**8. 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 19 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**

1. GC/MS - Agilent 5973N Mass Selective Detector interfaced to a 6890 gas chromatograph which is equipped with a 7683 automatic liquid sampler with EI source.
2. GC/MS – Thermo Scientific ISQ QD single quadrupole GC-MS with Trace 1310 GC and with automatic liquid sampler.
3. GC/MSMS - Thermo Scientific TSQ 8000 Evo Triple Quadrupole GC-MS/MS, equipped with Triplus RSH autosampler and EI and CI (methane) sources.
4. MARKES Thermal desorption Unity-xr with Ultra-xr (100 sorbent tubes) autosampler. Interfaced to Thermo ISQ QD GC single quadrupole mass spectrometer.
5. Thermo-Finnigan LTQ LC/MSMS linear Ion-trap mass spectrometer with ESI source.
6. Bruker maXis Plus ultra-high-resolution quadrupole time of flight (QTOF) mass spectrometer with Waters Acquity H-class UPLC. Equipped with Bruker ESI and APCI sources.
7. Bruker Daltonics MALDI-TOF Microflex LRF mass spectrometer (with FlexAnalysis/ Biotools software)
8. LC/TOF-MS (accurate mass) Agilent 6224 walk-up time-of-flight mass spectrometer (WTOF) interfaced to an Agilent 1200 HPLC with electrospray and multi-mode (ESI/APCI) sources, and an IonSense Direct Analysis in Real Time (DART) ambient ionization source.
9. LC/TOF-MS (accurate mass) Agilent 6230 Agilent time-of-flight mass spectrometer (BTOF) interfaced to an Agilent 1290 Infinity UHPLC with electrospray and multi-mode (ESI/APCI) sources.
10. LC/QTOF-MSMS (accurate mass) Agilent 6510 quadrupole time-of-flight mass spectrometer (QTOF) interfaced to an Agilent 1200 HPLC with electrospray and multi-mode (ESI/APCI) sources
11. Waters Xevo UPLC-MSMS triple quadrupole with Waters Acquity H-class UPLC, with ESI ionization.
12. Waters Acquity UPLC with PDA detector.

**NMR/EPR Spectroscopy**

1. Agilent (Varian) 400MR: Equipped with Automated Tuning and a 7620 96-slot Sample Changer.
2. Bruker US400: Equipped with BBFO SMART Probe and SampleCase.
3. Bruker NEO400: Equipped with a Prodigy BBFO Cryo-Probe and SampleCase.
4. Bruker Ascend 400: Equipped with BBFO smart probe, sample case, and extended range VT.
5. Agilent Inova 500: With three channels, 3-axis gradients and many other accessories including HCN, broadband probes and a NANO (HRMAS) probe.
6. Agilent Inova 600: With four channels, 2H decoupling, 3-axis gradients and many other accessories including HCN and a flow-probe.
7. Bruker ELEXSYS E500 X‐Band CW EPR Spectrometer System with Bruker cold edge and cryostat. Dual band and high sensitivity probe options are available.
8. Bruker EMX X-band EPR Spectrometer System.
9. Spare Parts Store (working): Three Inova Consoles, Two Mercury Plus Consoles, one mothballed narrow bore (NB) self-shielding Magnex US400 magnet and accessories, two de-energized NB 300 oxford magnets, Magnex Charging Kit, Stainless hydraulic solenoid lift kit, Variety of Varian solution probes, one 3.2mm Varian 400 MHz CPMAS probe.

**Spectroscopy**

1. 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.
2. Agilent (Cary) UV-Vis-NIR equipped with VASRA or Variable Angle Specular Reflectance Accessory that is used with thin films at angles from 20 to 70 degrees; Praying Mantis diffuse reflection analysis of solids and powders.
3. 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.
4. 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**

1. Quantum Design PPMS – 9T, DC Resistivity, Electrical Transport, Vibrating Sample Magnetometer (VSM), Thermal Transport, Heat Capacity, Horizontal Rotator, Multi-Function Probe, VT from 1.8 K to 1000 K
2. Quantum Design MPMS3 – 7T, DC Resistivity, SQUID, AC, Electrical Transport, Vibrating Sample Magnetometer (VSM), Thermal Transport, Heat Capacity, Horizontal Rotator, Multi-Function Probe, VT from 1.8 K to 1000 K.
3. Quantum Design Dilution Refrigerator Probe, VT to 50mK (Prof. Kate Ross, Physics)
4. Quantum Design iQuantum Helium-3 Insert, VT to 500 mK (Prof. Kate Ross, Physics)

**Thermal Analysis**

1. TA Modulated DSC 2500 with sub-ambient accessory and multi-position sample holder.
2. TA TGA Q500 Thermogravimetric analyzer measures thermal stability, multi position sample holder for measurements from ambient up to 900ºC.

**X-ray Science**

1. Bruker D8 Discover Series II Diffractometer with Parabolic Göbel mirror for parallel and monochromatic beam, ¼-circle Eulerian cradle, Equipped with 4-Bounce monochromator capable of HRXRD, XRR and GAXRD.
2. Bruker D8 Discover – DAVINCI with Flip-Stick sample stage, Lynx-Eye Detector, Diffrac.EVA, TOPAS and other software for powder XRD, adaptable for VT experiments with Anton Parr HTK1200N stage.
3. Bruker D8 Discover Series II – theta-theta mode, Göbel mirror or Bragg, Cu radiation, Lynx-Eye detector upgrade
4. Bruker APEXII single-crystal diffraction system.
5. Rigaku Small Angle X-ray Scattering with Cu rotating anode and MicroMax-007HF
6. Bruker D8 Quest Single Crystal XRD with fixed CHI, Photon 50, sealed Mo tube, Triumph monochromator and motorized track.

**Helium Recovery**

1. Quantum Design ATP30 Helium Purifier and ATL160 Helium Liquifier – 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, as well as a few ARC-ISS surface analysis instruments (XPS, CAG, VASE).

**Chemistry High Field Basement NMR Laboratory** is a 400 square foot lab with a 14 Tesla narrow bore, unshielded NMR magnet and console, B2.

**Chemistry B115 XRD Laboratory** is a 600 square foot laboratory in the 1st floor B-wing with office space. Instruments found here include a powder XRD, a single crystal XRD and a SAXS.

**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 5 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 RemotePCTM, 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 RemotePCTM:

* 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 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.

**Post-Doctoral Research Associates** – one Post-Doctoral Research Associate to provide research support in the various areas of the ARC-MMA, and where relevant, develop methodologies and applications for newly acquired instrumentation.

**Graduate Research Assistants** – two to three graduate student teaching/research assistants are assigned to MMA laboratories via collaborative opportunities provided by Chemistry, OVPR and the School of Advanced Materials Discovery (SAMD). These students receive advanced training in the instrument arts, are involved in all aspects of the MMA laboratory including teaching, training, assisting with classroom labs and demonstrations, instrument maintenance and method development

**Undergraduate Student Interns** – three to five undergraduate student hourly employees and for-credit internships from the Chemistry department that 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 Office Management** – ARC-MMA is aided by one full-time-equivalent business manager, in charge of all ARC business management, recharge center cost-accounting, iLab and grant proposal pre-and post-award management.

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

**B.1. Equipment**

**Electron Microscopy**

1. JEOL JSM-6500F field emission scanning electron microscope (FESEM) with EDAX an Oxford SDD EDS detector and EDAX EBSD cameras, a Nabity e-beam Lithography and JEOL STEM-in-SEM holder.
2. 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.
3. JEOL JEM-1400 transmission electron microscope (TEM) equipped with several different specimen holders (a single specimen holder, ±26°; a high tilt specimen holder, ±70°; a Fischione dual axis Tomography holder, ±70°; and a Gatan liquid nitrogen-cooled specimen holder, ±70°), an Orius fastscan digital camera, and a Gatan Ultrascan high-resolution digital camera. Direct magnification range on this TEM is between 50x and 1,200,000x.
4. JOEL JEM-2000 EX-II transmission electron microscope (TEM) equipped with a ±60° tilting (goniometer) stage, operates at accelerating voltages from 80kV to 200kV, and has a magnification range from 50x to 500,000x. It is capable of selected area diffraction from 100 to 2,500mm. Two specimens can be loaded simultaneously. Images are currently captured on film.

**Optical Microscopy**

1. Bruker BioScope Resolve atomic force microscope (AFM) integrated with the Nikon Eclipse Ti-E confocal microscope.

The AFM, designed for integration with inverted light microscopes, is configured to provide the industry standard highest resolution imaging in both air and fluid samples in contact mode, tapping mode, and Bruker’s unique PeakForce Tapping mode. The cantilever deflection is detected with an IR (850 nm) laser to prevent interference with optical imaging modes. Air and fluid cantilever holders are included. Standard magnetic sample clamps for slides, coverslips, petri dishes, and contact and tapping mode tips are also included for calibration and training.

The inverted Nikon Eclipse Ti-E confocal microscope is equipped with extra fine/fine/coarse focusing drive, motorized nosepiece, motorized filter cube turret, motorized x,y stage, DIC components, CFI plan apochromat lambda 10x, 20x, 40x, and 100x oil immersion objectives. LUNV monolithic laser combiner with and acousto-optic tunable filter (AOTF) with 20 mW 405 nm, 70 mW 488 nm, 70 mW 561 nm, and 40 mW 640 nm lines. The system includes a Perfect Focus System (PFS) to compensate for sample drift in real time.

1. Olympus FV1000 laser-scanning confocal microscope with widefield fluorescence visualization, brightfield and differential interference contrast. Four channel spectral and filter-based confocal scanning includes a transmitted light channel for DIC. Objectives on this system are 10X, 20X, 40X, and 100X. This instrument also has a second set of galvanometer mirrors allowing simultaneous photo-activation/stimulation/bleaching during imaging experiments. The second scan unit allows activation and depletion of fluorescent probes for analysis of temporal and spatial activity in live samples. A spectral detector based PMT system allows for specific bandwidth selection in co-localization experiments plus spectral scanning and separation of overlapping fluorophores. The FV1000 also has a motorized, programmable stage that can be used for multipoint time-lapse and mosaic imaging. The four lasers with AOTF control allow six different wavelengths to be selected: 405 nm, 457 nm, 488 nm, 514 nm, 559 nm and 635 nm. Other features include multimode imaging in six dimensions including: XYZ, time, wavelength, mosaic scanning, and multipoint high content imaging. Fluorescence Recovery after Photobleaching (FRAP) and Photoactivation (PA) is facilitated by the easy software wizard with any laser line. The system also includes co-localization software module for complete analysis including scattergrams and statistical data ready for easy export.
2. Zeiss LSM 980 laser-scanning confocal microscope. This microscope has been purchased and will be installed in early 2021.

**Surface Analysis**

1. PE-5800 X-ray Photoelectron Spectroscopy (XPS), also known as Electron Spectroscopy for Chemical Analysis (ESCA) with Scanning Auger Microscopy, sputter depth profiling and Ultraviolet photoelectron Spectroscopy (UPS).
2. Bruker DektakXT Contact Profilometer
3. Woolam VASE or Variable Angle Spectroscopic Ellipsometer, with 250-1700nm spectral range- used to measure the thickness, refractive index and other optical properties of thin films and multi-layer films.
4. Kruss DSA10 Drop Shape Analyzer Contact Angle Goniometer (CAG)

**Sample Preparation**

1. Denton Vacuum Desk II Gold Sputter Coater. Gold sputtering is possible with thicknesses ranging from approximately 5 nm to 50 nm in 5 nm increments.
2. Carbon Coater. Samples may be coated by evaporating carbon, with thickness ranging from 10 to 200 nm.
3. 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.
4. 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.
5. 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 4375 square feet of space is assigned to the ARC-ISS***

**Chemistry Main Basement Laboratory**: ARC-ISS equipment in Chemistry is located in laboratory space that is shared with ARC-MMA. Total space is 6800 square feet for staff office space, break area (1200 sq ft of total) and investigator collaborative area, C1; laboratory equipment floor space C2B, C3 (CAG, VASE), C4 (XPS) and C5; 400 square foot NMR Lab, C3E; 700 square feet of additional space for project staging, C2; and a 100 square foot gender neutral bathroom, C2A.

**Yates Hall Y101 Surface Science 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 TEM, SEM, AFM and profilometer as well as surface preparation equipment.

**Anatomy & Zoology Electron Microscopy Laboratory** is a 1500 square foot laboratory that houses the JEOL JEM-1400 and JEOL JEM-2000 EX-II TEMs, a dark room, sample preparation area and approximately 150 square feet of office space.

**Walter Scott Jr. Biomedical Engineering Laboratory**  is a 225 square foot laboratory that houses the AFM+confocal hybrid microscope.

**Research Innovation Center Confocal Microscopy Laboratory** is a 300 square foot laboratory housing the Olympus FV1000 laser-scanning confocal microscope. This lab is located on the CSU Foothills Campus in the Infection Disease Research Complex.

**B.3. Other Resources (Staff)**

**Staff Scientists –** One full time PhD scientist and one 80% time PhD scientist providing expertise in physics, engineering, optical microscopy, electron microscopy and spectroscopy.

**Post-doctoral Research Associates –** One postdoctoral researcher with focus on electron microscopy, x-ray photoelectron microscopy and surface analysis.

**Graduate Research Assistants** – one graduate student teaching/research assistant is assigned to ISS laboratories via collaborative opportunities provided by Chemistry, OVPR and the School of Advanced Materials Discovery (SAMD). This student receives advanced training in the instrument arts, and is involved in training, assisting with classroom labs and demonstrations, as well as instrument maintenance and method development.

**Non-student hourly employee** ­ – One hourly employee providing services in TEM imaging and sample preparation.

**Business and Office Management** – ARC-ISS is aided by one full-time-equivalent business manager, in charge of all ARC business management, recharge center cost-accounting, iLab and grant proposal pre-and post-award management.

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

**C.1. Equipment**

**Major equipment**

1. Thermo-Finnigan Orbitrap Velos with a Waters nanoAcquity UPLC system (controlled by a Dell PC and Xcalibur/Bioworks software)
2. Waters Synapt G2-Si Ion Mobility enabled Q-TOF mass spectrometer with a capillary Waters Aquity UPLC and nanoAcquity UPLC unit (controlled by a Lenovo PC and MassLynx software);
3. Waters Xevo G2 ESI-Q-TOF mass spectrometer with a capillary Waters Aquity UPLC unit and an Agilent GC coupled using an atmostpheric pressure (APGC) ionization source. (controlled by an HP PC and MassLynx software)
4. Waters Xevo G2 XS ESI-Q-TOF mass spectrometer with a capillary Waters Aquity UPLC unit (controlled by a Lenovo PC and MassLynx software)
5. Perkin Elmer ELAN DRC ICP-MS (controlled by a Lenovo PC running Syngistix software)
6. Two Waters Xevo TQ-S mass spectrometers with Waters Acquity or nanoAcquity UPLC units (controlled by a Dell PC and MassLynx software)
7. 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

**Other smaller equipment**

One dimensional agarose and SDS-PAGE gel electrophoresis apparatus; seven chemical fume hoods; incubators ; Two Savant Speed Vac systems with refrigerated vapor trap; refrigerated bucket centrifuge and microfuge, room temperature microfuge, standalone Gerstel sample preparation robot with mVorx vortex unit and SPE prep station, 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 7 FTE scientists 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. Three High RAM (32 GB or greater) workstations for processing large datasets. In addition, the lab maintains current licenses for several bioinformatics programs, including Mascot, Scaffold, SimcaP, 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, which is backed up to the cloud using Dropbox Business.

**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** – Two full-time PhD scientists, two full time MS scientists, and two full time BS scientists, with an additional 35% time PhD level scientist manage all instrumentation, sample preparation, consultation, and data analysis performed in the ARC-BIO.

**Post-Doctoral Research Associates** – one Post-Doctoral Research Associate with current focus on proteomics and metaproteomics applications (posted position, currently unfilled).

**Stockroom Manager** – The ARC-BIO stockroom supplies enzymes and regents supporting molecular and biochemical reagents including protein and nucleic acid gels, plastic consumables, and media. A full time stockroom manager runs the facility, additionally providing purchasing, HR, and accounting support to the ARC-BIO lab staff.

**Business and Office Management** – ARC-BIO is aided by one full-time-equivalent business manager, in charge of all ARC business management, recharge center cost-accounting, iLab and grant proposal pre-and post-award management.