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Use of Positron Annihilation Spectroscopy for Stress-Strain Measurements

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Project Title:

Use of Positron Annihilation Spectroscopy for Stress-Strain Measurements

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AAA Research Area: **Transmutation Sciences**

Funding Profile: **2002-2003:** $120,438 **2003-2004:** $116,212 **2004-2005:** TBD

Note: LANL employees do not require funding from UNLV to participate in this project.
ISU employees do not require funding from UNLV to participate in this project.

Abstract

The purpose of this collaborative research project involving the University of Nevada, Las Vegas (UNLV) and Idaho State University (ISU) is to evaluate the feasibility of determining residual stresses of welded (after pre-straining) engineering materials using a new nondestructive technique based on positron annihilation spectroscopy. The proposed technique is to use γ-rays

from a small MeV electron Linac to generate positrons inside the sample via pair production. This method can be used for materials characterization and investigation of defects in thick samples that could not be accomplished by conventional positron techniques or other nondestructive methods. The data generated will be compared to those obtained by other methods such as neutron diffraction (for thin samples only) and ring-core techniques. Materials to be tested in the initial phase will be unirradiated austenitic (Type 304) and martensitic (EP-823) stainless steels that will be cold-worked and welded prior to the evaluation of their residual stresses. Metallurgical microstructures will also be evaluated. Later, irradiated austenitic materials (Type 316L stainless steel and Alloy 718) may be included in this program.

Work Proposed for Year 1 (Summer 2002 through Spring 2003) and beyond

Austenitic Type 304 and martensitic EP-823 stainless steel plates will be procured from vendors. The graduate students will be trained on the fundamental and applied metallurgical aspects including cold deformation, welding and thermal treatment of engineering metals and alloys. The test materials will be rolled to the desired levels (1, 5 and 10%) at the vendor's facility. Welding of the plate materials will be performed at the Los Alamos National Laboratory (LANL). A part of these cold-worked and welded plates will be subjected to appropriate heat treatment operations to minimize residual stresses generated during plastic deformation and welding. Microstructural evaluation will be performed by using optical microscopy, scanning electron microscopy (SEM), and transmission electron microscopy (TEM) at the University of Nevada, Las Vegas (UNLV). Subsequently, stress measurements will be done by using positron annihilation and ring-core methods. A limited number of measurements will also be performed using neutron diffraction techniques on thin specimens. Stress measurement by positron annihilation spectroscopy will be performed at the Idaho State University (ISU). Ring-core method will be used at Lambda Research. Stress measurement involving thin samples will be conducted at LANL.

Background and Rationale

Plastic deformation of metals and alloys produces an increase in the number of lattice imperfections known as dislocations, which by virtue of their interaction results in a higher state of internal stress and reduces ductility. This type of deformation which is carried out in a temperature region and over a time interval such that the strain hardening is not relieved is called cold-work. When cold-working is excessive (greater than uniform elongation), the metal will fracture before reaching the desired size and shape. Thus, in order to avoid this drawback, cold-working operations are usually carried out in several steps, with intermediate annealing operations to soften the cold-worked metal and restore the ductility. This sequence of repeated cold-working and annealing is frequently called the cold-work-anneal cycle. By suitably adjusting this anneal cycle, the part can be produced with any desired degree of strain hardening. However, in order to remove the undesirable internal stresses, a stress relief thermal treatment needs to be done.

During welding of engineering components, thermal cycles cause changes in physical state, metallurgical phase transformation, and transient thermal stress. The welded part may contain physical discontinuities that arise due to excessively rapid solidification, or adverse

microstructure that are due to inappropriate cooling, or tensile residual stresses and distortion resulting from the existence of incompatible plastic strains. Presence of high tensile residual stresses in and around the welded region (such as the heat-affected-zone) can cause premature failure under certain conditions.

Materials used in accelerator-driven transmutation systems (ADS), such as target and other structural parts, are likely to be influenced by adverse residual stresses resulting from cold work and welding. In view of this rationale, this research project will be aimed at evaluating the residual stresses of cold worked and welded austenitic Type 304 and martensitic EP-823 stainless steels by three different techniques. Alloy EP-823 is a leading structural material to contain lead-bismuth-eutectic (LBE) nuclear coolant needed for fast spectrum operations of the ADS systems. Type 304 stainless steel is a universally known corrosion resistant iron-nickel-chrome alloy having optimum formability and weldability.

Experimental Procedure

Type 304 and EP-823 stainless steels will be received from the vendor in the form of plates of desired dimensions. The dimensions of both thick and thin plates of these two test materials will be decided later. They will be procured in properly heat-treated conditions. Austenitic Type 304 stainless steel is commonly used in a solution-annealed condition. On the other hand, Alloy EP-823 is austenitized and quenched, followed by tempering to achieve a fully tempered martensitic metallurgical microstructure. Subsequently, these materials will be subjected to three levels (1, 5 and 10%) of cold deformation and welding, respectively. Welding of similar and dissimilar plate materials will be performed using the Gas-tungsten arc welding (GTAW) technique at LANL. Metallurgical microstructures of both materials will be evaluated in the as-received, cold-worked and welded conditions using optical microscopy, SEM and TEM at UNLV.

Three different techniques, namely γ-ray induced positron annihilation spectroscopy; neutron diffraction and ring-core method will be used to determine the residual stresses present in the test materials. Positron annihilation spectroscopy is a well-established non-destructive tool to characterize materials and defects. However conventional positron annihilation spectroscopy uses slow positron beams or wide energy spectrum beams from radioactive sources. The thickness of the samples under investigation is severely limited by the range of the impinging positrons inside the sample, which is less than 1 mg/cm^2. The technique proposed here exploits high penetrability γ-rays to extend positron annihilation spectroscopy into thick samples and enable measurement of stress, strain and defects in engineering materials. The collimated bremsstrahlung beam from a small electron accelerator (6 MeV pulsed Linac) is used to generate positrons inside the test specimen via pair production. No photon-induced activation is involved in this process. Each generated positron thermalizes and annihilates with one of the sample electrons emitting two annihilation photons (511 keV) back to back. The annihilation photons are recorded by a high-energy resolution HPGe detector, and the data will be analyzed in terms of line shape parameters of the 511 keV annihilation peak. The character and concentration of defects can be investigated from these measurements. The portability, reliability and relatively low cost of small-pulsed electron accelerators can create significant interest in commercial or industrial applications. Stress measurements using this technique will be performed at ISU.

Neutron diffraction is also a non-destructive method, which is based on measuring the spacing, *d*, between the atomic planes of a crystal lattice. When a neutron beam of known wavelength is impinged upon a crystalline specimen, neutrons are diffracted at an angle that depends on *d*. With accurate measurement of the diffraction angle, the *d*-spacing between the lattice planes can be calculated, to determine if the planes are being pushed together (compression), or pulled apart (tension). The measured patterns of residual stress, as determined by this technique, provide knowledge of the possible location of fractures and the effectiveness of thermal treatments to relieve the internal stresses arising from welding and cold deformation. However, this technique is limited to very thin specimens with the neutron beam penetrating only a small depth (a few millimeters) below the specimen surface. Further, this method is not effective if the grain size is larger than 100 μm. In view of these deficiencies, a limited number of measurements will be performed on thin samples using a LANSCE facility at LANL.

The ring-core method is a mechanical/strain gage technique employed to determine the principal residual stress field as a function of depth in polycrystalline or amorphous materials. The method involves placing a strain gage rosette at the surface at the location of interest on a given component. An annular groove is machined around the strain gage rosette at predetermined depth increments. The strain relaxation that occurs as a function of machined depth is recorded. The final residual stress values are calculated using the measured change in strain with depth. The ring-core method works well on materials that are coarse grained, such as cast metals and weldments. Lambda Research of Cincinnati, Ohio will provide these types of measurements.

Expected Data

The proposed research program will develop the following scientific/technical information, elucidating the applicability of positron annihilation spectroscopy:

- Metallurgical microstructures of as-received, cold-worked, welded and stress-relieved material(s)
- Residual strains resulting from cold-work and welding operations
- Estimation of residual stresses corresponding to measured strain values

Research Capabilities at UNLV

<u>Heat Treatment Facilities</u>

Two high temperature furnaces are currently available:

1) Lindberg Furnace
   The maximum temperature is 1200 ^{o}C (2200 ^{o}F).
   The working dimensions are 15” x 7.5” x 5.5”.

2) Thermodyne Furnace
   The maximum temperature is 1200 ^{o}C (2200 ^{o}F).
   The working dimensions are 6.5” x 4.5” x 4.5”.

A third furnace (Lindberg) with larger working dimensions and a maximum temperature of 1200°C has just been procured, that will be installed soon in the UNLV Materials Performance Laboratory sponsored by the UNLV AAA program.

Machine Shop

The UNLV College of Engineering has a machine shop with two vertical mills, two lathes, a welding station, and a variety of band saws, shear breaks, and drill presses. None of this equipment is automated so we have developed good working relationships with several local machine shops. There are several good local shops with CNC, EDM, water jet, and laser cutting capabilities that can be contracted at reasonable rates.

Mechanical Testing

The UNLV College of Engineering has a 55 kip Axial/Torsional Servo hydraulic MTS Materials Testing System. The machine has hydraulically controlled actuator with 5.5" of stroke and approximately 55° of angular rotation. It also has a hydraulic grip supply and two different hydraulic grips: a set of 55 kip axial/torsional collet grips and a set of 27 kip wedge grips. The axial motion can be controlled by force, displacement, or an external signal such as a strain gage. The torsional motion can be controlled by torque, angular position, or an external signal. The machine is equipped with an 8-channel signal-conditioning box from the Measurements Corporation for monitoring strain gages, extensometers, and other sensors. Signals from this box are processed directly by the MTS control software programs TestStar and TestWare SX. Other accessories for this machine include: digital longitudinal and transverse extensometers and a digital deflectometer. This machine has been used for tensile, torsion, flexure, and compression testing of metals, polymer composites, and polymer foams.

Several elevated temperature chambers are currently on order for a corrosion related research project sponsored by the UNLV-Yucca Mountain Cooperative Agreement Program. Additionally, an order for a high temperature autoclave has been placed for a recently funded AAA corrosion-related research project. Furthermore, a high-temperature inert gas chamber with extensometer, and extension rod assembly having water-cooled adapter have been ordered from MTS Systems Corporation, that should arrive at the laboratory by the end of April 2002.

Microstructural Analysis

The UNLV Mechanical Engineering Department has a photomicroscopy lab with two 3-wheel sample polishing stations along with a sample potting machine and sanding wheels. The lab has a Unimet Unitron 8644 Inverted Metallurgical Microscope with 800X magnification equipped with a digital camera and computer for recording micrographs. The lab also has a Leco M-400A microhardness tester, several Wilson and Clark Rockwell hardness testers, and a Beuler sample mounting press. Equipment funding for improvements for a dedicated AAA materials preparation facility has been approved in the previous round of proposals. A new Abrasimet 2 Abrasive Cutter has just been added to the existing sample preparation unit. More recently, a LEICA DM IRM BF/DF Inverted Microscope having a 1000X magnification has been ordered, that is scheduled to arrive at the new Materials Performance Laboratory by the end of April 2002.

Scanning Electron Microscopy (http://www.unlv.edu/Colleges/Sciences/Geoscience/EMIL.htm)
The UNLV Geosciences Department has a JEOL-5600 Scanning Electron Microscope (SEM). It is optimized for imaging micron to millimeter scale topographic detail of solid materials. Resolution of up to 50 nm at 100,000 times magnification is possible. The SEM is equipped with a BSE detector and an Oxford ISIS EDS system, capable of semi-quantitative analysis (± 10%). The topographic and compositional images can be processed directly on the screen to show pseudo-color and critical point measurement of features. The images can also be combined, allowing for easy comparison of samples or different magnifications. The manual stage can accommodate four 1-cm diameter samples or one sample up to 3.2-cm diameter. The SEM and EDS are controlled by two networked Windows 95 operating systems allowing for intuitive, simple operation.

The UNLV Geosciences Department also has a JEOL-8900 Electron Probe Microanalyzer (EPMA). It is optimized for quantitative, non-destructive chemical analysis of solid materials on a micron scale. Four fully automated wavelength dispersive spectrometers (WDS) are equipped with 2 crystals each and are capable of quantifying elements ranging from boron to uranium. Concentrations of at least 0.10 wt % can be measured to within ±1% of the measured abundance. In addition, elements present in smaller concentrations can be measured with somewhat less precision. The energy dispersive spectrometer (EDS) collects a full spectrum of x-rays at once and is capable of rapidly qualifying up to 8 elements at one time. Both EDS and WDS can also be used to obtain high-precision x-ray maps and line scans of spatial variation in chemical composition. The instrument is also equipped with backscattered electron, secondary electron, and cathodoluminescence detectors capable of producing "real time" images, or automated images in tandem with x-ray mapping to further characterize the area of interest. A fully automated stage, capable of holding up to nine one-inch round samples (or six petrographic sections) has reproducibility of less than one micron. Unmounted samples up to 15 cm in diameter can also be accommodated. The EPMA is controlled by a graphical user interface on a HP-UX UNIX workstation.

Transmission Electron Microscopy
A transmission electron microscopy (TEM) facility is planned to be established as part of the UNLV AAA program. The UNLV AAA infrastructure committee is currently evaluating the capabilities of three different TEM manufacturers, and a procurement order will be placed with the successful company. The anticipated date for the establishment of this facility is in the fall of 2002. TEM work will be arranged with Los Alamos National Lab if it is needed before this facility is completed.

Research Capabilities at ISU

The Idaho Accelerator Center at Idaho State University (ISU) provides opportunities for nuclear physics research and development to university, industrial, and governmental organizations. The center combines accelerators owned by the U.S. Department of Energy and the State of Idaho with the university's facilities and the technical expertise of university faculty and researchers. The IAC's mission is to conduct and to promote research and development in radiation science and accelerator applications. The laboratory creates partnerships with scientists and engineers in government, university and the private sector designed to lead to new advances and practical

applications in nuclear and radiation science. The Center occupies some 16,000 square feet of laboratory space on the Idaho State University campus, including the Accelerator Center Building completed in October 1998, which houses Center operations and the major electron LINAC accelerator. Center management is in the hands of a director and two part-time associate directors. Proposals for accelerator and facilities usage and advice on operations is given by a Users Advisory Group comprised of representatives from the university and national laboratories. Strategic direction and peer review is given by the Advisory Board, a group of nationally prominent scientists, public policy and business leaders.

The Center has available the following accelerators:

1. A 30 MeV electron linac that can produce 10 to 50 ps, 10nC pulses in the short pulse mode. The energy range in this mode is 0.5 to 28 MeV. Long pulses to 4 microseconds are also available. Repetition rates are to 360Hz. Beam energy spread can be as small as 0.5%. Three beam ports are available.
2. Two Van de Graaff type positive ion accelerators one is equipped for materials analysis studies (back-scattering, PIXE, channeling, etc.). The other Van de Graaff is principally for variable energy neutron production, using (p,n) and (d,n) reactions.
3. A mobile, variable energy (2-12 MeV) electron linac for photo-nuclear studies and applications.
4. A 6 MeV electron linac, equipped for radiation effects studies can deliver high radiation dose rates with precision dosimetry.
5. An 18 MeV electron linac for photo-nuclear studies.
6. A field portable 4MeV electron linac for radiography and neutron generation.
7. A large-scale industrial Scientific Measurements Systems x-ray tomography system, which can be equipped with 450keV or 4MeV x-ray source.

The Center has available a wide range of nuclear detector types, including neutron detectors, and supporting electronics. Custom electronics and mechanical design and fabrication are available.

Research & Applications

Current research activities include:

- Radiography, tomography and nuclear techniques for NDE/NDA.
- Industrial and agricultural applications of accelerator-produced radiation.
- Ion and photon beam analysis for environmental and mineral extraction needs.
- Radiation science in medicine; radioisotope production, accelerator based neutron sources
- BNCT and other forms of neutron therapy.
- Instrument and radiation detector testing for weapons surety studies and other applications.

Education

The Idaho Accelerator supports educational activities at all levels of ISU's academic areas, including:

- Physics
- Health Physics
- Engineering
- Waste Management
- Geology
- Biological Sciences
- Health Sciences

Facilities and services

Two other IAC facilities on campus house positive ion accelerators, scanners, imaging facilities, and support services. This arrangement provides a venue for convenient, inexpensive proof of principle testing, integrated demonstrations, and basic research. The broad range of ongoing scientific and engineering activities facilitates collaboration from a variety of private, university and governmental agencies, while providing an academic research environment with all the amenities of a university.

The Center can provide in house expertise in:

- Neutron and photon transport calculations using various codes including MCNP, and ACCEPT.
- Neutron spectroscopy using various detector types
- A wide range of nuclear and radiation measurements
- Precision dosimetry for gamma radiation and neutrons

Research Capabilities at LANL

Los Alamos National Laboratory (LANL) has numerous capabilities for manufacturing and characterizing materials. The facilities proposed to be used in this work include qualified gas-tungsten arc welding (GTAW) by Felix Olivas of LANSCE-2, and neutron diffraction using the facilities at the Manuel Lujan Neutron Scattering Center by Mark Bourke. After a proposal is submitted and accepted, stress measurements by the neutron diffraction technique can be performed during the July-December 2002 run cycle.

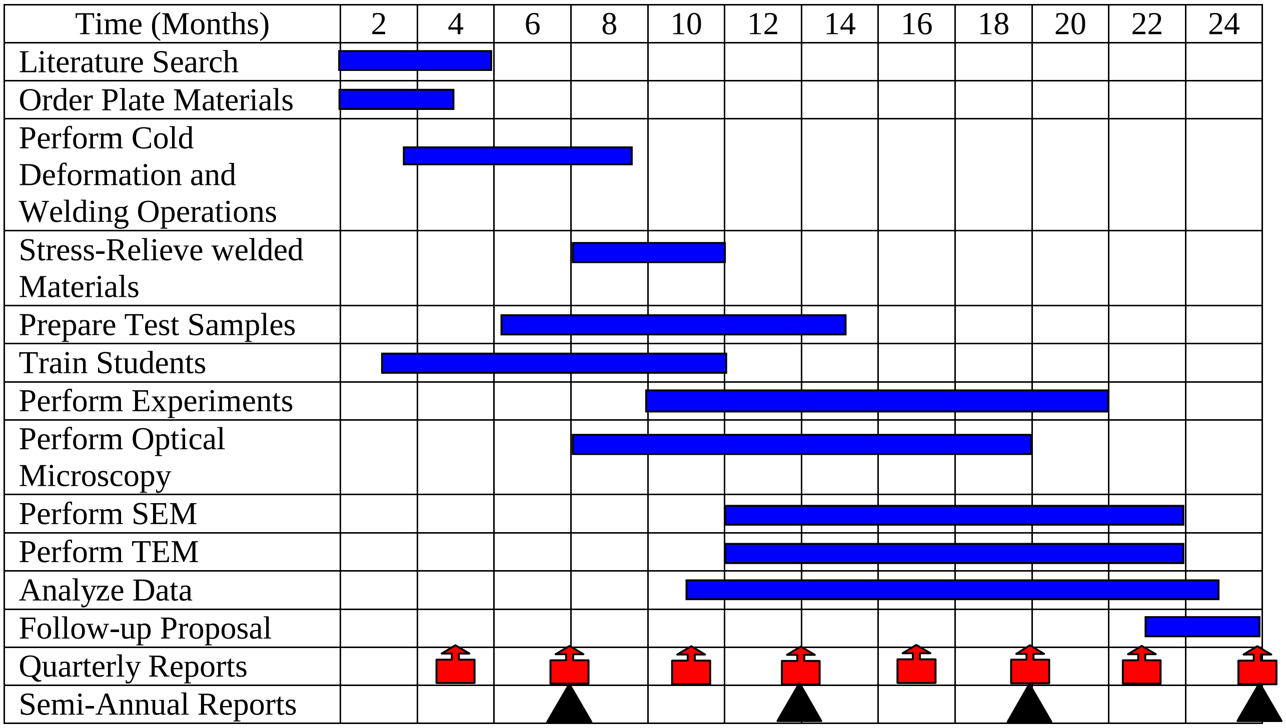
Project Timeline

Timeline Narrative

The proposed research is planned over two years, starting in summer of 2002. Initial tasks will be ordering properly heat-treated plate materials from a reputable manufacturer/vendor. Some of these plates will be subjected to cold deformation at three desired levels of 1, 5, and 10% at a selected vendor's facility. As-received and cold-deformed plates will be welded at LANL using GTAW technique. Some of these welded plates will further be stress relieved at suitable temperatures using the heat-treating facility at UNLV. The test samples will be cut to the desired sizes for microstructural analyses at UNLV using different techniques. Simultaneously, the test materials of desired sizes will be sent to all three research facilities (ISU, LANL and Lambda Research) for measurement of residual stresses in samples prepared under different metallurgical conditions. The UNLV research team (faculty and students) will visit both ISU and LANL during the first quarter to meet with the collaborators from the two laboratories to finalize the testing strategy including the preparation of test matrices, sample preparation technique, and welding of plates. Periodic visits will also be made to Lambda Research facility to develop and monitor the stress measurements of plate materials subjected to varied metallurgical conditions. Emphasis will be placed on defining a set of realistic research objectives for two graduate students to develop and pursue their thesis topics.

Brief quarterly reports will be prepared, and detailed semi-annual reports will be written. It is anticipated that the two graduate students will be able to complete their Master's degree towards the end of the second year of this project. It is also anticipated that a follow-up proposal aimed at evaluating the residual stresses in irradiated materials (Type 316L stainless steel and Alloy 718) using similar techniques will be submitted towards the end of the second year. A two-year schedule is shown in Table 1.

Table 1: Two-Year Research Plan



<u>Year 1 Milestones (Assuming a start date of May 20, 2002)</u>

- (August 2002) All materials have been obtained.
- (January 2003) Cold deformation and welding operations have been completed.
- (March 2003) Post-weld thermal treatments have been completed
- (October 2002) Sample preparation has started.
- (December 2002) Metallography has started.
- (January 2003) Stress measurements have been initiated at three research laboratories.
- (June 2003) Year 1 report is submitted.

<u>Deliverables</u>

- **Train Graduate Students:** The primary deliverable will be two graduate students trained in a field relevant to the national AAA program needs. An undergraduate student will also be added to train in relevant technical areas.
- **Collaboration with DOE project:** Monthly communications (by phone or in person) with the National Project collaborator and/or technical lead to update on progress, discuss problems, and allow for re-focusing if necessary to address shifts in direction by the National Project.
- **Progress Reports:** Brief reports indicating progress will be provided every quarter (to support DOE AAA quarterly meetings).
- **Bi-Annual Reports:** Written reports detailing experiments performed, data collected and results to date.

- **Final Report:** Written report detailing experiments performed, data collected, results, and conclusions to be submitted at the end of the project.
- **Project Samples:** For archival purposes, samples generated during the experimental campaigns will be turned over to the National Laboratory partner. For experiments where multiple samples were prepared, only one sample will be turned over. This sample archive will allow the Project researchers (either from the national laboratories or UNLV or other academic partners) to re-examine samples as necessary, either in support of this work or for use in other research projects.

Roles and Responsibilities

UNLV Researchers

As Principal Investigator (PI), Dr. Roy will take the lead in the overall coordination of this project. He will assume responsibility for many different aspects of this project to ensure that all desired tasks are accomplished in a timely and cost-effective manner. He will train students to performing the various research tasks, supervise the preparation of their thesis, and provide them with an interdisciplinary working environment so that they can make steady progress towards their research goals. As their supervisor, Dr. Roy himself will not perform the related research work but will ensure that high quality work is performed by these students through continuous guidance and consultation in areas of metallurgy, mechanics, thermal treatment, fractography and fabrication techniques. He will also be responsible for specifying and ordering test materials from prospective vendors. The graduate students will conduct and monitor the related experimental work, and will record all test data in the scientific notebooks under the supervision of the PI. Dr. Roy will analyze the resultant data, and will subsequently outline the follow-up experimental work to be performed by the graduate students. He will also prepare the interim and final reports.

ISU Collaborators

Doug Wells, Assistant Professor and Farida Selim, Post Doctoral researcher at ISU will be responsible for the overall design and completion of the experiments of positron annihilation spectroscopy, which will be performed at ISU. They will perform positron measurements on the specimens supplied from UNLV to evaluate the residual stresses and microstructures and provide UNLV with the data. They will also provide guidance and daily hands on scientific expertise to the students involved in the project.

RESUME OF DOUGLAS P. WELLS

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PROFESSIONAL PREPARATION

Rutgers University	Physics	B.A. 1982
University of Virginia	Mathematics	M.S. 1984
University of Illinois	Physics	M.S. 1985
University of Illinois	Physics	Ph.D. 1990

APPOINTMENTS

1997 - present:	Assistant Professor of Physics, (tenure-track), Department of Physics and Health Physics, Idaho State University, Pocatello, ID.
1996 - 1997:	Associate Professor of Health Physics, (non-tenure-track) Department of Physics and Health Physics, Idaho State University, Pocatello, ID.
1993 - 1996:	Radiation Health Physicist, Radiation Protection Division, Washington State Department of Health, Olympia, WA.
1990 - 1992:	Post-Doctoral Research Associate, Department of Physics, University of Washington, Seattle, WA.

SELECTED RECENT PUBLICATIONS

1. D.P. Wells, J.L. Jones, W.Y. Yoon and F. Harmon, *"Cabinet-Safe" Study of 1-8 MeV Electron Accelerators,* Nuclear Instruments and Methods in Physics Research A 463, 118 (2001).
2. D.P. Wells, J.F. Harmon, W.W. Scates and R. Spaulding, *A Test of the Exponential Decay Law by Photo-Production of Nuclear Isomers*, 16th International Conference on the Application of Accelerators in Research and Industry CAARI 2000, AIP Press, Denton, Texas (2001).
3. J. L. Alvarez, R. Geddes, J. E. Rice, T. F. Gesell, and D. Wells, *Elemental Phosphorous Slag Exposure Study in Southeastern Idaho, USA*, 5th International Conference on High Levels of Natural Radiation and Radon Areas: Radiation Dose and Health Effects, Munich, Germany, 2000. (Accepted for publication in International Conference Series No. 1225: 5th International Conference on High Levels of Natural Radiation and Radon", January, 20012)
4. Chouffani, K., Wells, D.P., Harmon, J.F., *Optical Transition Radiation from Copper, Aluminum and Silicon Crystals*, Proceedings of the 21st ICFA Beam Dynamics International Conference on Colliding Beams, Brookhaven, NY, (2001).
5. Selim, F.A., D.P. Wells, J. F. Harmon, W. Scates, J. Kwofie, R. Spaulding, S.P. Duttagupta, J.L. Jones, T. White and T. Roney , *Doppler Broadening Measurements of Positron Annihilation using Bremsstrahlung Radiation,* 11th International Positron Conference, Sante Fe, NM, July, 2001. (Accepted for Publication in Nucl. Instr. Meth. B, 2002)
6. D.P. Wells, D.P., F. A. Selim, J. F. Harmon, W. Scates, J. Kwofie, R. Spaulding, S.P. Duttagupta, J.L. Jones, T. White and T. Roney, Development *of Accelerator–Based X-ray Fluorescence for Large Sample Assay*, 40th International Denver X-ray Conference, Steamboat Springs, CO, July 2001. (Accepted for publication in *Advances in X-Ray Analysis*, Volume 45 (2002).)
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8. Kwofie, J., D.P. Wells, F. A. Selim, F. J. Harmon, W. Scates, R. Spaulding, G.Erickson, S.A. Parke, S.P. Duttagupta, J.L. Jones, T. White and T. Roney, *Accelerator-Based XRF for Subsurface Science*, 1st Inland Northwest Research Alliance Conference on Sub-surface Science, Aug. 2001.
9. Wells, D.P., Kwofie J.E., Selim, F., Harmon, J.F., and Scates, W., *Accelerator-Based X-Ray Fluorescence (AXRF) for Waste Assays and Environmental Applications,* Health Physics 80, S114 (2001).
10. Scates, W., Harmon, J.F., Nigg, D., Harker, Y., and Wells, D.P., *Monte-Carlo Investigation of Photo-Neutron Sources for Boron Neutron Capture Therapy*, Health Physics 80, S108 (2001).

RESUME OF FARIDA SELIM

Department of Physics
Idaho Accelerator Center
Idaho State University
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EDUCATION:

Ph.D. in Eng. Phys., Alexandria University, 1999
(Channel program between Harvard and Alexandria University)
Thesis: Penetration of energetic positrons through amorphous and crystalline media

PROFESSIONAL EXPERIENCE:

Jan. 2001- now: Post doctoral researcher, Department of Physics, Idaho State University.
1999 - 2000: Assistant professor, Department of Physics, Alexandria University.

RESEARCH:

Post doctoral researcher, Department of Physics, Idaho State University, Current research spans several areas of applied physics, including Material research, Accelerator-based XRF and Positron Annihilation Analysis, Isomeric Photo-Nuclear Physics.

SELECTED PUBLICATIONS:

*F.A. Selim, D.P. Wells, et al., *Doppler Broadening Measurements of Positron Annihilation using Bremsstrahlung Radiation*, 11th International Positron Conference (Accepted for Publication in Nucl. Instr. Meth. B, 2002)

*F.A. Selim, D.P.Wells, et al., Development of Bremsstrahlung-based Positron Probe for Assay and Defect Analysis, Subsurface science symposium, Idaho Falls, 2001

*F.A. Selim, Positron dechanneling by electronic and nuclear scattering, Mat. Sci. Forum 363-365 (2001), p. 487

*F.A. Selim, A.W. Hunt, R.H. Howell, K.G.Lynn, J. A. Golovchenko, Developments on positron scattering experiments including beam production and detection, Mat. Sci. Forum. 363-365 (2001), p. 614

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*F.A. Selim, A.W. Hunt, R.H. Howell, K.G.Lynn, J. A. Golovchenko, Multiple scattering measurements of energetic positrons in a thin gold polycrystal, Nucl. Inst. & Meth. B 168 (2000), p. 1

*D.P. Wells. F. A. Selim, J. F. Harmon, et al., *Development of Accelerator–Based X-ray Fluorescence for Large Sample Assay*, 40th Intl. Denver X-ray Conf., *Advances in X-Ray Analysis*, Volume 50 (2002).

*A.W. Hunt, D.B.Cassidy, F.A. Selim, R. Haakenaasen, T.E. Cowan, R.H. Howell, K.G.Lynn, J. A. Golovchenko, Spatial sampling of crystal electrons by in flight annihilation of fast positrons, Nature 402 (1999), p. 157

Note: ISU employees do not require funding from UNLV to participate in this project.

LANL Collaborators

Felix Olivas – LANSCE-2 (GTA welding)
Mark Bourke – MST-8 (Neutron diffraction at LANSCE)

Note: LANL employees do not require funding from UNLV to participate in this project.

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Phone: (702) 895-1463 email: aroy@unlv.edu

Subject: Support for Proposal entitled: "Use of Positron Annihilation Spectroscopy for Stress-Strain Measurements"

Dear Dr. Roy:

I enthusiastically support your proposal on the "Use of Positron Annihilation Spectroscopy for Stress-Strain Measurements" after welding of Alloy EP823 and 316L stainless steel. I believe that this proposal will lead to proof for using such a method for analyzing residual stresses. Such results will be extremely important for the design of the targets for the ATW project and such research is not being performed at any other facilities that I am aware of.

Sincerely,
Stuart A. Maloy
AAA Materials Team Leader

Stuart A. Maloy