**URL:** <http://www.eng.utoledo.edu/cmsc/>

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**Description**

*Square Footage*: 4000 sq. ft.

*Facility Location*: Main Campus, North Engineering Building, Rooms 1496, 1479, 1477A and 1470F.

The Center for Materials and Sensor Characterization (CMSC) is one of The University of Toledo’s core facilities for materials and chemical characterization, and advanced materials related research. The facility has multiple laboratories housing high-end characterization equipment and highly trained personnel to operate them and perform research and development. CMSC provides solutions to characterization and research needs for investigators from all UToledo campuses, outside universities, and industries. The vision of CMSC is to produce competitive researchers, advance materials characterization, and research, and promote economic growth in the region.

**Major Equipment**

* **Hitachi S-4800 II Scanning Electron Microscope (SEM**) is a cold field emission ultra-high-resolution scanning electron microscope (SEM). It has a guaranteed resolution of 2.0 nm at 1kV for low voltage applications, with a full range of 500V to 30KV. The instrument has a full set of additional detectors, including a 50 mm2 Oxford Silicon Drift energy dispersive spectroscopy (EDS) detector, a YAG backscattered electron detector (BSED), and two Secondary electron (SE) detectors. A specimen stage for large sample applications with 110mm x 110mm stage movement and computer controlled 5 axes motorization with graphical interface software. It also allows for quick sample exchange.
* **FEI Quanta 3D FEG Electron Microscope** is a dual beam systemequipped with multiple analytical and manipulative tools to apply different techniques and methods within the same chamber. This system features three SEM imaging modes: high vacuum, low vacuum and environmental SEM. The system contains both an ion column (Gallium ion source) and a field emission scanning electron column. It has a resolution of 2 nm at 30KV in the SEM modes and 10nm at 30KV in the ion beam mode. The ion column has the ability to focus highly energetic ions (typically 30 kV Gallium ions) to extremely small spot sizes, which in combination with a rastered movement of the ion beam allows for

the controlled removal of material via ion sputtering interaction. In addition, the FIB-SEM instrument is equipped with a backscattered detector (BSED), low KV back- scattered detector, a 50 mm2 Oxford Silicon Drift EDS detector, Pt deposition, an Autoprobe 200 nanomanipulator, and a Peltier cooling stage. The ion and electron beam can be used in combination with a gas injection system.
* **Hitachi HD-2300A Scanning Transmission Electron Microscope** is a high throughput,Schottky field emission, dedicated scanning transmission electron microscope (STEM). It has a resolution of 0.2 nm at 200KV accelerating voltage for achieving atomic resolution images of specimens. It is also capable of running at 120KV. It is equipped with a 50 mm2 energy dispersive spectroscopy (EDS) detector. A particular strength of the instrument is the rapid specimen exchange of within 2 minutes and the rapid start of high voltage applications in 3 minutes (standby condition to 200kV on). It also has automated column alignment and high resolution image viewing functions in TEM, SEM and Z contrast mode. Single and Double tilt sample holders are available for the instrument. The STEM also has a live diffraction camera for nano-area electron diffraction analysis with simultaneous display of STEM images. It is a versatile instrument when high resolution imaging is required.
* **Veeco Multimode Nanoscope IIIa is Scanning Probe Microscope (SPM)**, also known as an atomic force microscope (AFM). It has a resolution of ~ 0.3 nm with the A scanner. The instrument is capable of imaging areas ~ 1 sq. µm (using the standard A scanner), ~12 sq. µm. (using vertical engagement EV scanner) and ~125 sq. µm (using vertical engagement JV scanner) in the XY direction. The scanning range in the Z direction for EV and JV scanner are ~ 2 µm and ~ 5 µm respectively. The AFM is capable of imaging in Contact mode, Phase Contrast mode and Tapping mode with Nanoindentation capabilities. Attachments include a Fluid Cell for imaging in liquids (Contact and Tapping mode) and an Anti-vibration suspension mount for atomic resolution imaging. A 15 mm sample disc is used to mount the samples with access to ~ 2-3 mm area at the center of the sample. AFM imaging is particularly useful for samples that cannot be imaged under vacuum and delicate samples. The Fluid Cell attachment also allows for in situ measurements of processes.
* **PerkinElmer Frontier FTIR Spectrometer** is a powerful and adaptable spectrometer that offers superior quality in the near and middle infrared region. Frontier can support extensive IR analysis using a single instrument by simply switching the sampling accessories. The same interferometer platform also powers the Spotlight imaging system, a high performance FT-IR microscopy and FT/IR/NIR imaging system. This system reveals the identity of a vast array of chemical components within materials, as well as displaying areas of homogeneity and variation. The imaging system is capable of transmission and reflection micro-sampling. Its Micro-ATR provides information down to

areas as small as 3 microns. This can be used for various applications such as troubleshooting manufacturing problems, identify product contaminants, confirm quality of materials, develop new products, pharmaceuticals, packaging materials, coatings, electronic materials, reverse engineering, and laminated layers identification.
* **Agilent FTS 4000 with UMA 600 FTIR** can be used as a fingerprint to help identify and characterize samples. The minimum sample area that can be analyzed in this FTIR is about 15 microns. The FTIR can run in two different modes: The bench, FTS 4000 is used for samples in the form of thin films, powders and liquids. ATR accessories are available. The microscope, UMA 600 is used for samples in the form of solids (non-abrasive materials) or films. The data can be collected in reflectance and transmittance mode. A micro-ATR with Ge crystal is available for sample analysis. The microscope has the capability of generating spectral data from small areas on the surface of the sample (~15 µm). The Bio-Rad spectral library is also available with the FTIR. This powerful tool can be used for analysis and identification of unknown materials.
* **Jobin Yvon Horiba confocal Raman spectrometer** can be used for chemical identification, characterization of molecular structures, effects of bonding, stress on a sample and determination of its crystallographic orientation. Raman requires little or no sample preparation. It does not need the use of Nujol, or KBr matrices and is largely unaffected by sample cell materials such as glass and provides very high level of spatial resolution and depth discrimination. The Raman spectrometer includes the following accessories: He-Ne laser with line excitation at 632 nm and 785 nm diode laser, diffraction grating of 1800 g/mm and 600 g/mm, confocal pinhole adjustable from 0 to 1500 µm, Olympus BX41 microscope with objectives 10x, 50x and 100x, CCD detector and optical imaging that enables to focus on individual particles as small as 10 µm in diameter.
* **RamanScope III coupled with the FT-Raman spectrometer MultiRAM** can be used to analyze solid (films, nano-particles and surfaces) and liquid samples. The spectrophotomer provides a spectral range of 3600 to 50 cm-1 and counts with a Nd:YAG laser diode with excitation at 1064nm. The system is equipped with a Ge detector (cooled with liquid nitrogen). This detector offers ultra low signal detection with minimal noise assuring excellent sensitivity. The RamanScope III counts with a 40x objective and a color video camera for performing measurements at the microscopic level for analysis of morphological details of a sample. Additionally, the system is also suitable for samples that tend to fluoresce when exposed to laser radiation. At 1064nm, the excitation energy is low enough for these samples not to fluoresce or only to a minor degree.
* **Thermo Scientific XSeries 2 ICP-MS** (Inductively Coupled Plasma Mass Spectrometer) is a sensitive instrument that allows for multi-elemental analysis of a variety of samples from a wide range of applications and sample matrices. The instrument features automated torch positioning that ensures consistent results as well as an off-axis quadrupole that provides high signal-to-noise ratio. The Xt Interface that minimizes polyatomic species in complex matrices enhances detection limits. Typically, elements can be measured in the parts per billion (ppb) range and some as low as the parts per trillion (ppt) range. Solution samples are required for analysis and are normally dissolved/digested for proper detection. Solid samples, such as polymers, plant tissue or soil samples are digested in a CEM Mars Xpress Microwave. An autosampler that is capable of analyzing 240 samples is also attached to the instrument to increase sample throughput.
* **Varian 320-MS LC/MS** is a triple quadruple mass spectrometer that provides maximum performance for pharmaceutical, toxicological, environmental, and other applications requiring quantitation in a heavy matrix. The LC-MS/MS is commonly used in; pharmacokinetic studies of pharmaceuticals and is the frequently used technique in the field of bio analysis, for proteomic analysis of a complex sample where peptide masses must be detected and identified, for the development of various drugs. The analyzer mass range is up to 2000 Da at scan rates of up to 6000 Da/sec. The triple quadrupole modes include Q1MS and/or Q3MS for SIM or full scan, Precursor scan, Product scan, Neutral loss scan and Selected Reaction Monitoring (SRM). The system has an auto-sampler and temperature controller.
* **Shimadzu LCMS/MS-8050** is capable of simultaneously obtaining both qualitative and quantitative information in a single analysis. Acquisition occurs so rapidly that MS/MS scans and MRM measurements can be performed concurrently while maintaining quantitative accuracy. MS/MS scans are usable and reliable because even at 30,000 u/sec, a 0.1 u scan step is used. It provides very low detection limits of <1 ppb for analysis of compounds in trace amounts.
* **PerkinElmer Diamond Differential Scanning Calorimeter (DSC)** is used for different types of thermal analysis experiments, which include melting, crystallization, glass transition, polymorphism, specific heat, kinetic study and curing reaction. The features include: very high sensitivity for the detection of weak transitions or small polymorphic forms; use of platinum resistance thermometer (PRT) for the measurement of sample temperature which provides better accuracy and reproducibility than thermocouples; power-compensation temperature null principle; measures temperature and energy directly, rather than differential temperature (DT); independent dual furnaces constructed of platinum-iridium alloy with independent platinum resistance heaters and temperature sensors with furnace mass less than 1g. Temperature range: -170 °C to

730°C; Scanning rates heating/cooling: 0.01 °C to 500 °C/min; Available cooling options are Intracooler 2P: -75 °C to 730 °C and Cryofill: -170 °C to 300 °C
* **TA Instruments Q50** is a compact, general purpose, thermo gravimetric analyzer. Its integral mass flow control, gas switching capability, and ease-of-use make it particularly useful. TGA is used to measure properties such as thermal stability of materials, oxidative stability of materials, composition of multi-component systems, estimated lifetime of a product, decomposition kinetics of materials, moisture and volatile contents for materials. The specifications of this instrument are: Temperature Range ambient to 1000°C Isothermal; Temperature Accuracy ±1°C; Isothermal Temperature Precision ±0.1°C; Heating Rate Range 0.1 to 100°C/min in 0.01°C/min increments (standard furnace) 0.1 to 50°C/min in 0.01°C/min increments (EGA furnace); Furnace Cooling Forced Air 1000°C to 50°C in < 12 min; Weighing Capacity 1.0 grams; Sensitivity 0.1 g; Weighing Precision ± 0.01%.
* **TA Instruments Q800 Dynamic Mechanical Analyzer (DMA)** is used to measure properties such as stiffness modulus and energy dissipation of composites, thin films and elastomers, tan delta, glass transition temperatures and secondary transitions. The available modes of operation include Isostrain, Multi-frequency mode, Creep/stress relaxation, Controlled force/strain and Multi-stress/strain mode. The accessories available include: thin film tension clamps: ideal for films, fibers and low modulus materials. A spring-loaded grip insures constant contact with the sample; Single/dual cantilever bending clamps: Ideal for general-purpose mode for evaluating thermoplastics and highly damped materials, the samples is clamped at both ends.
* **Rigaku Ultima III high resolution X-ray diffraction (XRD)** instrument is used for various applications such as in-plane and normal geometry phase identification, quantitative analysis, lattice parameter and crystallite size determination and depth-controlled phase identification. In addition to standard Bragg Brentano geometries, the system is capable of grazing incidence diffraction (GIXRD), transmissive and reflective small-angle X-ray scattering (SAXS). Instrument Specifications: Generator: Cu target with a rated tube voltage of 20-60KV operated at 40KV and 44 mA, Detector: Scintillation Counter, Goniometer: In plane arm with a radius of 285 mm; scanning modes of theta S, theta d and theta S/theta d coupled are available with a minimum step size of 0.0001 degrees, Optics: Automatic alignment of tube height, goniometer, optics and detector. Soller slits - incident beam and diffracted beam 0.5 and 5 degrees, Accessories: Monochromator and Transmission SAXS holder and software such as Jade 2010, Nano-Solver v3.4, ICSD database are also available.
* **Micromeritics ASAP 2020 Accelerated Surface Area and Porosimetry System** provides versatility in gas selection and high vacuum for high-resolution low surface area measurements. It utilizes the principle of physical adsorption or chemical adsorption to obtain adsorption and desorption isotherms and information regarding the surface area and porosity of a solid material. The surface area analyses plus pore size and pore volume distributions are performed using UHP nitrogen as the standard gas. Parameters such as BET and Langmuir surface areas, average and total pore volume, BJH pore size distribution and micro-pore analysis can be determined using this instrument. It employs a range of standard theories for the calculations such as Horvath-Kawazoe, Dubinin-Radushkevich, Dubinin-Astakov, t-plot, MP-method, BET, Langmuir and Density Functional Theory. The specifications include: measurement of surface area down to 0.0005 sq.m/g; pore diameters in the range of 3.5 to 5000 A; micropore volumes up to 0.0001 cc/g requires about 1 gm of the sample. The sample tube stems are 1/2 in in diameter with 9 cubic cm bulbs. The various gases that can be used are N2, O2, Ar, Kr, CO2, and H2. Chemisorption accessory is also available

**Minor Equipment**

* Mars 230/60 Microwave system
* Microfluidic based particle imaging velocimetry (PIV) system
* SensiQ Discovery Surface Plasmon Resonance (SPR)
* YSI 2300 STAT PLUS Glucose and Lactate Analyzer
* Shimadzu UV-2450 UV/Vis Spectrophotometer
* Gamry Instruments Reference 600 Potentiostat
* Instruments to support analyses, such as sputter coater, critical point dryer, ultramicrotome, precision saw, optical microscopes and fluorescent microscopes are also available.