THE KUIPER-ARIZONA LABORATORY FOR ASTROMATERIALS ANALYSIS (K-ALFAA) AT THE UNIVERSITY OF ARIZONA. T. J. Zega, J. J. Barnes, P. Haenecour, D. S. Lauretta, E. Bloch, Y. J. Chang, K. Domanik, and Z. Zeszut. \(^1\) Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ (tzega@arizona.edu).

Introduction: The chemical and physical history of our solar system is encoded within the solid relics left over from its birth over 4.5 billion years ago. Deciphering that history and addressing fundamental questions on our origins requires cutting-edge instrumentation capable of analyzing planetary materials such as meteorites and samples returned by spacecraft. Here we describe the Kuiper-Arizona Laboratory for Astromaterials Analysis (K-ALFAA) at the University of Arizona (UA), founded in 2016, and motivated by the need for world-class instrumentation in support of research on planetary samples. K-ALFAA is supported by the NASA PSEF program and UA.

Location: K-ALFAA is housed in the Gerard P. Kuiper building for Space Sciences at the University of Arizona. Home to the Lunar and Planetary Laboratory (LPL), the building was originally constructed in 1966 with funds provided by NASA. Located approximately 30 ft. below ground and slab-on-grade, the basement was renovated and repurposed to house a state-of-the-art facility with electron and ion microscopes, shared spaces for sample preparation, meetings and workshops, and offices for laboratory scientists and visitors.

Instrumentation: K-ALFAA consists of parallel instrument bays housing complementary instruments for coordinated analyses of materials from the cm to atomic scale (Fig. 1). A utility corridor was constructed behind them to house service equipment, e.g., roughing pumps, chillers, and uninterruptible power supplies for the instruments. K-ALFAA houses scanning electron microscopy (SEM), electron probe microanalysis (EPMA), a Raman spectrometer, focused-ion-beam scanning-electron microscopy (FIB-SEM), transmission electron microscopy (TEM), and nanoscale secondary ion mass spectrometry (NanoSIMS). We describe each below.

The SEM suite currently houses two microscopes. The Hitachi S-4800 cold-field emission gun (cold FEG) can operate between 0.5 keV and 30 keV. This SEM was upgraded last year with the new Oxford Instruments Aztec Live/x-stream/Ultimax 170 SDD-EDS detector and a new photodiode-backscattered electron (PD-BSE) detector funded by the State of Arizona Technology and Research Initiative Fund (TRIF). These upgrades facilitate video-rate electron and chemical imaging in real time with live tracing features to document analysis locations and element compositions. In collaboration with Hitachi, we have also developed a new custom-made microelectromechanical systems (MEMS) heating holder that enables in situ heating of samples directly inside the microscope. All experiments can be conducted in the vacuum of the microscope at temperatures from room up to 1075 °C. This holder is similar to the one on the Hitachi HF5000 transmission electron microscope (TEM) discussed below, enabling coordinated heating experiments on samples in both the SEM and TEM on the same heating chips. The Hitachi S-3400 is a W thermal emitter with a variable-pressure chamber. It is equipped with secondary-electron and backscattered-electron detectors, a Thermo-Noran SDD EDS system operating NSS software, and a Renishaw inVia Raman spectrometer with optical microscope and 514 and 785 nm lasers. The SEM suite also has laboratory benchtop space for sample-preparation and includes a chemical fume hood.

The Focused-Ion-Beam Scanning Electron Microscope (FIB-SEM) Lab houses an FEI Helios NanoLab 660. The Helios is equipped with an Elstar electron gun and monochromator, and is capable of electron beam resolution down to 0.6 nm from 15 kV to 2 kV. Its Tomahawk Ga\(^+\) ion column can be operated between 65 nA and 500 V for, respectively, removal of large volumes of material and final sample polishing. Under standard operating conditions, an ion beam resolution 2.5 nm at 30 kV is achievable. The Helios is equipped with in situ micromanipulation for creation and transfer of lamellae for TEM analysis. It is also equipped with an EDAX EDS system and electron backscatter diffraction analysis system for compositional and crystallographic analysis in two and three dimensions. Multiple polygons are supported for device patterning as well as the ability to directly import...
customized shapes for patterning or deposition. The Helios is equipped with C and Pt gas-injection systems.

The Transmission Electron Microscope (TEM) lab houses a Hitachi HF5000. The HF5000 has a cold FEG and comes with alignments at 200 keV and 60 keV. It is equipped with a Hitachi 3rd-order spherical aberration corrector for the scanning TEM (STEM) probe, as well as STEM bright-field, high-angle annular-dark-field (HAADF), and annular-bright-field detectors. Spectroscopic capabilities include: (1) Oxford Instruments twin silicon-drift detectors (SDD) for EDS providing a total solid angle of 2.0 sr and rapid mapping of samples in minutes instead of hours; and (2) Gatan Quantum Imaging Filter (GIF) for electron energy-loss spectroscopy (EELS). The HF5000 is capable of ≤0.4 eV energy resolution for EELS and 78 pm point-to-point resolution in STEM mode for atomic-resolution imaging.

The Electron Microprobe (EMPA) lab houses Cameca SX-50 and Cameca SX-100 Ultra instruments. The SX-50 was installed in 1991 and has been in continuous service for 31 years. It is equipped with a 30 keV W thermal emission gun, four wavelength dispersive X-ray spectrometers (WDS), 12 diffracting crystals, and a legacy Princeton-Gamma Tech Si(Li) EDS system, allowing analysis of elements with Z≥4. The SX-100 Ultra was installed in 2011 and has been in service for nearly 11 years. It is equipped with a 30 keV LaB₆ filament, five WDS, 14 diffracting crystals, and an SDD-EDS system, allowing analysis of elements with Z≥5.

The NanoSIMS lab houses a next-generation CAMECA NanoSIMS HR instrument. The NanoSIMS HR was installed in Fall 2023. The instrument is based on the NanoSIMS 50L design with improvements to lateral and mass resolution, large-area mapping capabilities, and overall stability and usability. The NanoSIMS HR is equipped with both CAMECA Cs and Oregon Physics RF oxygen plasma sources. The NanoSIMS HR is capable of multi-isotope detection with its seven detectors (interchangeable between electron multiplier and faraday cup) one of which is fixed. The instrument is capable of ion imaging, spot mode, and depth profiling. We expect the instrument to be commissioned and available for outside use in late 2024.

In addition to the electron and ion beam laboratories, the planetary materials research group at LPL (https://www.lpl.arizona.edu/PMRG/home) maintains a suite of interconnected laboratories with capabilities in wet chemistry (perchloric acid-rated hood for dissolution of meteoritic materials), ultramicrotome sample preparation of thin electron-transparent samples, optical microscopy (petrographic and stereo microscopes with digital image acquisition), a stereo microscope equipped with dual micromanipulators, a Keyence VHX-7000 Series digital microscope, and an 11-m² class-1000 cleanroom for handling and preparation of sensitive materials.

Management and Business Model: K-ALFAA is managed by a combination of Staff Scientists, Instrument Scientists, a Scientific Director, a Scientific and Technical Oversight Committee (STOC), the LPL Director, and administrative personnel (https://kalfaa.lpl.arizona.edu/people). Staff scientists are responsible for managing daily operations, instrument performance, maintenance, scheduling, user training, and billing. Instrument scientists are responsible for the scientific integrity, personnel, hardware, and financial status of the specific laboratory within K-ALFAA that is under their supervision. The Scientific Director is responsible for the scientific integrity of the K-ALFAA as well as the day-to-day management of personnel, hardware, and financial resources. The Scientific and Technical Oversight Committee (STOC) assists in the management of the K-ALFAA and meets regularly to discuss the scientific output, technical performance, financial status, personnel issues, and future opportunities.

K-ALFAA operates as a recharge center. It recovers its operating costs through a combination of hourly recharge rates, subsidy provided by LPL, the UA College of Science, the Office of Research, Innovation, and Impact, and externally by NASA’s Planetary Science Enabling Facilities (PSEF) program.

How to Use the Facility: To request access, visit https://kalfaa.lpl.arizona.edu. Requests are evaluated based on a short proposal either via email or an attachment to email (two pages maximum) after a conversation with one of the laboratory managers. Requests are prioritized on a first come, first serve basis. The costs to use the K-ALFAA are listed at https://kalfaa.lpl.arizona.edu/user-information/rates. Users with a NASA Research and Analysis grant will not incur an hourly fee.

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