

**Materials Science and Engineering  
(EQUIPMENT INVENTORY)**

## **Equipment and Facilities (Sirriner Hall)**

The Clemson Material Sciences Department also contains 11 laboratories, comprised of the Weaving Laboratory and Nonwoven Laboratory, the Dyeing, Finishing & Printing Laboratory, the Clemson Apparel Research Facility, a Composites Fabrication Facility, physical testing and fiber physics laboratories, an electrical/electronic fiber and fabric properties laboratory, an extrusion and rheology facility, an analytical laboratory, and an Analytical Laboratories Advanced Metallic and Composites Group. Graduate students from the School also have access to the University's excellent electron microscopy (scanning, transmission and Auger microanalysis) laboratory, a newly installed X-ray diffractometer in Ceramic Engineering, stereo lithography in Bioengineering, and hydraulic mechanical testing for fatigue analysis in Mechanical Engineering. Clemson University also provides its graduate students with universal Internet access and outstanding mainframe, mini and micro-computational support.

### **Weaving Laboratory**

The Weaving Lab contains a Herzog Braider with 2-16 Spool Discs; A Herzog Winder with a 2 Spool w/Creel.

**The New Nonwoven Lab** contains a CMC Rando - Opener/Cleaner, a Bamatic Chute Feeder, a Bamatic Card, a Bamatic Cross Lapper, and an Automatex Needle Puncher.

**The Web Formation lab** contains a 12" Rando Webber, a 20" Proctor and Schwartz Roll-Top Card, and an EVAC Vacuum System,

**The Web Finishing Lab** contains a 20" Aztec Hot-Air Thru Oven 20"; a Benz Thermal Bonding Calendar; a James Hunter 9" Pin-Sonic Bonder for fusing thermoplastic binders; a 12" Fiber Locker Needle Punch; and a 12" Hydro-Entanglement Water Jet System.

**The Dyeing, Finishing & Printing Laboratory** contains two (2) Despatch Ovens, an Ernst Benz Oven, a Rotary Washer, a Centrifugal Extractor, a Speed Queen Industrial Dryer, a Padder and Ern Benz oven for industrial comparisons of latex trials, a Stork Roller Printer, a Werner Mathis Steamer, a Paddle Wheel Dyer, two Atlas Launderometers, a Flat Bed Screen Printer, an Ahiba Dyer, and an Atlas Fadeometer with a carbon arc lamp.

**Composites Fabrication Laboratory** contains a Carver 18x18" 60 Ton, 350 C, Hydraulic Press.

**Physical Evaluation Facility**—Room 270/272—The PEF, which serves **the** Graduate Students, and Faculty of the School of Materials Science and Engineering, is also available to other

Departments in the COES and the University. The Laboratory uses various published "Standards" such as American Society Testing & Materials (ASTM), Federal Test Methods (FTM), American Association of Textile Colorists & Chemists (AATCC ) as well as "Standards" written by individuals and companies to accomplish the testing required. This assures compatibility and repeatability between tests and other facilities.

The PEF has the following equipment.

#### Fiber and Yarn Property Characterization

- Zellweger Uster HVI 900
- Zellweger Uster AFIS
- Zellweger Uster, Uster Tester III
- Zellweger Uster, Uster Tester IV
- Techno Statimat II M
- Lawson Hemphill CTT Yarn Tester
- Lawson Hemphill EIB Yarn Tester

#### Fiber/Yarns/Fabric Characterization

- Instron 1125R/5500
- Instron 5582
- Textest 3000 Hydrostatic Head Tester
- Textest 3300 Air Permeability Tester
- Textest 3700 Digital Elmendorf
- Pilling, Abrasion, Burst, Drape, Flammability

#### Optical Microscopy and Image Analysis Systems (2)

- Aus Jena JENAPOL U INTERPHAKO Polarizing Mach Zehnder Interference Research Microscope (Birefringence)
- Leitz Labrolux R/T w/lightfield and darkfield
- Fiber Microtomes
- Beuhler Two Head Polisher/Grinder & Isomet 1000 Saw for sample Preparation
- Image Analysis Systems ( Color )
- Sony Video Printer
- Sony Digital Camera Model 90 with Martin Microscope Camera to Microscope Adapter
- Sony Super VHS Recorder with Camera and Lens

#### Color Measurement

- MacBeth ColorEye 3000 Spectrophotometer
- Xrite SP78 Spectrophotometer

**The Fiber Physics Laboratory** is equipped with a computer-controlled single filament torsional modulus instrument, a breaking twist angle tester, a Keithley, Inc., System for electrical, conductivity measurements, electrostatic voltmeters, a thermal conductivity testing apparatus, a

single fiber acoustic emission failure analyzer, a sonic modulus analyzer, a Keithly 6517A Electrometer/High Resistance Meter, and a Keithly 182 Sensitive Digital Voltmeter.

**The Electrical/Electronic Fiber and Fabric Properties Laboratory** is equipped with a Hewlett Packard 8757XB Microwave Scaler Network Analyzer 100MHz to 50GHz, a Hewlett Packard Scaler Analyzer (S parameter test), a Questek 2010 Excimer Laser, an Alessi Four Point Probe, a Keithly 228A Voltage/Current Source, a Keithly 220 Current Source, a Keithly 197A Microvolt Digital Multimeter, and Keithly 2000 and 2001 Digital Multimeters.

**The Extrusion and Rheology Laboratory** has a Hills, Inc. Pilot Scale Fiber Extruder, 1", 1800 m/min, a Barmag SW7 High Speed Winder, a Instron Capillary Rheometer, a Haake Rheocord 90 Rheometer, a Brookfield DV-III Rheometer, a Lab Scale Wet Spin Line, an Instron 4502 with Model 3210 Rheometer, and a Headway Research, Inc. PM 101DT-R790 Spin Coater.

The **Analytical Laboratories** have equipment for conducting work in the following areas.

- **Chemical Analysis, Separation Science:** Equipped with a Dionex Liquid Chromatograph with GP50 Pump & AD25 Absorbance Detector; a Waters Breeze Gel Permeation Chromatograph with Waters 2487 UV/Vis, Waters 2414 DRI, Waters 717 Auto-Sampler & PolymerLabs PL-ELS 2000; and a Selerity Series 4000 SFC.
- **Spectroscopy:** a Nicolet Magna 550 with NicPlan FT-IR Microscope and Mapping Stage, a Thermo 6700 FTIR with Continuum FTIR Microscope, a Shimadzu 3101-PC UV-Vis-NIR Spectrometer, an FT-NMR Spectrometer, and a Thermo Finnigan Trace GC/MS.
- **Chemical Instrumentation:** a Cahn Dynamic Contact Angle Analyzer, a SensaDyne Bubble Tensiometer, a Kruss DSA 10 Contact Angle Analyzer, a Suprex PrepMaster Supercritical Fluid Extractor, a Dionex ASE 200 Accelerated Solvent Extractor, a Wyatt Technology Dawn DSP Laser Light Scattering: 18 angle Ar+, and an Optilab DSP Differential Refractometer.
- **Thermal Analysis:** a 2950 Hi-Res Thermogravimetric Analyzer, a 2920 Differential Scanning Calorimeter, a TA Instruments Q1000 DSC, Q5000 TGA, and Q800 DMA, a Seiko Instruments SSC 5300 Thermal Analysis System, a Seiko DMS 210 Dynamic Thermal Mechanical Analyzer, a Seiko TMA/SS 350 Thermal Mechanical Analyzer, a Solomat TSC/RMA Relaxation Spectrometer, and a Parr 1455 Solution Calorimeter.

- **AMRL:** a Waters Gel Permeation Chromatograph: 815 HPLC Pump, Heated Columns, 410 DRI, 486 Abs. Det.; a Viscotek T50A Differential Viscometer; a Bio-Analytical Systems 100B Electrochemical Analyzer; and a Jupiter Instrument Co. Membrane Osmometer Model 231.

The **Advanced Metallic and Composites Facilities** have equipment for conducting research in the following areas.

- **Materials Processing:** a planar flow caster, an Ajax induction melting system, two Centorr arc melters, an Inert atmosphere melt spinner, a Lombard 150 ton vertical extrusion/forging press, a Stanat 2/4/6 high instrumented rolling mill, an equal channel angular extruder, a Solidica Form-ation ultrasonic consolidation system, two attritor mills, three powder blenders, shaker sieves, a spec's mill, a high temperature (2000C) inert atmosphere furnace, a single crystal puller, six Lindberg tube furnaces, five Lindberg box furnaces, six thermcraft salt baths, two low temperature oil baths, a Huppert recirculating air furnace, a Marshall vertical quench furnace, a high temperature(1650C) inert atmosphere quench furnace, a high pressure infiltration system, a low pressure infiltration system, and a Quartz Encapsulation system
- **Material Characterization:** a Scintag XDS 2000 x-ray diffractometer, a Nikon inverted optical microscope, a Netzsch differential calorimeter (-110C to 1600C), two in-situ, inert atmosphere high temperature resistivity systems, an Eddy current apparatus, a dynamic modulus apparatus with assorted transducers, twelve high temperature creep machines, two MTS/Instron closed loop servohydraulic machines, Instron/MTI screw driven test machines, three RR Moore rotating beam fatigue machines, an RI Thermal fatigue apparatus, three automated reciprocating sliding wear apparatus, two pin-on-disk wear apparatus, a high velocity gas gun, and an instrumented SATEC impact machine
- **Metallographic Equipment:** a Struers Cut-off machine, a Buehler high speed diamond cut-off machine, a South bay abrasive wire saw, a Buehler hot press, surface grinder, four Buehler grinders, six Struers automatic polishers, three Vibramet automatic polishers, two Buehler electropolishers, a fatigue/tensile sample electropolisher, a South bay core grinder, a high definition scanner, two Gatan ion millers, a Gatan dimple grinder, a Gatan ultrasonic disk cutter, and a Fischione TEM jet polisher.

The lab also has software licenses for ABAQUS, Thermo-Calc, Carine Diffract, Adobe Photoshop, Image Pro and Fovea Pro.

The Clemson University School of Materials Science and Engineering (MSE) has a substantial inventory of equipment available for experimentation for the development of new polymers, fibers, ceramics, composites and metals. A list of this equipment is provided below.

#### **Knitter Analysis Fiber (Lawson)**

The FAK produces standard samples of knitted fabric with yarn consumption tolerances of 1 percent from sample to sample, or machines to machine. The FAK's Stitch Control System eliminates tension variations, which can cause unevenness in the knitted fabric.

Yarn Types: Synthetic and natural fibers, monofilament, filament yarns and spun yarns

Yarn Denier: Alternate cylinders are available to knit yarns from 7 denier to over 1,000



Knitter Analysis Fiber

#### **Chromatograph Liquid watch**

HPLC is a popular method of analysis because it is easy to learn and use and is not limited by the volatility or stability of the sample compound. Modern HPLC has many applications including separation, identification, purification, and quantification of various compounds.

Chemical Separations can be accomplished using HPLC by utilizing the fact that certain compounds have different migration rates given a particular column and mobile phase. Thus, the chromatographer can separate compounds from each other using HPLC; the extent or degree of separation is mostly determined by the choice of stationary phase and mobile phase. For more information



HPLC Chromatograph

please see following website: <http://www.pharm.uky.edu/ASRG/HPLC/hplcmtry.html>.

### **Thermogravimetric Analyzer**

Thermogravimetric Analysis (TGA) is a thermal analysis technique used to measure changes in the weight (mass) of a sample as a function of temperature and/or time. TGA is commonly used to determine polymer degradation temperatures, residual solvent levels, absorbed moisture content, and the amount of inorganic (noncombustible) filler in polymer or composite material compositions

A simplified explanation of a TGA sample evaluation may be described as follows. A sample is placed into a tared TGA sample pan which is attached to a sensitive microbalance



Thermogravimetric Analyzer

The sample holder portion of the TGA balance assembly is subsequently placed into a high temperature furnace.

The balance assembly measures the initial sample weight at room temperature and then continuously monitors changes in sample weight (losses or gains) as heat is applied to the sample. TGA tests may be run in a heating mode at some controlled heating rate, or isothermally. Typical weight loss profiles are analyzed for the amount or percent of weight loss at any given temperature, the amount or percent of noncombusted residue at some final temperature, and the temperatures of various sample degradation processes.

### **Gas Chromatograph**

Gas chromatography - specifically gas-liquid chromatography - involves a sample being vaporized and injected onto the head of the chromatographic column. The sample is transported through the column by the flow of



Gas Chromatograph

inert, gaseous mobile phase. The column itself contains a liquid stationary phase which is

adsorbed onto the surface of an inert solid. There are many detectors which can be used in gas chromatography. Different detectors will give different types of selectivity. A *non-selective* detector responds to all compounds except the carrier gas, a *selective detector* responds to a range of compounds with a common physical or chemical property and a *specific detector* responds to a single chemical compound.





Gas Chromatograph

Gas chromatography - specifically gas-liquid chromatography - involves a sample being vaporized and injected

Analyzer Particle Size Horiba onto the head of the chromatographic column. The sample is transported through the column by the flow of inert, gaseous mobile phase. The column itself contains a liquid stationary phase which is adsorbed onto the surface of an inert solid.

#### Factors which affect GC separations

Efficient separation of compounds in GC is dependent on the compounds traveling through the column at different rates. The rate at which a compound travels through a particular GC system depends on the factors listed below:

- **Volatility of compound:** Low boiling (volatile) components will travel faster through the column than will high boiling components
- **Polarity of compounds:** Polar compounds will move more slowly, especially if the column is polar.
- **Column temperature:** Raising the column temperature speeds up all the compounds in a mixture.
- **Column packing polarity:** Usually, all compounds will move slower on polar columns, but polar compounds will show a larger effect.
- **Flow rate of the gas** through the column: Speeding up the carrier gas flow increases the speed with which all compounds move through the column.
- **Length of the column:** The longer the column, the longer it will take all compounds to elute. Longer columns are employed to obtain better separation.

**The boiling points of the different components are the primary factor** when separating compounds on the GCs in the teaching labs. For more information please see the following website. <http://www.shu.ac.uk/schools/sci/chem/tutorials/chrom/gaschrn.htm>  
<http://orgchem.colorado.edu/hndbksupport/GC/GC.html>



Graphite Element Furnace System with Pyrometer



X ray diffraction system



Horiba Particle Size Analyzer

**Extensometer Calibration Fixture W-Data Unit:** An extensometer is used to measure the elongation (the length change) of the specimen directly attached at two points along the test piece along the line of the applied force. The change in length measured by the extensometer (extension) is divided by the distance between the two contact points (gauge length) to give the strain.

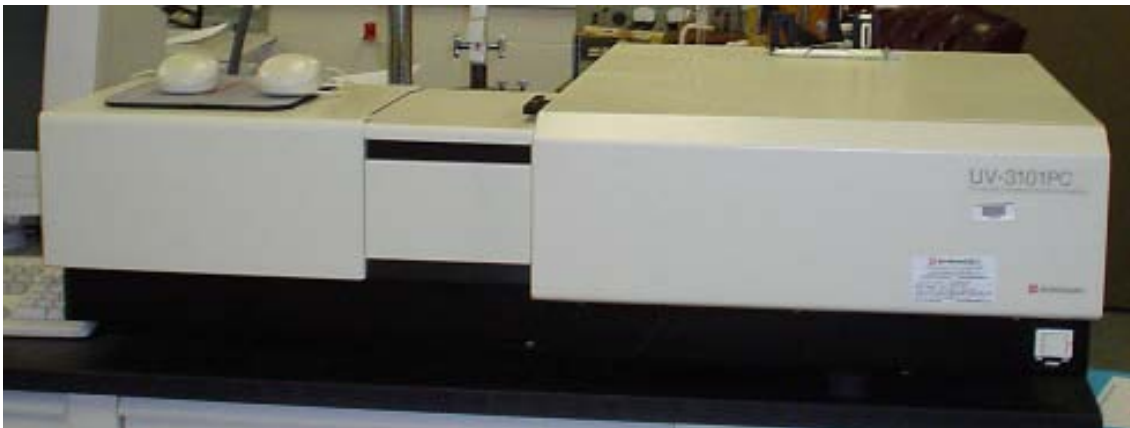


**195730---Module Cell Base TGA:** Thermogravimetric Analysis (TGA) is used to measure weight changes in a material as a function of temperature (or time) under a controlled atmosphere. It can also be used to determine the fraction of volatile components in a material. The TGA equipment consists of a very sensitive balance and an oven. The fractional weight loss as a function of temperature is registered by a computer. The basic description of this instrument is shown as below.

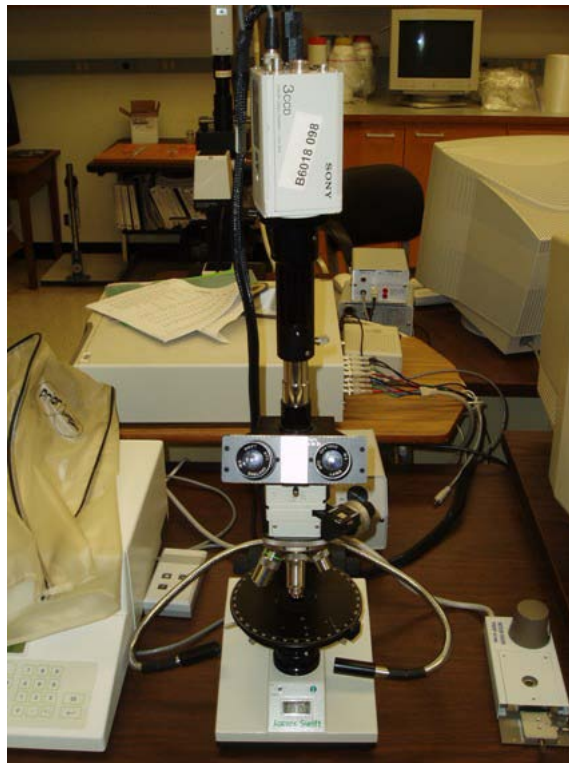
- Model temp range: RT to 1000 °C
- Mass Range: 0 to 1500mg
- Maximum Sample Volume: 500 $\mu$ L
- Baseline noise:  $\pm 0.05\mu$ g
- Dynamic Range: 1000mg
- Balance Accuracy:  $\pm 0.1\%$
- Automated Sample Handling



**Shimadzu UV-3101PC Advanced Productivity Pack System:** Used to determine qualitative molecular structure and also the quantitative characteristics of chemical reactions. This instrument provides fast and non-destructive inspection of absorbance and reflectance of samples such as thin films, solutions and powders on a wide wave length of 190-3200 nm.

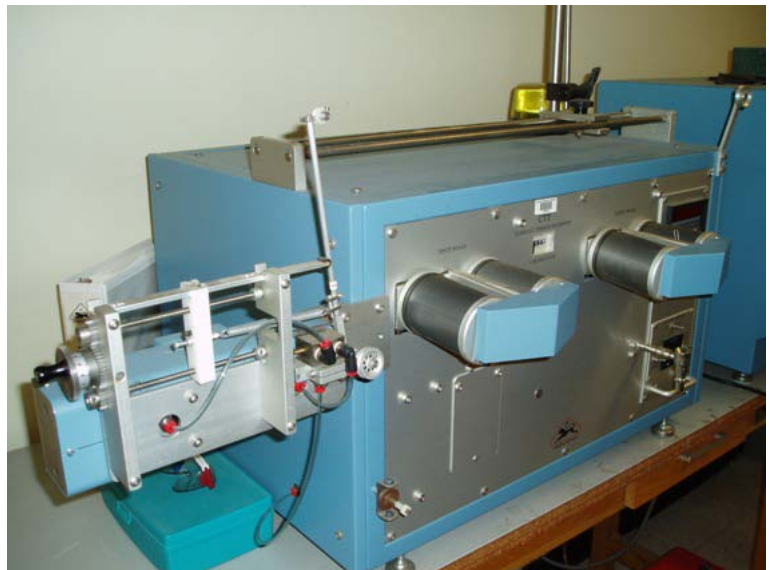


**Trinocular Polarizing Microscope:** Optical microscope equipped with a Sony CCD camera. The sample stage can be lowered to accommodate large samples.



**Constant Tension Transport –**

The CTT is a dynamic testing unit which allows for modifications of accessories in order to achieve many tests such as lint, weak spots, abrasion, friction, shrinkage and appearance for spun and synthetic fibers. This instrument is used to study study yarn appearance, weak spot testing, abrasion and lint properties, air texturizing properties of yarn, entanglement, and fiber shrinkage.



## Electronic Inspection Board Instrument

This instrument is designed for use in analyzing entanglements in filament yarns. Using the high resolution camera and software, the imperfections in a yarn can be detected. There are three software modes.



1. Profile Mode: The CCD camera captures and records the actual profile of running yarns. The profiles can be viewed and events such as entanglements, balloons and tight spots can be analyzed.
2. Production Entanglement Mode: It is the only software that detects sections of missing entanglements. The software provides complete statistical output including limits, summary printout and histograms.
3. Inspection Board Mode: Long sections of entangled yarn can be viewed and analyzed. Event size thresholds can be set which allows unentangled, entangled or tight spot areas to be grouped by length and a fabric simulation shown to view their distribution.

**1700c Furnace Linberg Tube:** The Furnace/Lindberg 1700C Tube is a controlled temperature and high temperature tube configuration furnace to +1700°C. This furnace provides superior radial and linear temperature uniformity with resistance to thermal shock. The independent digital temperature control has multiple programmable segments useful for a wide range of applications.



### **TesterHydrostaticHeadFx3000**

The TEXTEST FX 3000 Hydrostatic Head Tester is designed to determine the resistance of plastic foils, coated and uncoated fabrics, and non-wovens to water penetration. This test procedure employs the use of a hydrostatic head tester.



### **TesterAirPremeabilityFx3300**

The FX3300 air permeability tester is used for fast, simple, and accurate determination of the air permeability of all kinds of flat materials and of foam cubes. The measuring range covers dense papers and airbag fabrics as well as extremely open non-wovens and forming fabrics.



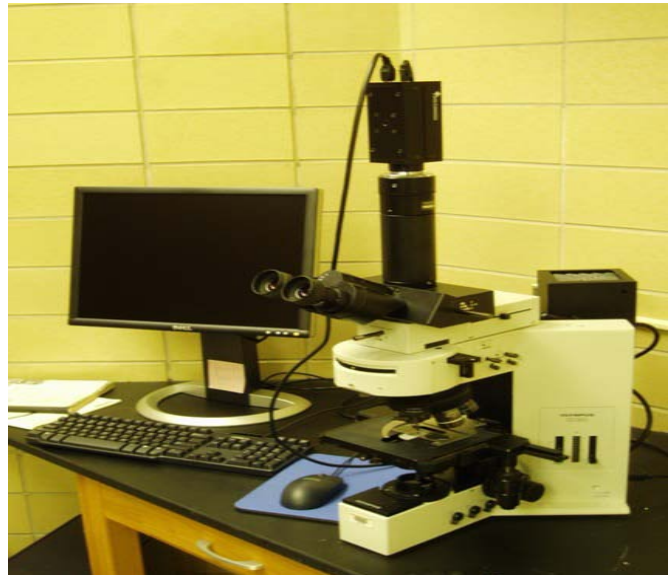
**ASE200 Accelerated Solvent Extractor:** The ASE (Accelerated Solvent Extraction) is used for extracting solid and semisolid samples with liquid, organic or aqueous solvents. Extractions can be done in minutes with unparalleled labor savings. It can extract up to 24 samples, unattended, and deliver filtered extracts, ready for cleanup and analysis. Only 15mL of solvent is required for a 10 gram sample. Approximately 70-80percent of all ASE extractions are completed in less than 15 minutes using the standard ASE extraction conditions (100 C, 1500psi). If these initial parameters fail to provide desired recoveries, simply increase the temperature to improve extraction efficiency. Adding static cycles, increasing static time, and selecting a different solvent are additional variables used to optimize methods.



**410 Differential Refractometer:** This instrument is used as a refractive index detector. It can monitor the difference in refractive index between the eluent and the pure mobile phase continuously. It is a universal detector unlike an UV detector in that you will get a response for any polymer that has a significant difference in refractive index as compared to the eluent.

**High Voltage Amplifier with Cables:** Used to precisely produce a high voltage output replica of a low voltage waveform. A maximal voltage is 4kV and the maximal current is 20mA.

**Olympus BX60 Brightfield Darkfield Microscope:** The Olympus BX60 is an optical microscope for reflection and transmission. In both modes polarized light is employed for sample analysis. The total magnification in the present configuration is 1000x. The sample stage can be lowered to accommodate large samples. This microscope is equipped with a CCD camera, monitor and computer on which "Image J" picture software is installed. Objectives, 5, 10, 20, 50, 100x are available.





**Automated Dynamic Contact Angle (DCA):** Surface analyzer to understand the complex interactions at liquid-liquid and liquid-solid surfaces. Whether you need to improve adhesion, apply a coating or modify a surface, a DCA system provides solutions for:

- Surface energies, wettability, cleanliness and topographical homogeneity of solid sheets, films, and fibers
- Surfactant analysis with the automatic Critical Micelle Concentration, CMC, program
- Dry material absorption, wicking rate.
- Contact angle of powders, Washburn Method





**Induction Furnace** - Used for heat treatment quenching. The samples can be heated to a certain temperature under air or another gas and quickly plunged into cold water to cool down the temperature at a sufficiently high rate.



**PL-EMD Evaporative Mass Detector**

### **Gretag-Macbeth Spectrophotometer**

This spectrophotometer accurately measures the widest variety of sample shapes, sizes, textures and opacity. The Color i 5 is the only instrument with a built-in profile that lets you select between measurement compatibility with legacy data or today's higher precision data. Instrument features include

- Tri-beam technology that simultaneously measures specular component included and excluded for simplified gloss assessment.
- Multiple area of view in both reflectance and transmittance for the most versatility in measuring non-uniform and variable size samples.
- Self-adjusting, dual zoom lens that eliminates configuration errors between aperture plates and lens position.
- Video preview and sample drop door for precision targeting and measurement accuracy.
- Automated ultraviolet adjustment for speed and convenience when measuring fluorescent or optically brightened samples.

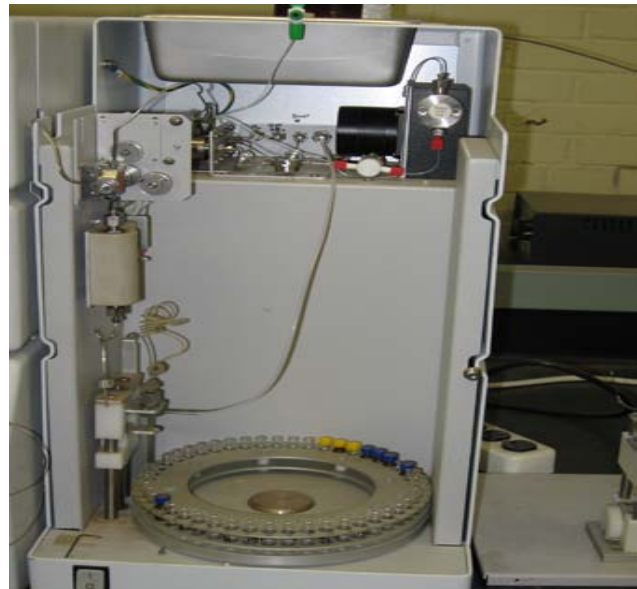
**Ravenel Center autoclave pre-assembled mini-bonder** – The Mini-Bonder autoclaves are available for composite materials bonding, glass laminating, printed circuit board laminating, sterilizing, and rubber curing and vulcanizing. They are used for graphite-to-epoxy bonding, honeycomb structural bonding, and glass-to-metal bonding. Cycle times, temperatures, and pressures can be determined, and raw materials ensuring quality can be evaluated.



**Workstation SPARC IPX SUN** - Housed in 102 Rhodes, this workstation has the computer software that interfaces with the equipment and instruments.

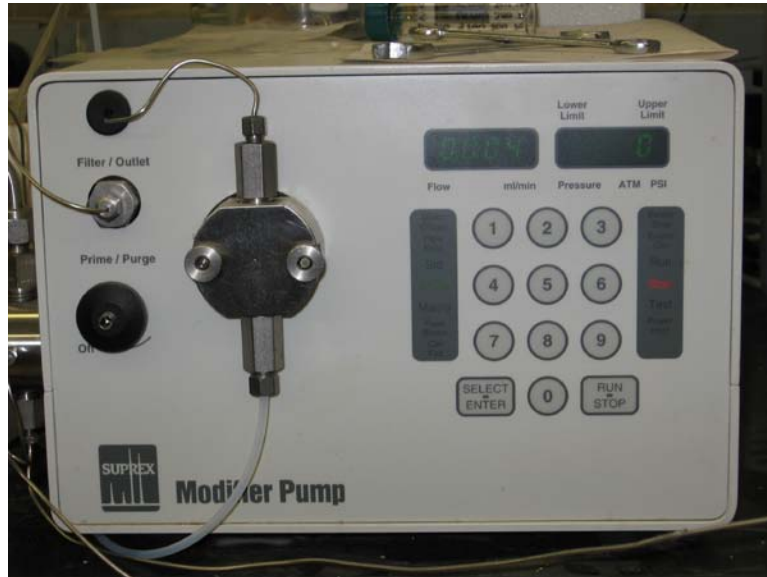


**Prepmaster Integrated SFE System**



**ACCUTRAP Cryogenic Module with Restrictors**

All the above three instruments together form equipment used for extraction of samples using super-critical carbon-dioxide and thereby a super-critical treatment of materials. General samples used for the extraction are fibers and result obtained is in the form of the amount of material extracted.



**Pump Modifier**

The impedance analyzer is an integrated solution for efficient impedance measurement and analysis of components and circuits covering a broader test-frequency range with Basic impedance accuracy:  $\pm 0.08\%$ . The Excellent High Q/Low D accuracy enables analysis of low-loss components. The wide signal-level ranges enable device evaluation under actual operating conditions. The test signal level range is 5m V to 1 Vrms or 200  $\mu$ A to 20m Arms, and the DC bias range is 0 V to  $\pm 40$  V or 0m A to  $\pm 100$ m A. Advanced calibration and error compensation functions eliminate measurement error factors when performing measurements on in-fixture devices. This is a powerful tool for design, qualification and quality control, and production testing of electronic components. Circuit designers and developers can also benefit from the performance/functionality offered.



## Impedance Analyzer



The purpose of this test is SOLOMAT TSC/RMA 9100 out materials by using their molecular mobility. Thermally stimulated currents/relaxation map analysis is applied to any semi-conductor or isolating material to analyze the relationship between a material and its molecular structure. Samples can be in the form of films, gels, powder, pellets or liquid. The measurement does not need any preparation, such as a metallic deposit, with thicknesses of one millimeter measured by micrometer.

The Differential Scanning Calorimetry (DSC) is a thermal analysis technique which has been used for more than two decades to measure the temperatures and heat flows associated with transitions in materials as a function of time and temperature. Such measurements provide qualitative and quantitative information about physical and chemical changes that involve endothermic and exothermic processes, or changes in heat capacity.



This technique measures temperatures and heat-fluxes as a function of temperature and time. This type of DSC provides useful information about: melting points, glass transition temperatures, crystallinity, heat capacity, and thermal stability and transformation temperatures.

The DTA is used to check complex phase changes in ternary and even quaternary melt systems. Such systems are often industrially relevant as for example perovskites (high temperature superconductors) and garnets (laser host crystals) reveal with certain compositions such as complex behaviors.



Microscope NIC Plan  
w/Objective



NICOLET Spectrometer High Performance

Fourier Transform Infrared Spectroscopy (FTIR) is an analytical technique used to identify organic (and in some cases inorganic) materials. This technique measures the absorption of various infrared light wavelengths by the material of interest. These infrared absorption bands identify specific molecular components and structures.

The USTER AFIS is a single fiber testing machine suitable for spinning mills. It has have different modcules: comprising i) Module N for the analysis of the nep count, and nep size; ii) Module L&D to measure fiber length and diameter; iii) Module T determines the number and size of particles of foreign matter, dust and trash; iv) the Multi-Data module to simultaneously determine neps, trash, dust, fiber length and diameter of a sample; and v) the Auto-jet module for automatic loading of the test sample. With USTER AFIS unsuitable cotton types, incorrect machine setting, and changes of quality can be recognized quickly and reliably. Above all maintenance costs can be reduced particularly with respect to card clothing.



The testing principle is the same regardless of the model. A test sample is clamped between two circular plates with a pneumatic system. Fluid displaced from a chamber by a piston moving at a constant rate forces a heavy rubber diaphragm to expand through the lower plate opening and exert a constantly increasing pressure against the unsupported area of the sample. When the sample bursts the pressure drops, and the force required to burst the sample is displayed.



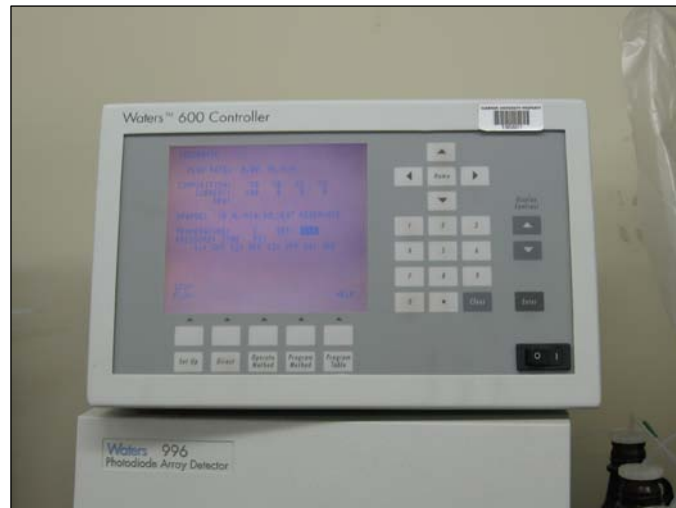
**Diaphragm Burst with Test Gauge**

Load cells use bonded foil and semiconductor so that your sensor will provide the best measurement possible given the conditions encountered in your application. These units measure a wide range of force; 25 grams to 20,000 lbs. Load cells also offer the highest levels of accuracy and commercially available today; 0.05% to 0.5% F.S. while coping with temperatures from  $-60\frac{1}{4}F$  up to  $320\frac{1}{4}F$ . There is a wide range of load cell sizes including miniature load cells along with an extensive list of connector types including submersible, underwater cable connections.



**Cell Tension Compression Load**

The Multisolvent Delivery System is used for the separation analysis of various applications in High Pressure Liquid Chromatograph (HPLC) systems



Multisolvent Delivery System

Chemisorption, refers to the chemical adsorption and desorption phenomena by which gas or vapor molecules bond to or are liberated from the solid surface of sample material. Because the chemisorptive (gas or vapor) adsorbs only on surfaces having particular chemical properties and does so only under certain thermal conditions, it can be used to probe a surface for a specific molecular species. The most widely used application of this aspect of chemisorption is to determine the surface area only of specific adsorption sites on a heterogeneous surface, for example, the active metal surface residing on a supporting substrate. This typically is expressed in terms of active metal surface area, metal dispersion or percent metal.



Pulse Chemisorption and Surface Area Analyzer



The Tensiometer QC 6000 Surface/Sensadyne Instrument technology used for the SensaDyne is a refinement of the Maximum Bubble Pressure Method. An inert process gas (nitrogen or dry air) is bubbled slowly through two probes of different radii that are immersed in a test fluid. The bubbling of the nitrogen through the probes produces a differential pressure signal ( $\Delta P$ ) which is directly related to fluid surface tension. Keeping the two probes at the same immersion depth cancels the effects of liquid level. All the effects influencing the pressure value, such as liquid density, radius of the bubble tube orifice, gravitational constant and depth of bubble formation are fully and accurately identified, measured, and resolved.



The IsoMet 4000 saws is a precision sectioning tool capable of cutting virtually any material, including brittle and ductile metals, ceramics, composites, cements, laminates, plastics, electronic components and biomaterials

The Randcastle Microtruder is a single screw extrusion system for films and fibers. The screw has a 1/4-inch diameter (6.35 mm), typical amounts for one run are around 10 g. The barrel temperature is controlled independently by three heating zones, one extra temperature controller is responsible for the die block or film die. For fibers, the melt is extruded vertically, films are drawn over a chill-roll horizontally. No pressure gauge or vacuum degassing is possible, the feed stock must be ground to appr. 1000 microns diameter, commercially pellets can't be fed. Feeding zone and gear plate are water cooled.



**Randcastle Microintruder**

The KZK Powder Testing Center provides basic information necessary in designing and controlling a dry powder compaction process. The tests are also used for evaluation and quality control of powders not destined for compaction. The testing capability covers a wide range of powders: metallic, ceramic, refractories, nuclear, pharmaceutical, abrasives, explosives, chemicals and others. A pressure holding option accommodates powders that require time for internal reactions. The testing process is computer controlled and automated. A typical test takes less than 10 minutes (for cold dies) allowing testing for direct quality control on production lines.



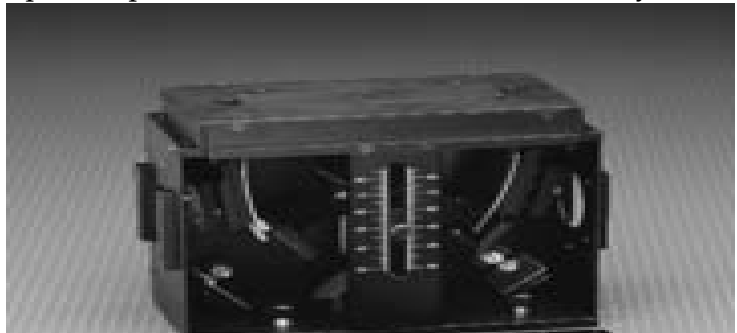
KZK Powder Testing Center

The scope of application for the Drop Shape Analysis System ranges from treated polymer and foil surfaces to paper, textiles, wafers and liquid polymers. Automation produces a user-independent, and reproducible, result.



Drop Shape Analysis System

Specular Reflectance is a technique for analyzing transparent films which usually yield weak spectra by ordinary transmission techniques. Applications include surface coatings on reflecting substrates; film thickness measurements by interference fringes and reflectivity coefficient determinations of metals. The application is the determining factor when deciding which angle of incidence should be selected. A 30 degree angle of incidence is normally chosen for more routine samples which have coating thicknesses in the micrometer range. For very thin coatings in the nanometer thickness range, an 80 degree angle of incidence would be appropriate. When sample thickness is unknown, the full range of specular reflectance analysis can be performed conveniently with the VeeMax II, Variable Angle 30 - 85 degree accessory. Simply move the sliding lever on the graduated scale to the desired angle. Using the precision angle adjustment, the angle of incidence can be increased or decreased depending upon the sensitivity requirements of the sample. As the angle of incidence changes the depth of penetration and absorbance intensity...the angle is selected to optimize sensitivity. Measured absorbance is directly related to the depth of penetration controlled by the angle of incidence. Sensitivity can be further enhanced with the use of a wire grid polarizer.



Vee Max II



Master Cycle Gradient

## MTI-2000 Dual Channel Fotonic Sensor Mainframe; Serial # 1506

The MTI-2000 is an equipment to exactly measure displacement and vibrations of tools. It sets new performance standards with resolution to 0.01 microinch (2.5 angstroms) and frequency response from direct-coupled (dc) to 150 kHz. Dual-Channel Capability permits simultaneous measurements of amplitude and phase at two locations. Digital Display Readout in engineering units eliminates the need to convert volts to displacement units or to double integrate acceleration signals. A Peak-to-Peak Display mode allows the MTI-2000 to be used as a self-contained vibration measurement tool. An Easy-to-Read Bargraph Display simplifies setup and gives an "analog feel" to the instrument. An Out-of-Range Indicator notifies the user if a probe moves out of preset range, preventing measurement error. Pushbutton Operation simplifies the calibration of fiber-optic probes. Interchangeable Probe Modules allow the user to select from seven standard fiber-optic probe designs for the sensitivity, range and frequency response they need. Custom modules can be supplied to meet specific frequency response or gain requirements.



## High resolution TGA 2950

TGA measures the weight loss of the sample over a given temperature range. The concentration of volatiles, degradation temperature, or any reaction taking place in the applied temperature conditions can be monitored and studied. The instrument can be connected to N<sub>2</sub> supply and the sample can be tested in inert conditions. By controlling the rate of heating, occurring events can be separated.



TGA 2950

### **NT Controller, TC15 Mettler TGA**

The Mettler Toledo TC15 TA Controller (thermal analysis) allows TGA measurements from -170 to 600°C. The experiment parameters are composed in a PC and sent to the TC15 where the segments of the temperature program are controlled. During a measurement the data are transferred to the PC for an on-line curve in the module control window. (No pic)

### **Dynamic Mechanical Analyzer and Accessories**

Dynamic Mechanical Analysis measures the mechanical properties of materials as a function of time, temperature, and frequency. Dynamic mechanical rheological testing (DMRT) is probably the most versatile thermal analysis method available, and no other single test method provides more information about a sample in a single test. Besides providing important material property data, DMRT provides a direct link between a material's chemical makeup and its mechanical behavior. Materials can be characterized by DMRT regardless of their kind, their physical state, or the form in which they are used. (no pic)

**Lab Unit, Olin hall 103** - Six fume hoods and lab benches

### **Electromet 4 Electropolisher**

Electrolytic sample preparation provides an efficient method for polishing and etching of solid solution alloys including stainless steel. It consists of a power source, an etching cell, polishing cell and accessories. It has various automated features like voltage and temperature control, presetting the time of etching or polishing etc.



Electromet Electropolisher

### **RT66A Ferroelectric test system; HVA4040 1- 206T**

The RT66A Standardized Ferroelectric Test System is specifically designed to perform the tests required for characterizing non-linear ferroelectric thin films or specific bulk ceramic devices. It combines the features of a function generator, an electrometer and a digital oscilloscope in a single package. The tester is controlled from a IBM PC or compatible. The user specifies the operations, which the tester is to perform from a menu driven interface. The RT66A software then executes the appropriate hardware commands, collects and processes the data, and then displays the results on the user's screen.

## Laboratory jaw crusher

## MLSSA 2000 measurement system

The MLSSA allows to perform both frequency response and impedance measurements of loudspeakers. Impedance and frequency response curves can be displayed and printed together on the same graph. Reference loopback measurements of even the highest powered amplifiers are performed automatically and safely. The MLSSA also includes a four-input microphone multiplexer for automated spatially averaged room measurements. Up to four units can be daisy chained to expand the number of inputs and/or power amplifiers supported by a single *MLSSA 2000* card.

## Thermo Finnigan Trace GC/MS:

The instrument is capable of performing Gas chromatography applications usually limited to volatile organic compounds. The Mass Spectrometer provides structural information about the target analyte.



## Dual Evaporation system Denton

This is a dual e-beam/thermal evaporator for the deposition of Au, Ag, Cu, Ni, Cr, Al, Ti, Fe, Co and W. It has a six pocket electron gun, two electrodes for thermal sources, wafers from 2" to 6," 4 wafer capacity, cryopumped with a base vacuum of 5E-8T, uniformity shield yielding thickness uniformity of 4 % over 4" wafers.



### **Generator, ONXDS Scintag Research Unit**

The ONXDS is used to measure the texture of the crystallites. These measurements involve the study of variations in intensity of a single Bragg reflection as the sample is both tilted ( $\psi$ ) and rotated ( $\phi$ ) in a specially modified diffractometer. The graphical pole figure diagram presents contours that indicate intensity levels as a function of sample orientation



### **Capillary Flow Porometer; Serail**

The PMI Capillary Flow Porometer provides fully automated through-pore analysis including bubble point, pore size distribution, mean flow pore size, hydro-head, integrity, and liquid, gas, Frazier, Gurley, and Ray permeability. PMI's Capillary Flow Porometer is versatile - it allows the user to test samples under compression, tension, or elevated temperature, thereby simulating operating conditions. User-friendly and non-destructive, the Capillary Flow Porometer is an asset in quality control and R&D environments.

### **Preform Production Equipment**

#### **Fiber Prooftester/ Respooler**

#### **Programmable Substrate Heater Package; Griffith Building**

#### **Target Carousel Flange Assembly**

#### **Minilab Micro Compounder**

The HAAKE MiniLab microcompounder offers the ability to start formulation development with a limited amount of the new drug compound (only 5g). By using the optional force feeder, continuous hot melt extrusion with very small volumes is possible.



### **SA3100 Surface Area and Pore Size Analyzer**

The SA 3100 Series is a bench top BET surface area and pore size analyzer, which uses the static dosing method. This reference method uses helium to measure the sample tube free-space for highly accurate data. The unit has three vacuum out-gassing stations and one analysis port. User control is by an innovative touch screen. The SA 3100 with automated dewar lift is a complete systems with integrated outgassing stations and vacuum pump and is highly accurate. It features continuous saturation pressure measurement, has a minimum manifold volume to enhance sensitivity, and performs a multipoint helium free space measurement, to improve repeatability and accuracy. The system is PC Network compatible. An optional SA-PREP™ Surface Area Outgas Station is designed for customers who need extra capacity.



### **Six James Swift Polarizing Microscopes**

The Polarizing microscope provides information on absorption color and boundaries between minerals of differing refractive indices obtainable in brightfield microscopy, and also can distinguish between isotropic and anisotropic materials. The technique exploits optical properties of anisotropy to reveal detailed information about the structure and composition of materials, which are invaluable for identification and diagnostic purposes.



### **Instrument Planer Flow Casting System**

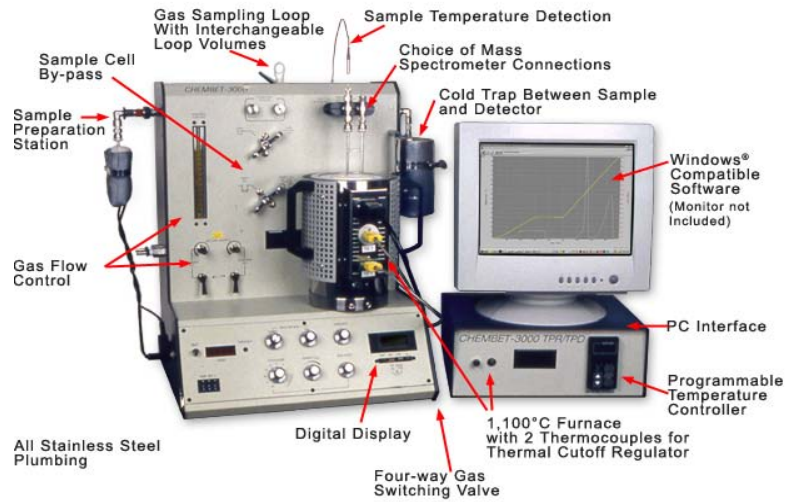
#### **High Temp Box Furnace**

This Fischer Science high temperature box furnace is used to heat, cure or dry samples. Temperatures as high as a 1000C are possible.



## 210936 Motex Detector- Pin Diode Detector

**Pulse Chemisorption and Surface Analyzer** – This device is designed to perform comprehensive catalyst studies via temperature programmed reduction, temperature programmed desorption, temperature programmed oxidation, pulse titration, and physisorption for B.E.T. Surface Area and Pore Volume

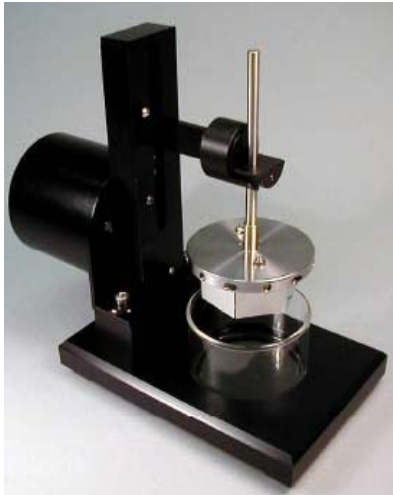


## 211019; Leica DM LM Microscope

The Leica DM LM Microscope is a light microscope used for routine materials analysis which is a magnification up to 100x. The CDA "color-coded diaphragm assistant" makes it easy to determine the proper diaphragm settings, and the built-in focus stop protects both your specimens and the front lens of the objective.

### **Q1000 modulated Differential Scanning Calorimeter:**

The Q1000 is a modulated DSC that measures  $T_g$ , Temperature of crystallization, Melting Point, Percentage crystallinity etc. the equipment is capable of analyzing 50 samples at one time. It has liquid nitrogen cooling system and modulated DSC technology which gives it increased sensitivity to detect weak transitions. The temperature that the equipment is normally operated at is  $-150^{\circ}\text{C}$ -  $400^{\circ}\text{C}$ .

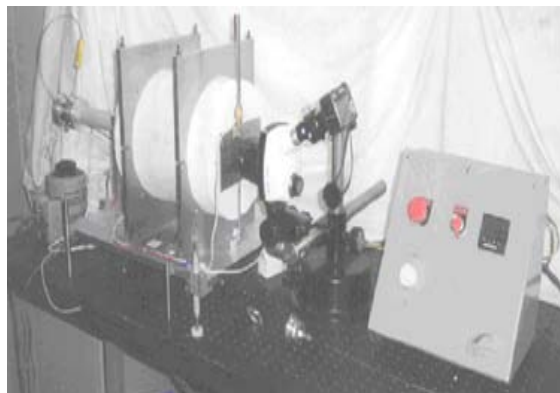


### **Model DC-Multi Dip Coater**

The Nima Dip Coater allows the fabrication of thin films by the sol-gel technique and monolayer self assembly. Parameters such as speed, immersion depth, wait intervals and dipping sequences can all be programmed. 8 beakers can be used for dip coating at a given time with a single substrate holder.

### **Elevated Temperature Droplet Imaging System**

It consists of a fluid dispensing system, an oven and an optical microscope in order to do the contact angle measurements at high temperatures. The oven is HTF55000 and the fluid dispenser is KW-4AD Fluid Dispenser.





### **Electrochemical Analyzer with cell stand**

The cell is enclosed in a Faraday cage to minimize electrical interference. A built-in gas control enables purging or blanketing of a sample prior to or during analysis. A magnetic stirrer allows for controlled agitation of the sample for experiments requiring convective mass transport of electrolyte or analyte to the electrode surface.



### **Osmometer Recording Membrane**

This system measures osmotic pressures of various samples. Samples are prepared according to the operations manual.



### **Chromatograph, Gel Permeation**

This system is a multisystem computer linked to a set of chromatographic instruments that perform acquisition, processing and management of chromatographic information. It is typically used to determine molecular weight of polymers.



### **FTIR (Infrared) Spectrometer**

This spectrometer allows the user to collect spectra in the visible, near-IR, mid-IR and far-IR ranges. Samples are typically slide mounted films or filters.



### **Spectrophotometer/Lambda/Perkin-Elmer**

This spectrometer allows the user to collect spectra in the UV, visible and near-IR ranges. The sample compartment is 200 x 220 x 300mm and will accommodate cuvettes or slide mounted samples.



### **LS-50B Luminescence Spectrometer Computer**

This spectrometer measures fluorescence, phosphorescence and chemi- or bio-luminescence of samples. The sample compartment will accommodate cuvettes or slide mounted samples.



### **Dielectric Analyzer**

The Dielectric Analyzer (DEA) measures the electrical properties of a material as a function of time, temperature and frequency. Dielectric measurements characterize the capacitive and conductive nature of the material. The DEA can be used to characterize molecular relaxations and monitor the flow and cure of resins. Liquid or solid samples can be analyzed, following strict sample preparation guidelines provided in the instrument manual.



### **Differential Scanning Calorimeter**

The Differential Scanning Calorimeter (DSC) Purity Analysis program can be used to calculate the absolute purity of a sample based on data obtained from the DSC according to ASTM procedure E0928. Analysis is based on the van't Hoff equation:



$$T_s = T_0 - \frac{RT_o^2 X}{\Delta H_f} \left( \frac{1}{F} \right)$$

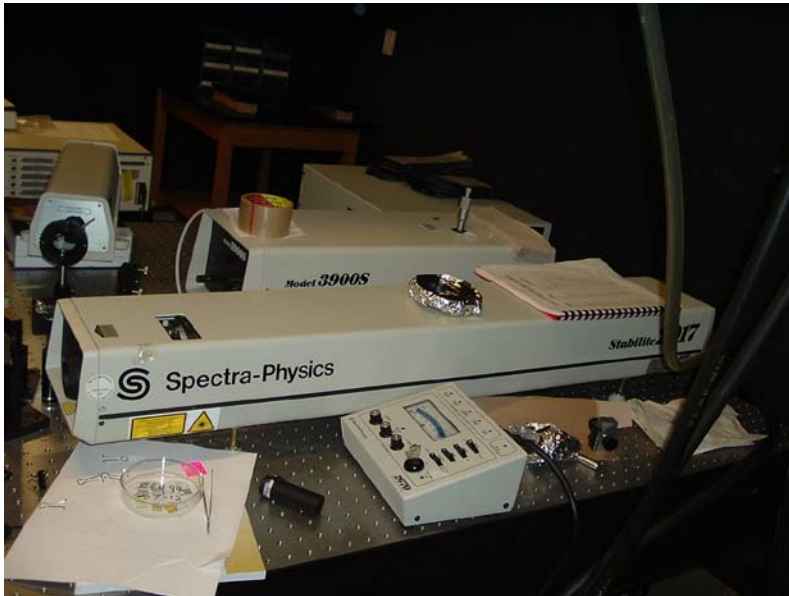
The heat of fusion is calculated using the total peak area of a known value, and the impurity level of your sample is calculated from the slope of the TS versus 1/F line. Sample size should be 1.7mg and tightly encapsulated to minimize temperature gradients and/or sample movement. Samples must be dry solids.

#### **Spectrophotometer, 177V/60Hz**

The 740GL goniospectrophotometer is an instrumental color measurement tool using multiple incidence angles of reflection and one angle of detection to determine the wavelength of light reflected by a material. Samples are prepared in accordance with the operations manual.



Argon Ion System w/ Tunable Laser Argon laser system, tunable over a range 333.6 to 454.5nm wavelengths.



#### **M\_44 Manual Angle Ellipsometer**

This unit is a variable angle ellipsometer, calculating thin film thickness as a function of reflectance and refraction of an incident light beam. The user can determine film thickness and index of refraction of various thin films, typically deposited onto silicon or glass substrates.





### **MTI-2000 Dual Channel Photonic Sensor Machine**

The Photonic Sensor is a dual-channel, fiber-optic measurement system that performs non-contact displacement and vibration measurements. The fiber-optics enable the unit to impose no load on the measurement target and is not affected by electromagnetic fields. The user is able to measure displacement motions ranging from 2.5Å to 5.08mm.



### **High-Resolution TGA 2950**

The Thermogravimetric Analyzer (TGA) Kinetics Analysis program analyzes data obtained from the TGA by running a sample at various heating rates. The program allows the user to analyze results from TGA data files to calculate the heating rate at each conversion percentage, and to generate plots and tables of kinetic analysis results. The program operates in accordance with the ASTM Standard E1641. Samples must be dry solids and parameters are outlined in the operation manual.

### **Dynamic Mechanical Analyzer and Accessories**

The Dynamic Mechanical Analyzer (DMA) uses time-temperature superposition to characterize the viscoelastic properties of a material at various temperatures over a time or frequency range. Samples must be dry solids and parameters are outlined in the operation manual.



**Target Carousel Flange Assembly**

### **Minilab Micro Compounder**

The MiniLab is a micro compounder for compounding and extruding very small amounts of material.



### Dynamic Light Scanner

This is a submicron particle sizer. The user can analyze emulsions, particles in suspension and molecules in solution with diameters ranging from 3-3000nm. This unit calculates particle size or molecular weight distribution from the measurement of the sample diffusion coefficient by photon correlation spectroscopy. Data returns particle size distribution.



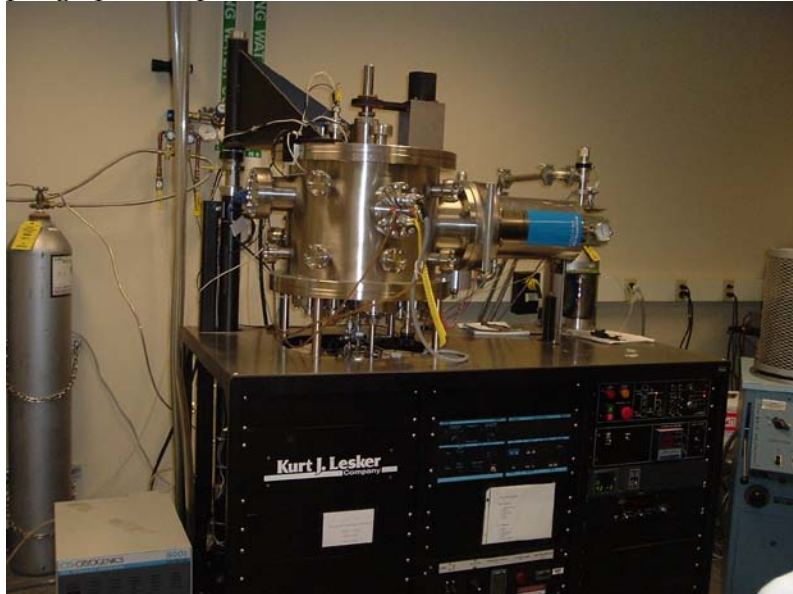
### Spin Coat System

Programmable spin coat system. Spin speed range is 100 to 9,999 RPM with a ramp up and down range of 0 to 60 seconds. System will support almost any flat solid substrate (typically glass or silicon wafers) up to 5" (12.7cm) in diameter. Substrates are held in place via a vacuum chuck. Material is deposited manually.



### Heated Substrate Holder

Kurt J. Lesker RF sputtering unit. This is a plasma-enhanced chemical vapor deposition (PECVD) system with a mechanical roughing pump and a CTI-Cryogenics high-vacuum cryo-pump. Substrate holder rotates for even film deposition and can be heated for in-situ annealing of films. The system has three gas inlets, two for process gas and one for system purge post-deposition.



### Electrometer and Data Acquisition

The Keithley electrometer is a GPIB interface unit that measures current, voltage, charge, V/I resistance and surface/volume resistivity.

