Lasers

25 Watt CO_2 Laser - An Ultra Lasertech model PX2500 CO_2 laser system. This transverse mode (TEM_{oo}) continuous wave, sealed tube laser system produces a maximum of 25-30 watts of infrared energy at the output wavelength of 10.6 microns.

Nd:YAG Laser (pulsed) - Continuum Corp. model NY-61-10. This laser has both oscillator and amplifier rods, plus second, third and fourth harmonic generators capable of providing UV light with 170 mJ/pulse at 355 nm, and 60 mJ/pulse at 266 nm. Q-switching provides 4-ns pulses (266 nm) at 10 Hz repetition rate.

Helium Neon Lasers - Melles Griott, power outputs of 2.5 mW and 25 mW.

Instrumentation

MKS Multi-Gas® 2030 FT-IR Gas Analyzer - AFR has six 2030 Multi-Gas Analyzers, which employ a 2100 Process FT-IR Spectrometer to obtain high resolution infrared spectra which are compared to quantitative library reference spectra for high sensitivity and accurate analysis of most gases and vapors. The FT-IR is coupled to a Model 20/20™ long path gas cell with non-spherical, aberration - correcting mirrors. The cell provides more than twice the throughput of a standard White Cell. Robust quantitative analysis software can simultaneously analyze up to 50 gases.

Gas Chromatograph - A Carle AGC 400 gas chromatograph, is available for gas analyses. Both FID and TCD detectors are used with automatic switching of packed columns to analyze for H_2, N_2, O_2, CO, H_2S, and all hydrocarbons up through C_4`s. Larger hydrocarbons can be estimated from a backflush peak.

Gas Chromatograph - A HNU Model 421 gas chromatograph is available for liquid analyses. It has a FID detector and is fitted with a fused silica capillary column.

Waters HPLC system equipped with a model 450 variable wavelength UV-VIS detector is modified to be able to operate in the scanning mode for the whole spectral range (200-700 mm). The system was recently equipped with a concentrator-fiber optic IR transmittance micro cell to collect direct hyphenated FT-IR spectra in the HPLC-FT-IR coupled mode.

TG/FT-IR - This apparatus allows a thermogravimetric (TG) analysis to be performed on a sample at the same time as the evolved products (including condensables) are analyzed by FT-IR. This instrument has been developed by AFR in conjunction with Bomem, Inc. (an FT-IR manufacturer). The apparatus consists of a Dupont 951 TGA coupled with a multi-pass infrared cell. As the sample is heated, the evolving volatile

species are carried out of the furnace directly into the cell for analysis by a Bomem Michelson 100 FT-IR and provides for on-line quantitative analysis of CO, CO_2, H_2O, CH_4, C_2H_6, C_2H_4, C_2H_2, C_3H_8, benzene, heavy paraffins, heavy olefins, HCN, HCl, NH_3, SO_2, CS_2 COS, CH_3OH, CH_3COOH, CH_3COCH_3, and other species.

Laboratory Reactor Systems - Several laboratory reactors are available, ranging from 1 inch to 6 inch diameters. These can be used for programmed pyrolysis, gasification or oxidation reactions.

ISI SEM and PGT X-Ray Analyzer - For characterizing the morphology and impurities of materials, an ISI model SX-30 scanning electron microscope with Princeton Gamma-Tech System 4 x-ray analyzer is available. This microscope system has an ultimate resolution of 60A. The attached x-ray analyzer system has the capability of measuring elements heavier than sodium.

Electronic Equipment

Digital Storage Oscilloscope - A Hewlett-Packard 54601A, 4 channel 100 MHz digital oscilloscope with Fourier-Transform function and RS-232 interface.

Analog Storage Oscilloscope - A Tektronix 466, 2 channel 20 MHz oscilloscope.

Lock-in Amplifier - AFR has an EG&G Princeton Applied Research Model 5210 two phase lock-in amplifier suitable for use from 0.5 Hz to 120 kHz. This lock-in can easily be operated under computer control.

Electronic Materials & Devices

Film Deposition System - AFR, Inc. has assembled a complete system for UV laser ablation and film deposition (referred to as Pulsed Laser Deposition, PLD). The system is based on a Continuum Corp. Nd:YAG laser, model NY-61-10. This laser has both oscillator and amplifier rods, plus second, third and fourth harmonic generators capable of providing UV light with 170 mJ/pulse at 355 nm, and 60 mJ/pulse at 266 nm. Q-switching provides 4-ns pulses (266 nm) at 10 Hz repetition rate. A Scientech volume-absorbing UV power meter is used for tuning the laser. A motor-driven dichroic mirror scanner and a focusing lens direct the laser beam onto the target through a Suprasil UV-quartz window. Two vacuum deposition chambers are available for PLD. Both are designed around a 6-inch ID, 6-way cross with ISO flanges, for flexibility in configuration. The first is pumped through a 4-inch ID gate valve by a Balzers turbomolecular system to a base pressure of $3x10^{-7}$ mbar. The turbo pump is backed by

a liquid-nitrogen cold trap and membrane forepump to ensure entirely oil-less pumping. A micrometer leak valve allows process gases to be admitted to the chamber, with flow through to the pump, during film deposition. Oxygen, with very low carbon content, is used for oxide (e.g., ceramic superconductor YBaCuO) film depositions. Alternatively, an effusion cell can direct a beam of thermally evaporated mercury, or other low vapor pressure, atoms onto the substrate during the PLD process (e.g., for growth of HgCdTe semiconductor films). This chamber also has a regulated and programmable substrate heater system, with adjustable target-substrate distances. Direct heating of substrates in the range of 30-850 ^{o}C is provided by a silicon-carbide bar element. Presently, substrates are single-crystal wafers of metal oxides (e.g., $LaAlO_3$, YSZ), and semiconductors (e.g., Si, GaAs, and CdTe) up to 10x10 mm^2. A modification is being developed for wafer substrates 50 mm in diameter. Target mounting in the chamber is on a translatable finger, allowing multitarget operation during a single deposition routine. The finger is pneumatically actuated and can rapidly position various targets for ablation, allowing, for example, multilayers to be deposited onto a buffer layer film (i.e., total of three film types). In the second chamber a 6-inch ID diffusion pump and single target operation are used. This system has been used successfully to grow epitaxial films of diamond-structure b-SiC on Si wafers by PLD. The chamber is also equipped to deposit diamond films by the tungsten-filament CVD method, and various films by rf-plasma CVD.

Rapid Thermal Processing (RTP)/Deposition Tool - The RTP tool is a water-cooled, 12- inch diameter x 14-deep stainless steel cylindrical chamber. The RTP system includes a rotating wafer support for rotating 150 mm wafers or smaller wafers during processing up to 120 rpm. The substrate heater consists of a six-zone array of tungsten-halogen linear lamps and a water-cooled aluminum reflector located outside of the chamber, separated by a 0.75-inch thick x 10-inch diameter quartz window. With this configuration, silicon wafer temperatures up to 900 °C are possible during processing. The RTP system is currently configured with a two-inch magnetron sputter source (AJA International model ST20) in an upwards deposition geometry. The dc power supply is an Advanced Energy MDX 500 1 kV (500 W) power supply with arc suppression. A gas ring and chimney on the sputter source minimize deposition on chamber ports and walls. Metal oxides can be deposited by reactive sputtering in an argon/oxygen environment.

Deposition Monitors - Vacuum and process gas pressures are measured with a CVC, Inc. model GPT-450 gauge covering the range of 1 atm to 10^{-8} mbar. A Minolta-Land, Cyclops 52, pyrometer is used for direct observations of the substrate surface temperature. A pair of IR access windows on the chamber allow reflection Fourier-Transform Infrared Spectroscopy (FT-IR) *in situ* monitoring of film growth surface temperature, composition, and thickness. The spectrometer is a Bomem 102, modified to use two MCT detectors allowing simultaneous emission and reflectance with 4 cm^{-1} resolution. On-line computer control of the laser, its shutter, the temperature regulator, and the FT-IR allows for efficient execution and monitoring of elaborate deposition procedures.

Ablation Targets - AFR has a full wet lab for superconductor precursor material processing. A ten-ton pill press is used to form the 0.5 inch diameter targets. A tubular muffle furnace, capable of sustained temperatures up to 1050 ^{o}C in flowing oxygen, is used to sinter the targets. This system allows, for example, the fabrication of YBaCuO targets with on or off-stoichiometry and cation substitutions, or targets of zirconia, magnesia or ceria with various compositions, e.g., yttria-stabilized zirconia (YSZ) with 9 M% yttria in the cubic-fluorite phase. Presently, we also use commercial targets from various sources.

Substrate Preparation and Film Patterning - To prepare silicon-wafer substrates for film deposition, cleaving tools, a wet bench and dry glove box for etching are used. This latter process is adapted from the Xerox PARC and JPL methods to *spin etch* Si wafer surfaces with a solution of HF in ethanol, which produces atomically clean, passive and oxide-free surfaces. After deposition, superconductor-oxide films are patterned in a yellow room with a spin-on positive photoresist (Shipley 1400 series), contact masking and wet etching with nitric or EDTA acids, in an attenuated ultrasonic bath. A class-100 clean bench is used for the lithography. The masks are drawn by CAD, laser printed, and photo-reduced (typically, by ~20:1 or 100:1) onto Kodak 35-mm *Technical Pan* film. Full in-house facilities allow rapid device-pattern design and modifications. The current design limit for patterned lines is ~3 mm, and patterned gold films have been realized with edges resolved to 1-2 mm. Electrical contact metallizations are made by gold or silver which is DC-sputtered, slurry-painted, or PLD-ablated (through contact shadow masks) onto the superconductor films. Superconductor films are passivated by a protective coating of dense, transparent YSZ deposited in the PLD system, onto near-room-temperature film devices.

Device-Testing & Cryostats - For superconductor device characterization, AFR has two, variable-temperature, cryostats and associated electronics for measuring DC and AC current-voltage (I-V), electrical noise, and IR-visible radiation-response characteristics. In one cryostat, samples, up to 1x1 cm^2 in size, are mounted at the bottom and face up the bore axis of the cryostat tube for operation from 4.2 to 300 K. Quick contact is made in a jig by gold or silver spring pins. The optical (IR) characteristics of this apparatus have been calibrated with an FT-IR spectrometer for use with a KRS-5 (TlBrI) window and a Globar thermal source of known emission spectrum and sample irradiance. The other cryostat is a Janis Research, model VFP-100-LN2-SSVT, with 77 to 300 K operation, high lead-wire count, four windows and 3-inch ID bore. The testing electronics include a custom low-noise, wide-range constant current source, a Keithley model 224 programmable constant-current source, a Fluke model 8842A programmable digital microvoltmeter, a Lake Shore model DRC-91C programmable temperature regulator, Tektronics model 7100 oscilloscope with high-gain differential preamplifiers and Tektronics model 2221A 100-MHz digital storage scope, and a PAR model 5210 programmable lock-in amplifier. The later is used for AC characterization (e.g., photoresponse or switching) and narrow-band noise measurements from 0.5 Hz to 100 kHz. This system has an IEEE-488 bus for computer (PC-386) control and data logging of measurements in the cryostats. The cryostats are

also used for pulsed light (xenon strobe and YAG laser) illumination, modulated microwave (11.5 GHz waveguide), and FT-IR spectroscopy of samples and detectors.

Imaging/Microscopes/SEM

Video Camera - A Sony 8 mm camera has a very sensitive CCD detector which can reach low light levels and obtain single pictures at 1/4000 sec shutter speed.

Optical Microscope - Olympus FZ-1145 series with stereo, zoom, and maximum magnification greater than 200x

SEM - For characterizing the morphology and composition of materials and films, an ISI model SX-30 scanning electron microscope (SEM) with Princeton Gamma-Tech, System 4 x-ray analyzer, energy dispersive spectroscopy (EDS), is available. This microscope system has an ultimate resolution of 10 nm. The attached x-ray analyzer system has the capability of measuring quantitatively all elements heavier than sodium

Flat Bed Color Scanner - The HP ScanJet 4c scanner is a versatile flatbed scanner that captures both black and white and color drawings, photographs, and text at high resolution (2400 dpi enhanced resolution and 600 dpi optical resolution). If using optical character recognition (OCR) software, the HP ScanJet 4c scanner can scan text into a format that can be edited.

Digital Camera - Olympus D-300L. A 1024x768 High Quality Image camera with: all glass aspherical F2.8 autofocus lens, video out, 3 levels of compression, exposure controls, auto flash with "red-eye" reduction.

Wet Lab

AFR has a fully equipped Wet Laboratory with vacuum hoods, solvent cabinets, acid cabinets, and dry chemical storage. The facility has number of devices and equipment such as: balances, ultra sonic cleaners, heated stirring plates, pH meters, centrifuges, and a vast array of glassware for experimentation.

Computer Software

LabVIEW 5.1 - AFR uses LabVIEW for much of its data acquisition and analysis. LabVIEW is a graphical programming language which allows rapid development of programs.

NeuralWare - NeuralWorks Professional II/PLUS is the world's standard in professional neural network development systems. NeuralWorks Professional II/PLUS allows you to build, train, refine and deploy neural network solutions.