

Directory of Research Facilities and Laboratories



NORTHWESTERN
UNIVERSITY

**Materials Research Science & Engineering
Center
NU-MRSEC**

INTRODUCTION

The Materials Research Science & Engineering Center (MRSEC) at Northwestern University is pleased to provide this print directory of its research facilities and laboratories. A complete list of facilities is also available on our web site at <http://www.mrsec.northwestern.edu/>

NU-MRSEC is at the forefront of materials innovation, playing a leadership role in interdisciplinary research, the development of new technologies, and the commercial application of advanced materials. The activities and programs of NU-MRSEC are primarily supported by the National Science Foundation (DMR #0520513).

Facilities and Laboratories described herein are available for use by members of the Northwestern University research community and other academic institutions. Qualified research personnel from profit and nonprofit organizations may also use these resources, provided that comparable services are not available on a commercial basis in the private sector and such use will not interfere with the progress of internal research projects.

In most cases, users are given the necessary instructions to operate the instrumentation independently; however, ongoing assistance is available when needed. Modest fees are charged for facility use to help defray operational expenses. Charges may vary and are subject to change without notice.

If you would like additional information about the NU-MRSEC, use of facilities, or research activities, please feel free to contact us.

November, 2007
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TABLE OF CONTENTS

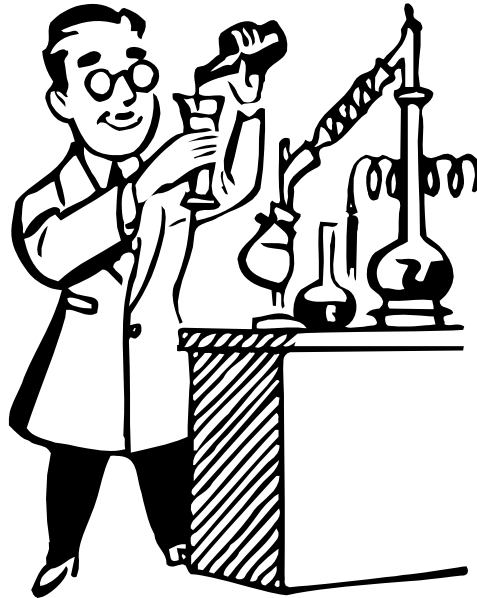
Facilities

Advanced Optical Facility.....	4
Center for Atom Probe Tomography (NUCAPT).....	6
Electron Probe Instrumentation Center (EPIC).....	8
Surface Science Facility.....	10
Jerome B. Cohen X-ray Diffraction Facility.....	12
Materials Processing & Crystal Growth Facility – Cleanroom.....	14
Central Laboratory for Materials Mechanical Properties (CLaMMP).....	16
Magnet and Low Temperature Facility.....	18
High Resolution Electron Microscopy and Surface Structure Facility.....	20
Optical Microscopy & Metallography Facility.....	22

Laboratories

Impedance Spectroscopy Laboratory.....	24
Advanced Thin Film and Laser Laboratory.....	25
Analytical Services Laboratory.....	26
Ceramics Laboratory.....	29
Polymer Characterization Laboratory.....	30
Charge Transport Laboratory.....	31
Synchrotron Research Facility.....	32

FACILITIES



Advanced Optical Facility

Facility Director:

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Facility Technician:

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Location: Technological Institute FB36

Function

The facility provides instrumentation for the optical and spectroscopic characterization of materials with special emphasis on the non-linear optical response.

Equipment

1. Quantronix 416 Nd: YLF laser CW modelocked, 1.053 μm , < 100 ps, 100 Hz
2. Optical CSK Superdoubler for frequency doubled output
3. Optical Parametric Oscillator (OPO) LBO crystal based, tunable from 0.65 to 2.2 μm -Driven by the Quantronix YLF laser
4. ESKPLA Nd:YAG laser Cavity dumped active/passive mode-locked 35 ps pulses at 10 Hz Doubled and tripled frequency outputs Optical Parametric Amplifier BBO crystal based, tunable from 400 nm - 2.2 μm Driven by the Continuum YAG laser
5. Quanta Ray Nd: YAG laser, model DCR-1
6. Spectra Physics 164 argon ion laser
7. Model 375B dye laser (driven by the argon laser)
8. Spectra Physics 164 krypton ion laser
9. Spectra Physics argon ion laser, model 2025-05
10. Spectra Physics krypton ion laser, model 2025-05
11. Two temperature controlled optical dewars (LN₂, L₄He, and L₃He)
12. Jarrell Ash half-meter grating monochromator, model 82-415
13. Stanford-Computer-Optics Image-intensified ICCD, model 4picos
14. SPEX 500M grating spectrometer
15. SPEX 1401 double-grating spectrometer
16. SPEX Spectrum-One LN-cooled CCD detector
17. InGaAs LN-cooled IR detector
18. Numerous prism spectrometers;
19. Two general purpose SHG arms at 1.053 μm and 527nm (Quantronix YLF) 2. Poling SHG

- arm (Quanta Ray) 3. Angular dependent SHG arm (Quanta Ray) 4. Time resolved SHG arm (Quanta Ray) 5. Variable wavelength SHG arm (OPA) 6. Electro-optic coefficient characterization, @He-Ne wavelength 632.8um 7. Variable temperature optical capability.
20. Photochemical Research Associates Nitrogen LN1000 laser
 21. Mellinea 532nm 5w YAG laser
 22. Pulsed Ti Sapphiere laser
 23. Magneto-optical set up
 24. Displex refrigerated optical cryostat

Northwestern University Center for Atom-Probe Tomography (NUCAPT)

Facility Director:

Professor **David N. Seidman**, Materials Science & Engineering Department

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Facility Manager:

Research Assistant Professor **Dieter Isheim**, Materials Science & Engineering Department

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Location: Cook Hall 1086, Tel (847) 491-7826

<http://nucapt.northwestern.edu>

Function

Understanding the properties and performance of materials requires knowledge of their characteristic structures and local compositions, often at an atomic scale and in three dimensions. NUCAPT is a laboratory where such measurements can be performed with atom-probe tomography. The microstructural features studied might typically be of the following types: Composition of second-phase precipitates or inclusions (down to 1nm diameter) or small clusters, compositional variation in modulated structures, layer-by-layer analysis of ordered phases or multi-layer thin-film structures, dopant profiles of semiconductor structures (transistors), and observation of interfaces (e.g. chemistry of grain boundaries).

Equipment

1. **LEAP 3000X manufactured by Imago Scientific Instruments:** This instrument, a local electrode atom-probe (LEAP) tomograph, has an ultrafast detector capable of collecting up to 72 million atoms per hour. Atoms are evaporated from the sample surface either by voltage or laser pulses and a computer reconstructs a three-dimensional image with both the chemical identity and positions of individual atoms, with a depth resolution of a single atomic plane of 0.1 - 0.3 nm. A microelectrode allows the analysis of microtips, prepared by FIB (ion-milling and/or lift-out technique to target specific features), or wire tips prepared by conventional electropolishing. A forthcoming upgrade will feature increased data collection rates, digital field-ion microscopy and a larger field-of-view.
2. **Three-dimensional Atom Probe (3DAP)** for wire specimens, with voltage-pulsed field-evaporation, energy compensating reflectron lens for high mass resolution, and phosphor-screen based field-ion microscopy.

3. A **specimen preparation laboratory** for preparing needle-shaped specimens for atom-probe tomography. Our lab features a high-speed precision saw to cut specimen blanks, an electropolishing station with a high-resolution stereo-microscope, and a Simplex Electropointer automated electropolisher.

Electron Probe Instrumentation Center (EPIC)

Facility Director:

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Facility Managers:

TEM/JEOL-JEM 2100F:

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TEM Electron Microscopist and Specimen Preparation Facility Manager:

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SEM Facility Manager and Scanning Electron Microscopist:

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Location: EPICTEM Cook Hall 1154 / EPICSEM Cook Hall 1114

<http://www.nuance.northwestern.edu/epic/>

Function

The Electron Probe Instrumentation Center (EPIC) EPIC facility offers a wide range of electron microscopy (both transmission and scanning), accessory instrumentation, and expertise to the scientific and engineering community through education, collaboration, and service. The laboratory provides facilities for the preparation and examination of many types of bulk and thin specimens (foils/films), fine particles, and replicas, including biological materials, by transmission and scanning electron microscopy.

Collectively, the Electron Probe Instrumentation Center (EPIC) offers instrumentation, techniques, and expertise for all aspects of microstructure materials. Detailed information about surface morphology, size and shape analysis, local chemistry, crystallography, and texture can be obtained with the scanning electron microscopes (SEM). The SEM facility has four SEMs with digital image acquisition, including three equipped with field emission gun (FEG), and several have EDS systems. The transmission electron microscopes (TEM) allow researchers to probe the crystal structure, defects, local chemistry, electronic structure, and related information at the nanometer or less length scale. The TEM facility currently has three TEMs, one cold field emission gun (cFEG) (HF2000), one Schottky field emission gun (JEM2100F), and one thermal

emission gun (H8100). All three microscopes are equipped with Energy Dispersive X-ray Spectroscopy (EDS) system for local chemistry analysis; two are equipped with Gatan Imaging Filter (GIF) for spectral imaging and EELS analysis. Both FEG microscopes are equipped with STEM detectors. The JEOL JEM2100F FEG TEM/STEM has sub 0.2nm probe capability, equipped with high-angle annular dark field (HAADF) detector, which gives atomic resolution of Z-contrast imaging of STEM.

Both SEM and TEM facilities are equipped with specialized specimen stages for dynamic studies involving deformation, fracture, current transport, applied electrical and magnetic fields, and temperature variation from -184°C to 1000°C. The diversity and quality of SEM and TEM instrumentation, along with the numerous analytical accessories, makes EPIC one of the most advanced laboratories in the country.

Please visit the EPIC web site (<http://www.nuance.northwestern.edu/epic/>) for more detailed information about the capabilities and contact information.

Surface Science Facility

Facility Director:

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Function

The Surface Science Facility provides multiple-technique characterization of a variety of surfaces with regard to atomic structure, surface chemical composition, and chemical bonding characteristics.

Equipment

1. **PHI 590A Scanning Auger Microprobe:** This scanning Auger microprobe is capable of standard Auger analysis with 200 nm lateral resolution and provides composition information in the top few atomic layers with about 1% monolayer sensitivity. It is equipped with in situ fracture and argon ion sputter for depth profiling. A fast entry system allows rapid specimen turnaround.
2. **VG ESCA/SIMS system:** This is a fully computer-controlled instrument from Vacuum Generators that combines two analytical instruments into a single workstation, viz., x-ray photoelectron spectroscopy (XPS) and secondary ion mass spectrometry (SIMS). The XPS subsystem can be run with a normal Al/Mg anode or a monochromatized Al anode for higher energy resolution. A small spot mode allows analysis down to 150 microns. The SIMS subsystem works with a quadrupole mass spectrometer with unit mass resolution up to $m/e = 800$ and single ion detection capability. A fast entry system permits rapid sample introduction and interchange. A high-pressure cell is also incorporated for simulation of processes occurring at pressures up to 30 atmospheres.
3. **Nanoscope IIIa Scanning Tunneling Microscope/Atomic Force Microscope:** This instrument provides rapid surface topographic examination in air and under liquids. Contact, noncontact, friction and magnetic force imaging modes are all available. An off-line workstation is available for detailed image analysis. An upgrade allows imaging at up to 250 C.
4. **Nanoindentors:** Two nanoindentation instruments (**Hysitron** and **UMIS**) are available to determine surface mechanical properties and tribological behavior. An additional nanoindenter is being installed that allows nanoindentation and friction measurements at up to 500 C.

Training Seminars/Workshops

Provisions have been made to accommodate routine short-term measurements by user groups as well as more extended studies. User and research groups are encouraged to work with the facility staff to tailor the facility resources to the research project.

Jerome B. Cohen X-Ray Diffraction Facility

Facility Director:

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Location: Cook Hall 1016

<http://www.research.northwestern.edu/research/xray/>

Function

The primary function is to provide general-purpose x-ray equipment for diffraction and fluorescence studies. The facility can also make accommodations for non-routine experiments such as, special attachments for high and low temperatures, vacuum or protective atmospheres, monochromators, special detectors, etc. Examples of current measurements are: powder diffraction, single-crystal diffraction, thin-film reflectivity, thin-film diffraction, crystal truncation rod scattering, small angle scattering, Laue diffraction, wave-length dispersive x-ray fluorescence, x-ray standing waves and high-resolution x-ray diffraction.

Equipment

There are presently fourteen experimental x-ray stations available, five of which have rotating anode sources.

Computers and Software:

All of the x-ray stations operate via networked PC's with software that allows for control via stepping motors and data collection via counters. A networked printer is available. ICDD database, JADE diffraction analysis, CaRine crystal builder simulation and Laue diffraction software packages are available. SPEC and CPLOT are available on three of the stations.

Available apparatus:

1. **Rigaku AXT-G Thin-film Diffraction Workstation:** A high intensity 18kW copper x-ray source is coupled to a multilayer mirror. The system has selectable x-ray optical configurations suitable for work with single crystal, thin-film or poly-crystalline film samples. Also supported are grazing incidence and in-plane diffraction geometries. Other

features are the 5-axis goniometer with several 4-crystal monochrometers that couple to the multilayer mirror.

2. **18kW Rigaku:** High-resolution 4-circle diffractometer with Osmic Max-Flux multi-layer mirror, coupled to Si or Ge monochromator, SPEC software control, high-count rate scintillation detector, automated beam attenuator and multi-channel analyzer fluorescence spectroscopy system.
3. **12kW Rigaku:** Medium resolution 4-circle diffractometer with SPEC software control and automated beam attenuator.
4. **18kW Rigaku:** 2-circle diffractometer with Osmic Max-Flux multi-layer mirror, high-count rate scintillation detector and multi-channel analyzer fluorescence system.
5. **Bruker S4:** Automated wavelength dispersive x-ray fluorescence (WD-XRF) system.
6. **Scintag XDS2000:** Automated diffraction system, with four-circle pole-figure and residual stress device, thin film diffraction attachment and solid-state detector.
7. **Rigaku Dmax:** Automated powder diffraction stations featuring Jade Analysis software.
8. **PC data analysis workstation:** JADE powder diffraction analysis software, CaRine diffraction simulation software, JCPDS powder diffraction database and Laue analysis software.
9. **Blake High Resolution tangential goniometer:** 5-Bounce high-resolution rocking curve-scan system. Sealed tube x-ray source.
10. **Small-angle scattering system:** Micro-beam rotating anode, Bruker Hi-Star 2-dimensional detector, elevated temperature attachment and GADDS, software. ($q=0.1 \text{ \AA}^{-1}$)
11. **Rigaku S-MAX 3000 High Brilliance SAXS System** (Available Oct 2007) Rotating anode with multilayer mirror, 2-D wire detector, SAXS-GISAXS, WAXS capabilities including high temperature. $q(\text{min}) = 0.04 \text{ \AA}^{-1}$

Other Available Equipment

1. A variety of x-ray anode targets and source sizes to accommodate the four high intensity rotating anode generators and the nine sealed- tube x-ray generators.
2. Various Si, Ge, Graphite and LiF crystals and multi-layer mirrors are available for incident or diffracted beam monochromators.
3. Environmental chambers for vacuum, atmosphere, low temperature ($>2 \text{ K}$) or high temperature ($<2300 \text{ K}$) operation.
4. Six solid-state detectors with associated electronics, SCA's and MCA's.
5. Three gas-filled 1-dimension linear position sensitive detectors.
6. Variety of film cameras: Debye-Scherrer, Laue, rotating crystal, cylindrical, topographic, Buerger precession, Guinier, high pressure and darkroom facilities.

Materials Processing & Crystal Growth Facility - Cleanroom

Facility Director:

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Facility Manager:

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Location: Cook Hall 4026, (847) 491-5959

Function

The Materials Research Center (MRC) cleanroom facility is devoted to materials processing, growth, device fabrication, and electronic & photonic materials. The MRC cleanroom complex in Cook Hall provides **microfabrication** and **thin film processing** capabilities. Facility includes class 100 and 1000 cleanrooms. The facility provides microfabrication tools for general use by the Northwestern community, government and industrial researchers. Various techniques are available for the growth, preparation, and processing of a wide range of thin film materials including **in-process characterization**. Training of equipment and assisted use within the MPCGF is available to provide the necessary expertise.

This provides a centralized resource for the deposition of metal, semiconductor & dielectric thin films, photolithography, and processing. Standard microfabrication processes have been established. Available techniques include plasma enhanced chemical vapor deposition, e-beam evaporation, reactive ion etching, photolithography and some characterization instrumentation.

Equipment

1. Quintel Q-2000 Mask Aligner
2. Quintel Q-4000 Mask Aligner (0.5 μm)
3. Headway Spinners / Wet Bench
4. Baking Furnace / Hot Plates
5. Oxford Instruments μ P 80 PECVD
6. Edwards Auto 306 e-beam Evaporator
7. Edwards Auto 500 FL400 e-beam Evaporator
8. Oxford Instruments μ P 80 RIE
9. Kulicke & Soffa 4524D Ball-Ball Wire Bonder
10. West Bond 7374E Wedge-Wedge Wire Bonder
11. ilmetrics F-20 Thin Film Analyzer
12. Metricon 2010 Prism Coupler

13. Resistivity and Hall Effect (4K Cryostat)
14. Tencore P-10 Surface Profiler
15. Nomarski Microscope

List of equipment fees are available online at:

<http://www.mrsec.northwestern.edu/content/facilities/cleanroom.htm>

Central Laboratory for Materials Mechanical Properties (CLaMMP)

Facility Directors:

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Professor **Katherine Faber** , Department of Materials Science & Engineering

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Facility Manager:

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Location: Cook Hall 1034

<http://www.matsci.northwestern.edu/clammp/index.html>

Function

The facility provides testing equipment for studying the mechanical behavior of materials. We have the capability of conducting tension, compression, fatigue, creep, stress rupture, impact, and 3 or 4-point bend tests. Specialized equipment is also available to perform tests in controlled atmospheres or vacuum and cover the temperature range of 4.2°K to 77.2°K.

The computer-interfaced MTS machines can perform static and dynamic mechanical tests that relate an applied force to the elastic, anelastic, and/or plastic deformation of solid materials. The facility also makes available investigation of strain or stress controlled fatigue experiments, fatigue crack initiation studies, fatigue crack propagation studies, cyclic hardening, cyclic softening and cyclic stress-strain curve measurements under computer control.

Equipment

1. Five MTS machines; three servo-hydraulic, one servo-electric, and one screw driven tensile machine are available to perform static and dynamic mechanical tests and control such parameters as strain rate and rate of loading. Tests can be performed up to 50,000 lb (250kN).
2. Three ATS constant load creep apparatus can be used for creep and stress rupture experiments in atmosphere to 1100°C.
3. Charpy tests can be conducted in the ranges; 0 - 357 J and 0 - 22.5 J. Izod tests can be conducted in the range; 0 - 22.5 J
4. A laser extensometer, several contact extensometers and crack opening displacement gages are available for both static and dynamic tensile or compression tests. These include extensometers that can be used to 1100° C.

5. One of the units is equipped with a Centorr high temperature environmental chamber. Test environments including vacuum, inert gas, liquids, or a controlled atmosphere can also be carried out.
6. A metallurgical microscope can be attached to the testing units enabling observation of real-time fatigue crack growth and examination of specimen surfaces during test cycling.

Please visit the CLaMMP web site (<http://www.matsci.northwestern.edu/clammp>) for more detailed information about our capabilities and contact information.

Magnet and Low Temperature Facility

Facility Director:

Professor **John B. Ketterson**, Physics & Astronomy Department

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Facility Technician:

Oleksandr Chernyashevskyy

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Location: Technological Institute FB24

Equipment

Our equipment includes cryostats, magnets, magnetometers, a nanovoltmeter, constant-current sources, and constant-voltage sources. The magnetometers include a computer-controlled Quantum Design (<http://www.qdusa.com>) Magnetometer (MPMS5) that permits SQUID magnetic-moment sensitivity (and a user probe for transport measurements), a LAKESHORE AC susceptometer for measuring both real and imaginary components of susceptibility, and a quick-turnaround AC bridge susceptometer. The MPMS provides the exceptional sensitivity of a SQUID-based magnetometer in a fully automated, analytical instrument. It provides a much needed solution for a unique class of magnetic measurements, meeting the needs of research in key areas such as high-temperature superconductivity, biochemistry, and magnetic recording media. This system was upgraded in 2004 by the addition of a horizontal rotator option and an "oven" insert for high-temperature measurements. This instrument can measure DC magnetic susceptibility and magnetic moments on samples as small as a few mg.

Field range: -5.0 T to 5.0 T

Temperature range: 1.8 to 700 K

Measurement range: 10^{-7} to 100 emu

Absolute sensitivity: 10^{-7} emu

Additional cryostats include a computer-controlled Quantum Design Physical Properties Measurement System (PPMS) and a SHE VTS 50 SQUID susceptometer outfitted for low-noise transport measurements. The PPMS was designed to measure heat capacity, thermal transport, and thermoelectric effects. Key optional features of the MPMS have been greatly expanded and improved in the PPMS. The PPMS brings a new level of measurement automation to researchers in rapidly expanding fields such as materials science, condensed matter physics, biology and analytical chemistry. The tremendous flexibility of the PPMS - open architecture - lets you create your own experiments and easily interface your own third-party instruments to the PPMS hardware. For example, we can connect a user's equipment to PPMS analog outputs with signals proportional to magnetic field, system temperature, bridge resistance, bridge excitation, etc.

Field range: -9.0 T to 9.0 T

Temperature range: 1.9 to 390 K

Thermal conductance accuracy: 5%

Heat capacity sample size: 1 to 200 mg Heat capacity resolution: 10nj/K
at 2 K

Ease Of Use

The hallmarks of our instruments are automation and ease of use. We can quickly and easily configure them to perform different types of measurements. In a matter of minutes we can install a measurement application, set up an automated sequence, and start collecting meaningful data. And, our equipment is designed to run 24 hours a day, 7 days a week. We know your time is valuable, so we have laboratory automation on a new level. While the PPMS or MPMS runs your measurements, you can be analyzing data from previous measurements, planning your next experiment, and creating new materials. The MPMS and PPMS work like dedicated systems, but their tremendous flexibility lets you perform different types of measurements. Plus, we can easily integrate a user's unique experiment with our measurement systems. Samples can be easily prepared from a variety of materials. The exceptional dynamic range of our devices allows us to accommodate samples in many forms, from single crystals to bulk solids, films and powders.

High Resolution Electron Microscopy & Surface Structure Facility

Facility Director:

Professor **Laurence D. Marks**, Materials Science & Engineering Department

Tel: (847) 491-3996

E-mail: L-marks@northwestern.edu

Location: Catalysis Center, B12

<http://www.numis.northwestern.edu/>

Function

This facility provides unique equipment to investigate the atomic scale structure of both the surface and subsurface region of a sample combined with in-situ growth and chemical characterization. Please visit the High Resolution Electron Microscopy and Surface Structure Facility web site for more information about instrumentation capabilities and contact information: <http://www.numis.northwestern.edu/>

Equipment

1. **SPEAR:** The Specimen Preparation Evaluation Analysis and Reaction System is a system of interconnected Ultrahigh Vacuum (UHV) chambers for the preparation and study of surfaces and interfaces. The Analytical Chamber is equipped with a PHI Electronics Duoplasmatron Ion Gun, a PHI Electronics Dual-Anode X-ray Source, a A FEI Thermally Assisted Schottky Field Emission Electron Gun, and a the PHI Electronics Spherical Electron Energy Analyzer. The ion gun can produce oxygen, argon, or xenon ions which, when coupled with a secondary electron detector, generate useful Secondary Electron Microscopy (SEM) images during sputtering. The electron energy analyzer can acquire XPS data from either Al K-alpha or Mg K-alpha x-rays from the X-ray source, as well as highly spatially resolved Auger electron data generated by the electron gun. The electron gun can also be used for the direct heating of samples. The Transfer Chamber allows samples to be moved between the Load-Lock, the Analytical chamber, and various other connected systems (UHV-HREM, MIBE, SINBAD) while at all times remaining in a UHV environment.
2. **UHV-HREM:** The Hitachi UHV-H9000 High Resolution Electron Microscope is the first conventional transmission instrument to achieve routine mid 10E-11 torr operation. It is equipped with a Gatan Parallel EELS and CCD Camera, both interfaced to computers. Routinely the instrument will resolve at about 0.18nm for bulk spacings and atomic structure of surfaces at about the 0.25nm level.
3. **MIBE:** The main goal of the Magnetron and Ion Beam Epitaxy System is to combine deposition processes with the analytical capabilities of SPEAR and an UHV TEM. Samples can be grown in MIBE and then transferred to SPEAR where analytical techniques can be performed. It has two metal ion sources currently fitted with boron and carbon targets, two

d.c. magnetron sputtering sources used to form ZrN and CNx multilayer materials, and one gas ion source.

4. **SINBAD:** The Stabilizing Ion and Neutral Beam Assisted Deposition system is a specially designed system for the in-situ investigation of thin solid films. It is designed to handle and the deposition of thin films onto thin 3mm TEM ready samples and investigate the effect of energetic particles on materials. The sample manipulation stage can be used for d.c. biasing of the sample as well as resistive heating during deposition and the unit is equipped with a single position electron-beam evaporator, a 4 keV ion-gun, and a compact electron cyclotron resonance (ECR) plasma source. It is also connected to the SPEAR system.
5. **Computers:** Two Linux clusters, JosephSmith and HyrumSmith, are used for running DFT calculations and compiling code. Additionally, computers are used for image simulation and diffraction calculations. The primary software is NUMIS, a combination of Semper 6 and multislice/imaging programs. Originally these calculations were run on UNIX machines, but are gradually being moved to PC's running an X-windows environment. Additionally, the EDM software package, which is continually being updated, is used to combine various aspects of image processing and manipulation of high resolution images and diffraction patterns as well as direct methods.

Optical Microscopy & Metallography Facility

Facility Director:

Professor **Kenneth Shull**, Materials Science & Engineering Department

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Facility Manager:

Kathleen Stair, Materials Science & Engineering Department

Tel: (847) 491 7827

E-mail : kstair@northwestern.edu

Location: Cook Hall 2008

Function

This facility is equipped for the metallographic preparation of specimens by producing strain-free surfaces usually examined by optical microscopy. Other applications of mechanically polished specimens involve producing strain-free (surface) tensile specimens, optically flat electrodes, and flat substrates for subsequent thin-film depositions.

Both transmitted light and reflected light metallographs are available for photomicrography and microstructural characterizations. The Lab Manager is available for consultation and training.

Equipment

Fourteen microscopes ranging from 6X to 1600X are in the facility. Selected microscopes have brightfield and darkfield modes, and polarized light. 4" X 5" or 35mm camera formats are available for taking photomicrograph as well as digital image capture. A micro hardness tester (loads from 10 grams to 1000 grams with either Knoop or Vickers indentors), and interference microscope, and a hot state (300EC maximum) for viewing optically clear specimens are available. In addition, a "digital" darkroom is available with AV Macintosh, scanner, and dye-sublimation printer capable of photographic quality prints.

Metallographic specimens can be cut with diamond-tipped blades on either a slicer/dicer, low-speed, or high-speed cut-off saw. Samples can be encapsulated in either cold-mount acrylics or phenolic resins. Manual abrading with silicon carbide paper or with variable speed 12" diameter SiC platens can be done in the facility.

Various 8" diameter platens for polishing are available with diamond paste sizes ranging from 30 to 0.1 micrometer. Alumina slurry polishing is also available with sizes from 1.0 to 0.05 micrometer. A semi-automatic Buehler Ecomet IV Abrasive and Polishing System is capable of preparing up to eight specimens simultaneously with reproducible parameters of platen speed, pressure, and diamond concentrations. The system is very useful in preparing ceramic specimens due to the higher pressures that can be produced.

LABORATORIES



Impedance Spectroscopy Laboratory

Laboratory Director:

Professor **Thomas Mason**, Materials Science & Engineering Department

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Location: Cook Hall 3072

Equipment

This laboratory houses Agilent Technologies 4192A and Solartron 1260 impedance analyzers, fully computer-controlled, for making frequency-dependent impedance/dielectric spectroscopy studies of materials. Recent materials and topics under investigation include fiber-reinforced composites, the aging of polymer wiring insulation in aerospace applications, interface/electrolyte characterization of solid oxide fuel cells and materials, the characterization of thin film electroceramics for grain vs. grain boundary effects, and the measurement of powder conductivities via the novel "power-solution-composite" method. The potential also exists for the characterization of soft materials, including biological and biomaterials.

Advanced Thin Film & Laser Processing Laboratory

Laboratory Director:

Professor **R.P.H. Chang**, Materials Science & Engineering Department

Tel: (847) 491-3598

E-mail: r-chang@northwestern.edu

Location: Cook Hall 1062

Function

This laboratory has equipment which supports the synthesis and processing of thin film systems ranging from ultra thin films to multi-layers and superlattices. Both physical deposition systems, such as sputtering and electron beam equipment, as well as chemical vapor deposition systems, such as metalorganic chemical vapor deposition equipment, are available. The laboratory also provides a means of forming metastable materials with a laser, and is equipped with a scanning ellipsometer which can be used from IR through the visible range. Software is available to perform simulation on multi-layer structures.

Equipment

1. **Thermal Vacuum Evaporator:** Diffusion pumped (base pressure 5×10^{-7}) Glass Bell Jar and guard
2. **Two Pulsed Organometallic Chemical Vapor Deposition Systems:** Each system can handle up to eight solid or liquid sources for deposition. All the source materials are fed into the main chamber via computer controlled valves. Microwave power is available to sustain a gas discharge at 10^{-3} torr. Thus complex oxides and nitrides can be made by this machine with precise stoichiometry. In addition, superlattice film of oxides can be synthesized. These systems are the only ones of its kind in the world.
3. **SOPRA Scanning Ellipsometry System:** This spectroscopic ellipsometer with an automated computer control allows samples of thin film to be measured and mapped with high precision for the dielectric function as well as the layer thickness. The ellipsometer covers an optical range from near IR to visible. Computer software is available for simulating film composition, multilayered structures, as well as surface roughness.
4. **Laser ablation:** This system is used for thin film processing.

Analytical Services Laboratory

Laboratory Director:

Dr. **Andrew Ott**, Department of Chemistry
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Laboratory Staff:

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Location: Technological Institute K Wing Ground Level

<http://pyrite.chem.northwestern.edu/analyticalserviceslab/asl.htm>

Function

The Analytical Services Laboratory, operated by the Department of Chemistry, is a shared facility for performing a full range of chemical analyses. Such analyses include qualitative composition determination, quantitative analysis, and molecular structure determination. Instrumentation housed in this facility includes NMR spectrometers, mass spectrometers, X-ray crystallography equipment, optical spectrometers, elemental analysis equipment, and chromatography equipment. Users may be trained to use most of these instruments independently or samples may be submitted to the ASL staff for analysis.

Equipment

Nuclear Magnetic Resonance (NMR) Spectrometry

Varian Gemini 2000

Varian 400 (Solid State)

Varian INOVA 400

Varian Mercury 400 (with Varian SMS autosampler)

Varian INOVA 500

Varian INOVA 600

Probes for most instruments for a full range of NMR active nuclei, VT operation, a full range of multidimensional NMR experiments

Mass Spectrometry

Agilent 1100 MSD with HPLC interface

Applied Biosystems 2000 (ESI/APCI) electrospray triple quadrupole mass spectrometer with HPLC interface

Applied Biosystems 3000 (ESI/APCI) electrospray triple quadrupole mass spectrometer

Applied Biosystems Voyager DE Pro MALDI (matrix assisted laser desorption ionization) - TOF (time of flight) mass spectrometer

Hewlett Packard 6890 GC/MS

Waters Q-TOF2 (ESI) electrospray quadrupole / Time of Flight high resolution mass spectrometer

VG Isotech isotope stabilized mass spectrometer

Thermo Finnigan MAT 900 high resolution mass spectrometer

Thermo Finnigan LCQ Advantage ion trap mass spectrometer

X-Ray Crystallography

Bruker SMART1000 single crystal X-ray diffractometer with CCD detector

Bruker KAPPA APEXII single crystal X-ray diffractometer with CCD detector (July 2007) workstations for X-ray crystallography data analysis

Atomic Analysis

Varian VISTA-MPX Inductively Coupled Plasma (ICP) spectrometer

VG PQ ExCell ICP/MS

Optical Spectroscopy

Infrared and Raman:

Mattson Polaris FTIR spectrometer

BioRad FTIR spectrometer (near, mid and far IR) with microscope

BioRad FT-Raman II spectrometer

Ultraviolet/Visible:

Cary 1 UV/visible spectrometer

PTI QM-2 fluorescence/phosphorescence spectrometer

Chromatography

Gas Chromatography:

Hewlett Packard 5890 with capillary column for chiral separation

Varian 3700 HPLC: HP 1090 with reverse phase and gel permeation columns and UV and refractive index detectors

HP 1100 (used as an attachment for the electrospray mass spectrometer) with UV detector

GC/MS: Hewlett Packard 6890

Waters Alliance GPCV 2000 high T gel permeation chromatograph with viscosity, refractive index and light scattering detectors

Waters room temperature GPC system with refractive index and UV/Vis detectors.

Thermal Analysis

Instrument Specialists differential scanning calorimeters (DSC) miscellaneous: calorimeters, viscometers

Polarimeter

Optical Activity AA-100 automatic digital polarimeter

Ceramics Laboratory

Laboratory Director:

Professor **Scott Barnett**,

Tel: (847) 491-2447

E-mail: s-barnett@northwestern.edu

Location: Cook Hall 3006

Function

This laboratory houses equipment used to process and characterize ceramic materials. Equipment is available for the preparation, milling and characterization of ceramic powders and subsequent fabrication by pressing, tape casting, slip casting, extrusion, and sinter forging. The laboratory is also equipped with a an ultrasonic machine tool for drilling, planning, and milling ceramic particles.

Equipment

1. **Powder processing:** Ball mill, Vibratory mill, Sonic sifter, Mettler balance (0.1 mg resolution), Porsimeter, centrifuge, Sedigraph, Freeze-dryer
2. **Forming Equipment:** Uniaxial platen press, Hot isostatic press, Extruder, Tape caster
3. **Furnaces:** 1000C box furnace, 1200C box furnace, Tungsten furnace, 1600C CM rapid temperature box furnace, 1500C Lindberg box furnace, Carbon furnace 1700C, CM tube furnace, 1500C tube furnace, 1200C vertical tube furnace
4. **Additional Instruments:** Branson ultrasonic machine tool, diamond saw, Low speed Isomet saw

Polymer Characterization Laboratory

Laboratory Director:

Professor **John Torkelson**, Chemical & Biological Engineering Department

Tel: (847) 491-7449

E-mail: j-torkelson@northwestern.edu

Location: Cook Hall 2022

Function

This laboratory is oriented toward the polymer community, providing the researchers with space and specialized instrumentation for the physical characterization of polymeric materials. Determination of molecular weight, mechanical properties, and thermal behavior of polymer solids are routinely performed in this lab.

Equipment

1. The **chromatic Low-Angle Laser Light Scattering photometer** and modified **Brice-Phoenix refractive index increment apparatus** are used for molecular weight characterization. Moreover, dilute solution viscometers are available for obtaining the absolute molecular weight and are thermostated for work up to 180°C.
2. For Thermodynamic Characterization, the **Perkin-Elmer DSC-7 differential scanning calorimeter** is capable of automatic data acquisition and analysis of transition temperatures and heats of melting, crystallization, and reaction. The calorimeter is interfaced with a thermogravimetric analyzer (TGA), an automatic balance with microgram sensitivity, and the same data station for data acquisition and analysis of weight loss measurements. Density gradient columns are available for determining density of polymer solids.
3. **Mechanical Characterization Bohlin VOR Mechanical Spectrometer** is equipped for the measurement of viscoelastic properties of polymer solutions, melts, and solids at various shear rates and temperatures.
4. The **Precision Profilometer**, the **Tencor Model P10 surface Profiler** and the **Spin Coater** are used for producing thin polymer films.

Charge Transport Laboratory

Laboratory Director:

Professor **Mark Hersam**, Materials Science & Engineering Department

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Location: Cook Hall 4082

Function

The Charged Transport Laboratory includes equipment to perform variable temperature DC electrical conductivity and Hall measurements (mobility and carrier concentration), from 4.2 K to 340 K using a computer automated four- and five-probe technique, respectively.

Typical samples can range from thin films to single crystals, with specimens mounted on interchangeable sample holders. Hall measurements are made with a magnetic flux density of 0.74 Tesla. The measurements of the sample cross-sectional area and voltage probe separations (Hall and conductivity) are made with a calibrated Bausch & Lomb binocular microscope.

Equipment

DC electrical conductivity and Hall measurements: Liquid helium/liquid nitrogen cryostat and associated equipment (such as vacuum pumps), and lab-made dipsticks for sample mounting. Keithley and Lake Shore rack-mounted source-measure and switching equipment are all GPIB controlled by a computer running control software written using LabView. A Lake Shore electromagnet and power supply are used for the Hall measurements. Sample preparation includes various fine tweezers and wire, conductive daps, colloids, pastes, etc.. A calibrated Bausch & Lomb binocular microscope is used to mount and physically characterize the specimens under test.

Northwestern Synchrotron Research Center

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Function

The Synchrotron Research Center manages the operations of the DuPont-Northwestern-Dow Collaborative Access Team (DND-CAT) instrumentation at the Advanced Photon Source at Argonne National Laboratory. Funds for construction, management, and operations to date have been obtained from E.I. DuPont de Nemours & Co., the Dow Chemical Company, the National Science Foundation through the Academic Research Infrastructure program and the Materials Research Center, the State of Illinois through the Department of Commerce and Community Affairs and the Higher Education Cooperation Act, and the US Department of Energy.

University sources of funds include the McCormick School of Engineering and Applied Science, the office of the Vice President, and the Office of Research. The facility supports state of the art x-ray research in the fields of biology, physics, chemistry, chemical engineering, environmental science, and materials science and engineering.

Equipment

DND-CAT operates five experimental stations. Three of these utilize undulator radiation and two utilize a part of the dipole radiation fan. DND-CAT currently supports several interdisciplinary x-ray techniques including x-ray spectroscopy, macromolecular and inorganic crystallography, small angle x-ray scattering, x-ray tomography and powder diffraction. Please visit the DND-CAT web site (<http://www.dnd.aps.anl.gov>) or contact the facility for detailed information on available equipment and capabilities.