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University Capability Statement

Institution: Hunter College of the City University of New York

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OVERVIEW

About Hunter College

Located in the heart of Manhattan, Hunter is the largest college in The City University of New York system. Founded in 1870, it is also one of the oldest public colleges in the country and is famous for a student body that is as diverse as the city itself. Most Hunter students are the first in their families to attend college and many go on to top professional and graduate programs, winning Fulbright scholarships, Mellon fellowships, National Institutes of Health grants, and other competitive honors. More than 23,000 students currently attend Hunter, pursuing undergraduate and graduate degrees in more than 170 areas of study. The 1,700 full- and part-time members of Hunter's faculty are unparalleled. They receive prestigious national grants, contribute to the world's leading academic journals, and play major roles in cutting-edge research. They are fighting cancer, formulating public policy, expanding our culture, enhancing technology, and more. Research capabilities for our physics, chemistry, biology, and computer science departments are described below, but the PAST PERFORMANCE section is for physics only (i.e. the department in which this grant is housed).

RESEARCH CAPABILITIES

Physics: Materials research on batteries, ferroelectric thin film supercapacitors; biomedical imaging; femtosecond optical spectroscopy; condensed matter theory including semiconductor and quantum device simulation; quantum information theory.

FACILITIES

Physics:

300, 400, and 500 MHz **NMR spectrometers** equipped with solid state and diffusion probes, fast-fieldcycling broadband NMR relaxometer. Argon glovebox for air-sensitive samples.

The Materials Fabrication Laboratory (MFL) is equipped with a Denton Vacuum Discovery 18 Deposition System with multiple sputtering sources, a Sharon Vacuum E-Beam Evaporator System with multiple crucibles and substrate heaters, chemical hoods, and various Rapid Thermal Annealing (RTA) and Chemical Vapor Deposition (CVD) furnaces for thin film production and research. The Discovery 18 Deposition System uses three sputter sources (Two DC/DC pulse and one RF) and has the ability to heat, apply RF bias, and rotate the substrate. The source size is 3" dia., and wafer sizes up to 5" can be accommodated. Argon, Oxygen, and Hydrogen can be employed as process gases. Energy levels are up to 300 W for DC and 600 W for RF. Vacuum of 2×10^{-8} is achievable by means of an Alcatel rotary vane mechanical roughing pump and an Alcatel TMP-151 turbo molecular pump. The Sharon Vacuum system includes Telmark four pocket 6-kW electron beam gun, single thermal source with SCR controlled 2-kW power supply, Sycon deposition controller, dual shutters, CT-8 cryo. pump, and water cooled rotary substrate stage. There are also a full range of characterization equipment available in the MFL and Hunter College including TEM, NMR, FTIR, Raman, X-ray diffraction, electronmicro analysis, SEM, STM/AFM, electrical transport measurement system, Solar simulators, and all kinds of optical spectrometers.

The Ultrafast Optical Laboratory (UOL) is equipped with time-resolved pump-probe spectroscopy, nonlinear optical spectroscopy, and near-field microscopy based on a mode-locked Ti:sapphire oscillator (Tsunami, spectra-Physics), a Ti:sapphire Amplifier (RegA9000, Coherent), and an Optical Parametric Amplifier (OPA9400, Coherent). The UOL recently received funding from DURIP of AFOSR, and installed the Libra-F-1K-HE-200, a femtosecond amplifier in one box, along with the TOPAS prime and TOPAS prime UV systems. We now have one of only several (fewer than 10) such facilities in the U.S. access to a broad, gap-free wavelength range from UV to the mid IR (290 nm – 2.6 μ m). For the low temperature and magnetic field dependent studies, an electromagnet (GMW 5403), two Janis optical cryostat systems including the continuous flow model (ST-300) and the other model (VPF100) with a built-in nitrogen reservoir can be used. The accessible temperature ranges from 1.4 K to 325 K and a magnetic field is up to ~ 2.0 Tesla. For high temperature experiments, a home-made vacuum chamber can be used to perform time-resolved optical measurements with a temperature up to 1000 K. Moreover, an alpha300S Scanning Near-field Optical Microscope (SNOM, WITec) can be employed to study optical reflection, photoluminescence, electro-luminescence, time-resolved photoluminescence, confocal and multi-photon imaging with ~ 50 nm spatial resolution. The experiments can be carried out by combining with the existing time-resolved optical spectroscopy with a temporal resolution of ~ 50 fs. The operative wavelength range of the instrument is from 400 to 1050 nm which covers the most interesting spectra of the materials proposed in this proposal.

The **ultrasonic thin film printing room** is equipped with a Sono-Tek ExactaCoat coating system for non-vacuum fabrication of thin films. The ExactaCoat machine is a fully-enclosed, programmable 3-axis robot that is ideal for any precision lab scale spray coating application. This flexible, fully contained coating system employs robust ball-screw slides driven by brushless DC servo motors.

Access to CUNY's high speed computer, national and international grid infrastructure.

Computer Science

The CS Department has multiple 3.50GHz NVIDIA GPU machines with 12 CPUs and powerful Linux workstations equipped with three Titan Nvidia and two Nvidia QuadPro P600 GPUs. All of the

computer systems are interconnected via a Gigabit Ethernet local area network, which in turn is connected to the campus-wide network. A system administrator maintains all Linux-based and Macintosh computers in the department. Individual PIs and research labs also have access to computer security, augmented reality headsets and software, vision scanners and cameras and robotics instruments many funded by NSF MRI grants. The Department of Computer Science has allocated the PIs lab space that adequately accommodates the PIs and student researchers. The space encourages collaboration between all members of the department. The space is also conducive to meetings between the PIs and student researchers.

All faculty have access to the newly acquired cloud-ready environment at the Grad Center Computer Science Department consisting of 144 TB of persistent storage and 288 TB of distributed storage, and a total of 364 CPU cores and 3TB of RAM. The environment has a dedicated network switch and nextgen firewall with 100Gbps capabilities for integration with other cloud services in a hybrid cloud model. The system is built to scale out on demand, e.g. allowing Google Colab to switch between cloud-based resources (with a limited free-tier) and our on-premise systems depending on resources availability. The key hardware components include:

1. Storage System: 64 cores, 256GB of RAM, and a 144TB disk array/NAS
2. Analytic Server: a multi-core, high-memory machine of 52 CPU cores and 1TB of RAM, and capable of hosting GPU devices to facilitate machine learning tasks
3. Computing cluster: 6 big data nodes consisting of 312 CPU cores, 2 TB of RAM, and 288 TB of distributed storage.
4. Networking devices: a network fabric of Mellanox 100Gbps core switch and a perimeter 1Gbps next-gen firewall.

Biological Sciences currently hosts 16 active research laboratories working on cutting edge research questions in the biomedical sciences. The Department has three or more labs working in the following biomedical sub-fields:

Molecular and Cellular Neurobiology

Molecular Biology of Cell Signaling in Cancer

Microbiology and Infectious Disease

Bioinformatics of Genomes and Transcriptomes Intracellular

transport and High Resolution Imaging

Facilities:

Core Facilities: Hunter College houses several core research facilities to support the research conducted by faculty, staff, and students. The facilities are:

Bio-Imaging Facility: The following shared equipment is found in the Digital Bio-Imaging Facility

In room 826 of the North Building.

- Gemini EM microplate spectrofluorometer
- GloMax®-96 Microplate Luminometer
- Image Analysis Stations

- JEOL JEM-100C/CX Transmission Electron Microscope
- Leica CM 3050S Cryostat
- Leica Confocal Microscope TCS SP2
- Leica Confocal Microscope TCS SP8 Confocal Microscope with Digital Light Sheet and STED Super Resolution Imaging
- Molecular Dynamics Typhoon 9410
- Nikon Eclipse E 400 Color Image Analysis System
- Nikon Eclipse TE 200, Calcium Ratio Imaging & Microinjection"
- Nikon Eclipse Ti, TIRF/SIM"
- Nikon Eclipse Ti, With & Mosaic/MicroPoint System with FRAP"
- Odyssey Infrared Imager
- Perkin Elmer UltraView ERS
- PowerWave HT Microplate Spectrophotometer

On the 4th floor of the Belfer Building

- Bio Tek Synergy HTX Microplate Reader
- GE FLA 7000 Typhoon
- Nikon A1R Confocal Microscope
- Nikon Eclipse Ti-S Fluorescence Microscope

The Genomics Facility contains the following equipment that is used across multiple departments •

RT-qPCR

- Liquid scintillation counter
- NanoDrop Spectrophotometer
- Perkin Elmer Thermocycler
- Film developers
- Beckman L80 and L90 Ultracentrifuges
- RT-PCR (Belfer)
- Ultracentrifuge (Belfer)

Flow Cytometry: This Facility can provide analyses of up to 7 parameters in eukaryotic cell populations and sort cells under sterile conditions. These analyses can be used to identify and isolate rare cell populations, determine chromosome ploidy in individual cells, study apoptosis, and study cell-signaling, among other applications. This facility houses the following equipment heavily utilized by Biology:

- FACS Calibur located in room 919B North Building, 407 sq ft.
- FACS Scan located in room 919B North Building, 407 sq ft.

- FACS Vantage cell sorter in room 919A North Building, 304 sq ft

The Animal Facility: located on the 15th floor of the North Building houses the animals used in our research labs. Below is a brief description of the resources in this facility.

The main facility is a 7,635 square foot, single corridor, conventional facility located on the 15th floor of North Building of Hunter College. Completed in 1988 and partially renovated in 1997-98, it is separately ventilated, heated, cooled and humidified. The facility contains 22 rooms that can be used to house animals. Most rooms are shared space and are not assigned permanently to any department or faculty member. The only exception is a room that houses salt water aquatics. In addition to animal housing rooms, the facility contains two rodent surgical suites, procedure room, locker and shower rooms for staff, two offices, a cage wash area divided into dirty and clean sides, bedding storage room, cold room, euthanasia room, and several small rooms that are used for behavioral testing. The procedure room provides an area where researchers can carry out injections, blood sampling, and minor surgical procedures. It contains a downdraft fume hood and an anesthesia machine. The euthanasia room has a CO₂ chamber and a freezer. The cage wash area is equipped with a Basil stainless steel pass-through cage washer and an ETC pass-through hi-vacuum sterilizer.

Chemistry and Biochemistry Department

Additive Manufacturing: A few techniques dominate 3D printing: stereolithography (SLA), fused deposition modeling (FDM), selective laser sintering (SLS), and inkjet printing. The 3D printers in the facility use FDM and SLA methods to manufacture parts. FDM is a mechanical (rather than chemical) process, that builds up layers through the extrusion of semi-molten materials, typically thermoplastics. Resolution is limited by the extrusion cross-section of material (i.e., the filament size), a few tenths of a millimeter on most printers. Final printed resolutions are typically a few hundred microns. Hunter's FDM machine is an Ultimaker 3, capable of printing a wide variety of thermoplastic materials. If your desired material isn't on hand, filament can be ordered. Ultimaker has a number of first-party materials available for purchase, as well as a number of compatible third-party materials that have been tested for compatibility. SLA is done via optical curing of specially formulated liquid resins. Generally this is done by using a UV laser, rastering the laser to form an image, or by displaying a UV mask over the printing surface using a projector. SLA is capable of very high resolutions, as low as a few dozen microns.

Elemental Analysis: The Elemental Analysis facility is located at Hunter College on the 13th floor of North building. The facility provides multi-elemental analysis services to all CUNY campuses,

Memorial Sloan Kettering as well as outside parties. The mission of the facility is to perform a quantitative bulk elemental composition for a wide variety of sample types (solids, powder, liquids, and suspensions) of both macroscopic and tracer amounts with a detection limit close to 1 µg/L for certain elements. The facility is capable of determining more than 70 elements in seconds. The elemental analysis is performed employing an Inductively Coupled Plasma -Optical Emission spectroscopy of Optima 7300 DV. The instrument is equipped with dual viewing of the plasma and two solid-state detectors for offering a superior detection limits and true simultaneous measurements.

Mass Spectrometry: a CUNY core facility at Hunter College which provides mass spectrometry services to all CUNY campuses, as well as non-CUNY institutions and organizations. The goal of this facility is twofold: first to integrate mass spectrometry into the research experience at Hunter College and CUNY through training and support; and second, to work with scientists, collaborate with laboratories in order to facilitate new or ongoing research. Presently the facility houses two LCMS based instruments: the Agilent 6340 ion trap, and the 6550 iFunnel Q-ToF. Accurate-mass quadrupole time-of-flight (Q-ToF) spectrometer complete with Agilent 1290 capillary HPLC system.

Ionization Sources Dual Agilent Jet Stream Electrospray (AJS ESI) - incorporates an orthogonal nebulizer for use of reference masses; Multimode Ion Source - for simultaneous electrospray (ESI) and atmospheric pressure chemical (APCI) ionization

NMR Facility: 600 MHz Bruker Avance III The 600 MHz Bruker Avance III instrument is the newest addition to our NMR facility. This ¹H cryoprobe-equipped four-channel spectrometer is a state-of-the-art ultra-shielded magnet with an impressively small stray field, yielding increased lab safety and field homogeneity. The ¹H signal-to-noise specification is ~5000:1 for this instrument. Currently, this instrument is reserved almost exclusively for the laboratory of Dr. Nancy Greenbaum for structural biology studies of macromolecules.

500 MHz Bruker Avance DRX This is our workhorse instrument, used by numerous researchers every day. Unique among our instruments is the carbon-proton cryoprobe of this spectrometer. This probe gives a sensitivity enhancement of a factor of up to 10 over conventional probes, for both carbon and proton observe experiments. The instrument boasts signal-to-noise ratios of ~2300:1 for proton and 1500:1 for ¹³C. Researchers benefit from the probe's ultra-high sensitivity. The probe makes possible the performance of ¹³C experiments in a short time frame, as well as 2D experiments on sample quantities that are too small to analyze on conventional probes. This instrument has moved into automated data collection with the addition of a sample changer.

400 MHz Bruker Avance III The Bruker 400 is another new addition. It provides probes and accessories for investigating the full range of NMR active nuclides, variable temperature from -150 to 150°C and solids as well as liquids in full automation. It is equipped with a 4mm MAS solids probe, a workhorse broadband probe tunable from ~16MHz to 400MHz with ¹⁹F detection on the broadband coil allowing ¹H decoupling, a 10mm broadband probe tunable from ¹¹⁹Sn to ¹⁰³Rh (149 to 12.6MHz) and a special HPX probe for triple resonance experiments on phosphorus compounds.

The Radiochemistry facility at Hunter College provides Hunter's faculty, staff and students with the necessary training and support for both research and academics. In accordance to the New York City Charter and Articles 175 of NYC health code, the Radiochemistry facility at Hunter College is committed to ensure the safety of hunter's workers and working area. The mission of the facility is threefold: **Regulatory Control:** Working with the EH&S on license amendments, the facility works on improving and updating the radiation safety training program to be suitable with the recent license update and the NRC regulations; **Radiation Safety:** Conducting contamination monitoring survey for the radioactive laboratories to ensure safety and good laboratory practice among faculty members and provide fast support and response during any emergency situations.; **Education and research:** Training of faculty, staff and students in radiochemistry techniques. In addition to the evaluation of suitable isotopes and instrumentation for experiments, assist the PI and students in their design of experimental procedures (from setup to cleanup) and publication support.

CUNY X-Ray Crystallography facility to perform X-ray diffraction on single crystals for the structure determination of small molecules. It is the ultimate method for definitive determination of molecular structures at the atomic level for both organic and inorganic compounds. Its uses range from simple identification of compounds to various configuration and conformational studies. The facility is open for submissions by members of Hunter's Department of Chemistry and those from other CUNY departments as well as outside parties. For more information or the submission of crystals for analysis, please contact the facility director. **Instrumentation:** Bruker Kappa X8 Apex II System. The X-rays are generated from a molybdenum source. A Mo source is particularly well-suited for inorganic compounds containing heavy atoms to minimize absorption-correction errors, though the structures of lighter organic compounds can also be readily determined.

PAST PERFORMANCE for Physics Department only

Physics:

U.S. Air Force Office of Scientific Research, Program on Materials for Extreme Environments. Work on optical characterization of ferroelectric thin films for energy storage.

Department of Energy, Nuclear Magnetic Resonance characterization of battery and fuel cell materials.

U.S. Office of Naval Research, characterization of thin film capacitor dielectrics

Air Force Research Laboratory Space Vehicles Directorate, and National Science Foundation, research on semiconductor device simulation.

U.S. Army Research Office, quantum information theory