# Olin's Materials Science Lab Equipment

## Structure/Composition

**X-ray Diffraction (XRD) (Shimadzu).** The x-ray diffractometer is useful for structural and compositional determination of materials. X-rays interact with charge density, and will reflect coherently off of ordered arrays of atoms, resulting in peaks of intensity at the correct angles (corresponding to the different periodicities present in the sample). It is primarily used to identify the crystal structures and lattice constants of inorganic substances and frequently enables you to identify the materials present in the sample from this, but will also give information about ordering in polymer and other organic materials, albeit with lower signal. (Askeland 3-9, Callister 3.16W on website and cd)

**Fourier Transform Infrared (FTIR) Spectrometer (Bruker).** The molecular bonds in (usually organic) materials can vibrate around their characteristic length or angle in response to stimulation by the energy in infrared radiation. The vibrating bond dissipates energy by emitting radiation of its own at a frequency characteristic of that particular bond and its surroundings. The radiation that is absorbed or transmitted can therefore be used to determine which combinations of bonds are present in the sample, giving a characteristic spectrum that can be used to identify the organic compound. Olin's FTIR has the capability of analyzing solids or liquids, and it has an attached IR microscope for microscale analysis.

**X-ray Fluorescence (XRF) (Innov-X).** The XRF system provides compositional information by collecting characteristic x-rays that are emitted from a sample following excitation of atomic electron energy levels by an x-ray source. XRF testing only takes a few minutes, so it is the fastest way to get compositional information on certain materials (great for many metals, not so great for light elements). XRF is also used to detect the presence of hazardous materials (e.g., lead) in polymeric components or environmental samples.

**Scanning Electron Microscope (SEM) and Energy Dispersive X-Ray Spectrometer (EDS) (JEOL and Thermo Noran).** A beam of electrons is accelerated and focused onto the surface of your sample, exciting the emission of secondary electrons from the sample which are detected and used to image the topography of the sample surface with resolution down to tenths of microns (1 millionth of a meter) scale. Can show: grain structure (etched sample), micro-scale structure, surface treatments, fracture details.

In conjunction with SEM, some of the electrons will interact with the sample, causing the sample to emit characteristic x-ray radiation which can show the composition of the sample both on the macro-scale and with nearly the same resolution as the imaging part of the SEM (ie micro-scale composition). (Callister 4.9)

**Atomic Absorption Spectrophotometer (AAS) (Shimadzu).** The AAS system measures the concentration of various elements in solution. For example, you could measure the amount of lead or copper in your drinking water. Or, if you dissolve a solid (e.g., a metal in acid) and dilute the solution, you can use AAS to measure bulk composition of samples. AAS is rather time consuming, and we are limited to testing only elements for which we have an AAS lamp: Fe, Cu, Ni, Co, Cr, Ca, and Pb.

**Optical Microscopes (Leica and Olympus).** Visual imaging down to about 10 microns. Olin's Leica stereo microscope is great for lower magnification imaging (up to about 40x magnification); and our Olympus inverted optical microscopes are particularly useful for metallographic analysis of polished and etched specimens. All of our optical microscopes have attached digital cameras. (Callister 4.9)

## THERMAL PROPERTIES

**Thermogravitometric Analyzer (TGA) (TA Instruments)**

The TGA detects the change in mass of a sample as function of temperature (or time) under a controlled atmosphere. Its principal uses include measurement of a material's thermal stability and composition. TGA may be used to measure water loss or solvent loss with temperature, and weight gain by oxidation at elevated temperatures. With an externally applied magnetic field, the TGA can be used to measure the Curie temperature of some samples. Olin's TGA has a temperature range of ambient to 1000 °C.

**Thermomechanical Analyzer (TMA) (TA Instruments).** Thermomechanical analyzers (TMAs) are used to measure a variety of material properties, including coefficients of thermal expansion (CTE), melting temperatures (though this is better done with the DSC below), glass transition temperatures, heat deflection, and elevated temperature creep or stress relaxation behavior. Olin's TMA has a temperature range of -150 to 1000 °C.

**Differential Scanning Calorimeter (DSC) (TA Instruments).** The differential scanning calorimeter (DSC) measures the energy absorbed (endotherm) or produced (exotherm) as a function of time or temperature. It is used to characterize melting, glass transitions, heat capacity, crystallization temperature, percent crystallinity (polymers), resin curing, loss of solvents, and other processes involving an energy change. Olin's DSC has a temperature range of -80 to 500 °C.

## MECHANICAL PROPERTIES

**(Askeland Ch. 6 and 7, Callister Ch.6 and 8)**

**Universal Mechanical Tester (large Instron system).** Measure the mechanical behavior and properties (stress vs. strain, elastic modulus, tensile strength, fracture strength, ductility, yield strength, etc) of bulk materials in compression, extension, or bending. Olin's large Instron system is for relatively strong or stiff materials (metals, engineering polymers, ceramics), as it has a 100 kN load capacity. We also have an environmental chamber for the large Instron system, to enable mechanical testing from -100 to 300 °C. Attaching the small Instron's load cells to the large Instron system is also a possibility, if you have large samples that take low load.

**Universal Mechanical Tester (small Instron system).** If you have a material that is too soft for the large Instron system, check out our smaller Instron universal mechanical tester. It has a set of tension, bending, and compression fixtures, like the large machine. But the small Instron has more sensitive load cells (better for lower loads), and a maximum load capacity is 5 kN.

**Environmental chamber for Instron.** As noted above, our large Instron has an environmental chamber attachment that enables testing of samples at temperatures between -80 °C and 300 °C.

**Impact Tester (Instron).** The impact tester measures forces and energies during impact, and it enables you to characterize the ability of materials to absorb energy during fracture or deformation under high strain rates.

**Rockwell Hardness Tester.** Determines the hardness of a material (its resistance to surface deformation or abrasion) on the Rockwell hardness scale. Produces 0.1mm to mm scale indentations.

**Durometer Hardness Testers.** Measures the hardness of polymeric specimens on Shore A and Shore D scales.

**Microhardness Tester (Buehler).** Determines the hardness of a material on the Vickers or Knoop hardness scale with indentations on the order of tens of microns. Useful to discriminate between different constituents.

## Electrical Properties

**Four point probe and nanovolt meter (Agilent).** Determines the electrical conductivity (or resistivity) of solid samples or thin films by applying an electrical current and measuring the voltage drop.

**High resistance meter (Keithley)**. Enables conductivity testing of high resistance samples (of a uniform geometry), such as conductive polymers.

**Power supplies, function generators (Agilent)**. These instruments are great for a variety of testing, or sample processing such as electrolytic polishing, electroplating, or electrolytic etching.

## Other Equipment

**Gas pycnometer (Quantachrome).** Determines volume of materials by gas displacement; great for calculating an accurate density.

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## Sample Preparation/Processing equipment:

- Thermal Evaporator (thin film deposition).
- Spin Coater.
- Sonicator (surface cleaning)
- Programmable muffle furnaces (melting, sintering, reacting, refining)
- Tube furnaces (melting, sintering, reacting, refining in controlled atmosphere such as $O_2$, $N_2$, or Ar)
- Electric melting furnaces (used for casting)
- Ovens (drying, melting, reacting)
- Mounting presses (encapsulating small samples in polymer for cutting/polishing)
- Grinders and polishers (creating a smooth surface for single crystal x-ray scattering, microhardness testing, grain boundary identification on SEM).
- Rolling mill (cold working metals)
- Horizontal band saw (cutting samples)
- Precision saws (cutting ceramics, most metals, some composites and polymers)
- Laboratory press with heated platens
- Ball mill (for grinding)
- Sieve shaker (separating powder samples into differently sized particles)
- Casting equipment (wax injector, vacuum casting machine)
- Forging equipment (anvil, hammers, anvil tools)
- Sputter coater (preparing non-conductive specimens for SEM analysis by coating with Ag or Au)
- Carbon coater (coating with carbon as opposed to Ag or Au with the sputter coater