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FR47HM - SHEPPARD ROTH

Proceedings of the First World Conference, San Diego, California, December 7-10, 1981

Nuclear nonproliferation and nuclear security require tools to detect, characterize, and locate special nuclear material (SNM). The measurement of neutrons emitted from SNM offers a non-destructive means of doing so, and neutron imaging is a particularly attractive application of neutron measurements to better understand a neutron source for various applications. A field-deployable neutron imager could, for example, be used to locate an improvised nuclear device for emergency response, verify the presence of a nuclear warhead in a disarmament scenario, confirm nuclear material declarations for nuclear safeguards, or find a nuclear weapon in certain envisioned warfighting situations. Unfortunately, the established methods of neutron imaging are difficult to translate from a laboratory setting to the field, primarily due to large sizes and limited maneuverability. The neutron imaging method with the greatest potential for compactness and portability is the neutron scatter camera (NSC) because it requires no modulation of the incoming signal, no moving parts, and does not use gases in the system. Beneficially, NSCs in principle also offer full four-pi angular sensitivity and inherently measure the energy of incident neutrons on an event-by-event basis. Advances in light sensor technology, for example in the development of silicon photomultipliers (SiPMs), have enabled the conception of truly compact NSCs: the single volume NSC and the quasi-single volume NSC. The close spacing of and position sensitivity within detector elements in these designs also enables much greater imaging efficiency. The quasi-single volume NSC is likely more feasible to construct in the near-term, and, within this design space, multiple imager configurations are possible with different performance in different characteristics such as detection efficiency, angular resolution, and cost. Performance in these characteristics typically varies inversely with that of the others, and different applications might prefer different qualities, discouraging a one-size-fits-all approach. This dissertation develops a compact, portable quasi-single volume NSC with an emphasis on inexpensively achieving a high detection efficiency. To accomplish this objective, SiPMs and plastic scintillators are chosen to comprise the imager, and a channel multiplexing method is used to increase the number of detector elements that can be used given digitization hardware restrictions. Extensive assessment of SiPM technology is carried out, and a novel sinusoid-based multiplexing method designed for SiPMs is created and shown to be effective and to maintain good detector performance. Geant4 simulations are used to design the multiplexed neutron imager (MiNI) and understand the effects of multiplexing, leading to the selection of a 32-scintillator 16-digitizer channel configuration. A number of calibrations are carried out to enable the imaging and spectroscopy capability of the MiNI, and where appropriate, these are also used as a large-scale test of the multiplexing method. The MiNI is tested with a 252Cf spontaneous fission source and its imaging capability is demonstrated with the source at multiple locations around the MiNI, as well as its spectroscopic capability. The MiNI developed in this dissertation is the first multiplexed NSC and the first reported quasi-single volume NSC composed of more than eight elements or plastic scintillators to fully demonstrate effective neutron imaging. Ultimately, the MiNI establishes the feasibility of multiplexing a compact NSC and demonstrates a route to achieve high imaging efficiency in a cost-effective manner.

This publication contains examples of how neutron imaging has been used in applications requiring the identification of (light) materials inside solid samples. It provides detailed information on how the technique has become a standard method for various applications, from the examination of nuclear fuels, explosives, electronic components and engine turbine blades to the characterization of fuel cells and geological samples.--Publisher's description.

Thermal neutrons (with mean energy of 25 meV) have a scattering mean free path of about 20 m in air. Therefore it is feasible to find localized thermal neutron sources up to ~30 m standoff distance using thermal neutron imaging. Coded aperture thermal neutron imaging was developed in our laboratory in the nineties, using He-3 filled wire chambers. Recently a new generation of coded-aperture neutron imagers has been developed. In the new design the ionization chamber has anode and cathode planes, where the anode is composed of an array of individual pads. The charge is collected on each of the individual 5x5 mm2 anode pads, (48x48 in total, corresponding to 24x24 cm2 sensitive area) and read out by application specific integrated circuits (ASICs). The high sensitivity of the ASICs allows unity gain operation mode. The new design has several advantages for field deployable imaging applications, compared to the previous generation of wire-grid based neutron detectors. Among these are the rugged design, lighter weight and use of non-flammable stopping gas. For standoff localization of thermalized neutron sources a low resolution (11x11 pixel) coded aperture mask has been fabricated. Using the new larger area detector and the coarse resolution mask we performed several standoff experiments using moderated californium and plutonium sources at Idaho National Laboratory. In this paper we will report on the development and performance of the new pad-based neutron camera, and present long range coded-aperture images of various thermalized neutron sources.

Small accelerator neutron sources offer considerable potential for applied neutron radiography applications. Among the desirable features are relatively low costs, limited operating hazards, opportunities for tailoring primary neutron spectra, compactness and portability, and modest licensing requirements (compared to fission reactors). However, exploitation of this potential has been somewhat limited, in part, by incomplete knowledge of the primary-neutron yields and energy spectra from the favorable source reactions. This work describes an extensive experimental determination of zero-degree neutron yields and energy spectra from the 9Be(d, n) 1°B source reaction, for incident deuterons of 2.6 to 7.0 MeV on a thick beryllium metal target. This information was acquired by means of time-of-flight measurements that were conducted with a calibrated uranium fission detector. Tables and plots of neutron-producing reaction data are presented. This information provides input which will be essential for applications involving the primary spectrum as well as for the design of neutron moderators and for calculation of thermal-neutron yield factors. Such analyses will be prerequisites in assessing the suitability of this source for various possible neutron radiography applications and, also, for assisting in the design of appropriate detectors to be used in neutron imaging devices.

This book comprehensively presents the concepts of neutron physics and imaging including neutron properties, neutron matter interaction, neutron imaging, comparison with X-ray and physics and design of neutron sources. It discusses how neutron imaging has gained importance as a powerful non-destructive technique to understand the internal structures of materials/engineered components in wide range of industries, including defense, aerospace, and healthcare. The book also covers the topics of neutron optics and detectors, basic principles of neutron radiography and tomography, and standards, safety and regulations in neutron imaging. In the last section of the book, it covers wide range of applications of neuro imaging in the areas of aerospace industry, nuclear power and manufacturing industry, 3D printing, materials science and engineering, geomechanics, archeology and palaeontology, national security, biological, and medical industries. Given its scope, the book will be highly useful for postgraduate students, researchers and industry professionals working in the area of engineering and physics, especially non-destructive testing and non-destructive evaluation of neutron imaging.

Neutron capture therapy (NCT) is based on the ability of the non-radioactive isotope boron-10 to capture thermal neutrons with very high probability and immediately to release heavy particles with a path length of one cell diameter, which in principle allows for tumor cell-selective high-LET particle radiotherapy. This book provides a comprehensive summary of the progress made in NCT in recent years. Individual sections cover all important aspects, including neutron sources, boron chemistry, drugs for NCT, dosimetry, and radiation biology. The use of NCT in a variety of malignancies and also some non-malignant diseases is extensively discussed. NCT is clearly shown to be a promising modality at the threshold of wider clinical application. All of the chapters are written by experienced specialists in language that will be readily understood by all participating disciplines.

Proceedings of the Third World Conference held in Osaka, Japan, May 14-18, 1989

This dissertation advances the capability of autonomous manipulation systems for non-destructive testing applications, specifically computed tomography and radiography. Non-destructive testing is the inspection of a part that does not affect its future usefulness. Radiography and tomography technologies are used to detect material faults inaccessible to direct observation. An industrial 7 degree-of-freedom manipulator has been installed in various x-ray and neutron imaging facilities, including the Nuclear Engineering Teaching Laboratory and Los Alamos National Laboratory, for imaging purposes. Inspection of numerous components manually is laborious and time consuming, and there is the risk of high radiation dose to the operator. As Low As Reasonably Achievable exposure can be significantly reduced by installing a robot in an x-ray or neutron imaging facility to perform part placement in the beam for radioactive parts and nuclear facilities. Automation has the additional potential benefit of improving part throughput by obviating the need for human personnel to move or exchange parts to be imaged and allowing for flexible orientation of the imaged object with respect to the x-ray or neutron beam. When the process is fully automated, it eliminates the need for a human to enter the beam area. The robot needs to meet certain performance requirements, including high repeatability, precision, stability, and accuracy. The robotic system must be able to precisely position and align parts, and parts need to be held still while the image is taken. Any movement of the specimen during exposure causes image blurring. Robotics and remote systems are an integral part of the ALARA approach to radiation safety. Robots increase the distance between workers and hazards and reduce time that workers must be exposed. Research performed aims to expand the role of automation at nuclear facilities by reducing the burden on human operators. The robot's control system must manage collision detection, grasping, and motion planning to reduce the amount of time that an operator spends micro-managing such a system via tele-operation. The subject of this work includes modeling (in MCNP) and measuring flux, dose rates, and DPA rates of neutron imaging facilities to develop predictions of radiation flux, dose profiles, and radiation damage by examining neutron and gamma fields during operation. Dose and flux predictions provide users the means to simulate geometrical and material changes and additions to a facility, thus saving time, money, and energy in determining the optimal setup for the robotic system.

The field of x-ray radiography is well established for doing non-destructive evaluation of a vast array of components, assemblies, and objects. While x-rays excel in many radiography applications, their effectiveness diminishes rapidly if the objects of interest are surrounded by thick, high-density materials that strongly attenuate photons. Due to the differences in interaction mechanisms, neutron radiography is highly effective in imaging details inside such objects. To obtain a high intensity neutron source suitable for neutron imaging a 9-MeV linear accelerator is being evaluated for putting a deuteron beam into a high-pressure deuterium gas cell. As a windowless aperture is needed to transport the beam into the gas cell, a low-emittance is needed to minimize losses along the high-energy beam transport (HEBT) and the end station. A description of the HEBT, the transport optics into the gas cell, and the requirements for the linac will be presented.

' Inelastic neutron scattering (INS) is a spectroscopic technique in which neutrons are used to probe the dynamics of atoms and molecules in solids and liquids. This book is the first, since the late 1960s, to cover the principles and applications of INS as a vibrational-spectroscopic technique. It provides a hands-on account of the use of INS, concentrating on how neutron vibrational spectroscopy can be employed to obtain chemical information on a range of materials that are of interest to chemists, biologists, materials scientists, surface scientists and catalyst researchers. This is an accessible and comprehensive single-volume primary text and reference source. Contents:The Theory of Inelastic Neutron Scattering SpectroscopyInstrumentation and Experimental MethodsInterpretation and Analysis of Spectra Using Molecular ModellingAnalysis of INS SpectraDihydrogen and HydridesSurface Chemistry and CatalysisOrganic and Organometallic CompoundsHydrogen BondingSoft Condensed Matter — Polymers and BiomaterialsNon-Hydrogenous Materials and CarbonVibrational Spectroscopy with Neutrons — The Future Readership: Users and potential users of neutron scattering spectroscopy (academics, staff of neutron scattering institutes, researchers and graduate students); solid state vibrational spectroscopists. Keywords:Inelastic Neutron Scattering;Vibrational Spectroscopy;Hydrogen;Solid State;Density Functional Theory;Hydrogen Bonding;Water;Proton;Polymer;Biominerals;Phosphate;Catalyst;Zeolite;Sulfide;Cross Section-Key Features:Acquaints the reader with the basic concepts of neutron scatteringOffers an insight into how theory and experiment connect in the interpretation of INS scattering dataShows how useful information can be extracted from experimental dataDescribes studies of dihydrogen and its compounds using INS spectroscopy-Provides a comprehensive listing of compounds and materials studied by INSReviews:"This book provides a very good account of the principles and applications of Inelastic Neutron Scattering (INS) as a vibrational spectroscopic technique, without assuming a high level of background knowledge. It is a piece of work factually novel and done properly, which meets the needs of graduate students as well as both users and potential users of inelastic neutron spectroscopy at academic and research institutions. On the whole the book is quite clearly written, the subject matter rather well developed and the applications of the INS well described in a wide range of materials and problems."Notiziario Neutroni e Luce di Sincrotrone '

Neutron radiography has proven itself to be an invaluable research tool in the field of nuclear engineering. There are a great many applications that utilize neutron imaging, and further research continues to increase its applicability to a growing number of fields. Many new facilities have been built over the past several years, and an even greater number of existing facilities have been upgraded to more sophisticated neutron sensory equipment. The Sandia National Laboratories has been home to a neutron imaging facility for several decades. Over this time, it has been used with great success in a number of applications. However, with the great advances in neutron collimation and neutron detection in the recent years, it is not unlikely that the facility may soon be retrofitted with more up-to-date technologies. As such, the neutron and gamma ray parameters of the facility must be well-established. This work sought to characterize the neutron beam for the neutron radiography facility at Sandia National Laboratory in Albuquerque, New Mexico. Furthermore, a model of the neutron radiography tube assembly, experiment chamber, and collimator assembly was written and amalgamated to the existing MCNP core deck. The validity of the MCNP model will ultimately be confirmed by performing a number of experiments. These experiments will consist of flux foil calculations at the imaging surface and along various points within the experiment chamber and radiography tube assembly. Additionally, L/D collimation ratios will be found using the ASTM standard method.

The neutron scatter camera (NSC), an imaging spectrometer for fission energy neutrons, is an established and proven detector for nuclear security applications such as weak source detection of special nuclear material (SNM), arms control treaty verification, and emergency response. Relative to competing technologies such as coded aperture imaging, time-encoded imaging, neutron time projection chamber, and various thermal neutron imagers, the NSC provides excellent event-by-event directional information for signal/background discrimination, reasonable imaging resolution, and good energy resolution. Its primary drawback is very low detection efficiency due to the requirement for neutron elastic scatters in two detector cells. We will develop a singlevolume double-scatter neutron imager, in which both neutron scatters can occur in the same large active volume. If successful, the efficiency will be dramatically increased over the current NSC cell-based geometry. If the detection efficiency approaches that of e.g. coded aperture imaging, the other inherent advantages of double-scatter imaging would make it the most attractive fast neutron detector for a wide range of security applications.

Neutron Imaging is a key diagnostic for use in inertial confinement fusion (ICF) experiments, and has been fielded on experiments at Omega and Z. It will also be a key diagnostics at the National Ignition Facility (NIF) located at Lawrence Livermore National Laboratory (LLNL) and eventually at the Laser Megajoule in France. Most systems are based on a neutron pinhole array placed at the target chamber while it is imaged by a scintillating fiber block. The light output of this scintillator is coupled via a reducer to a fiber bundle which transports the image to a CCD camera. Alternatively some systems use optical lens assemblies to focus the light onto a camera. For ICF applications the neutron imaging systems will primarily look at 14.2 MeV neutrons. However, 2.2 MeV and 20+ MeV neutrons will also be present and will potentially provide key information.

Proceedings of the Second World Conference, Paris, France, June 16-20, 1986

Neutron Applications in Earth, Energy and Environmental Sciences offers a comprehensive overview of the wide ranging applications of neutron scattering techniques to elucidate the fundamental materials properties at the nano-, micro- and meso-scale, which underpin research in the related fields of Earth, Energy and Environmental Sciences. Introductions to neutron scattering fundamentals and instrumentation are paired with a thorough review of the applications to a large variety of scientific and technological problems, written through the direct experience of leading scientists in each field. Tailored to a wide audience, this volume provides the novice with an inspiring introduction and stimulates the expert to consider these non-conventional problem solving techniques in his/her field of interest. Earth and environmental scientists, engineers, researchers and graduate students involved with materials science will find Neutron Applications in Earth, Energy and Environmental Sciences a valuable ready-to-use reference.

Neutron radiography represents a powerful non-destructive testing technique that is still very much in development. The book reveals the amazing diversity of scientific and industrial applications of this technique, the advancements of the state-of-art neutron facilities, the latest method developments, and the expected future of neutron imaging.

Neutron Imaging and Applications offers an introduction to the basics of neutron beam production in addition to the wide scope of techniques that enhance imaging application capabilities. An instructional overview of neutron sources, detectors, optics and spin-filters allows readers to delve more deeply into the discussions of radiography, tomography and prospective applications available in neutron holography techniques. A section devoted to current applications describes imaging single grains in polycrystalline materials, neutron imaging of geological materials and other materials science and engineering areas. Coverage of thermal neutron imaging of biological tissues, plant physiology, Homeland Security and contraband detection explore the future prospects of this cutting-edge research. Written by key experts in the field, researchers and engineers involved with imaging technologies will find Neutron Imaging and Applications a valuable reference.

Neutron optics studies the interactions of a beam of slow neutrons with matter. This book updates various advances on neutron optics. There will be a focus on the very active topics of neutron imaging (NI) and neutron spin optics (NSO). The book will also present applications of neutron beams in biomedicine, such as Boron Neutron Capture Therapy (BNCT) and related techniques. Features: Discusses diffraction and interference of slow neutrons, including computational approaches Reviews neutron imaging (NI) and neutron spin optics (NSO) Treats two major sources of slow neutron beams: (1) fission reactions at nuclear reactors and (2) collisions in particle accelerators (small ones, spallation sources) of charged particle beams with targets of heavy atoms Selects subjects on fundamental quantum aspects of slow neutrons and on confined propagation and waveguiding thereof Updates slow neutron beams and BNCT

The need for this book arose from my teaching, engineering, and -search experience in the non-power aspects of nuclear technology. The lack of a comprehensive textbook in industrial applications of radiation frustrated my students, who had to resort to a multitude of textbooks and research publications to familiarize themselves with the fundam- tal and practical aspects of radiation technology. As an engineer, I had to acquire the design aspects of radiation devices by trial-and-error, and often by accidental reading of a precious publication. As a researcher and a supervisor of graduate students, I found that the needed literature was either hard to find, or too scattered and diverse. More than once, I discovered that what appeared to be an exciting new idea was an old concept that was tried a few decades earlier during the golden era of “Atom for Peace”. I am hoping, therefore, that this book will serve as a single comprehensive reference source in a growing field that I expect will continue to expand. This book is directed to both neophytes and experts, and is written to combine the old and the new, the basic and the advanced, the simple and the complex. It is anticipated that this book will be of help in - viving older concepts, improving and expanding existing techniques and promoting the development of new ones.

In evaluating the feasibility of neutron radiography and tomography in the 10-14 MeV region, it is important to estimate the radiation backgrounds that could potentially interfere with the measurements. In this context, backgrounds refer to all counts in the detector other than those due to neutrons transmitted through the sample without scattering. There are two principal sources of backgrounds: (1) neutrons and gammas resulting from incident neutrons interacting in the sample, and (2) events in the detector arising from neutrons scattering in the accelerator vault and collimation system, together with natural and induced activation. Counts due to these backgrounds are spread fairly uniformly across the detector, and therefore do not compromise the ability to identify small features in the sample on the millimeter scale in a tomographic reconstruction; however, they do increase the neutron dose required to achieve sufficient statistical accuracy to reveal features of interest. Backgrounds are generally considered to be tolerable if their count rates are less than or comparable to the rates from the transmitted (uncollided) beam. If they are significantly above this level, they are a potentially serious problem. Understanding radiation backgrounds is thus critically important in determining the required source strength and running time. The backgrounds must be characterized by their energy, radiation type (neutron or gamma), and their timing relative to emission time at the source. These properties may have a profound effect on the design of the source and detector (e.g., whether a pulsing-and-timing technique is necessary to reduce backgrounds, and whether a simple plastic-scintillator based integrating detector will suffice). In the geometry that we have chosen to study, the sample is located approximately two meters from the neutron source, and the detector (a plastic-scintillator neutron-imaging camera; Ref. 1) is located another two meters downstream. A thick shielding wall with a collimating channel approximately 30 cm in diameter is located between the sample and detector to reduce room-scattered backgrounds. We have studied the first source of background (''internal'' or ''sample'' scattering) in this geometry using the COG Monte Carlo radiation transport code, and have found that these backgrounds should be tolerable (the effect of internal scattering should, in fact, be minimized in a system geometry with 2:1 magnification). The second type of background (''external'' or ''room'' scattering and activation) is more difficult to study with a simulation code because these backgrounds are dependent on specific details of a facility that are difficult to know a priori. We have therefore carried out a measurement of these backgrounds in an existing facility, the Ohio University Accelerator Laboratory (OUAL), whose layout closely resembles the system geometry we envisage using for neutron radiography. These measurements were carried out in February, 1996. The results of this experiment indicate that room-scattering and residual activation backgrounds are low enough to allow the use of an integrating plastic-scintillator-based detector in radiographic applications. It appears that neither time gating nor neutron/gamma discrimination will be necessary to obtain satisfactory images. This results in a significant simplification of the requirements for both the neutron source and the detector; however, it is clear that the detector must be placed in a sufficiently well isolated detector cave, and attention must be paid to optimizing the shielding in the neighborhood of the detector. While these measurements were carried out with 10 MeV neutrons from the D+D reaction, it is likely that the results would be similar for 14 MeV neutrons from a D+T source. We currently favor a D+D source for a practical facility, largely because there is no need for handling tritium with this source.

High resolution neutron imaging is an essential tool used for fundamental characterization of novel x-ray opaque microstructures. Currently, advanced neutron scattering facilities enable users to image materials with state-of-the-art neutron radiography spatial resolutions of approximately 10-15 microns. Continued progress towards micron resolution is limited by the intensity and the linearity of available thermal neutron fluxes. This places an emphasis on increasing neutron conversion/detection efficiency while maintaining the spatial accuracy of the projected radiograph.This dissertation reports the results of experimental fabrication and characterization of a microstructured multicore 6-lithium-glass scintillating fiber as a proof-of-concept high resolution neutron imager. The approach towards micron-level thermal neutron imaging and fundamental scintillator materials research for relevant imaging technologies are presented. Fabrication trials and neutron/gamma discrimination observations for an initial square--packed multicore design are described first. Then the fabrication process used for a proof-of-concept hexagonal-packed multicore design,and an evaluation of its radioluminescence and chemical stability is presented. Scintillation characteristics of a neutron imaging face plate were estimated, and its spatial resolution was experimentally measured. The ultimate resolving power of the proof-of-concept multicore was comparable to the state-of-the-art. The impact of even higher resolution designs, with potential to track neutron conversion particles using smaller core pitch or different cladding material, is discussed. Neutron imaging often requires nonlinear detection systems that can accurately represent the spatial features of an irradiated object. While thin film and microchannel plate detectors have been heavily researched for this application, little effort has been made to create selective scintillating regions within structured silicate glass detectors. This dissertation presents the continued research of diffusing trivalent cerium in lithium loaded glass. The creation of near surface regions of scintillation with thermal diffusion of the Ce3+ activator into 6Li glass is presented, and its use for neutron imaging with a bent optical fiber taper is discussed. The activation energy of Ce within the silicate is calculated and its valance state is observed as a function of diffusion depth. The diffusion process is then adopted for use with YAP (YAlO3:Ce) for associated particle imaging applications.

This work demonstrates the neutron sensitivity of single crystal lithium indium diselenide (LiInSe2 or LISe [lithium indium diselenide]). The study aimed to design and characterize a neutron imaging system capable of achieving spatial resolution less than 50 [mu]m [micrometer], operating as a first of its kind direct conversion semiconductor neutron detector. Early detection experiments utilized lithium-6 indium diselenide, enriched to 95% in 6Li [lithium-6], following the experimental investigation of enriched chalcopyrites for semiconductor detection. In this work, lithium indium diselenide (LISe) interchangeably refers to its isotopically enriched complement (6LiInSe2 or 6LISe [lithium-6 indium diselenide]). The primary detection mechanism follows the 6Li(n, [alpha])3H [lithium-6, neutron, alpha, hydrogen-3] reaction, with a Q-value of 4.78MeV. The proof-of-concept detector consisted of a single LISe crystal patterned with thin film gold contacts on opposite surfaces. After showing a semiconductor response to both alpha particles ([alpha]'s) and mixed neutron spectrum, the technology was extended to a 4×4 pixel detector using square pixels of 50 [mu]m size and 550 [mu]m pitch. Using the super-sampling technique, this system successfully resolved features of 300 [mu]m, roughly half the pixel pitch, in a cold neutron beam. Concurrently in the study, higher optical quality LISe sensors demonstrated a scintillation response to neutron exposure. An array of scintillating LISe sensors achieved a resolution of 34 [mu]m, calculated via modulation transfer function (MTF), and were used to reconstruct a neutron computed tomography (nCT) of a small biological sample. Bolstering these results, a semiconducting LISe sensor was patterned with the 55 [mu]m pitch pattern, derived from the 256×256 channel Timepix. The Timepix coupled LISe imager (LISePix) completed the groundwork for the detector as a high-resolution neutron imager, surpassing the design goal with a published spatial resolution limit of 34 [mu]m (full width at half maximum (FWHM) of 111 [mu]m) for LISe. This project has demonstrated the first application of direct conversion semiconductors for neutron detection and imaging, while qualifying a viable neutron detection material for solid-state devices. The LISePix imaging technology offers a low-cost, low-power, compact neutron detection platform comparable to state-of-the-art neutron imaging technologies.

Small Angle X-Ray and Neutron Scattering with Applications to Geomaterials provides techniques for the analysis of geomaterials, which is of great significance for humans because geomaterials are related to earthquake, resource development, underground spaces, carbon dioxide storage, and more. The book introduces the fundamental theory of small angle X-ray and neutron scattering and covers pore accessibility characterization for natural rocks from four aspects, including quantitative evaluation of pore structure heterogeneity and anisotropy, quantification of pore modification in coals due to pulverization, estimation and modeling of coal pore accessibility, and nanoscale coal deformation and alteration of porosity and pore orientation under uniaxial compression. Finally, interactions between pore structures and fluid behaviors in geomaterials are introduced, along with the connections between small-angle scattering and other techniques (NMR cytophotometry, Transmission Electron Microscopy and synchrotron radiation SAXS and nano-CT) described. Covers both theory and applications of small angle X-ray and neutron scattering as related to geomaterials Provides context for using the techniques described in the book in connection with other well-known techniques Includes analysis methods of interactions between pore structures and fluid behaviors in geomaterials

This book provides an extensive overview of the application of neutron characterization techniques in cultural heritage to a broad audience and will be of interest to both scientists and non-scientists in the field. Archaeologists, paleontologists, restaurateurs and conservators, historians and collectors will be fascinated by the wealth of information that can be obtained using neutron techniques, while material scientists and engineers will find details of the experimental techniques and materials properties that can be determined. Neutrons, due to their weak interactions with materials, provide a penetrating, but non-invasive probe of bulk properties. They allow the characterization of the composition and mechanical properties of materials, helping to answer questions related to the dating, the manufacturing process or the state of degradation of artefacts. They allow detailed interrogation of the internal structures of objects that may be otherwise hidden from view. The first section of the book is dedicated to stories describing spectacular discoveries brought about by the use of neutron techniques in a range of applications. The second section covers the experimental techniques in appropriate detail: basic principles, limitations and fields of application.

We are proceeding with the development of a high-energy (10 MeV) neutron imaging system for use as an inspection tool in nuclear stockpile stewardship applications. Our goal is to develop and deploy an imaging system capable of detecting cubic-mm-scale voids, cracks or other significant structural defects in heavily-shielded low-Z materials within nuclear device components. The final production-line system will be relatively compact (suitable for use in existing or proposed facilities within the DOE complex) and capable of acquiring both radiographic and tomographic (CT) images. In this report, we will review our programmatic accomplishments to date, highlighting recent (FY06) progress on engineering and technology development issues related to the proposed imaging system. We will also discuss our preliminary project plan for FY07, including engineering initiatives, proposed radiation damage experiments (neutrons and x rays) and potential options for conducting classified neutron imaging experiments at LLNL.

The reflection of and neutrons from surfaces has existed as an x-rays exp- imental for almost it is in the last technique fifty Nevertheless, only years. decade that these methods have become as of enormously popular probes This the surfaces and interfaces. to be due to of several appears convergence of intense different circumstances. These include the more n- availability be measured orders tron and sources that can over (so reflectivity x-ray many of and the much weaker surface diffuse can now also be magnitude scattering of thin films and studied in some the detail); growing importance multil- basic the realization of the ers in both and technology research; important which in the of surfaces and and role roughness plays properties interfaces; the of statistical models to characterize the of finally development topology its and its characterization from on roughness, dependence growth processes The of and to surface scattering experiments. ability x-rays neutro4s study four five orders of in scale of surfaces over to magnitude length regardless their and also their to ability probe environment, temperature, pressure, etc. , makes these the choice for buried interfaces often probes preferred obtaining information about the microstructure of often in statistical a global surfaces, the local This is manner to complementary imaging microscopy techniques, of such studies in the literature witnessed the veritable by explosion published the last few Thus these lectures will useful for over a resource years.

Retaining its proven concept, the second edition of this ready reference specifically addresses the need of materials engineers for reliable, detailed information on modern material characterization methods. As such, it provides a systematic overview of the increasingly important field of characterization of engineering materials with the help of neutrons and synchrotron radiation. The first part introduces readers to the fundamentals of structure-property relationships in materials and the radiation sources suitable for materials characterization. The second part then focuses on such characterization techniques as diffraction and scattering methods, as well as direct imaging and tomography. The third part presents new and emerging methods of materials characterization in the field of 3D characterization techniques like three-dimensional X-ray diffraction microscopy. The fourth and final part is a collection of examples that demonstrate the application of the methods introduced in the first parts to problems in materials science. With thoroughly revised and updated chapters and now containing about 20% new material, this is the must-have, in-depth resource on this highly relevant topic.

Neutron and synchrotron facilities, which are beyond the scale of the laboratory, and supported on a national level in countries throughout the world. These tools for probing micro- and nanostructure research and on fast dynamics research of atomic location in materials have been key in the development of new polymer-based materials. Different from several existing professional books on neutron science, this book focuses on theory, instrumentation, an applications. The book is divided into five parts: Part 1 describes the underlying theory of neutron scattering. Part 2 describes the various instruments that exist and the various techniques used to achieve neutron scattering or bombardment. Part 3 discusses data treatment and simulation methods as well as how to assess the environment of the sample (temperature, pressure, shear, and external fields). Part 4 addresses the myriad applications of small and large molecules, biomolecules, and gels. Part 5 describes the various global neutron sources that exist and provides an overview of the different reactors.

Radiography with neutrons can yield important information not obtainable by more traditional methods. In contrast to X-rays as the major tool of visual non-destructive testing, neutrons can be attenuated by light materials like water, hydrocarbons, boron, penetrate through heavy materials like steel, lead, uranium, distinguish between different isotopes of certain elements, supply high quality radiographs of highly radioactive components. These advantages have led to multiple applications of neutron radiography since 1955, both for non-nuclear and nuclear problems of quality assurance. The required neutron beams originate from radioisotopic sources, accelerator targets, or research reactors. Energy "tailoring" which strongly influences the interaction with certain materials adds to the versatility of the method. Since about 1970 norms and standards have been introduced and reviewed both in Europe (Birmingham, September 1973) and the United States (Gaithersburg, February 1975). The first world conference on neutron radiography will take place in December 1981, in San Diego, U.S.A. . In Europe the interested laboratories inside the European Community have entered into systematic collaboration through the Neutron Radiography Working Group (NRWGl. since May 1979. This Handbook has been compiled as one of the common tasks undertaken by the Group. Its principal authors are J.C. Domanus (Ris0 National Laboratory). and R.S. Matfield (Joint Research Centre, Ispra) Major contributions have been received from R. Liesenborgs (SCK/CEN Mol) R. Barbalat (CEN Saclayl.

The growing demand for electrical power presents one of the major challenges for the well-being of future generations. For the foreseeable future, it seems highly unlikely that the projected energy needs can be met by fossil and/or alternative energy sources alone; therefore, nuclear power will continue to play a significant role in power generation. Neutrons can be used to study a wide range of problems related to these efforts, providing a unique probe ranging from crystal chemistry of nuclear fuels to engineering diffraction of structural materials used in nuclear reactors. Traditionally, most experimental investigations with neutrons invoke diffraction techniques. However, recent advances in neutron detection resulted in new capabilities of material characterization using neutron imaging, which provides unparalleled opportunities particularly for nuclear materials, where heavy elements (e.g., uranium) need to be imaged together with light elements (e.g., hydrogen, oxygen). The inherent energy sorting of the neutrons at pulsed sources permits performing isotope-specific studies through selected settings of the contrast to a particular isotope (via neutron resonances). Moreover, the application of state-of-the-art tomographic reconstruction algorithms allows reconstructing, in 3D, the spatial distribution in cm-sized samples of quantities derived from these effects, in particular element or isotope distributions. None of this is currently possible with X-ray or reactor neutron radiography, and at present this technique is only possible at pulsed neutron sources at Los Alamos Neutron Science Center (LANSCE), Spallation Neutron Source at Oak-Ridge National Laboratory, ISIS in the United Kingdom, and at the Japan Proton Accelerator Research Complex (J-PARC) in Japan, of which only the J-PARC facility has a dedicated beam line for this technique. In this dissertation, I present the results of spatially-resolved neutron imaging and diffraction experiments (including texture measurements) on non-irradiated nuclear fuels. Furthermore, I present absolute isotopic areal density measurements with a two-dimensional detector and a pixel size of 55[mu]m using the time-structured LANSCE neutron beam applied to some nuclear-engineering application for the first time. More specifically, I introduce a novel, energy-resolved neutron imaging technique that utilizes the physical properties of neutron cross sections by analyzing nuclear resonances with the SAMMY code, which was developed by Oak Ridge National Laboratory for the analysis of cross section data in the resolved and unresolved resonance regions. To the best of my knowledge, this work presents the first applications beyond demonstration experiments of absorption based energy-resolved neutron imaging by applying this technique to characterize the isotope distributions in nuclear fuel and study the diffusion of ions dissolved in aquaeous solution into cement. My dissertation emphasizes the benefits of neutron radiography as a non-destructive characterization method to guide future experiments on post-irradiated nuclear fuels, enabling the quantification of isotope concentrations for a variety of imaging problems.