

ARC - Facilities, Equipment, and Other Resources

The Analytical Resources CORE (ARC) is an established Institutional CORE at Colorado State University administered by the Office of the Vice President for Research (OVPR). The mission of the ARC is to enable cutting-edge STEM research and development programs at Colorado State University by providing access to analytical research instrumentation, expert guidance, services and education to CSU and the broader community. The ARC receives administrative support from the OVPR around HR, business management, accounting and cost-recovery, iLab and marketing. ARC has three centers, each available to on-campus researchers as well as external users on a fee-for-service basis:

- *The Materials and Molecular Analysis Center (ARC-MMA)*, an open-access research and training facility that specializes in the spectroscopic, spectrometric, X-ray and other materials characterization of synthetic, environmental and biological materials, both at the bulk and molecular scales.
- *The Bioanalysis and Omics Center (ARC-BIO)* provides analysis of complex biological samples using modern metabolomics and proteomics approaches, including supporting informatics.
- *The Imaging and Surface Science Center (ARC-ISS)* provides analysis of complex biological and inorganic samples using near- and far-field imaging methods, spectroscopy, and other surface analyses.

The OVPR supports over 30 CSU Core facilities and research resources by providing stewardship, visibility and leadership for strategic planning and vision. Infrastructure is supported through competitive internal funding requests sourced through a designated stream of research. These research facilities support a vibrant research community and are fully staffed to provide expert guidance, support, and instrumentation for their users. The OVPR's Cores program ensures access to state-of-the-art research tools and expertise across the University and enables development of new directions in emerging areas of research and technology.

A. ARC Center for Materials and Molecular Analysis (ARC-MMA)

A.1. Equipment

Mass Spectrometry

- GC/MS – Thermo Scientific ISQ QD single quadrupole GC-MS with Trace 1310 GC and with automatic liquid sampler.
- GC/MSMS - Thermo Scientific TSQ 8000 Evo Triple Quadrupole GC-MS/MS, equipped with Triplus RSH autosampler and EI and CI (methane) sources.
- MARKES Thermal desorption Unity-xr with Ultra-xr (100 sorbent tubes) autosampler. Interfaced to Thermo ISQ QD GC single quadrupole mass spectrometer.
- Bruker ultrafleXtreme™ MALDI-TOF/TOF high resolution mass spectrometer (with FlexAnalysis/Polytools/Polymerix software)
- Agilent 6545 quadrupole time of flight mass spectrometer (TOF-U) interfaced to an Agilent 1290 Infinity UHPLC with electrospray (ESI) and IonSense Direct Analysis in Real Time (DART) ambient ionization source.
- Waters Xevo G2 ESI-Q-TOF mass spectrometer with a capillary Waters Acquity UPLC unit (controlled by a Lenovo PC and MassLynx software)

NMR/EPR Spectroscopy

- Bruker US400: Equipped with BBFO SMART Probe and SampleCase.
- Bruker NEO400: Equipped with a Prodigy BBFO Cryo-Probe and SampleCase.
- Bruker Ascend 400: Equipped with BBFO smart probe, sample case, and extended range VT.
- Bruker AVANCE NEO 400 (AV400): 400 MHz NMR for liquids samples, equipped with iProbe, and 60 sample SampleCase (funded by NIH-SIG S10 2024; Award No. S10OD036347).
- Bruker AVANCE NEO 600 (AV600): 600 MHz NMR Liquids and Solids samples, equipped with a iProbe, HCN Prodigy Probe, 60 sample Sample Case, and a HXY 4mm Phoenix NMR solids Probe (funded by NSF-MRI 2024; Award No. 2406992).
- Bruker ELEXSYS ESR-300 X-band CW EPR spectrometer: Dual-band and high sensitivity probe options are available along with Bruker Cold Edge and cryostat for VT down to 5 K.

Spectroscopy

- Nicolet iS-50 FT-IR spectrometer with a single pass diamond ATR-ZnSe also a high index of refraction Ge crystal for thin films, powders and liquids; Harrick Grazing Angle Reflectance Accessory for thin films on metal or semiconductor substrates; Gemini Diffuse Reflectance Accessory for non-reflecting powder materials.
- Malvern Zetasizer Nano ZS with 633nm 'red' laser for size measurement of particles and molecules (e.g. proteins) dispersed in a liquid (using dynamic light scattering, DLS); zeta-potential of colloids and nano particles for predicting dispersion stability (using electrophoretic light scattering); and the measurement of microrheology of protein and polymer solutions. The high performance of this instrument also enables the measurement of molecular weight of macromolecules.
- Edinburgh FS5 spectrofluorometer for steady state (150 W xenon lamp) and time-resolved fluorescence emission measurements in the 230-870 nm spectral range. Fluorescence lifetime capability (TCSPC – Time Correlated Single Photon Counting) with EPLED 320nm, 365nm, 450nm, and 650nm LEDs, and EPL 510nm pulsed diode laser). Temperature controlled sample holder and solid sample holder. Integrating sphere for quantum yield measurements.

Magnetic and Physical Properties

- Quantum Design PPMS: 9 Tesla, DC Resistivity, Electrical Transport, Thermal Transport, Heat Capacity, Horizontal Rotator, Multi-Function Probe, Vibrating Sample Magnetometer, VT from 1.8 K to 1000 K.
- Quantum Design MPMS3: 7 Tesla supercon with SQUID AC susceptibility, Vibrating Sample Magnetometer for DC field measurements, Electric Transport, Horizontal Rotator, VT from 1.8 K to 1000 K.
- Quantum Design Dilution Refrigerator Probe, VT to 50mK
- Quantum Design iQuantum Helium-3 Insert, VT to 500 mK

Thermal Analysis

- TA Discovery 2500 Modulated Differential Scanning Calorimeter (DSC): Measured properties include glass transition, melting points, % crystallinity, heats of fusion, specific heat, kinetics, stability, purity, cure rate, and sub-ambient accessory and multi-position sample holder (-80 to 350°C).

X-ray Diffraction and Scattering

- Bruker D8 Discover DaVinci for X-ray diffraction analysis of powders. CuK α radiation, LYNXEYE-XE-T energy discriminating detector, Nine position sample changer with Phi rotation, and Electrochemical cell for in situ experiments. Adaptable for VT experiments with Anton Paar HTK1200N stage (w/ capillary extension).
- Bruker D8 Advance QUEST: Non-destructive technique that provides precise information about 3-D molecular and crystal structures of small molecule single-crystals with MoK α radiation. Features a Photon 50™ CMOS detector which is capable of high speed data collection in shutterless operation mode.

Helium Recovery

1. Quantum Design ATP30 Helium Purifier and ATL160 Helium Liquefier – high pressure recovery system, auxiliary storage components provide for approximately 25 liter per day of liquid.

A.2. Facilities

Approximately 8,150 square feet of space is assigned to the MMA

Chemistry Main Basement Laboratory: Total space is 6800 square feet for ARC-MMA. This includes staff offices and break area (1200 sq ft of total) and investigator collaborative area, C1; laboratory equipment and computer workstation floor space in C2B, C3, C4 and C5 (C5 includes undergraduate student intern office pod); 400 square foot NMR Lab, C3E; 700 square feet of additional space for project staging, C2; a 150 square foot gender neutral bathroom, C2A.

Equipment found here includes ARC-MMA mass spectrometers, NMRs, XRDs, Magnetic Properties, Spectroscopic tools and Thermal Analysis instruments.

Chemistry B2 High Field Basement NMR Laboratory is a 400 square foot lab that used to house a 14 Tesla narrow bore, unshielded NMR magnet and console, decommissioned in 2021. The room is dedicated and outfitted for high field NMR with plumbing in place for helium recovery.

Chemistry Research Building CRB-109 is 350 square feet of new laboratory space plus office with vibrationally isolated floor that holds two 400 MHz NMRs, a routine electrospray mass spectrometer.

Chemistry Research Building CRB-204Lb is 175 square feet of new laboratory space that houses a Bruker D8 QUEST single crystal XRD system capable of shutterless data collection.

Computers and Data Management Infrastructure. Instrument data are collected and stored on instrument hard drives for up to one year. A copy of the data is also be stored through automatic backups onto the CSU's ACNS Research Storage solution, RStor, which currently is configured with over 300 terabytes of storage. This is a recently implemented DELL Isilon storage platform located in the CSU campus data center and can be accessed directly from any computer workstation in the ARC-MMA lab. The ARC-MMA has three networked workstations in addition to our instrument computers where students can access and process data. Data is stored on RStor and accessible to users for 3 years. After this period, data files are transferred onto an external hard drive for archiving and cleared from RStor. This data management plan, which is implemented throughout the ARC-MMA, guarantees secure backup of any data collected on all instruments.

Software licenses

ARC-MMA maintains current licenses for several software packages, including data acquisition and processing software of vendors of the different instruments. Data can be analyzed by users using the instrument software on the workstations in the MMA, or remotely (for most instruments) from their own computers by RemotePC™, a license provided by the ARC-MMA to all users. The following licenses are offered to investigators for their own use and installation with an additional fee as they cannot be accessed through RemotePC™:

- Cambridge Crystallographic Data Centre (CCDC)

- CrystalMaker software package (including CrystalMaker, SingleCrystal, CrystalDiffract, and SingleCrystal Viewer)
- Inorganic Crystal Structure Database (ICSD-web)

A.3. Other Resources (Staff)

Staff Scientists – five full-time PhD research scientists cover all major instruments, chemistry, engineering and life science disciplines, provide expertise for student training and full collaborations as may be needed or desired.

Undergraduate Student Interns – on average three undergraduate student hourly employees support the ARC-MMA services and operations, and receive training and experience in laboratory operations and professional development around team science and soft skills. Many of these students become very proficient in sample preparation, instrument operation and basic maintenance.

Business and Administration Office – ARC-MMA is aided by one FTE business manager, in charge of all ARC business and finance management, property management, recharge center cost-accounting, purchases and billing, and grant proposal pre-and post-award management. A part-time HR support admin assists ARC with employee management.

B. ARC Center for Imaging and Surface Science (ARC-ISS)

B.1. Equipment

Electron Microscopy

- JEOL JEM-2100F transmission electron microscope (TEM) with UHR pole piece, with STEM capability and Gatan CCD camera equipped with an Oxford SDD EDS detector.
- JEOL JSM-IT800(HL) scanning electron microscope with an Oxford UltimMax 170 mm² energy dispersive X-ray spectrometer (EDS), Expert HKL electron backscatter diffraction (EBSD) detector, a Deben STEM detector, a JC Nability lithography system, a Deben Centaurus CL detector.

Sample Preparation

- EMS Quorum Q150T ES Plus Coater. Coating system capable of both carbon coating and metal sputtering, equipped with a turbomolecular pump.
- Carbon Coater. Samples may be coated by evaporating carbon, with thickness ranging from 10 to 200 nm.
- Pace Technologies PICO 155P Precision Cutter. Variable speed precision wafering saw for sectioning materials with extreme accuracy. The saw is useful for sectioning a variety of materials including metals, ceramics, and electronics.
- Pace Technologies NANO 2000T Grinder-Polisher. Variable speed double wheel grinder-polisher with 8-10 in. wheels for different combinations of materials and polishing compounds.
- Pace Technologies Giga-0900 Vibratory Polisher. With adjustable vibration frequency and voltage, the speed of polishing action can be controlled, allowing for large and small samples to be prepared separately or simultaneously.
- Turbo pumped plasma cleaner specifically for electron microscope sample holders and some selective samples. Used to remove hydrocarbon surfaces and to modify TEM substrate surfaces. Oxygen and Argon gases are available.

B.2. Facilities

Approximately 900 square feet of space is assigned to the ARC-ISS

Yates Hall Y101 Electron Microscopy Laboratory is a 900 square foot laboratory with vibrationally isolated floor, stray field compensation, precision temperature control, backup UPS, emergency natural gas generator that holds the ARC-ISS JEOL JEM-2100F TEM, JEOL JSM-IT800(HL) SEM, and imaging sample preparation equipment.

B.3. Other Resources (Staff)

Staff Scientists – One full time PhD scientist, one full time postdoctoral associate and one 75% time PhD scientist providing expertise in electron microscopy and spectroscopy.

Business and Office Management – ARC-ISS is aided by one FTE business manager, in charge of all ARC business and finance management, property management, recharge center cost-accounting, purchases and billing, and grant proposal pre-and post-award management. A part-time HR support admin assists ARC with employee management.

C. ARC Center for Bioanalysis and Omics (ARC-BIO)

C.1. Equipment

Mass Spectrometry

- Thermo-Scientific Orbitrap Eclipse, FAIMS-Pro Ion Mobility Interface, Vanquish Neo (nano) LC system, (controlled by a Dell PC and Xcalibur software, Proteome Discover 3.0 software)
- Waters XevoMRT multireflectron time of flight (Q-TOF) mass spectrometer with Acquity Premier inert UPLC (controlled by Lenovo PC and Waters Connect software)
- Waters Synapt G2-Si Ion Mobility enabled Q-TOF mass spectrometer with a capillary Waters Acquity UPLC and nanoAcquity UPLC unit (controlled by a Lenovo PC and MassLynx software)
- Waters Xevo G2-XS ESI-Q-TOF mass spectrometer coupled to an Agilent GC coupled using an atmospheric pressure (APGC) ionization source. Alternately connected to a Waters I-Class UPLC via ESI source. (controlled by an HP PC and MassLynx software)
- Perkin Elmer NexION 350D ICP-MS with prepFAST SC-2 autosampler (Elemental Scientific) (controlled by a Lenovo PC running Syngistix software)
- Waters Xevo TQ-S mass spectrometers with Waters Acquity UPLC (controlled by a Dell PC and MassLynx software)
- Two Thermo Scientific Trace ISQ GC-MS instruments (controlled by Dell PCs running Chromeleon software), one of which is serviced by a headspace/SPME/ITEX capable autosampler and an olfactory port for sensory evaluations
- Labman Metabolomics Sample Preparation robot.
- OpenTrons Flex Liquid Handling Robot.

Other smaller equipment

One dimensional agarose and SDS-PAGE gel electrophoresis apparatus; seven chemical fume hoods; incubators; Savant Speed Vac with refrigerated vapor trap; refrigerated bucket centrifuge and microfuges, room temperature microfuge, Lyophilization unit, Three nitrogen evaporators, Probe Sonicator, 2 bath sonicators, UV/Vis spectrophotometer, microplate reader; 4 -80C freezers; 3 -20C freezers and several refrigerators.

C.2. Facilities

The Bioanalysis and Omics Center of the Analytical Resources Core (ARC-BIO) is comprised of 3,200 sq. ft. on the 1st floor of the Microbiology Building on the main campus of CSU. This space accommodates 6

staff scientists, 7 fume hoods, and sample prep and major research instrumentation in the areas of chromatography and mass spectrometry, focused on targeted and non-targeted proteomics, metabolomics, and ionomics applications. There is also space to accommodate graduate students, post-doctoral scientists, user training as well as visiting and collaborating scientists.

Computer

Multiple computer stations equipped with scanners, printers, standard data analysis, word processing, and database software are housed within the laboratories. Four high RAM (32 GB or greater) workstations for processing large datasets. In addition, the lab maintains current licenses for several bioinformatics programs, including Mascot, Proteome Discoverer, and other data tools including in-house developed software and a heavy reliance on the open source R platform. The laboratory subscribes to expandable RAID protected centralized storage through CSU ACNS.

Office

The facility includes 604 total sq ft of office on the first floor of the Microbiology Building. These offices are adjacent to the laboratories and are equipped with a total of 10 Dell desktop PCs with 18" external monitors or larger. The computers are connected to the CSU network and networked printers.

C.3. Other Resources (Staff)

Staff Scientists – Four full-time PhD scientists and two full time BS scientists, with an additional 25% time PhD level scientist manage all instrumentation, sample preparation, consultation, and data analysis performed in the ARC-BIO.

Business and Office Management – ARC-BIO is aided by one FTE business manager, in charge of all ARC business and finance management, property management, recharge center cost-accounting, purchases and billing, and grant proposal pre-and post-award management. A part-time HR support admin assists ARC with employee management.