strain gauge alignment fixtures for precise alignment



## Nano Indenter

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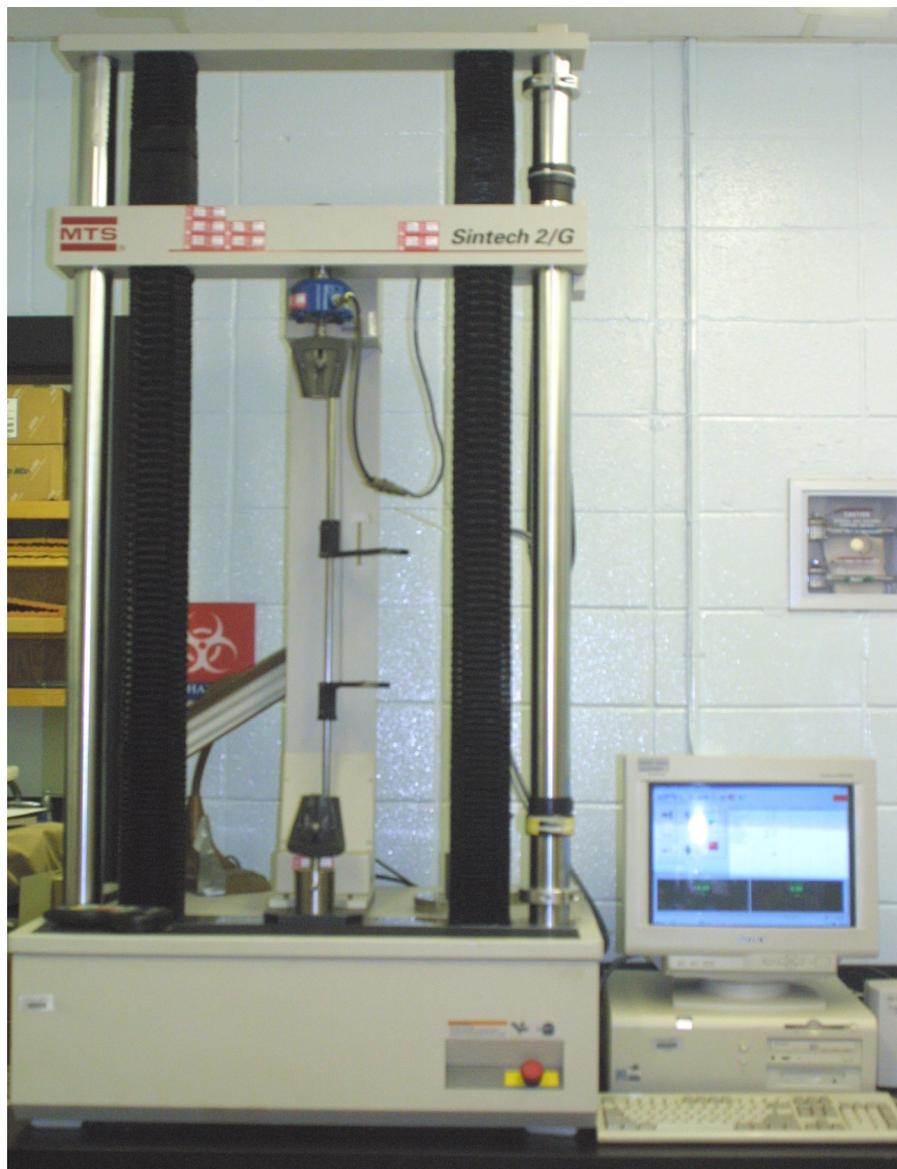
The MTS G200 Nano Indenter system provides a fast and reliable way to acquire mechanical data on the submicron scale. The system records stiffness data along with load and displacement data dynamically, allowing hardness and Young's modulus to be calculated at every data point during the indentation experiment. The Nano Vision software is capable of recording this data and creating 3D images.

- Conforms to ISO 14577-1, 2 and 3 delivering the utmost integrity in test results
- 200 mm of stage travel
- Displacement resolution of  $<0.01$  nm
- Total indenter travel of 1.5 mm
- Max indentation depth  $>500$   $\mu\text{m}$
- Loading Capability
- Maximum load 500 mN
- Load Resolution 50 nN
- Contact Force  $<1.0$   $\mu\text{N}$
- Positional Accuracy 1  $\mu\text{m}$
- Objective 10x and 40x



## High Elongation Screw Machine

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This MTS Sintech high elongation test system has a load capacity of 5 kN making it ideal for testing a variety of materials including polymers, metals, paper, ceramics, fine wires, composites, fabrics, films, fasteners, and wood. Test methods include tension, compression, flex, compliance, and peel/tear.

Tests can be conducted in either load, displacement, or strain control. Capable of measuring low loads with an 5 N load cell. This load system has a DXL strain gauge attached with capabilities of measuring strain in excess of 1000%.

## Biaxial Mechanical Testing System

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The ADMET eXpert 8602 system is an axial-torsional electric load frame with a screw-driven actuator. The actuator has the capability of both vertical and rotational control simultaneously or independently. The load capacity of this load frame is 500 lb (2224 N) in both tension and compression with an attached NIST traceable load cell. The actuator has a total displacement of +/- 4 in (100 mm) of travel with a total crosshead movement of 20 inches. The torsion capacity of this frame is 250 in-lb in both clockwise and counter clockwise directions without a maximum rotation limit. The maximum rotational speed is 60 RPM. This load frame is very versatile and is attached on top of an industrial cart so that it can be transported to other areas of the University for testing. This machine is ideal for orthopedic and dental screw testing (ASTM F 543 Test Annex A1-A4), biomechanical testing of cadaver and artificial bones and joints, spinal constructs, three and four point bending, simple tension testing, and many other applications. The test system is connected to a computer with MTESTQuatro® software which monitors and records all of the test data. The versatility of the load frame and software makes programming easy and offers a wide range of possible test procedures.



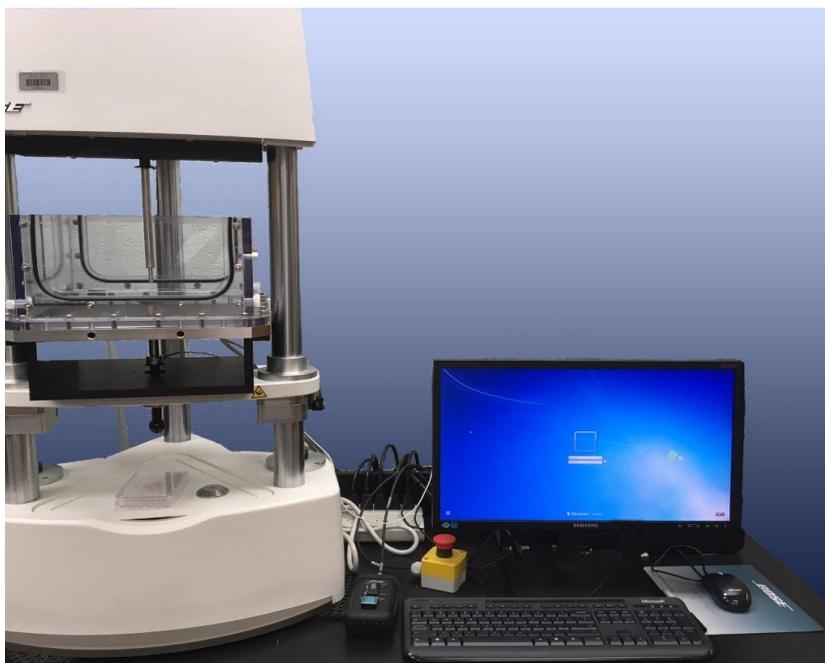
- Bi-Axial actuator
- Load, displacement, torsion, and/or rotational control
- Electrical motor
- 500 lb (2224 N) load capacity in tension and compression
- 4 in (100 mm) displacement
- 250 in-lb maximum torque
- 60 RPM maximum
- Unlimited rotation
- Versatile and easy to re-locate for testing needs within the UMMC campus
- MTESTQuatro® controller

## Uniaxial Dynamic Mechanical Analysis Testing System

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The TA Instruments 3220 Series III electroforce system is a low force, low displacement, high frequency load frame. The actuator is magnet driven with highly precise dimensional accuracy. This load frame exceeds ASTM E 2309 Class A's standard for accuracy and has nm displacement resolution. The load frame is equipped with a 50 lb (225 N) load cell capacity with smaller load cells available. The displacement of the actuator is a maximum of ¼ in (6.5 mm). At low displacements, the actuator is capable of testing at a frequency of 300 Hz. This frame is also capable of dynamic mechanical analysis (DMA) up to 200 Hz. The vertical testing space for this system is 17 in (43 cm). The system also has a temperature controlled bath for optional testing in solution.

- High frequency up to 300 Hz
- Dynamic mechanical analysis up to 200 Hz
- Nanometer displacement resolution with high accuracy
- Load capacity up to 50 lb (225N)
- Displacement maximum of ¼ in (6.5 mm)
- Optional temperature controlled environment chamber
- Load or Displacement control

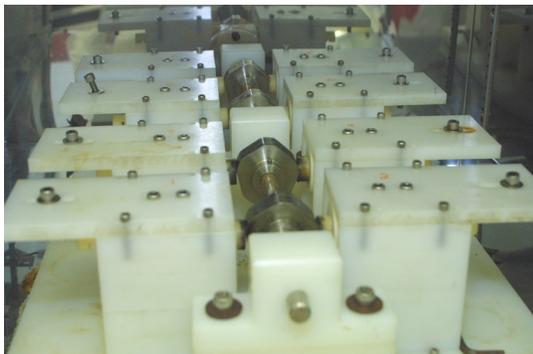


## Uniaxial Mechanical Testing Systems

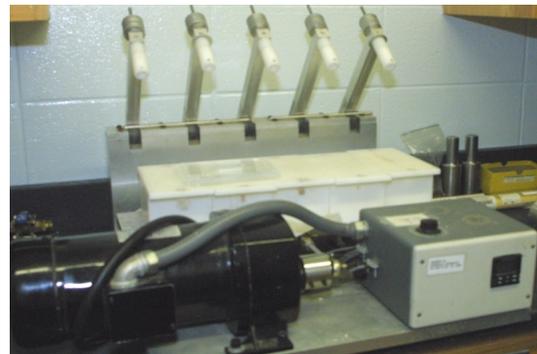
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Simulation of human joint motion for the purpose of testing and evaluation of prosthetic devices prior to clinical deployment is essential to assure the successful outcome of such surgical procedures. This simulator, equipped for wear in serum, has been designed with greater head space than most systems as well as load and torque cells at each of the eight stations. This configuration allows the placement of full hip stems, monitoring of load and torque at each station.

- For hips, loads and motions are generated to simulate walking. Other joints as well as components requiring rotation under load control may be evaluated.
- The laboratory also has the capability to perform pin-on-disc unidirectional wear testing and fretting corrosion testing in compliance with ASTM Test Method F897.



Fretting Corrosion System



Pin-on-Disk Wear Tester



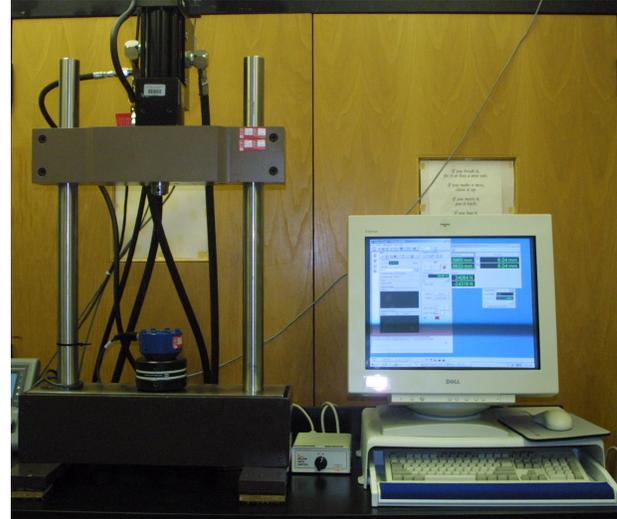
8-Station Hip Wear Tester

## Mini Frame Test System

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The Mini Frame test system is a closed loop servo-hydraulic system connected to the MTS Flex Test GT controller. The mini frame has a 25 kN load capacity and 100 mm displacement capacity. This load frame is used for a variety of mechanical tests including monotonic, static, cyclic loading and fracture mechanics. A COD (crack opening displacement) gauge can be connected to the controller to allow for fracture mechanics testing. The test system can be operated in load, displacement, or extensometer (COD) mode while acquiring data through MTS TestWorks or MTS crack growth software. A thermally controlled solution bath can also be installed for environmentally controlled testing. The mini frame also has a strain gauge alignment fixture attached for precise sample alignment. A test space maximum daylight of 24 inches (~60 cm) is available for test fixtures and samples.

- Closed loop servo hydraulic system
- Control modes of load, displacement, or strain
- MTS Flex Test GT controller with MTS TestWorks software
- Load capacity range to 25 kN
- Displacement range of 0 to 100 mm
- Strain capacity range from 2% to 20%
- MTS crack growth software for fracture mechanics testing



- COD (crack opening displacement) gauge can be connected to the controller to allow for fracture mechanics testing
- Fatigue crack-growth measurement using KRAK-GAGE technology
- A variety of tests can be performed including stress corrosion cracking, high and low cycle corrosion fatigue, and compression testing
- Capability of performing dynamic and monotonic testing in air or fluid environment under thermal control
- Strain gauge alignment fixture attached for precise sample alignment

## Laser Confocal Microscope

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The laser confocal microscope is a valuable tool for achieving high resolution images and three-dimensional reconstructions of surfaces. This instrument has the ability to produce blur-free images of thick transparent samples at various depths. The microscope is also configured to measure and display surface morphology of opaque samples using reflected light techniques.

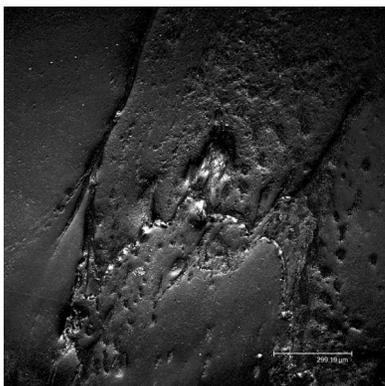
Photographs are taken by using a spatial pinhole to eliminate out-of-focus light. When photographs are taken, only the light within the focal plane can be detected producing high quality wide-field images.

Capabilities include:

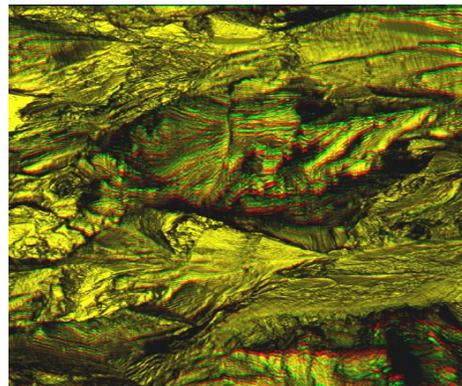
- Surface roughness measurements
- Creation of 3D photos of surface morphology
- Imaging in aqueous environments – Water-immersible objectives included
- Imaging of specimens stained with fluorescent dyes
- Rotation of collected images in 3 dimensions for assessment of specimen features



Artificial Hip Component

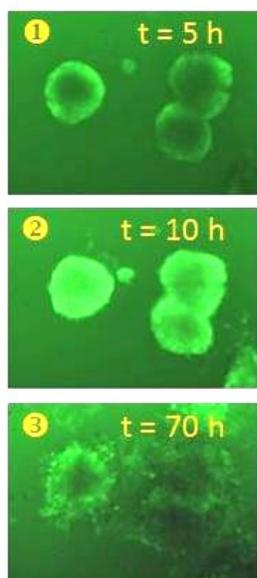


Worn Polyurethane Surface

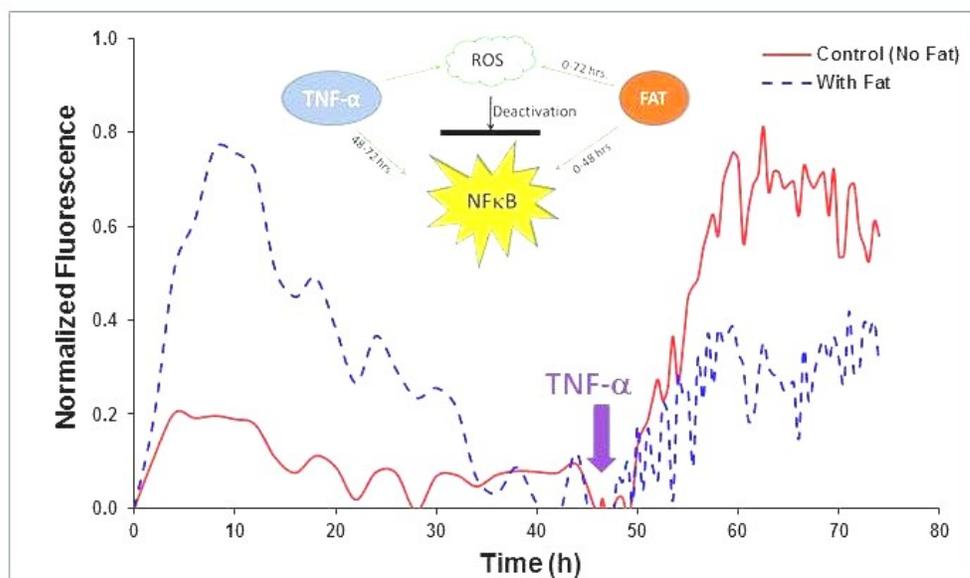


3D Image of Fracture Surface

## Optical and Fluorescence Microscope/Live Cell Chamber



Live Cells in Culture



### Optical and Fluorescence imaging capability:

Time lapse imaging capability allows observations of cell culture at specified time points. Motorized stage allows for pre-programmed imaging of multiple locations (especially helpful to image multi-well cell culture plates)

- Objectives: 2.5X, 4X, 10X, 20X, 40X, 60X.
- 1.6X magnification changer offering increased magnification to eyepieces and cameras without changing objectives.

**LiveCell™ Environmental Chamber** facilitates a long-term cell culture under the microscope. Independent control of temperature, %CO<sub>2</sub> and humidity achieved with the **LiveCell™** chamber, combined with the time lapse imaging capability and the motorized stage, allows long-term culture studies under the microscope

- Dedicated computer server
- Slidebook image acquisition/analysis software.



**Cell Culture Facility:** Complete cell culture suite with following equipment available:

- Tissue culture hoods – Nuaire
- Tissue culture incubators
- UV/Vis Spectrophotometer – Nanodrop
- Fluorescence/Luminescence MicroPlate Reader – BioTek
- Floor Incubator / Shaker – Inova

## Scanning Electron Microscope (FE-SEM) with EDS and EBSD Capabilities

### Scanning Electron Microscope:

Zeiss Supra 40 SEM with Schottky type field emitter system. Samples may be viewed using accelerating voltages as low as 100 V, allowing the viewing of beam sensitive samples and non-conductive samples without damage to the samples or charging effects in the images.

With the capability for accelerating voltages up to 30,000 V, sufficient beam energies may be achieved for efficient compositional analysis using EDS and microstructural analysis using EBSD.

### Detectors:

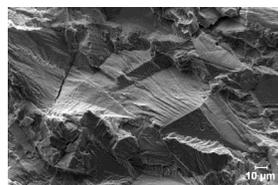
- Everhart-Thornley secondary electron detector
- 4-quadrant solid state backscattered electron detector
- High efficiency annular in-lens secondary electron detector system
- Forward scattered detector mounted on the EBSD camera

**Large Cylindrical Specimen Chamber,** allowing the insertion of large samples without requiring sectioning

**Imaging System:** Digital storage of images with resolutions up to 3072x2304 pixels, allowing printing of large-format images for presentations and reports.

### Energy Dispersive X-ray Spectroscopy (EDS)

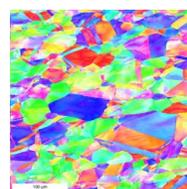
- Detecting unit capable of the detection of all elements down to and including Carbon.



Fractured Metal Surface



Rat Cochlea



Metal Crystal Structure



- Since the detector is mounted immediately adjacent to the EBSD detector, EDS data may be collected simultaneously with the collection of microstructural data.
- EDAX TEAM Analytical Software

### Electron Backscattered Diffraction (EBSD)

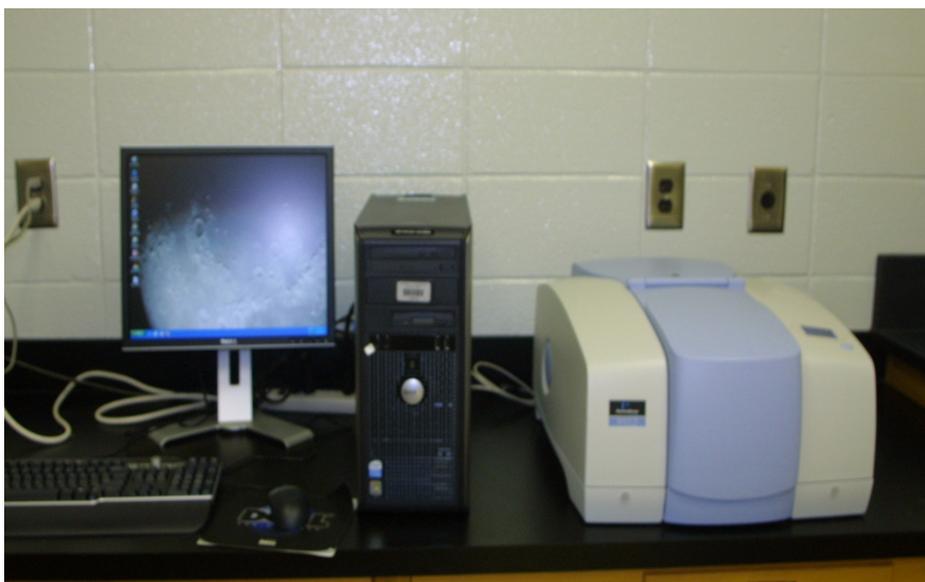
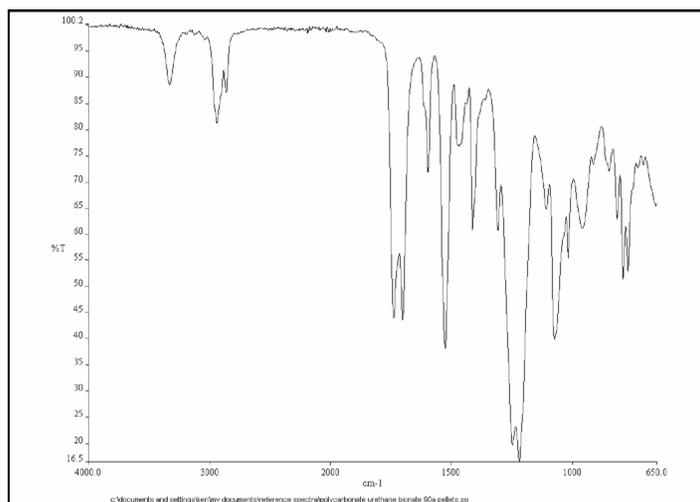
- EDAX High-Speed EBSD Camera with integrated forward scattered detector
- EDAX/TSL analytical software to allow identification of phases present and the composition and orientation of each phase with respect to other phases

## Fourier Transform Infrared Spectroscopy

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**Fourier Transform Infrared Spectrometry (FTIR)** is used to determine the molecular composition of a variety of materials.

- The samples may be analyzed in **transmission**, or thick samples may be analyzed in **reflection**.
- The technique may be used as a sensitive method for detecting additives in a polymer or for comparison of apparently similar polymers.
- Changes in a material due to oxidation or other chemical changes in the polymer structure can frequently be detected using a ratio of the areas of characteristic peaks.



## ICP-MS and Laser Ablation



The ELAN DRC II combines the power of patented Dynamic Reaction Cell technology, Axial-Field Technology, and high performance sample introduction with the ability to run any reaction gas (ammonia, methane, oxygen, and others).

- The lack of high-voltage ion extraction lenses results in lower on-peak background levels and lower equivalent concentrations leading to accurate quantitative measurements at ultra trace levels.
- Elan DRC II allows accurate determinations at the ppb levels for several important elements.
- The laser ablation system can volatilize solid samples into a gas carrier stream that can then be fed to the ICP-MS for compositional analysis.



The CETAC LSX-213 delivers high intensity 213 nm, 5 nanosecond laser pulses at rates of 1-20 Hz.

The homogeneous flat top energy profile of the laser produces aperture spot sizes from 10 to 200 micron while maintaining a constant energy density.

- The laser output energy is fully adjustable to produce as much, or as little ablation necessary to analyze virtually any solid sample - ideal for geological, forensic industrial and biological samples.
- For analysis, you can easily set precise points for a single point analysis, multi-point analysis, line scan analysis, area scan analysis, area raster analysis, depth profiling, or analyzing an arbitrary pattern.

## Thermo-Gravimetric and Thermo-Mechanical Analysis

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**Thermo-gravimetric Analysis (TGA)** is used to measure changes in the weight of a sample as a function of temperature and/or time. Thermo-mechanical Analysis (TMA) evaluates the deformation of a sample under stress as a function of changes in temperature.

### Liquid Nitrogen Cooled DSC 30 Module

- Temperature Range:  $-170^{\circ}\text{C}$  -  $600^{\circ}\text{C}$

### TGA50 Thermo-gravimetric Analysis Module

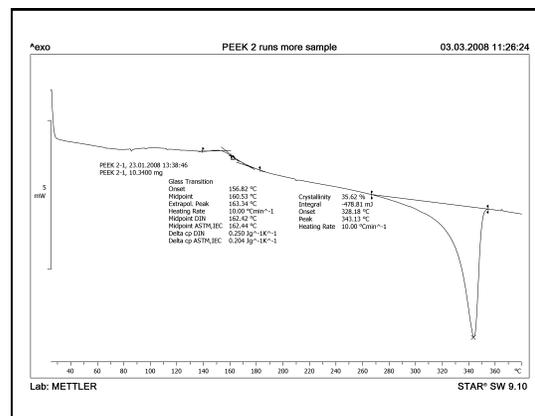
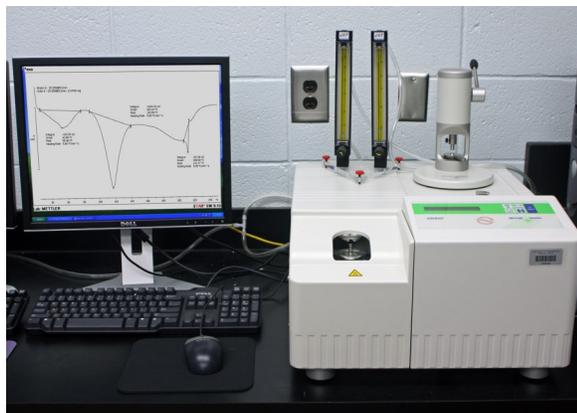
- Temperature Range:  $25^{\circ}\text{C}$  -  $1000^{\circ}\text{C}$
- Polymer thermal stability under various gaseous environments

### TMA 40 Thermo-mechanical Analysis System

- Coefficient of thermal expansion and contraction (CTE) as a function of temperature
- Effect of temperature on hardness and/or flexibility
- Sample holder which allows measurement while immersed in various liquids

## Differential Scanning Calorimeter (DSC)

### Differential Thermal Analysis (DTA)



**Differential Thermal Analysis (DTA)** is a technique for determining the difference in temperature between a substance and a reference sample as a function of either time or temperature as the materials are subjected to identical heating regimens. The system is commonly used for the determination of changes of phase in ceramics, metals, and polymers. An example is the determination of transition temperatures from one phase to another.

- Temperature Range: 200°C to 1600°C
- 1<sup>st</sup> and 2<sup>nd</sup> order transitions of ceramic compositions

**Differential Scanning Calorimeter (DSC)** is a technique in which the difference in the amount of heat required to increase the temperature of a sample is measured. Information on thermal expansion is obtained.

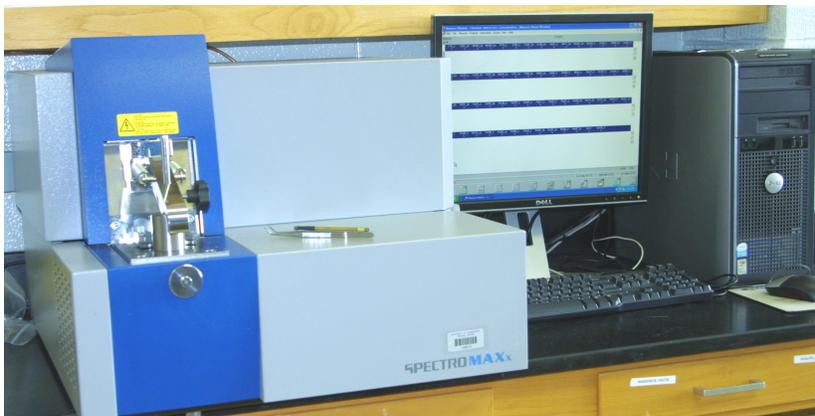
- Liquid Nitrogen Cooled
- Temperature Range: -150°C to 700°C for high sensitivity and resolution

#### Measurements

- Melting Point
- Glass Transition
- Crystallinity of Polymers
- Curing Reactions
- Thermal Decomposition

## SPECTROMAXX Compositional Analysis

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The Arc-Spark OES is used for both qualitative and quantitative compositional analysis of metals and alloys

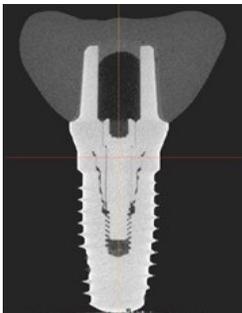
Using standards, the instrument provides concentrations in ppm of alloying elements including carbon, which is not readily obtainable by many alternative methods

- Samples must be electrically conductive in order to be tested using the SPECTROMAXX system; Non-conductive materials can be tested using the ICP-MS with laser ablation system
- Trace elements such as carbon, nitrogen, phosphorous, and sulfur can be analyzed in the ppm range
- Data is easily transferred to a spreadsheet for analysis and storage

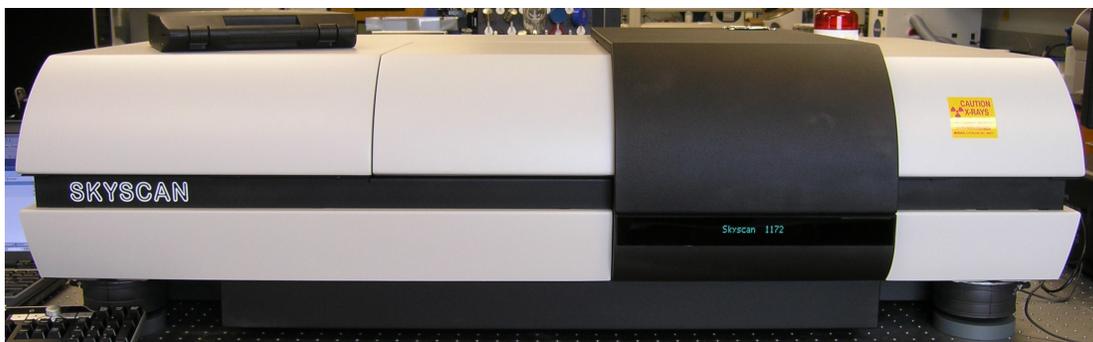
## X-Ray Microtomography (Micro-CT)

The system obtains multiple X-ray projections of the object from different angular views, as the object rotates on a high-precision stage. From these projections, cross section images of the object are reconstructed by a modified Feldkamp cone-beam algorithm, creating a complete 3D representation of internal microstructure and density over a selected range of heights in the transmission images.

- The virtual vantage point and object opacity can be adjusted to view external and/or internal surfaces.
- Microstructure can be viewed as coronal, sagittal, and transverse sections, and 3D quantitative analysis is available.
- Data are exported as bitmaps of cross-sections and can be converted to finite element models using our Mimics software.
- Max Specimen Size: 70 mm height 68 mm diameter
- Max Resolution: 1  $\mu\text{m}$
- Scan & Reconstruction Time: Variable (1 hour to 1 day)
- 2D and 3D quantitative analysis
- Export Formats: Finite element (Abaqus, Ansys), 3D animations, and 2D cross sections (.bmp, .tiff, .jpg.)



Images and 3-D reconstruction of dental implants



## Computer Modeling

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Our Dell Precision T7400 graphics workstation (dual quad-core processors, 32GB RAM, 2TB HD, 512MB graphics accelerator) is a powerful platform for several finite element modeling packages.

**Mimics (Materialise) software** can convert 3D models captured by our micro-CT scanner, as well as a variety of medical scanners into finite element models suitable for export to Abaqus or ANSYS.

- Rapid prototyping interface
- Assign material stiffness as function of radiolucency
- 3D quantitative analyses: distances, surface areas, and volumes
- Input formats: VFF, Raw, BMP, TIFF, DICOM, JPEG
- Output formats: IGES, STL, VRML, PLY, INP, OUT, NAS, MSH

**Abaqus FEA (Simulia) with fe-safe (Safe Technology) software** can predict the mechanically and thermally induced stress and microstrain distributions in a component or surrounding an implant. The necessary material elasticity constants are determined using our ultrasonic pulse apparatus and analytical balance. **Fe-safe** works in conjunction with Abaqus to predict fatigue lifetimes of components.

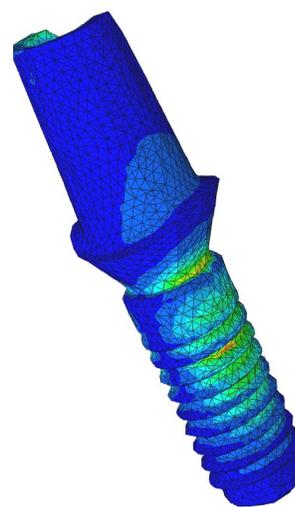
- Calculate: stress, strain, displacement, temperature, fatigue life, safety factor

- Graph types: contour plots and vector plots mapped onto component/interface or graphed along length of user defined path
- Solution types: static, transient, mechanical, thermal, coupled thermal-mechanical

### 25DL Plus ultrasonic thickness gauge (Panametrics-NDT)

- Density, shear sound velocity, longitudinal sound velocity
- Elastic constants: Poisson's ratio, Young's modulus, shear modulus, and bulk modulus

**ALTA Pro (Reliasoft) software** can analyze accelerated lifetime test data to predict product reliability and can perform Monte Carlo simulations to design more efficient fatigue tests.



3-D Reconstruction

## Corrosion Testing Equipment

### Gamry Series G 300 Potentiostat/ Galvanostat/ZRA

- Compliance Voltage:  $\pm 20$  V
- Frequency Range: 10 mHz-300 kHz
- Current Range: 3nA-300mA
- Oven: Temperature control to  $\pm 1^\circ\text{C}$

#### Software Applications include:

- DC105 (Tafel, Potentiodynamic, Cyclic Polarization, Galvanic Corrosion, Galvanodynamic)
- EIS300 (Potentiostatic EIS, Multi-Sine EIS, Galvanostatic EIS)

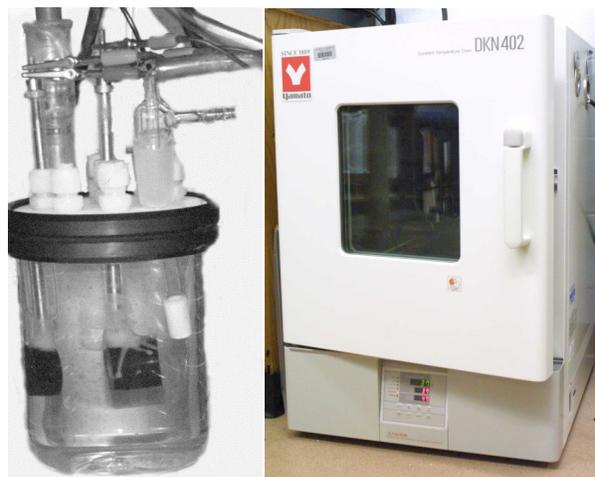
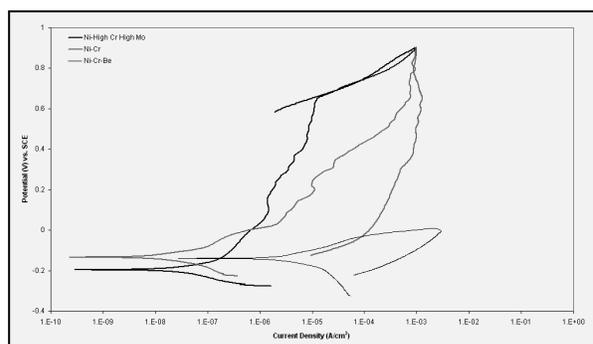
### Princeton Applied Research PARSTAT 2273 Potentiostat/Galvanostat/FRA w/ 20A Power Booster

- Compliance Voltage: up to  $\pm 100$ V
- Frequency Response Analyzer: DC and EIS analysis from 10mHz-10MHz
- Current Measurement Range: 40pA to -2A (higher w/booster)
- 20A Power Booster: allows for higher current applications such as battery research, corrosion of large electrodes electroynthesis, and electrodeposition
- Impedance Frequency Range: 10 mHz to 1 MHz

#### Software Applications include:

- PowerCV (Cyclic Voltammetry)

- PowerCORR (Tafel Plots, Linear and Cyclic Polarization, Galvanic, Galvanodynamic)
- PowerSINE (Potentiostatic EIS, Multi-Sine EIS, Galvanostatic EIS)



## Ceramic Processing

The ceramic processing laboratory contains the equipment typically found in a dental laboratory and allows the fabrication of a variety of all-ceramic prostheses (powder porcelain, pressable, glass-infiltrated, CAD-CAM, and sintered). Some of the techniques, such as lost wax method and air abrasion, are also useful in preparation or surface treatment of metallic and other materials for a variety of applications.

### Cerec inLab 3D dental CAD-CAM system (Sirona)

- In EOS scanner for rapid 3D model acquisition
- Restoration Types: veneers, inlays, onlays, crowns, FPDs, and non-dental specimens (using milling unit scanner)
- Materials: GFRP composites, glass-ceramics, polycrystalline ceramics, and clean burning “wax” (monolithic materials, frameworks, and press-to-fit)

### Sintramat sintering furnace (Ivoclar-Vivadent)

- Solid-state sintering of polycrystalline ceramics with max temperature 1600 °C

### Touch & Press furnace (Dentsply Detrey)

- Vacuum firing
- Materials: powder porcelains, pressable glass-ceramics, glass-infiltrated polycrystalline ceramics
- Max temperature 1200 °C



### Lost wax method auxiliary equipment

- Waxelectric I waxing unit with Vario E preheating reservoir
- Vacuum Powder Mixer Plus for investment plaster mixing
- 007EX wax burnout furnace

### Quattro IS air abrasion (sandblasting) unit (Renfert)

- Media Types: glass or alumina beads
- Pressure Range: 5-8 bar (73-116 psi)
- Media Sizes: 50 micron (270 mesh) or 125 micron (115 mesh)

### USB2000 optical spectrophotometer (Ocean Optics)

- Integrating sphere for color measurement without edge loss
- Measures specular, diffuse, and specular + diffuse reflection
- Output data: reflectance vs wavelength, CIELAB, XYZ, and contrast ratio (translucency)

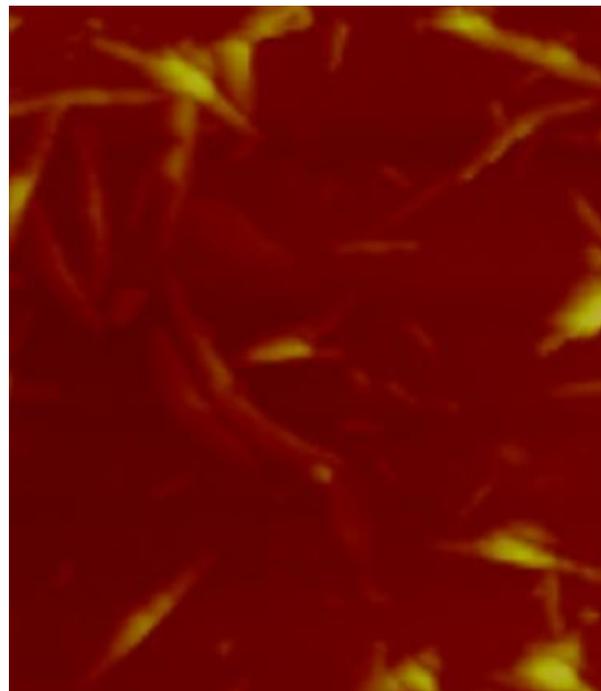
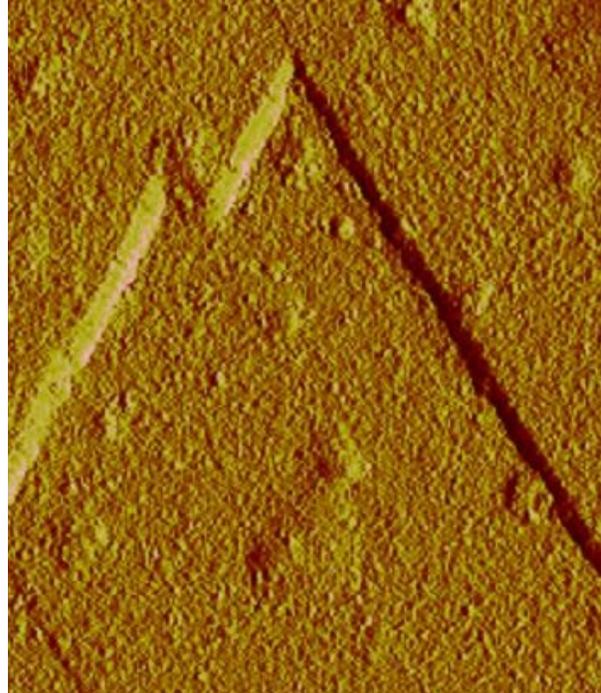
## Atomic Force Microscope (AFM)

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### Veeco Bioscope Catalyst with Veeco NanoScope V controller

Equipped with Easy Align tip alignment system, system isolation table, and heating perfusion chamber.

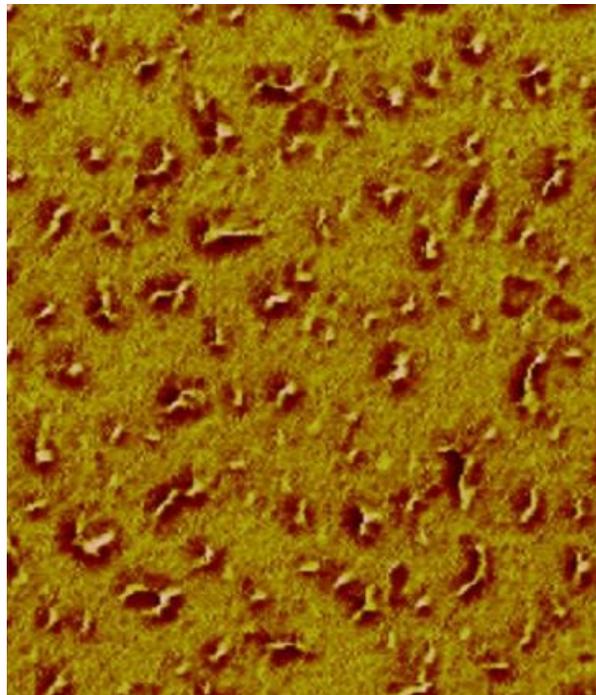
- **Acceptable samples:** Standard metal, ceramic, polymer, and composite specimens, live cells, tissues, and bacteria.
- **Sample Sizes / Types:** Petri dishes (35, 50, 60 mm dia, glass or plastic), cover slips, glass slides. Samples up to 10 mm thick. Larger samples can also fit on sample stage.
- **Perfusion / closed fluid cells:** Includes 50 mm perfusion cell, also includes microcell with  $<60\mu\text{L}$  sealed volume around the AFM probe, through which fluid can be exchanged
- **Sample heating:** Includes bio-heater (with full PID temp control) for imaging from RT to 40 C. "Cooled" (temps  $< \text{RT}$ ) sample temperatures can use same PID loop with cooled fluid
- **X-Y, Z range scanning:** 150  $\mu\text{m}$  closed loop,  $>180 \mu\text{m}$  open loop,  $>20 \mu\text{m}$  closed loop scanning and pulling range



## Atomic Force Microscope (AFM) cont'd.

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- **Motorization / tip approach:** X, Y, and Z axis fully motorized. Tip approach is motorized and controlled by software
- **Available imaging modes:** Contact mode, Tapping mode, ScanAssist, Nanoindenting/scratching. All modes scan either in air or fluid.
- AFM is designed to function both as an independent AFM as well as in conjunction with an inverted optical microscope such as the Olympus IX81 in our laboratory.
- When using the AFM in conjunction with an optical microscope, the Microscope Image Registration and Overlay (MIRO) software allows integration of optical images (from the CCD camera on the microscope) and AFM images.



## CNC Vertical Milling Machine

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The Haas Mini Mill is capable of performing most common machining operations such as profiling, slotting, facing, pocketing, drilling, reaming, and tapping.

- 7.5 hp 6000 rpm spindle
- Up to 500 inch per minute feed rate
- Travels: X axis: 16", Y axis: 12", Z axis: 10"
- Table can hold up to 500 lb work piece
- Mastercam Cad/Cam programming software
- Repeatable part to part accuracy and consistency
- Automatic tool changer with 10 pocket carousel
- Coolant flush minimizes heat generated in work piece
- Renishaw Wireless Intuitive Probing System for locating and measuring
- Haas machines are ISO 9001 certified



## CNC Toolroom Lathe

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The Haas Toolroom Lathe is capable of performing most common machining operations such as profiling, turning down diameters, facing, threading, drilling, reaming, and tapping.

- 7.5 hp 2000 rpm spindle
- Quick change tool post
- 3 jaw scroll chuck
- Max cutting diameter: 16”
- Max cutting length: 30”
- Mastercam Cad/Cam programming software
- Repeatable part to part accuracy and consistency
- Coolant flush minimizes heat generated in work piece
- Haas machines are ISO 9001 certified



## Sample Preparation

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TECHNICS Sputter Coater

LADD Critical Point Dryer

Calcified Tissue Histology

REICHERT-JUNG Polycut E Sledge  
Microtome

SHANDON Autosharp 5 Microtome Knife  
Sharpener

STREURS Accutom- 50 Sectioning Saw

LECO Grinder/Polisher

LECO Low Speed Sectioning Saw (MMA)

Coating Application

Allied High Tech -TechPrep grinder/  
polisher with MultiPrep head

Mitutoyo 543-452B thickness gauge

CHEMAT TECHNOLOGY Model KW-4A Spin  
Coater

Materials Processing

Leica-EM ACE 600 High Vacuum Sputter  
Coater

DELTECH Glass Melting Furnace

Box Furnaces (3)

PRO 100 Ceramic Vacuum Furnace

Lindberg Blue 1200 °C Tube Furnaces (2)  
Single-zone 2" dia.

Three-zone 6" dia.

Tissue Culture Facility

Polymer Synthesis Laboratory

Struers LectroPol - 5 Electropolisher

Struers Discotom-6 Cut-Off Saw

Struers Accutom-50 Sectioning Saw (2) --  
correction of item name

Struers TegraPol Automated Polisher (2)

Struers Citopress-20 Mounters (2)

Buehler Electroetcher

Buehler Vibromet 2 Vibratory Polisher

## Equipment Usage Rates

	Hour	Half-Day	Day	Week
X-Ray Diffraction	\$75	\$180	\$290	\$715
MTS 810 / 812 or ADMET Test Systems	\$75	\$180	\$290	\$715
MTS Multi-Frame Flex Test (per frame)	\$50	\$105	\$180	\$440
TA Instruments electroforce 3220 DMA	\$75	\$180	\$290	\$715
MTS/Sintech Screw Machine	\$50	\$105	\$180	\$440
MTS 8-Station Wear Tester	Call for Quotation			
MTS Mini-Frame Test / MTS Evolution	\$50	\$105	\$180	\$440
Nanoindenter	\$95	\$210	\$355	\$880
Laser Scanning Confocal Microscope	\$75	\$180	\$290	\$715
Optical & Fluorescence Microscope	\$50	\$105	\$180	\$440
Scanning Electron Microscope (SEM)	\$105	\$260	\$440	\$1105
Energy Dispersive X-Ray Spectrophotometer (EDAX)	\$80	\$205	\$335	\$845
Electron Back Scattered Diffractometer (EBSD)	\$80	\$205	\$335	\$845
Fourier Transform Infrared Spectrophotometer (FTIR)	\$55	\$130	\$225	\$555
Inductively Coupled Plasma Spectrophotometer (ICP-MS)	\$95	\$210	\$355	\$880
Laser Ablation / TGA/TMA System	\$55	\$130	\$225	\$555
Differential Thermal Analyser (DTA)	\$55	\$130	\$225	\$555
Differential Scanning Calorimeter (DSC)	\$75	\$180	\$290	\$715
SpectroMax-Arc/Spark Compositional	\$95	\$210	\$355	\$880
Micro-CT	\$95	\$210	\$355	\$880
Gel Permeation Chromatography	\$55	\$130	\$225	\$555
AFM	\$95	\$210	\$355	\$880
Gamry / Potentiostat Corrosion System	\$50	\$105	\$180	\$440
Cerec CAD/CAM System	Call for Quotation			
Mini Mill and Lathe	\$75			
Fretting Corrosion System				\$275



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