NATIONAL SYNCHROTRON LIGHT SOURCE II (NSLS-II)

National Institute of Standards and Technology
Beamline Development Proposals
(Submitted June 21, 2010)

NIST NSLS-II Spectroscopy Beamline Suite:
Materials Measurement to Promote Innovation and Industrial Competiveness

1) Soft and Tender X-ray Spectroscopy and Microscopy (100 eV to 7.5 keV canted undulator sources)

2) Hard X-ray Absorption Spectroscopy and Diffraction (4.5 keV to 40 keV 3-pole wiggler source)

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

NSLS-II Beamline Development Proposal

Type I ☐ Type II ☒

NIST Spectroscopy Beamline Suite: Soft and Tender X-ray Spectroscopy and Microscopy (100 eV to 7.5 keV canted sources) Three-Letter Acronym (SST-Spectroscopy Soft and Tender)	
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NIST NSLS-II Spectroscopy Beamline Suite: Materials Measurement to Promote Innovation and Industrial Competiveness

Executive Summary: The National Institute of Standards and Technology (NIST) and the Department of Energy (DOE) have a 30 year ongoing partnership at the National Synchrotron Light Source (building to NSLS-II) developing advanced synchrotron measurement methods and delivering excellence in material science impacting important societal challenges in energy, health, environment, and national security improving our quality of life. This partnership promotes innovation and enhances US industrial competiveness for inorganic and organic semiconductors, photovoltaics, SAMs, biological and environmental materials, batteries, catalysts, fuel cells, polymers, superconductors, ferroelectrics, and ferromagnets. Located at the NSLS, the NIST Synchrotron Methods Group of nine operates a suite of three state-of-the-art spectroscopy beamlines (U7A, X24A, and X23A2) that span the entire absorption-edge energy range of the periodic table to establish structure function relationships in advanced materials. More than 200 industry and academic researchers each year use the NIST Beamline Suite to accelerate the development of new materials into devices and systems with advanced functionality for a broad spectrum of industries. Building upon this success, NIST proposes to establish an NSLS-II spectroscopy suite of three state-of-the-art high throughput beamlines (with X-ray Diffraction capability) described in two beamline development proposals; *Soft and Tender X-ray Spectroscopy and Microscopy (100 eV to 7.5 keV canted sources)* and *Hard X-ray Absorption Spectroscopy and Diffraction (4.5 keV to 40 keV three-pole wiggler source).* Taken together, the NIST NSLS-II Spectroscopy Beamline Suite will be capable of measuring the electronic, chemical, and structural properties of almost any material, often at the nanoscale. NIST is committed to fully funding the construction of its proposed Spectroscopy Beamline Suite and to continuous world leading improvements in synchrotron measurement science and technology. Furthermore, NIST will build upon its NSLS based Synchrotron Methods Group to fully staff its stakeholder relationship in NSLS-II.

A. Science Case: Soft and Tender X-ray Spectroscopy and Microscopy (100 eV to 7.5 keV)

Synchrotron based X-ray Photoelectron Spectroscopy (XPS) and Near Edge X-ray Absorption Fine Structure (NEXAFS) spectroscopy are complementary techniques, probing occupied and unoccupied density of states respectively. The ability to perform both measurements on the same sample achieves a complete, non-destructive, depth selective measurement of electronic structure, chemistry, and bond orientation. *NIST proposes to build a pair of spectroscopy beamlines based on two canted undulator sources, one for soft x-rays (100 eV to 2.2 keV) and one for tender x-rays (1 keV to 7.5 keV).* The beamlines will have a total of 6 unique world class NEXAFS/XPS experimental stations (2 full field microscopes, 2 automated high-throughput, and 2 insitu high pressure); three will be served by the soft x-ray undulator and three by the tender x-ray undulator, thus a variety of soft and tender spectroscopy experiments can be accomplished simultaneously in this beamline complex. Two of the experimental stations (high-throughput XPS/NEXAFS and the XPS microscope) can utilize the soft and tender X-ray undulators (sequentially or even simultaneously) enabling a continuous selection of X-rays from 100 eV to 7.5 keV (at a common focal point) in a single experiment (unique capability, enhancing depth selectivity in XPS; i.e. in Hard X-ray Photoelectron Spectroscopy - HAXPES).

Enabled by the world class brightness of the proposed NIST NSLS-II canted undulator beamline pair, NIST is pioneering (at NSLS) two new and unique (large depth of field for practical materials) magnetic projection microscopes pushing the state-of-the-art in synchrotron XPS and NEXAFS spectroscopy full field imaging measurement science (details in appendix, page 13). (1) XPS microscope; combines nanometer scale spatial resolution with chemical and electronic state specificity and full three-dimensional mapping of the structure of nanomaterials and nanodevices at all points within their volume. (2) Large Area Imaging NEXAFS Microscope for high efficiency, highly parallel spectroscopic chemical and orientation maps of gradient samples, combinatorial arrays (e.g. 1000s of compositional samples at a time), and device arrays up to 4 cm^2 with simultaneous micron scale resolution.

The proposed *Soft and Tender X-ray Spectroscopy and Microscopy* beamline pair coupled with NIST's continuous development of automated high-throughput spectroscopy methods, world class high efficiency detectors, and unique NEXAFS and XPS microscopes will have a *large scale impact on the materials science of important societal challenges in energy, health, environment, and national security*. Some strategic science case examples follow. They illustrate how this proposed beamline pair will establish structure function relationships in advanced materials, often at the nanoscale, to accelerate the development of new materials into devices and systems with advanced functionality for promoting innovation and enhancing US industrial competitiveness.

1) Accelerating Organic Photovoltaics with Soft and Tender Spectroscopy and Microscopy
   Dean M. Delongchamp, NIST
2) Nanoscale Spectroscopy for Next Generation Semiconductor Microelectronics: CMOS and Beyond
   Pat Lysaght, SEMATECH

Additional Science Case Examples (3-13) appear in the appendix page 13:

3) Designing Biomaterials with High Through-Put Screening: Using the NIST NEXAFS Microscope
   David Castner (U. of Washington, Seattle)
4) Synchrotron Spectroscopy an Enabling Capability for the Defense and National Security Community
   Joseph Lenhart (WMRD, US Army Research Laboratory)
5) Nano to Microscale Spectroscopy for Environmentally Friendly Marine Anti-Fouling Coatings
   Edward Kramer (UCSB)
6) Spectroscopy and Microscopy for Advanced Hard and Soft Materials: Energy and Microelectronics
   Gary Mitchell (Dow)
7) Advanced Spectroscopy Promoting Breakthrough Catalysts for Energy Applications
   Simon Bare (UOP)