RMD Publications 1991 to 1993

428) **Growth, characterization and spectroscopic investigations of InI crystals for optical and radiation detector applications**

1998 Materials Research Society Symposium Proceedings Vol.487 Pages 597-604

Mandal KC, Klugerman M, Cirignano LJ, Moy LP, Shah KS, Squillante MR, Bhattacharyya RN

Abstract

Single crystals of InI (ESUBg equals 2.01 eV at 300 K) have been grown by vertical Bridgman technique using zone refined (ZR) starting materials. The quality of the grown crystal has been evaluated by X-ray diffraction (XRD), Electron probe microanalysis (EPMA) and Photoelectron spectroscopy (XPS). Chemically etched crystal wafer has been used to fabricate optical and nuclear detectors. The results are presented in this paper.

427) **Characterization of X-ray imaging properties of PbISUB2 films**

1998 Materials Research Society Symposium Proceedings Vol.487 Pages 351-360

Shah KS, Bennett P, Cirignano L, Dmitriyev Y, Klugerman M, Mandal K, Moy LP, Street RA

Abstract

This paper describes our recent research in developing vacuum sublimed lead iodide films for X-ray imaging. Lead iodide films are promising for this application due to their low dark current, high stopping efficiency, reasonably good charge transport, low cost, and relatively easy scale-up. Lead iodide films (up to 5 multiplied by 5 cmSUP2 area) have been grown and characterized by measuring their X-ray imaging properties such as spatial resolution, and contrast transfer function. Excellent spatial resolution (greater than 10 1p/mm with high CTF approximately equals 50%) has been recorded with PbISUB2 films. Relevant detection properties such as signal amplitude for given X-ray energy has also been measured and was found to be about 10 times larger as compared to standard phosphor screens used for X-ray imaging. Charge transport and timing characteristics of these films have been measured and the results indicate that these films should be capable of real-time operation. Application of these films for X-ray imaging such as mammography, fluoroscopy, and X-ray diffraction is addressed.

426) **High efficiency, spectroscopic CZT array**

1998 Materials Research Society Symposium Proceedings Vol.487 Pages 205-210

Cirignano L, Klugerman M, Dmitriyev Y, Bennett P, Shah KS, Bloser P, Narita T, Grindlay J, Edited by: James RB, Schlesinger TE, Siffert P, Dusi W, Squillante MR, O'Connell M, Cuzin M

Abstract

Compact, efficient, spectroscopic detector arrays which preferably operate without cooling have applications in the fields of x-ray astronomy, nuclear medicine and radioactive materials management. We have fabricated a 16 element CdZnTe detector array that provides a stopping efficiency of greater than 80%, a photopeak fraction of 44% and an energy resolution of 3.2 keV FWHM at 122 keV. The 4 multiplied by 4 array uses a pixel size of (1.5 mm)SUP2 with 0.2 mm spacing on a 5 mm thick substrate. The variation in spectroscopic properties amongst pixels has been characterized in terms of energy resolution and detection efficiency. Operation in current (or flux) mode for transmission imaging has also been investigated.

425) **Photon detection with high gain avalanche photodiode arrays**

1998 IEEE Transactions on Nuclear Science Vol.45 Pages 720-723

Vasile S, Gothoskar P, Farrell R, Sdrulla D

Abstract

The detection of light emitted in fast scintillating fibers and Cerenkov radiators used for fiber calorimetry and tracking applications in high energy colliders, requires fast detector arrays with high sensitivity to short wavelength photons. Photomultiplier tubes, the traditional imaging detectors for short wavelength optical radiation, have limited spatial resolution and require expensive anti-magnetic shielding. We report on short wavelength sensitivity improvement and detection efficiency performance for a novel p-n junction planar structure silicon avalanche photodiode (APD) array, operated in Geiger mode. The APD array provides a high sensitivity detector for applications requiring the detection of light spatial distributions with single photon sensitivity.

424) **Structured CsI(Tl) scintillators for x-ray imaging applications**

1998 IEEE Transactions on Nuclear Science Vol.45 Pages 492-496

Nagarkar VV, Gupta TK, Miller S, Klugerman Y, Squillante MR, Entine G

Abstract

We are developing large-area, thick, structured CsI(Tl) imaging sensors for a wide variety of X-ray imaging applications. Recently we have fabricated structured CsI(Tl) scintillators ranging from 30 mu m (16 mg/cmSUP2) to 2000 mu m (900 mg/cmSUP2) in thickness and up to 15 multiplied by 15 cmSUP2 in area. Even 2000- mu m-thick film showed well-controlled columnar growth throughout the film. Material characterization confirmed that the film is crystalline in nature and that the stoichiometry is preserved. To improve the spatial resolution of thick films, post-deposition treatments were performed. The effect of these treatments on film characteristics was quantitatively evaluated by measuring signal output, modulation transfer function left bracket MTF(f) right bracket , noise power spectrum left bracket NPS(f) right bracket , and detective quantum efficiency left bracket DQE(f) right bracket . The data show that by proper film treatments, the film DQE(f) can be improved.

423) **Multi-element CdZnTe detectors for gamma ray detection and imaging**

1998 IEEE Transactions on Nuclear Science Vol.45 Pages 417-420

Bennett PR, Shah KS, Cirignano LJ, Klugerman MB, Dmitryev YN, Squillante MR

Abstract

A small pixellated gamma-ray detector has been constructed from a 5 mm thick CdZnTe substrate and characterized for spectroscopic and spatial properties. Emphasis has been placed on revealing 'pixel-level' results to further understand optimum array design and operation. The anode design is (1.5 multiplied by 1.5) mmSUP2 pixels on a 1.625 mm pitch. Spectroscopic results with a SUP5SUP7Co source display an average energy resolution of 3.9 keV FHWM. Analysis of the electronic noise for different pixels showed good agreement with a theoretical model, and similar performance between edge and interior pixels. A test of spatial response with incident radiation scanned across the anode face show good agreement with the pixel geometry and an undetectable amount of dependance on interaction depth.

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1998 Materials Research Society Symposium Proceedings Vol.487 Pages 351-360

Shah KS, Bennett P, Cirignano L, Dmitriyev Y, Klugerman M, Mandal K, Moy LP, Street RA, Edited by: James RB, Schlesinger TE, Siffert P, Dusi W, Squillante MR, O'Connell M, Cuzin M

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This paper describes the recent research in developing vacuum sublimed lead iodide films for X-ray imaging. Lead iodide films are promising for this application due to their low dark current, high stopping efficiency, reasonably good charge transport, low cost, and relatively easy scale-up. Lead iodide films (up to 5 x 5 cm sup 2 area) have been grown and characterized by measuring their X-ray imaging properties such as spatial resolution, and contrast transfer function. Excellent spatial resolution (> 10 1p/mm with high CTF approx 50%) has been recorded with PbI sub 2 films. Relevant detection properties such as signal amplitude for given X-ray energy has also been measured and was found to be about 10 times larger as compared to standard phosphor screens used for X-ray imaging. Charge transport and timing characteristics of these films have been measured and the results indicate that these films should be capable of real-time operation. Application of these films for X-ray imaging such as mammography, fluoroscopy, and X-ray diffraction is addressed.

420) **Prototype imaging Cd-Zn-Te array detector**

1998 Materials Research Society Symposium Proceedings Vol.487 Pages 153-158

Bloser PF, Narita T, Grindlay JE, Shah KS, Edited by: James RB, Schlesinger TE, Siffert P, Dusi W, Squillante MR, O'Connell M, Cuzin M

Abstract

The authors describe initial results of their program to develop and test Cd-Zn-Te (CZT) detectors with a pixellated array readout. Their primary interest is in the development of relatively thick CZT detectors for use in astrophysical coded aperture telescopes with response extending over the energy range approximately 10--600 keV. The coded aperture imaging configuration requires only relatively large area pixels (1--3 mm), whereas the desired high energy response requires detector thicknesses of at least 3--5 mm. They have developed a prototype detector employing a 10 x 10 x 5 mm CZT substrate and 4 x 4 pixel (1.5 mm each) readout with gold metal contacts for the pixels and continuous gold contact for the bias on the opposite detector face. This MSM contact configuration was fabricated by RMD and tested at Harvard for uniformity, efficiency and spatial as well as spectral resolution. The authors have developed an ASIC readout (IDE-VA-1) and analysis system and report results, including approximately 4% (FWHM) energy resolution at 60 keV. A prototype design for a full imaging detector array is discussed.

419) **Performance of p-i-n CdZnTe radiation detectors and their unique advantages**

1998 Materials Research Society Symposium Proceedings Vol.487 Pages 245-255

Sudharsanan R, Stenstrom CC, Vakerlis GD, Bennett P, Edited by: James RB, Schlesinger TE, Siffert P, Dusi W, Squillante MR, O'Connell M, Cuzin M

Abstract

The authors present the performance characteristics of CdZnTe radiation detectors with a new P-I-N design and their unique advantages over metal-semiconductor-metal (M-S-M) devices. In M-S-M CdZnTe detectors the bulk resistivity of the substrate largely determines the leakage current. High leakage current is a dominant noise factor for CdZnTe detector arrays, coplanar detectors, and detectors used for low X-ray energy applications. P-I-N devices provide low leakage currents. Early CdZnTe detectors exhibited polarization, were limited to small detection volumes, and some required high deposition temperatures. They have developed a new heterojunction design which can be deposited at low temperatures so that even high-pressure Bridgman CdZnTe can be used. Using the P-I-N design, CdZnTe detectors with high detection volumes (> 200 mm sup 3) were fabricated and exhibited low leakage current, good energy resolution, and no polarization. These detectors have significant advantages over M-S-M detectors in three specific areas. First, X-ray fluorescence studies require detectors with low leakage currents to provide less spectral broadening due to electronic noise. Second, less expensive vertical Bridgman CdZnTe material can be used for imaging applications since it normally possess too low of a bulk resistivity to be useful as a M-S-M detector. Third, leakage currents across the anode grid in large volume coplanar detectors can be significantly reduced.

418) **Growth, characterization and spectroscopic investigations of InI crystals for optical and radiation detector applications**

1998 Materials Research Society Symposium Proceedings Vol.487 Pages 597-603

Mandal KC, Klugerman M, Cirignano LJ, Moy LP, Shah KS, Squillante MR, Bhattacharyya RN, Edited by: James RB, Schlesinger TE, Siffert P, Dusi W, Squillante MR, O'Connell M, Cuzin M

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Single crystals of InI (E sub g = 2.01 eV at 300 K) have been grown by vertical Bridgman technique using zone refined (ZR) starting materials. The quality of the grown crystal has been evaluated by X-ray diffraction (XRD), Electron probe microanalysis (EPMA) and Photoelectron spectroscopy (XPS). Chemically etched crystal wafer has been used to fabricate optical and nuclear detectors. The results are presented in this paper.

417) **Photon detection with high gain avalanche photodiode arrays**

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Vasile S, Gothoskar P, Farrell R, Sdrulla D

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The detection of light emitted in fast scintillating fibers and Cerenkov radiators used for fiber calorimetry and tracking applications in high energy colliders, requires fast detector arrays with high sensitivity to short wavelength photons. Photomultiplier tubes, the traditional imaging detectors for short wavelength optical radiation, have limited spatial resolution and require expensive anti-magnetic shielding. The authors report on short wavelength sensitivity improvement and detection efficiency performance for a novel p-n junction planar structure silicon avalanche photodiode (APD) array, operated in Geiger mode. The APD array provides a high sensitivity detector for applications requiring the detection of light spatial distributions with single photon sensitivity.

416) **Structured CsI(Tl) scintillators for x-ray imaging applications**

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Nagarkar VV, Gupta TK, Miller S, Klugerman Y, Squillante MR, Entine G

Abstract

The authors are developing large-area, thick, structured CsI(Tl) imaging sensors for a wide variety of X-ray imaging applications. Recently they have fabricated structured CsI(Tl) scintillators ranging from 30 micro m (16 mg/cm sup 2) to 2,000 micro m (900 mg/cm sup 2) in thickness and up to 15 x 15 cm sup 2 in area. Even 2,000- micro m-thick film showed well-controlled columnar growth throughout the film. Material characterization confirmed that the film is crystalline in nature and that the stoichiometry is preserved. To improve the spatial resolution of thick films, post-deposition treatments were performed. The effect of these treatments on film characteristics was quantitatively evaluated by measuring signal output, modulation transfer function MTF(f), noise power spectrum NPS(f), and detective quantum efficiency DQE(f). The data show that by proper film treatments, the film DQE(f) can be improved.

415) **Multi-element CdZnTe detectors for gamma ray detection and imaging**

1998 IEEE Transactions on Nuclear Science Vol.45 Pages 417-420

Bennett PR, Shah KS, Cirignano LJ, Klugerman MB, Dmitryev YN, Squillante MR

Abstract

A small pixellated gamma-ray detector has been constructed from a 5 mm thick CdZnTe substrate and characterized for spectroscopic and spatial properties. Emphasis has been placed on revealing pixel-level results to further understand optimum array design and operation. The anode design is (1.5 x 1.5) mm sup 2 pixels on a 1.625 mm pitch. Spectroscopic results with a sup 57 Co source display an average energy resolution of 3.9 keV FHWM. Analysis of the electronic noise for different pixels showed good agreement with a theoretical model, and similar performance between edge and interior pixels. A test of spatial response with incident radiation scanned across the anode face show good agreement with the pixel geometry and an undetectable amount of dependence on interaction depth.

414) **X-ray imaging with semiconductor films**

1998 Proc. SPIE - Int. Soc. Opt. Eng. Vol.3446 Pages 102-113

Shah KS, Bennett P, Cirignano L, Dmitriyev Y, Klugerman M, Mandal K, Moy LP, Street RA

Abstract

*In this paper, a novel approach for developing a large area, high spatial resolution X-ray imaging detector is discussed. This approach integrates the flat panel amorphous silicon readout technology with the polycrystalline lead iodide photoconductive X-ray detection technology. This PbI/sub 2/ detector design is promising because it provides high X-ray stopping efficiency, high efficiency conversion of X-ray energy into electronic change, high signal amplitude due to efficient collection of these changes, and high spatial resolution due to electro-static focusing of these changes. We have designed and fabricated prototype 2"*2" imagers with 200 mu m pixels (256*256 elements) using this approach. The performance of these imagers is characterized by measuring their dark current, X-ray induced signal amplitude, spatial resolution, and uniformity of response. Some basic properties of lead iodide films are also evaluated and presented.*

413) **Low-frequency magnetoresistive eddy-current sensors for NDE of aging aircraft**

1998 Proc SPIE Vol.3397

Rempt R, Blessing G, Boltz ES, Cutler W, Tiernan TC

412) **Identification of the Fe-O-O bending mode in oxycytochrome P450cam**

1998 J Am Chem Soc Vol.120 Page 2670

MacDonald IDG, Christian JF, Unno M, Sligar SG, Champion PM

411) **Investigation of putidaredoxin binding effects in oxy-P450cam using resonance Raman spectroscopy**

1998 42nd Annual Biophys Soc Meeting, Kansas City, MO Vol.Feb. 22-26

Christian JF, Unno M, Kumar ATN, MacDonald IDG, Benson DE, Sligar SG, Champion PM

410) **Multi-element CdZnTe detectors for gamma ray detection and imaging**

1997 IEEE Nuclear Science Symposium & Medical Imaging Conference Vol.1 Pages 561-564

Bennett PR, Shah KS, Cirignano LJ, Klugerman MB, Dmitryev YN, Squillante MR

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A small pixellated gamma-ray detector has been constructed from a 5 mm thick CdZnTe substrate and characterized for spectroscopic and spatial properties. Emphasis has been placed on revealing pixel-level' results to further understand optimum array design and operation. The anode design is (1.5 multiplied by 1.5) mmSUP2 pixels on a 1.625 mm pitch. Spectroscopic results with a SUP5SUP7Co source display an average energy resolution of 3.9 keV FWHM. Analysis of the electronic noise for different pixels showed good agreement with a theoretical model and similar performance between edge and interior pixels. A test of spatial response with scanned sources incident on the anode face showed good agreement with the pixel geometry and an undetectable amount of dependence on interaction depth.

409) **Photon detection with high gain avalanche photodiode arrays**

1997 IEEE Nuclear Science Symposium & Medical Imaging Conference Vol.1 Pages 339-342

Vasile S, Gothoskar P, Sdrulla D, Farrell R

Abstract

The detection of light emitted in fast scintillating fiber bundles and Cerenkov radiators used for fiber calorimetry and tracking applications requires fast detector arrays with high sensitivity to short-wavelength photons. Photomultiplier tube arrays, the traditional imaging detectors for short-wavelength optical radiation, have limited spatial resolution and require expensive anti-magnetic shielding. We report on short-wavelength sensitivity improvement and detection efficiency performance for a new p-n junction planar structure silicon avalanche photodiode (APD) array, operated in Geiger mode. The APD array provides a high-sensitivity detector for applications which require mapping of light spatial distributions with single photon sensitivity.

408) **Structured CsI(Tl) scintillators for X-ray imaging applications**

1997 IEEE Nuclear Science Symposium & Medical Imaging Conference Vol.1 Pages 226-230

Nagarkar VV, Gupta TK, Miller S, Klugerman y, Squillante MR, Entine G

Abstract

We are developing large-area, thick, structured CsI(TI) imaging sensors for a wide variety of X-ray imaging applications. Recently we have fabricated structured CsI(Tl) scintillators ranging from 30 mu m (16 mg/cmSUP2) to 2000 mu m (900 mg/cmSUP2) in thickness and up to 15 multiplied by 15 cmSUP2 in area. Even 2000- mu m-thick film showed well-controlled columnar growth throughout the film. Material characterization confirmed that the film is crystalline in nature and that the stoichiometry is preserved. To improve the spatial resolution of thick films, post-deposition treatments were performed. The effect of these treatments on film characteristics was quantitatively evaluated by measuring signal output, modulation transfer function left bracket MTF(f) right bracket , noise power spectrum left bracket NPS(f) right bracket , and detective quantum efficiency left bracket DQE(f) right bracket . The data show that by proper film treatments, the film DQE(f) can be improved.

407) **CCD based high resolution non-destructive testing system for industrial applications**

1997 Applied Radiation and Isotopes Vol.48 Pages 1459-1465

Nagarkar VV, Vasile S, Gothoskar P, Gordon JS, Gupta TK

Abstract

We have developed a large area structured CsI(Tl) imaging sensor for high resolution non-destructive evaluation using X-rays. The sensor is grown on a specially designed substrate. Our work has produced sensors which show up to a factor of 5 more light output per X-ray, the limiting spatial resolution of 20 lp/mm, and several orders of magnitude faster speed of response compared to the existing sensors. With these new sensors, CCD detectors with millisecond data acquisition times and high spatial resolution suitable for modern digital NDT will be possible.

406) **Quantitative measurement of lead in paint by XRF analysis without manual substrate correction**

1997 Applied Radiation and Isotopes Vol.48 Pages 1425-1431

Afshari S, Nagarkar V, Squillante MR

Abstract

A new instrument, the RMD LPA-1 system, developed based on X-ray fluorescence technology automatically provides a rapid quantitative measurement of lead in paint with a 95% confidence level. The improved performance is due to geometric enhancements and a mathematical approach incorporating corrections for both random and systematic errors. Incorporated in a hand-held X-ray fluorescence lead paint analyzer system, the new instrument maintains a very narrow and task specific focus, giving optimum performance to meet regulatory requirements of lead paint testing in the most efficient manner.

405) **High efficiency pixellated CdTe detector**

1997 Nuclear Instruments & Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment Vol.392 Pages 260-263

Bennett PR, Shah KS, Klugerman M, Squillante MR

Abstract

Position sensitive detectors constructed from compound semiconductors (CdTe, CdZnTe, HgISUB2) are being developed for a variety of applications where high sensitivity and improved energy resolution are significant advantages over scintillator or gas based systems. We have investigated the possibility of using a CdTe detector array in a SPECT gamma camera that would require a high efficiency at 140 keV. The problem of worsening photopeak efficiencies in thick detectors (due to incomplete charge collection) makes it difficult to maintain a high efficiency which, ironically, is the primary reason for choosing a thicker detector. Recent research has shown that following a simple geometrical design criterion can greatly reduce this deleterious effect. This paper reports on the results from a small prototype pixellated array fabricated using this design. We verify the 'small pixel effect' for a detector thickness and pixel size significantly larger than those used in most other work. A 9-element detector (1 multiplied by 1 mm pixels, 4 mm thick) has been fabricated and characterized in terms of energy resolution, peak-to-valley ratio and detection efficiency. Testing of the detector in a fast pulse mode to obtain its high count rate response has also been performed.

404) **Advances in semiconductor photodetectors for scintillators**

1997 Nuclear Instruments & Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment Vol.387 Pages 194-198

Farrell R, Olschner F, Shah KS, Squillante MR

Abstract

Semiconductors photodetectors have long seemed an attractive alternative for scintillation detection, but only recently have semiconductor photodiodes been proven suitable for some room temperature applications. There are many applications, however for which the performance of standard silicon p-i-n photodiodes is not satisfactory. This article reviews recent progress in two different families of novel semiconductor photodetectors: (1) wide bandgap compound semiconductors and (2) silicon photodetectors with enhanced signal-to-noise ratio. The compounds discussed and compared in this paper are HgISUB2, PbISUB2, InI, TlBr, TlBrSUB1SUB minus SUBxISUBx and HgBrSUB1SUB minus SUBxISUBx. The paper will also examine unity gain silicon drift diodes and avalanche photodiodes with maximum room temperature gain greater than 10 000.

403) **Quantitative measurement of lead in paint by XRF analysis without manual substrate correction**

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Afshari S, Nagarkar V, Squillante MR

Abstract

The XRF determination of Pb in paint has hitherto suffered from the need for manual correction for the variable substrate, repeated measurements with long measurement times, some operator judgement and occasional confirmatory measurements for doubtful samples. These problems have been largely overcome by the hand-held dedicated LPA-1 instrument. This consists of a sensor head with a 10 mCi 57 Co source, a CdTe detector and collimators defining the sample viewed, together with a protective shutter. The sensor uses angled geometry, with collimation to ensure maximum sample area, while limiting the depth to 3/8 in. The detector signals pass through a pre-amplifier, a shaping amplifier and a multichannel analyzer, the output from which is evaluated with a microprocessor and a deconvolution algorithm. The results in mg/cm 2 are given on an LCD display and up to 4 000 readings can be stored. There is also an RS-232 port to a PC. The instrument weighs less 3 lb and is powered by a rechargeable battery, with 8 h operating time from one charge. Accuracy and precision are reported for a series of ten measurements of Pb contents up to 10 mg/cm 2 on each of four substrates. A Quick Mode operation is also described, where the analysis time is minimized by the program, to establish whether the Pb content is close to or above the permitted limit of, e. g. , 1 mg/cm 2 .

402) **Characterization of X-ray imaging properties of PbI/sub 2/ films**

1997 Semiconductors for Room-Temperature Radiation Detector Applications II. Symposium Vol.Dec. 1-5, Boston, MA Pages 351-360

Shah KS, Bennett P, Cirignano L, Dmitriyev Y, Klugerman M, Mandal K, Moy LP, Edited by: James RB, Schlesinger TE, Siffert P, Dusi W, Squillante MR, O'Connell M, Cuzin M

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401) **High efficiency, spectroscopic CZT array**

1997 Semiconductors for Room-Temperature Radiation Detector Applications II. Symposium Vol.Dec. 1-5, Boston, MA Pages 205-210

Cirignano L, Klugerman M, Dmitriyev Y, Bennett P, Shah KS, Bloser P, Narita T, Grindlay J, Edited by: James RB, Schlesinger TE, Siffert P, Dusi W, Squillante MR, O'Connell M, Cuzin M

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400) **Lead iodide optical detectors for gamma ray spectroscopy**

1997 IEEE Transactions on Nuclear Science Vol.44 Pages 448-450

Shah KS, Bennett P, Klugerman M, Moy L, Cirignano L, Dmitriyev Y, Squillante MR, Olschner F, Moses WW

Abstract

This paper describes the research performed in developing low noise, high quantum efficiency lead iodide photodetectors for use with scintillators. These photodetectors operate with very low leakage current and show high quantum efficiency (>60%) in 350 to 500 nm region. Successful scintillation studies have been performed at room temperature as well as elevated temperatures (100 degrees C) using PbI/sub 2/ photodetectors with LSO and CsI(Na) scintillators. Detailed analysis of noise has also been performed and potential applications are discussed.

399) **Quantitative measurement of lead in paint by XRF analysis without manual substrate correction**

1997 Appl Radiat Isot Vol.48 Pages 1425-1431

Afshari S, Nagarkar V, Squillante MR

Abstract

X-ray fluorescence analysis has been used for measurement of lead in paint for more than a decade. The early systems provided a nondestructive alternative technology to laboratory-based technologies, but were somewhat time consuming and often led to inconclusive results. The procedure required manual substrate correction, multiple measurements, operator's discretion in validating a measurement due to interfering elements and laboratory analysis of inconclusive samples. A new instrument, the RMD LPA-1 system, has been developed based on X-ray fluorescence technology that addresses all of the drawbacks to the older systems. This new system uses a carefully designed and controlled geometry and modern microprocessor technology to automatically provide a rapid quantitative measurement of lead in paint with a 95% confidence level. The improved precision and accuracy achieved with this system are due to geometric enhancements and a mathematical approach which incorporates corrections for both random and systematic errors such as matrix effects and Compton scatter. This technology has been incorporated in a hand-held X-ray fluorescence lead paint analyzer system. A key design philosophy for this system was to maintain a very narrow, task-specific focus, the system was not designed to be an all purpose XRF analyzer, rather it is optimized to meet regulatory requirements of lead paint testing in the most efficient manner. The development of the LPA-1 system is an example of what can be accomplished by listening to the needs and desires of the users, rethinking the design of an existing technique and incorporating modern microprocessor technology.

398) **Advances in semiconductor photodetectors for scintillators**

1997 Nuclear Instruments and Methods in Physics Research, Section A Vol.387 Pages 194-198

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Semiconductors photodetectors have long seemed an attractive alternative for scintillation detection, but only recently have semiconductor photodiodes been proven suitable for some room temperature applications. There are many applications, however for which the performance of standard silicon p-i-n photodiodes is not satisfactory. This article reviews recent progress in two different families of novel semiconductor photodetectors: (1) wide bandgap compound semiconductors and (2) silicon photodetectors with enhanced signal-to-noise ratio. The compounds discussed and compared in this paper are HgI sub 2 , PbI sub 2 , InI, TlBr, TlBr sub 1-x I sub x and HgBr sub 1-x I sub x . The paper will also examine unity gain silicon drift diodes and avalanche photodiodes with maximum room temperature gain greater than 10000.

397) **High efficiency pixellated CdTe detector**

1997 Nuclear Instruments and Methods in Physics Research, Section A Vol.392 Pages 260-263

Bennett PR, Shah KS, Klugerman M, Squillante MR

Abstract

Position sensitive detectors constructed from compound semiconductors (CdTe, CdZnTe, HgI sub 2) are being developed for a variety of applications where high sensitivity and improved energy resolution are significant advantages over scintillator or gas based systems. We have investigated the possibility of using a CdTe detector array in a SPECT gamma camera that would require a high efficiency at 140 keV. The problem of worsening photopeak efficiencies in thick detectors (due to incomplete charge collection) makes it difficult to maintain a high efficiency which, ironically, is the primary reason for choosing a thicker detector. Recent research has shown that following a simple geometrical design criterion can greatly reduce this deleterious effect. This paper reports on the results from a small prototype pixellated array fabricated using this design. We verify the 'small pixel effect' for a detector thickness and pixel size significantly larger than those used in most other work. A 9-element detector (1 x 1 mm pixels, 4 mm thick) has been fabricated and characterized in terms of energy resolution, peak-to-valley ratio and detection efficiency. Testing of the detector in a fast pulse mode to obtain its high count rate response has also been performed.

396) **Amorphous silicon, semiconductor X-ray converter detectors for protein crystallography**

1997 Nuclear Instruments and Methods in Physics Research, Section A Vol.399 Pages 38-50

Ross S, Zentai G, Alkire RW, Naday I, Westbrook EM, Shah KS

Abstract

Hydrogenated amorphous silicon (a-Si:H) is a semiconductor material which can be inexpensively deposited to create a large array detector or readout structure. Combining it with a suitable semiconductor X-ray sensitive converter would produce a large, sensitive detector for X-rays with energies of 6-20 keV such as used in measurements of diffraction patterns for protein crystallography. In these experiments, the diffraction patterns created when X-rays strike crystallized protein samples are used to infer the physical structure of the molecules. The requirements for the detector include the ability to record signal peaks to high diffraction order to obtain accurate mapping of the electron density of the protein molecule, plus rapid sampling of the diffraction pattern to minimize radiation dose to the exposed crystal, while maintaining high signal-to-noise ratios. In this paper we summarize our results to date measuring and modeling the suitability of various semiconductor thin films for direct X-ray detection, and of the noise and readout properties of an amorphous silicon matrix array. We provide sample diffraction patterns obtained from a protein crystal taken at the Argonne advanced photon source X-ray synchrotron using a phosphor coated a-Si:H array.

395) **Spectroscopic Effects of polarity and hydration in the distal heme pocket of deoxymyoglobin**

1997 Biochemistry Vol.36 Pages 11198

Christian JF, Unno M, Sage JT, Chien E, Sligar SG, Champion PM

Abstract

Distal pocket mutations at the E7 position (His64) of sperm whale deoxymyoglobin (deoxyMb) are used as a probe of distal pocket polarity and hydration. Changes of two key spectroscopic markers, the Fe-His(F8) stretch in the resonance Raman spectrum and the position of band III in the absorption spectrum, are monitored as the His64Tyr, His64Phe, His64Leu, and His64Gly mutations alter the distal heme pocket environment. The Fe-His vibration for the Phe, Leu, and Gly mutants is shifted to a lower frequency by 1-2 cm-1 relative to the Tyr mutant, wild type (WT), and native deoxyMb. Band III shifts to the red by approximately 4 nm (approximately 70 cm-1) relative to WT and native deoxyMb for all the His64 mutants examined in this work. We correlate the small shift in the Fe-His frequency to the local electrostatic environment directly above the heme iron, affected by the presence of a localized water molecule in the heme pocket that is hydrogen-bonded to the E7 residue. The position of band III is roughly correlated to the displacement of the iron from the heme plane; however, the relatively large scatter in this correlation, as well as its dependence on distal pocket mutations, suggests that the heme pocket environment, particularly the E7 residue, also affects the energy of this transition.

394) **Resonance Raman investigations of cytochrome P450cam complexed with putidaredoxin**

1997 J Am Chem Soc Vol.119 Page 6614

Unno M, Christian JF, Benson DE, Gerber NC, Sligar SG, Champion PM

393) **Avalanche photodiodes for anticoincidence detectors**

1996 SPIE Proceedings Vol.2806 Pages 561-568

Cirignano L, Farrell R, Redus R, Squillante MR, Hunter SD, Cuddapah R, Mukherjee R

Abstract

Anticoincidence detectors are required for a variety of satellite instruments, including high energy gamma-ray telescopes, in order to differentiate ambient background radiation from signals of interest. Presently, most anticoincidence systems use scintillators coupled to photomultiplier tubes. We have demonstrated that it is now possible to use very high gain solid state avalanche photodiodes (APDs) as photodetectors for this application. A single APD coupled to a 30 x 30 x 0.95 cm plastic scintillator tile demonstrated 100 percent detection efficiency for minimum ionizing particles, with a low false positive rate. Multiple APDs enhance the signal-to-noise ratio in addition to providing redundancy. Relative to PMTs, APDs are compact, low power, and mechanically robust devices. Ground test data of APDs for anticoincidence shields are presented.

392) **Gain and noise in very high gain avalanche photodiodes - Theory and experiment**

1996 SPIE Proceedings Vol.2959 Pages 288-297

Redus R, Farrell R

Abstract

Large-area silicon avalanche photodiodes have been fabricated with maximum avalanche gains exceeding 10,000 and excellent SNRs. A model for device performance has been developed in which previously developed general expressions are numerically integrated using actual fabrication parameters. The gain, statistical fluctuations in the gain, electronic noise, and total peak broadening have been computed using this model. The results are in good agreement with measurements. The parameter k(eff) was found to be 7.2 x 10 exp -4, allowing a high SNR at gains of several thousand.

391) **Cost effective segmented scintillating converters for hard X-rays**

1996 SPIE Proceedings Vol.2859 Pages 94-101

Vasile S, Gordon JS, Klugerman M, Nagarkar V, Squillante MR, Entine G, Watson S, Kauppila TJ

Abstract

We report on recent research of a new segmented X-ray imaging converter. This converter is fabricated using vacuum injection and crystal growth methods to induce defect-free, high density scintillating fibers into a collimator matrix. This method has the potential to fabricate large-area, thick segmented scintillators. Spatial resolution calculations of these scintillator-injected collimators show that the optical light spreading is significantly reduced compared to single crystalline scintillators, and sub-millimeter resolution can be achieved for 10-MeV photons. We have produced 2.5-cm-thick converters, and sub-millimeter resolution X-ray images acquired with the segmented converter coupled to a cooled CCD camera provided the resolution to characterize the converter efficiency and noise. The proposed concept overcomes the above-mentioned limitations by producing a cost-effective technique of fabricating large area X-ray scintillator converters with high stopping power and high spatial resolution. This technology will readily benefit diverse fields such as particle physics, astronomy, medicine, as well as industrial nuclear and nondestructive testing.

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Cirignano LJ, Farrell R, Redus RH, Squillante MR, Hunter SD, Cuddapah J, Mukherjee R

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389) **High efficiency detection of tritium using silicon avalanche photodiodes**

1996 IEEE Nuclear Science Symposium & Medical Imaging Conference Vol.2 Pages 845-847

Shah KS, Gothoskar P, Farrell R, Gordon J

Abstract

This paper describes our recent work in developing low noise silicon avalanche photodiodes (APD) for detection of tritium (SUP3H) beta -particles with high efficiency. In view of the very low energy of SUP3H beta -particles (ESUBmSUBaSUBx equals 18 keV), research was carried out to produce APD structures with a very thin entrance window. This involved using low energy boron implantation into the APD front surface, followed by pulsed excimer laser annealing of the implanted face to form a pSUP plus contact. The resulting devices had surface dead layer of about 0.07 to 0.1 mu m and operated with low noise threshold (250-300 eV) for 2 multiplied by 2 mmSUP2 size. The SUP3H beta -particle detection efficiency was measured to be approximately 50%. This is about the twice the detection efficiency achieved with standard APDs.

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Nagarkar VV, Gordon JS, Gupta TK, Vasile S, Gothoskar P, Entine G

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Film radiography has long served the aerospace industry as a principal method for hardware flaw detection. Although excellent in performance, this method is extremely time consuming, labor intensive, costly, and is unsuitable for real time inspections. Modern digital radiographic systems overcome some of these difficulties but are also limited in terms of speed of operation due to persistence of the sensor and a problematic tradeoff between the X-ray detection efficiency and spatial resolution. We are developing an innovative X-ray imaging detector consisting of a novel microstructured CsI scintillator coupled to a fiberoptic taper-based CCD. Thin-film deposition techniques, previously developed to produce thin, structured CsI screens have been extended to fabricate CsI screens, up to 450 mg/cmSUP2 (1,000 mu m) in thickness. These sensors are suitable to provide high detection efficiency with high image quality for NDE applications. A prototype high energy imaging system was constructed by integrating these screens into a fiberoptic-based CCD camera. The performance was compared to that of the same system using a standard polycrystalline phosphor for NDE imaging applications. The experimental evaluations were carried out at Scientific Measurement Systems, Inc., Austin, TX.

387) **Lead iodide optical detectors for gamma ray spectroscopy**

1996 IEEE Nuclear Science Symposium & Medical Imaging Conference Vol.1 Pages 21-24

Shah KS, Bennett P, Klugerman M, Moy L, Cirignano L, Dmitriyev Y, Squillante MR, Olschner F, Moses WW

Abstract

This paper describes the research performed in developing low noise, high quantum efficiency lead iodide photodetectors for use with scintillators. These photodetectors operate with very low leakage current and show high quantum efficiency (greater than 60%) in 350 to 500 nm region. Successful scintillation studies have been performed at room temperature as well as elevated temperatures (100 degree C) using PbISUB2 photodetectors with LSO and CsI(Na) scintillators. Detailed analysis of noise has also been performed and potential applications are discussed.

386) **Electronics for high resolution spectroscopy with compound semiconductors**

1996 Nuclear Instruments & Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment Vol.380 Pages 312-317

Redus R, Squillante MR, Lund JC

Abstract

A wide variety of applications require high resolution, high sensitivity, gamma ray spectrometers which are portable, compact, and rugged enough for field operations. We are developing a laboratory prototype of a semiconductor detector system meeting these requirements. This spectrometer uses multiple CdTe radiation detectors for high counting efficiency, digital nonlinear pulse risetime compensation circuitry for high energy resolution and high sensitivity, and a low power thermoelectric cooler for low electronic noise. The use of digital compensation allows arbitrary, very accurate compensation with no rejection. These three techniques were integrated in the prototype, which achieved an energy resolution of 5 keV (0.75%) FWHM at 662 keV, without rejecting any counts, using a detector volume of 4 multiplied by 4 multiplied by 2 mm CdTe. With a 1.6 cm diam multiplied by 2 mm CdTe detector, a resolution of 15 keV (2%) FWHM at 662 keV was measured. The same technology has been successfully applied to other compound semiconductors which also have performance limited by poor charge collection, such as CdSUBxZnSUB1SUB minus SUBxTe. A low power, compact, very portable, rugged implementation has been designed.

385) **Lead iodide x-ray detection systems**

1996 Nuclear Instruments & Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment Vol.380 Pages 266-270

Shah KS, Olschner F, Moy LP, Bennett P, misra M, Zhang J, Squillante MR, Lund JC

Abstract

Recent progress in the development of room-temperature lead iodide (PbISUB2) X-ray detectors is reported. Progress has been made in the areas of detector fabrication and preamplifier electronics, and this has resulted in improved detection performance. An energy resolution of 415 eV (FWHM) has been reported for 5.9 keV X-rays (SUP5SUP5Fe source) with 1 mmSUP2 detector at room temperature. A better estimation of the Fano factor in PbISUB2 has been carried out and the upper limit of the Fano factor is calculated to be 0.19. Larger lead iodide detectors (up to 25 mmSUP2) have been fabricated and their spectroscopic performance has been evaluated. The timing characteristics of lead iodide detectors have been investigated. A compact, portable lead iodide probe assembly has been designed and built for X-ray spectroscopic applications. Finally, optical and charge particle detection properties of lead iodide detectors have also been characterized.

384) **Characterization of indium iodide detectors for scintillation studies**

1996 Nuclear Instruments & Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment Vol.380 Pages 215-219

Shah KS, Bennett P, Moy LP, Misra MM, Moses WW

Abstract

Indium iodide (InI) is a wide bandgap semiconductor (ESUBg equals 2.0 eV) and has been investigated as an optical detector material for use in gamma -ray scintillation spectroscopy. Single crystals of InI have been grown by the Bridgman process using zone-refined starting material and optical detectors have been fabricated from such crystals. The performance of these detectors has been investigated by measuring their quantum efficiency, direct X-ray detection characteristics, and electrical resistivity. The InI photodetectors have been coupled to CsI(Tl) scintillators and room-temperature energy resolutions of 7.5% (FWHM) and 9.8% (FWHM) were recorded for 662 keV and 511 keV gamma -rays, respectively. Successful gamma -ray detection has also been accomplished with InI photodetectors coupled to LSO (LuSUB2SiOSUB5:Ce) scintillators, and a resolution of 14% (FWHM) has been recorded for 511 keV gamma -rays. Finally, analysis of the electronic noise behavior of the InI detectors has been performed.

383) **Novel concepts in X-ray and gamma -ray detection using compound semiconductors**

1996 Nuclear Instruments & Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment Vol.380 Pages 160-164

Squillante MR, Entine G

Abstract

Recently there has been considerable progress in detectors made from compound semiconductor materials as well as in the development of methods for electronically enhancing the signals obtained from them. This progress is largely based on researchers rethinking the use of these materials and using new concepts to take advantage of their inherent properties. This creativity has led to better performance and new capabilities and has opened the way to many new applications that were previously beyond the reach of the technology. For example, such advances have lead to detector systems with significantly larger size, higher resolution, and multi-element array configurations capable of generating impressive 2-dimensional images.

382) **Evaluation of CdTe for use in a prototype emission / transmission CT imaging system**

1996 IEEE Transactions on Nuclear Science Vol.43 Pages 2225-2229

Bennett PR, Shah KS, Squillante MR, Heanue JA, Hasegawa BH

Abstract

Cadmium telluride has been investigated for potential use in a prototype imaging system capable of acquiring both x-ray CT and SPECT data. The system is being designed to accumulate SPECT images with 140 keV gamma rays, thus requiring 4 mm detector thicknesses to achieve satisfactory stopping power. This study primarily investigates whether an alternative pixel orientation can be used with thick detectors to preserve the higher photopeak efficiencies normally associated with smaller thicknesses. Using SUP5SUP7Co (122 keV) as a substitute isotope to SUP9SUP9SUPmTc, small 2 mm CdTe cubes were investigated along with 'edge irradiated' 2x4x2 mm bars of both CdTe and CdZnTe. The photopeak efficiency of the large bars can be increased through the use of cooling but energy resolution remains less than desired. Small cubes of either material meet the resolution requirements, but the efficiency of patient dose would be sacrificed.

381) **Imaging nuclear survey system**

1996 IEEE Transactions on Nuclear Science Vol.43 Pages 1827-1831

Redus R, Squillante M, Gordon JS, Bennett P, Entine G, Knoll G, Wehe D, Guru S

Abstract

A combined video and gamma ray imaging system has been developed which can rapidly determine the location, distribution, and intensity of gamma ray sources. This instrument includes both a conventional video camera and a gamma ray imaging system, which is based upon a position sensitive photomultiplier tube, a scintillator, and a pinhole collimator. The gamma camera records the position and energy of each interaction, determining the energy spectrum and count rate from each direction. We have used a prototype of such an instrument in preliminary field tests to image radioactive sources with gamma ray energies between 120 keV and 2.4 MeV. At 662 keV, this new system achieves an angular resolution of 4 degree FWHM with an absolute efficiency of 1 multiplied by 10SUP minus SUP6 at 1 meter, with sensitivity such that a 0.5 mCi SUP1SUP3SUP7Cs source at 5 meters can be located in less than 60 seconds. Higher efficiency and sensitivity can be achieved at lower spatial resolution.

380) **High resolution x-ray sensor for non destructive evaluation**

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Nagarkar VV, Gordon JS, Vasile S, Gothoskar P, Hopkins F

Abstract

A large area structure X-ray imaging sensor is developed using CCD based radiographic and computed tomographic systems. The sensor is formed by vapor deposition of CsL(TI) onto a specially designed fiberoptic substrate. The X-ray sensor has a factor of 4.5 greater length output, at least three order of magnitude faster decay time response, and greater spatial resolution compared to the currently used high density TbSUB2OSUB3 doped fiberoptic glass scintillators. With these new sensors, the development of larger area fiberoptic taper based CCD detectors with millisecond data acquisition capabilities and high spatial resolution suitable for NDE applications are possible.

379) **Silicon drift photodiode array detectors**

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Olschner F

Abstract

Silicon drift photodiodes have been constructed in a two-dimensional array format for the purpose of position sensitive detection. The arrays are dimensioned 4 multiplied by 4, with pixel size 3 mm multiplied by 3 mm, and are intended to be used with discrete-channel readout electronics. This aspect of the design limits the overall array dimension in future prototype versions to approximately 10 multiplied by 10, but allows for higher total count rates than multiplexed or serial-read arrays. The photodiode arrays use the floating cathode ring design described by others. The design reported here, however, differs in that these devices have been specifically processed to maximize the detection efficiency of visible light. This feature makes these detectors attractive for use in position-sensitive scintillator readout. Measurements are presented using these photodiodes coupled to common scintillator crystals to detect gamma-rays. Measurements are also shown using these photodiodes to directly detect low energy X-rays. Typical room temperature noise (ENC) measured in the prototype arrays is 60 electrons rms.

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Vasile S, Gordon JS, Klugerman M, Nagarkar V, Squillante MR, Entine G, Watson S, Kauppila TJ

Abstract

Thick segmented scintillating converters coupled to optical imaging detectors offer the advantage of large area, high stopping power sensors for high energy X-ray digital imaging. The recent advent of high resolution and solid state optical sensors such as amorphous silicon arrays and CCD optical imaging detectors makes it feasible to build large, cost effective imaging arrays. This technology, however, shifts the sensor cost burden to the segmented scintillators needed for imaging. The required labor intensive fabrication of high resolution, large area hard X-ray converters results in high cost and questionable manufacturability on a large scale. The authors report on recent research of a new segmented X-ray imaging converter. This converter is fabricated using vacuum injection and crystal growth methods to induce defect free, high density scintillating fibers into a collimator matrix. This method has the potential to fabricate large area (>400 cm sup 2), thick (10 cm) segmented scintillators. Spatial resolution calculations of these scintillator injected collimators show that the optical light spreading is significantly reduced compared to single crystalline scintillators and sub-millimeter resolution can be achieved for 10 MeV photons. They have produced 2.5 cm thick converters and sub-millimeter resolution X-ray images acquired with the segmented converter coupled to a cooled CCD camera provided the resolution to characterize the converter efficiency and noise. The proposed concept overcomes the above mentioned limitations by producing a cost-effective technique of fabricating large area X-ray scintillator converters with high stopping power and high spatial resolution. This technology will readily benefit diverse fields such as particle physics, astronomy, medicine, as well as industrial nuclear and non-destructive testing.

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This paper describes our recent work in developing low noise silicon avalanche photodiodes (APD) for detection of tritium (sup 3 H) P-particles with high efficiency. In view of the very low energy of sup 3 H beta -particles (E sub max =18 keV), research was carried out to produce APD structures with a very thin entrance window. This involved using low energy boron implantation into the APD front surface, followed by pulsed excimer laser annealing of the implanted face to form a p sup + contact. The resulting devices had surface dead layer of about 0.07 to 0.1 mu m and operated with low noise threshold (250-300 eV) for 2x2 mm sup 2 size. The sup 3 H beta -particle detection efficiency was measured to be approximately 50%. This is about the twice the detection efficiency achieved with standard APDs.

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This paper describes the research performed in developing low noise, high quantum efficiency lead iodide photodetectors for use with scintillators. These photodetectors operate with very low leakage current and show high quantum efficiency (>60%) in 350 to 500 mn region. Successful scintillation studies have been performed at room temperature as well as elevated temperatures (100 degrees C) using PbI sub 2 photodetectors with LSO and CsI(Na) scintillators. Detailed analysis of noise has also been performed and potential applications are discussed.

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Nagarkar VV, Gordon JS, Vasile S, Gothoskar P, Hopkins F

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Nondestructive evaluation (NDE) using X-rays is becoming indispensable for detecting microdefects in new materials currently used in aerospace and other engineering disciplines. Existing X-ray sensors pose limitations on the speed of operation due to persistence of the sensor and a problematic tradeoff between the sensor thickness and spatial resolution. To address these limitations the authors are developing a large area structured CsI(Tl) imaging sensor for NDE using CCD based radiographic and computed tomographic systems. The sensor is formed by vapor deposition of CsI(Tl) onto a specially designed fiberoptic substrate. The work has produced X-ray sensors with a factor of 4.5 greater light output, at least three orders of magnitude faster decay time response, and greater spatial resolution (16% modulation transfer function, MTF(f), at 14 linepairs per millimeter (lp/mm)) compared to the currently used high density Tb sub 2 O sub 3 doped fiberoptic glass scintillators. These performance advances will address the limitations of existing detector technology by producing high quality images and fast scan times required for real-time NDE inspection. Performance measurements for prototype CsI(Tl) scintillator converters are presented. With these new sensors the development of larger area fiberoptic taper based CCD detectors with millisecond data acquisition capabilities and high spatial resolution suitable for NDE applications will be possible.

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363) **Portable high energy gamma ray imagers**

1996 Nuclear Instruments and Methods in Physics Research, Section A Vol.378 Pages 612-619

Guru SV, He Z, Wehe DK, Knoll GF, Redus RH, Squillante MR

Abstract

To satisfy the needs of high energy gamma ray imagers for industrial nuclear imaging applications, three high energy gamma cameras are presented. The RMD-Pinhole camera uses a lead pinhole collimator and a segmented BGO detector viewed by a 3 in. square position sensitive photomultiplier tube (PSPMT). This pinhole gamma camera displayed an energy resolution of 25.0% FWHM at the center of the camera at 662 keV and an angular resolution of 6.2 FWHM at 412 keV. The fixed multiple hole collimated camera (FMCC), used a multiple hole collimator and a continuous slab of NaI(Tl) detector viewed by the same PSPMT. The FMCC displayed an energy resolution of 12.4% FWHM at 662 keV at the center of the camera and an angular resolution of 6.0 FWHM at 412 keV. The rotating multiple hole collimated camera (RMCC) used a 180 antisymmetric rotation modulation collimator and CsI(Tl) detectors coupled to PIN silicon photodiodes. The RMCC displayed an energy resolution of 7.1% FWHM at 662 keV and an angular resolution of 4.0 FWHM at 810 keV. The performance of these imagers is discussed in this paper.

362) **Novel concepts in X-ray and gamma -ray detection using compound semiconductors**

1996 Nuclear Instruments and Methods in Physics Research, Section A Vol.380 Pages 160-164

Squillante MR, Entine G

Abstract

Recently there has been considerable progress in detectors made from compound semiconductor materials as well as in the development of methods for electronically enhancing the signals obtained from them. This progress is largely based on researchers rethinking the use of these materials and using new concepts to take advantage of their inherent properties. This creativity has led to better performance and new capabilities and has opened the way to many new applications that were previously beyond the reach of the technology. For example, such advances have lead to detector systems with significantly larger size, higher resolution, and multi-element array configurations capable of generating impressive 2-dimensional images.

361) **Electronics for high resolution spectroscopy with compound semiconductors**

1996 Nuclear Instruments and Methods in Physics Research, Section A Vol.380 Pages 312-317

Redus R, Squillante M, Lund JC

Abstract

A wide variety of applications require high resolution, high sensitivity, gamma ray spectrometers which are portable, compact, and rugged enough for field operations. We are developing a laboratory prototype of a semiconductor detector system meeting these requirements. This spectrometer uses multiple CdTe radiation detectors for high counting efficiency, digital nonlinear pulse risetime compensation circuitry for high energy resolution and high sensitivity, and a low power thermoelectric cooler for low electronic noise. The use of digital compensation allows arbitrary, very accurate compensation with no rejection. These three techniques were integrated in the prototype, which achieved an energy resolution of 5 keV (0.75%) FWHM at 662 keV, without rejecting any counts, using a detector volume of 4 x 4 x 2 mm CdTe. With a 1.6 cm diam x 2 mm CdTe detector, a resolution of 15 keV (2%) FWHM at 662 keV was measured. The same technology has been successfully applied to other compound semiconductors which also have performance limited by poor charge collection, such as Cd sub x Zn sub 1-x Te. A low power, compact, very portable, rugged implementation has been designed.

360) **Characterization of indium iodide detectors for scintillation studies**

1996 Nuclear Instruments and Methods in Physics Research, Section A Vol.380 Pages 215-219

Shah KS, Bennett P, Moy LP, Misra MM, Moses WW

Abstract

Indium iodide (InI) is a wide bandgap semiconductor (E sub g =2.0 eV) and has been investigated as an optical detector material for use in gamma -ray scintillation spectroscopy. Single crystals of InI have been grown by the Bridgman process using zone-refined starting material and optical detectors have been fabricated from such crystals. The performance of these detectors has been investigated by measuring their quantum efficiency, direct X-ray detection characteristics, and electrical resistivity. The InI photodetectors have been coupled to CsI(Tl) scintillators and room-temperature energy resolutions of 7.5% (FWHM) and 9.8% (FWHM) were recorded for 662 keV and 511 keV gamma -rays, respectively. Successful gamma -ray detection has also been accomplished with InI photodetectors coupled to LSO (Lu sub 2 SiO sub 5 :Ce) scintillators, and a resolution of 14% (FWHM) has been recorded for 511 keV gamma -rays. Finally, analysis of the electronic noise behavior of the InI detectors has been performed.

359) **Lead iodide X-ray detection systems**

1996 Nuclear Instruments and Methods in Physics Research, Section A Vol.380 Pages 266-270

Shah KS, Olschner F, Moy LP, Bennett P, Misra M, Zhang J, Squillante MR, Lund JC

Abstract

Recent progress in the development of room-temperature lead iodide (PbI sub 2) X-ray detectors is reported. Progress has been made in the areas of detector fabrication and preamplifier electronics, and this has resulted in improved detection performance. An energy resolution of 415 eV (FWHM) has been reported for 5.9 keV X-rays (sup 55 Fe source) with 1 mm sup 2 detector at room temperature. A better estimation of the Fano factor in PbI sub 2 has been carried out and the upper limit of the Fano factor is calculated to be 0.19. Larger lead iodide detectors (up to 25 mm sup 2) have been fabricated and their spectroscopic performance has been evaluated. The timing characteristics of lead iodide detectors have been investigated. A compact, portable lead iodide probe assembly has been designed and built for X-ray spectroscopic applications. Finally, optical and charged-particle detection properties of lead iodide detectors have also been characterized.

358) **Application of associative ionization to the observation of quantum beats in low lying atomic resonances**

1996 Phys Rev Vol.A53 Page 1894

Christian JF, Snoek LC, Clement SG, van der Zande WJ

357) **Water in the Heme pocket: Its effect on the Fe? Its stretch in the resonance Raman spectra of deoxymyoglobin**

1996 40th Annual Biophys Soc Meeting, Baltimore, MD Vol.Feb. 17-21

Christian JF, Unno M, Sage JT, Sligar SG, Chien E, Champion PM

356) **Resonance Raman investigation of P450cam? Putidaredoxin electron transfer complex**

1996 40th Annual Biophys Soc Meeting, Baltimore, MD Vol.Feb. 17-21

Christian JF, Unno M, Sage JT, Sligar SG, Chien E, Champion PM

355) **Position-sensitive microfiber arrays for x-ray imaging**

1996 Proc SPIE Vol.2859 Denver

Nagarkar VV, Altice ML Jr, Cherry J, Gordon TG, Guzik JR, Macri JR, McConnell ML, Ryan J, Vasile S

354) **Photoconducting ultraviolet detectors based on GaN films grown by electron cyclotron resonance molecular beam epitaxy**

1995 SPIE Proceedings Vol.2519 Pages 78-86

Misra M, Moustakas TD, Vaudo RP, Singh R, Shah KS

Abstract

We report the fabrication of photoconducting UV detectors made from GaN films grown by MBE. Semiinsulating GaN fills were grown by the method of electron cyclotron resonance microwave plasma-assisted MBE. Photoconductive devices with interdigitated electrodes were fabricated and their photoconducting properties were investigated. In this paper we report on the performance of the detectors in terms of UV responsivity, gain-quantum efficiency product, spectral response, and response time. We have measured the responsivity of 125 A/W and gain-quantum efficiency product of 600 at 254 nm and 25 V. The response time was measured to be on the order of 20 ns for our detectors, corresponding to a bandwidth of 25 Mhz. The spectral response showed a sharp long-wavelength cutoff at 365 nm, and remained constant in the 200 nm to 365 nm range. The response of the detectors to low-energy X-rays was measured and found to be linear for X-rays with energies ranging from 60 kVp to 90 kVp.

353) **An imaging nuclear survey system**

1995 Nuclear science symposium and medical imaging conference Vol.Oct. 23-28

Redus R, Squillante MR, Gordon JS, Bennett P, Entine G, Knoll G, Wehe D, Guru S

Abstract

A combined video and gamma ray imaging system was developed to rapidly determine the location, distribution, and intensity of gamma ray sources. This instrument includes both a conventional video camera and a gamma ray imaging system based on a position sensitive PM tube, scintillator, and pinhole collimator. The gamma camera records position and energy of each interaction, determining the energy spectrum and count rate from each direction. We have used a prototype of this instrument in preliminary field test to image radioactive sources with gamma ray energies between 120 keV and 2.4 MeV. This system achieves an angular resolution for the nuclear image of 6 degree with an efficiency of 3x10 sup -6 at 1 meter, which is suitable for many nuclear applications. Sensitivity is sufficiently high that, in a low background environment, a 1 mCi sup 137 Cs source at 5 meters can be located in <30 seconds. Alternatively, higher spatial resolution can be attained at lower efficiency and longer imaging times.

352) **Photoconducting ultraviolet detectors based on GaN films grown by electron cyclotron resonance molecular beam epitaxy**

1995 Annual meeting of the Society of Photo-Optical Instrumentation Engineers, San Diego, CA Vol.July 9-14

Misra M, Shah KS, Moustakas TD, Vaudo RP, Singh R

Abstract

We report for the first time, fabrication of photoconducting UV detectors made from GaN films grown by molecular beam epitaxy. Semi-instilating GaN films were grown by the method of electron cyclotron resonance microwave plasma-assisted molecular beam epitaxy (ECR-MBE). Photoconductive devices with interdigitated electrodes were fabricated and their photoconducting properties were investigated. In this paper we report on the performance of the detectors in terms of UV responsivity, gain-quantum efficiency product, spectral response and response time. We have measured responsivity of 125A/W and gain-quantum efficiency product of 600 at 254nm and 25V. The response time was measured to be on the order of 20ns for our detectors, corresponding to a bandwidth of 25Mhz. The spectral response showed a sharp long-wavelength cutoff at 365nm, and remained constant in the 200nm to 365nm range. The response of the detectors to low-energy x-rays was measured and found to be linear for x-rays with energies ranging from 60kVp to 90kVp.

351) **Imaging nuclear survey system**

1995 IEEE Nuclear Science Symposium & Medical Imaging Conference Vol.1 Pages 649-652

Redus R, Squillante MR, Gordon JS, Bennett P, Entine G, Knoll G, Wehe D, Guru S

Abstract

A combined video and gamma ray imaging system has been developed to rapidly determine the location, distribution, and intensity of gamma ray sources. This instrument includes both a conventional video camera and a gamma ray imaging system, which is based upon a position sensitive photomultiplier tube, a scintillator, and a pinhole collimator. The gamma camera records the position and energy of each interaction, determining the energy spectrum and count rate from each direction. The design of the instrument and results of preliminary field tests will be presented. We have used a prototype of such an instrument in preliminary field tests to image radioactive sources with gamma ray energies between 120 keV and 2.4 MeV. This new system achieves an angular resolution for the nuclear image of 6 degree with an efficiency of 3 multiplied by 10SUP minus SUP6 at 1 meter, a performance suitable for many nuclear applications. The sensitivity of the system is sufficiently high that, in a low background environment, a 1 mCi SUP1SUP3SUP7Cs source at 5 meters can be located in less than 30 seconds. Alternatively, higher spatial resolution can be attained at lower efficiency and longer imaging times.

350) **High resolution X-ray sensor for non destructive evaluation**

1995 IEEE Nuclear Science Symposium & Medical Imaging Conference Vol.1 Pages 644-648

Nagarkar VV, Gordon JS, Vasile S, Gothoskar P, Hopkins F

Abstract

Nondestructive evaluation (NDE) using X-rays is becoming indispensable for detecting microdefects in new materials currently used in aerospace and other engineering disciplines. Existing X-ray sensors pose limitations on the speed of operation due to persistence of the sensor and a problematic tradeoff between the sensor thickness and spatial resolution. To address these limitations we are developing a large area structured CsI(TI) imaging sensor for NDE using CCD based radiographic and computed tomographic systems. The sensor is formed by vapor deposition of CsI(TI) onto a specially designed fiberoptic substrate. Our work has produced X-ray sensors with a factor of 4.5 greater light output, at least three orders of magnitude faster decay time response, and greater spatial resolution (16% MTF at 14 1p/mm) compared to the currently used high density TbSUB2OSUB3 doped fiberoptic glass scintillators. These performance advances will address the limitations of existing detector technology by producing high quality images and fast scan times required for real-time NDE inspection. Performance measurements for prototype CsI(TI) scintillator converters are presented. With these new sensors the development of larger area fiberoptic taper based CCD detectors with millisecond data acquisition capabilities and high spatial resolution suitable for NDE applications will be possible. (Author abstract) 13 Refs.

349) **High-gain APD array for photon detection**

1995 Proceedings of SPIE - The International Society for Optical Engineering, San Diego, CA Vol.2550 Pages 266-273

Farrell R, Redus RH, Gordon JS, Gothoskar P

Abstract

Arrays of high speed, high gain avalanche photodiodes (APDs) have been developed for use as high sensitivity optical photon detectors. The 1 mmSUP2 area APD pixels yield a maximum avalanche gain of 40,000 and a high signal-to-noise ratio with only moderate cooling (minus 22 degrees to minus 43 degrees C). These devices demonstrate 70% detection efficiency for 6 photon optical pulses and 35% detection efficiency for 3 photon optical pulses. The rise time is less than 2 nsec, and the fall time less than 7 nsec. Pixellating the PAD into a monolithic array will significantly reduce the cost per pixel compared to discrete devices. These devices will have great utility in various applications, ranging from high energy physics to biological instrumentation. The measured performance of these APD arrays as optical detectors will be discussed.

348) **Photoconducting ultraviolet detectors based on GaN films grown by electron cyclotron resonance molecular beam epitaxy**

1995 Proceedings of SPIE - The International Society for Optical Engineering, San Diego, CA Vol.2519 Pages 78-86

Misra M, Moustakas TD, Vaudo RP, Singh R, Shah KS

Abstract

We report for the first time, fabrication of photoconducting UV detectors made from GaN films grown by molecular beam epitaxy. Semi-insulating GaN films were grown by the method of electron cyclotron resonance microwave plasma-assisted molecular beam epitaxy. Photoconductive devices with interdigitated electrodes were fabricated and their photoconducting properties were investigated. In this paper we report on the performance of the detectors in terms of UV responsivity, gain-quantum efficiency product, spectral response, and response time. We have measured responsivity of 125A/W and gain-quantum efficiency product of 600 at 254nm and 25V. The response time was measured to be on the order of 20ns for our detectors, corresponding to a bandwidth of 25Mhz. The spectral response showed a sharp long-wavelength cutoff at 265nm, and remained constant in the 200nm to 365nm range..

347) **Improved x-ray converters for CCD-based crystallography detectors**

1995 Proceedings of SPIE - The International Society for Optical Engineering, San Diego, CA Vol.2519 Pages 2 - 11

Nagarkar VV, Gordon JS, Vasile SA, Xie J, Phillips WC

Abstract

We are developing a large area structured CsI(Tl) imaging sensor for macro-molecular x-ray crystallography for use with both intense synchrotron sources and rotating-anode laboratory x-ray sources. The CsI(Tl) scintillator is grown on a specially designed optical substrate. Our work has produced x-ray sensors with up to 70% more light output, orders of magnitude faster decay time response, and greater spatial resolution (15% MTF at 20 lp/mm) than GdSUB2OSUB SUB2S screens currently used in CCD-based detectors for biological structure determination. These advances in performance will address some of the limitations of existing area detector technology. Performance measurements for a prototype CsI(Tl) scintillator are presented. With these new sensors the development of larger area x-ray crystallography detectors with millisecond data acquisition capabilities and high spatial resolution, suitable for synchrotron applications will be possible.

346) **High-gain APD array for photon detection**

1995 Proceedings of SPIE - The International Society for Optical Engineering, San Diego, CA Vol.2550 Pages 266-273

Farrell R, Redus RH, Gordon JS, Gothoskar P

Abstract

Arrays of high speed, high gain avalanche photodiodes (APDs) have been developed for use as high sensitivity optical photon detectors. The 1 mm super(2) area APD pixels yield a maximum avalanche gain of 40,000 and a high signal-to-noise ratio with only moderate cooling (-22 degrees to -43 degrees C). These devices demonstrate 70% detection efficiency for 6 photon optical pulses and 35% detection efficiency for 3 photon optical pulses. The rise time is less than 2 nsec, and the fall time less than 7 nsec. Pixellating the PAD into a monolithic array will significantly reduce the cost per pixel compared to discrete devices. These devices will have great utility in various applications, ranging from high energy physics to biological instrumentation. The measured performance of these APD arrays as optical detectors will be discussed.

345) **Cross-correlations in Ramsey pump-probe interferometry**

1995 Phys Rev Vol.A52 Page 3655

Christian JF, Broers B

344) **A new balloon-borne detector for high angular resolution hard X-ray astronomy**

1995 Proc. 24th Intl Cosmic Ray Conference, Rome Vol.August

Cherry ML, Altice PP, Barakat MB, Chen C-K, Dann BK, Drake A, Ellison SB, Gagne CJ, Gordon J, Guzik TG, Lockwood R, Johnston K, Macri JR, McConnell ML, Nagarkar V, Ryan J, Vasile S

343) **Novel material for visible-blind ultraviolet detectors**

1994 SPIE Proceedings Vol.2282 Pages 49-56

Mistra M, Zhou C, Bennett PR, Squillante MR, Ahmad F

Abstract

Boron nitride phosphide (BN(x)P(1-x)) films were grown on single crystal GaAs, using CVD. The films were smooth, well adhered to the substrate, and exhibited resistivities on the order of 10 exp 11 ohm-cm. Photoconductive detectors fabricated from these films showed quantum efficiencies of 33 and 40 percent at 254 and 365 nm, respectively, with a drop of an order of magnitude at wavelengths greater than 400 nm. These measurements demonstrate the potential of BN(x)P(1-x) as a material for visible-blind UV detectors.

342) **Performance characteristics of CdTe gamma-ray spectrometers**

1994 Materials Research Society (MRS Symposium Proceedings) Vol.299 Pages 259-264

Squillante MR, Cole H, Waer P, Entine G

Abstract

The use of cadmium telluride (CdTe) semiconductor nuclear detectors is continuing to expand into new areas because of their unique properties, which include room temperature operation and high detection efficiency. CdTe is by far the most developed of the compound semiconductors used in nuclear detector applications, and it offers a number of significant benefits to researchers, clinicians, and engineers who have special requirements relating to size, sensitivity, and operating temperature. Recently, there have been improvements in the growth of the crystalline material and in the fabrication procedures which have resulted in better performance and in the ability to produce arrays. This article describes the physical and electronic properties of CdTe nuclear detectors, discusses how the crystal growth and device fabrication procedures can affect these properties, and compares the performance to CdZnTe detectors.

341) **Flight prototype of a solid state neutron dosimeter for space applications**

1994 IEEE Transactions on Nuclear Science Vol.41 Pages 1333-1337

Nagarkar V, Entine G, Stoppel P

Abstract

A major impediment to the accurate measurement of neutron dose experienced by astronauts arises from the sensitivity of most neutron dosimeters to the large fluxes of protons which occur during a typical space mission. As a result, measurement of the neutron dose has remained largely an unsolved problem. Under NASA sponsorship, we have developed a special PIN diode that has good response to neutrons while being relatively insensitive to other forms of ionizing radiation. This new sensor has been incorporated into a very compact flight instrument to provide high quality real time measurement of neutron dose. The dosimeter is capable of measuring and periodically recording fast neutron dose (En is equal to or greater than 140 keV) from 50 microgray to tens of milligrays (5 mRads to several Rads) over a flight of up to 14 days with an accuracy of +/- 17.5 micrograys (+/- 1.75 mRads) or better. The latest measurements of the PIN diode performance, with a detailed description of the overall instrument, are presented.

340) **Flight prototype of a solid state neutron dosimeter for space applications**

1994 IEEE Nuclear Science Symposium & Medical Imaging Conference Vol.San Fran CA Pages 378-382

Nagarkar V, Entine G, Stoppel P

Abstract

A major impediment to the accurate measurement of neutron dose experienced by astronauts arises from the sensitivity of most neutron dosimeters to the large fluxes of protons which occur during a typical space mission. As a result, measurement of the neutron dose has remained largely an unsolved problem. Under NASA sponsorship, we have developed a special PIN diode that has good response to neutrons while being relatively insensitive to other forms of ionizing radiation. This new sensor has been incorporated into a very compact flight instrument to provide high quality real time measurement of neutron dose. The dosimeter is capable of measuring and periodically recording fast neutron dose (ESUBn greater than equivalent to 140 keV) from 50 microgray to tens of milligrays (5 mRads to several Rads) over a flight of up to 14 days with an accuracy of plus or minus 17.5 micrograys (plus or minus 1.75 mRads) or better. The latest measurements of the PIN diode performance, with a detailed description of the overall instrument, are presented.

339) **Lead sulfate scintillator crystal growth for pet applications**

1994 IEEE Nuclear Science Symposium & Medical Imaging Conference Vol.San Fran CA Pages 76-80

Zhang JG, Lund JC, Cirignano L, Shah KS, Squillante MR, Moses WW

Abstract

It has recently been shown that lead sulfate (PbSOSUB4) is a promising scintillator material for use in PET detector systems. However, for lead sulfate scintillators to be useful in such an application a technique must be developed to grow large optical quality crystals of this material. This paper describes our research into the high-temperature solution growth of PbSOSUB4 crystals. We report on the systematic selection of solvent materials including KCl, LiCl, PbClSUB2, NaSUB2SOSUB4 and LiSUB2SOSUB4. Our studies indicate that NaSUB2SOSUB4 is the best solvent. In the high-temperature solvent growth, we employed ACRT (Accelerated Crucible Rotation Technique) to resolve the constitutional supercooling problem. Use of this technique has increased the crystal yield by 17 percent and reduced the number of grains. Finally, we report on the scintillation properties of the PbSOSUB4 crystals we grew.

338) **Solid state tritium detector for biomedical applications**

1994 IEEE Transactions on Nuclear Science Vol.41 Pages 1494-1499

Gordon JS, Farrell R, Daley K, Oakes CE

Abstract

Radioactive labeling of proteins is a very important technique used in biomedical research to identify, isolate, and investigate the expression and properties of proteins in biological systems. In such procedures, the preferred radiolabel is often tritium. Presently, binding assays involving tritium are carried out using inconvenient and expensive techniques which rely on the use of scintillation fluid counting systems. This traditional method involves both time-consuming laboratory protocols and the generation of substantial quantities of radioactive and chemical waste. We have developed a novel technology to measure the tritium content of biological specimens that does not rely on scintillation fluids. The tritiated samples can be positioned directly under a large area, monolithic array of specially prepared avalanche photodiodes (APDs) which record the tritium activity distribution at each point within the field of view of the array. The 1 mmSUP2 sensing elements exhibit an intrinsic tritium beta detection efficiency of 27% with high gain uniformity and very low cross talk.

337) **Flight prototype of a solid state neutron dosimeter for space applications**

1994 IEEE Transactions on Nuclear Science Vol.41 Pages 1333-1337

Nagarkar V, Entine G, Stoppel P

Abstract

A major impediment to the accurate measurement of neutron dose experienced by astronauts arises from the sensitivity of most neutron dosimeters to the large fluxes of protons which occur during a typical space mission. As a result, measurement of the neutron dose has remained largely an unsolved problem. Under NASA sponsorship, we have developed a special PIN diode that has good response to neutrons while being relatively insensitive to other forms of ionizing radiation. This new sensor has been incorporated into a very compact flight instrument to provide high quality real time measurement of neutron dose. The dosimeter is capable of measuring and periodically recording fast neutron dose (ESUBn greater than equivalent to 140 keV) from 50 microgray to tens of milligrays (5 mRads to several Rads) over a flight of up to 14 days with an accuracy of plus or minus 17.5 micrograys (plus or minus 1.75 mRads) or better. The latest measurements of the PIN diode performance, with a detailed description of the overall instrument, are presented.

336) **Lead sulfate scintillator crystal growth for pet applications**

1994 IEEE Transactions on Nuclear Science Vol.41 Pages 669-674

Zhang JG, Lund JC, Cirignano L, Shah KS, Squillante MR, Moses WW

Abstract

It has recently been shown that lead sulfate (PbSOSUB4) is a promising scintillator material for use in PET detector systems. However, for lead sulfate scintillators to be useful in such an application, a technique must be developed to grow large optical quality crystals of this material. This paper describes our research into the high-temperature solution growth of PbSOSUB4 crystals. We report on the systematic selection of solvent materials including KCl, LiCl, PbClSUB2, NaSUB2SOSUB4 and LiSUB2SOSUB4. Our studies indicate that NaSUB2SOSUB4 is the best solvent. With NaSUB2SOSUB4 as the flux, we obtained PbSOSUB4 single crystals of several millimeters in size by Bridgman crystal growth method. We employed ACRT (Accelerated Crucible Rotation Technique), to resolve the constitutional supercooling problem, thus increased the crystal yield and reduced the number of grains. Finally, we compared the scintillation properties of synthetic PbSOSUB4 crystals we grew with previous measurements on natural anglesite and other synthetic crystals, and found them nearly identical.

335) **Combined video and gamma ray imaging system for robots in nuclear environments**

1994 Nuclear Instruments & Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment. Proc. of the Eighth Symp. on Radiation Measurements & Applications, Ann Arbor, MI, USA, May 16-19, 1994. Vol.353 Pages 324-327

Redus R, Squillante MR, Gordon J, Knoll G, Wehe D

Abstract

An integrated imaging sensor system is being developed to enhance operations of robots and telerobotic systems used in nuclear industry. This system combines a gamma ray image of the distribution of radioactivity with a video image of the area, allowing a rapid and intuitive determination of the source location. The gamma ray imaging system is based upon a position sensitive photomultiplier tube, a segmented scintillator, and a pinhole collimator which provides high quality images in the energy range of 0.1 to 1.5 MeV. The design and measured performance of a prototype of this system will be discussed.

334) **Radiation detection performance of very high gain avalanche photodiodes**

1994 Nuclear Instruments & Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment. Proc. of the Eighth Symp. on Radiation Measurements & Applications, Ann Arbor, MI, USA, May 16-19, 1994. Vol.353 Pages 176-179

Farrell R, Vanderpuye K, Cirignano L, Squillante MR, Entine G

Abstract

Large area silicon avalanche photodiodes (APDs) have been fabricated with maximum avalanche gains exceeding 10 000 and with relatively flat signal-to-noise performance from gains of a few hundred to gains of a few thousand. Gain and noise performance as well as detector speed of response is presented for APDs with active areas of 4 mmSUP2 and 64 mmSUP2. An overview of the performance of these devices as radiation detectors includes pulse height spectra using the APD as a scintillation spectrometer coupled to CsI(Tl) and to plastic scintillator, and also for direct detection of low energy X-rays.

333) **Electronic noise in lead iodide X-ray detectors**

1994 Nuclear Instruments & Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment. Proc. of the Eighth Symp. on Radiation Measurements & Applications, Ann Arbor, MI, USA, May 16-19, 1994. Vol.353 Pages 85-88

Shah KS, Lund JC, Olschner F, Bennett P, Zhang J, Moy LP, Squillante MR

Abstract

Noise models were used to analyze electronic noise in lead iodide bandgap semiconductor X-ray detectors. The noise sources were assumed in the lead iodide were assumed to be in the form of a combination of series thermal noise, detector shot noise and 1/f noise. Results show that 1/f noise is the most dominant noise source in most detectors at larger integration times. This noise was also found to be proportional to the input capacitance.

332) **High resolution CdTe detector systems**

1994 Nuclear Instruments & Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment. Vol.353 Page 59

Redus R, Squillante MR, Lund J, Cirignano L, Waer P, Pantazis J, Huber A

Abstract

Previous studies have shown that cadmium telluride (CdTe) detectors are very useful for room temperature gamma ray spectroscopy because of their high stopping power, compact size, reliability and long term stability. However, CdTe detectors can be used for other applications if the devices are larger and their performance are improved. The performance of such detectors is presently limited by charge collection distortion and noise, both of which are caused by the properties of the crystalline materials. Many approaches have been tried to achieve optimal energy resolution in CdTe detectors by controlling these factors. The results are encouraging and are expected to lead to a wider range of application for CdTe detectors.

331) **TlBrxI1 minus x photodetectors for scintillation spectroscopy**

1994 IEEE Transactions on Nuclear Science Vol.41 Page 2

Shah KS, Lund JC, Olschner F, Zhang J, Moy LP, Squillante MR, Moses WW, Derenzo SE

Abstract

This paper reports on the evaluation of photodetectors fabricated from a ternary semiconductor, TlBrSUBxISUB1SUB minus SUBx for application in scintillation spectroscopy. These photodetectors are characterized in terms of their resistivity, charge transport parameters, quantum efficiency as a function of wavelength, and finally their performance as scintillation spectrometers. The details about TlBrSUBxISUB1SUB minus SUBx purification, crystal growth and device fabrication are also addressed.

330) **Performance characteristics of CdTe gamma-ray spectrometers**

1994 Materials Research Society Symposium Proceedings Vol.299 Pages 259-264

Squillante MR, Cole H, Waer P, Entine G

Abstract

The use of cadmium telluride (CdTe) semiconductor nuclear detectors is continuing to expand into new areas because of their unique properties which include room temperature operation and high detection efficiency. In addition, they remain the material of choice in many critical applications such as nuclear medicine and power plant monitoring because of their reputation for reliability and long term stability. CdTe is by far the most developed of the compound semiconductors used in nuclear detector applications and it offers a number of significant benefits to researchers, clinicians and engineers who have special requirements relating to size, sensitivity and operating temperature. Recently, there have been improvements in the growth of the crystalline material and in the fabrication procedures which have resulted in better performance and in the ability to produce arrays. This article describes the physical and electronic properties of CdTe nuclear detectors, discusses how the crystal growth and device fabrication procedures can affect these properties, and compares the performance to CdZnTe detectors.

329) **Fabricating multifilamentary high-TSUBc superconducting bismuth cuprate tapes by metalorganic chemical spray pyrolysis**

1994 Applied Superconductivity Vol.2 Pages 281-294

de Rochemont LP, Maroni VA, Klugerman M, Andrews RJ, Kelliher WC

Abstract

This paper reports preliminary findings on research to develop chemical spray pyrolysis as a method for synthesizing multifilamentary bismuth cuprate (BSCCO) tape and wire components. Chemical spray pyrolysis is a solution process that allows oxide precursor material to be rapidly deposited on a variety of substrate materials. It is an inherently low cost manufacturing process that can be scaled to deposit chemically uniform ceramic coatings over arbitrarily large surface areas. BSCCO tapes have been successfully fabricated from ceramic precursor sprays pyrolyzed onto silver substrates and packaged in a silver sheath. Findings related to solution chemistry, the deposition process, tape construction, and thermomechanical processing that impact the ability to fabricate high-TSUBc superconducting wire and tape using this technique are presented and discussed.

328) **Flight prototype of a solid state neutron dosimeter for space applications**

1994 IEEE Nuclear Science Symposium & Medical Imaging Conference Vol.San Fran CA Pages 378-382

Nagarkar V, Entine G, Stoppel P

Abstract

A major impediment to the accurate measurement of neutron dose experienced by astronauts arises from the sensitivity of most neutron dosimeters to the large fluxes of protons which occur during a typical space mission. As a result, measurement of the neutron dose has remained largely an unsolved problem. Under NASA sponsorship, we have developed a special PIN diode that has good response to neutrons while being relatively insensitive to other forms of ionizing radiation. This new sensor has been incorporated into a very compact flight instrument to provide high quality real time measurement of neutron dose. The dosimeter is capable of measuring and periodically recording fast neutron dose (ESUBn greater than equivalent to 140 keV) from 50 microgray to tens of milligrays (5 mRads to several Rads) over a flight of up to 14 days with an accuracy of plus or minus 17.5 micrograys (plus or minus 1.75 mRads) or better. The latest measurements of the PIN diode performance, with a detailed description of the overall instrument, are presented.

27) **Lead sulfate scintillator crystal growth for pet applications**

1994 IEEE Nuclear Science Symposium & Medical Imaging Conference Vol.San Fran CA Pages 76-80

Zhang JG, Lund JC, Cirignano L, Shah KS, Squillante MR, Moses WW

Abstract

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326) **Solid state tritium detector for biomedical applications**

1994 IEEE Nuclear Science Symposium & Medical Imaging Conference Vol.San Fran CA Pages 1523-1527

Gordon JS, Farrell R, Daley K, Oakes CE

Abstract

Radioactive labeling of proteins is a very important technique used in biomedical research to identify, isolate, and investigate the expression and properties of proteins in biological systems. In such procedures, the preferred radiolabel is often tritium. Presently, binding assays involving tritium are carried out using inconvenient and expensive techniques which rely on the use of scintillation fluid counting systems. This traditional method involves both time-consuming laboratory protocols and the generation of substantial quantities of radioactive and chemical waste. We have developed a novel technology to measure the tritium content of biological specimens that does not rely on scintillation fluids. The tritiated samples can be positioned directly under a large area, monolithic array of specially prepared avalanche photodiodes (APDs) which record the tritium activity distribution at each point within the field of view of the array. The 1 mmSUP2 sensing elements exhibit an intrinsic tritium beta detection efficiency of 27% with high gain uniformity and very low cross talk.

325) **TlBr sub x I sub (1 minus x) photodetectors for scintillation spectroscopy**

1994 IEEE Transactions on Nuclear Science (Institute of Electrical and Electronics Engineers) (US) Vol.41 Pages 2715-2718

Shah KS, Lund JC, Olschner F, Zhang J, Moy LP, Squillante MR, Moses WW, Derenzo SE

Abstract

This paper reports on the evaluation of photodetectors fabricated from a ternary semiconductor, TlBr sub x I sub 1 minus x for application in scintillation spectroscopy. These photodetectors are characterized in terms of their resistivity, charge transport parameters, quantum efficiency as a function of wavelength, and finally their performance as scintillation spectrometers. The details about TlBr sub x I sub 1 minus x purification, crystal growth and device fabrication are also addressed.

324) **New, high performance nuclear spectroscopy system using Si-PIN diodes and CdTe detectors**

1994 IEEE Transactions on Nuclear Science (Institute of Electrical and Electronics Engineers) (US) Vol.41 Pages 1004-1008

Pantazis J, Huber A, Okun P, Squillante MR, Waer P, Entine G

Abstract

A compact, high resolution X-ray and gamma ray spectroscopy system has recently been developed which provides excellent energy resolution over a wide range of photon energies. Two detector types have been tested, a cooled silicon PIN photodiode for X-ray energies from 2 keV to 30 keV and a CdTe detector for energies from 20 keV to 1 MeV. The CdTe detector can be operated cooled or at room temperature. The heart of the system is a miniature preamplifier developed at AMPTEK which is used in combination with a small thermoelectric cooler to reduce the leakage current of the detectors. Using the cooled Si-PIN detector, 660 eV FWHM was achieved at 5.9 keV and using a CdTe detector 1.3 keV was achieved at 60 keV both with nearly 100% counting efficiency. Good resolution was also achieved at higher energies.

323) **Lead sulfate scintillator crystal growth for PET applications**

1994 IEEE Transactions on Nuclear Science (Institute of Electrical and Electronics Engineers) (US) Vol.41 Pages 669-674

Zhang JG, Lund JC, Cirignano L, Shah KS, Squillante MR, Moses WW

Abstract

It has recently been shown that lead sulfate (PbSO sub 4) is a promising scintillator material for use in PET detector systems. However, for lead sulfate scintillators to be useful in such an application, a technique must be developed to grow large optical quality crystals of this material. This paper describes the research into the high-temperature solution growth of PbSO sub 4 crystals. The authors report on the systematic selection of solvent materials including KCl, LiCl, PbCl sub 2 , Na sub 2 SO sub 4 and Li sub 2 SO sub 4 . The studies indicate that Na sub 2 SO sub 4 is the best solvent. With Na sub 2 SO sub 4 as the flux, the authors obtained PbSO sub 4 single crystals of several millimeters in size by Bridgmann crystal growth method. The authors employed ACRT (Accelerated Crucible Rotation Technique), to resolve the constitutional supercooling problem, thus increase the crystal yield and reduced the number of grains. Finally, the authors compared the scintillation properties of synthetic PbSO sub 4 crystals the authors grew with previous measurements on natural anglesite and other synthetic crystals, and found them nearly identical.

322) **Solid state tritium detector for biomedical applications**

1994 IEEE Transactions on Nuclear Science (Institute of Electrical and Electronics Engineers) (US) Vol.41 Pages 1494-1499

Gordon JS, Farrell R, Daley K, Oakes CE

Abstract

Radioactive labeling of proteins is a very important technique used in biomedical research to identify, isolate, and investigate the expression and properties of proteins in biological systems. In such procedures, the preferred radiolabel is often tritium. Presently, binding assays involving tritium are carried out using inconvenient and expensive techniques which rely on the use of scintillation fluid counting systems. This traditional method involves both time-consuming laboratory protocols and the generation of substantial quantities of radioactive and chemical waste. The authors have developed a novel technology to measure the tritium content of biological specimens that does not rely on scintillation fluids. The tritiated samples can be positioned directly under a large area, monolithic array of specially prepared avalanche photodiodes (APDs) which record the tritium activity distribution at each point within the field of view of the array. The 1 mm sup 2 sensing elements exhibit an intrinsic tritium beta detection efficiency of 27% with high gain uniformity and very low cross talk.

321) **Flight prototype of a solid state neutron dosimeter for space applications**

1994 IEEE NUCL SCI SYMP MED IMAGING CONF Vol.Part 1 Pages 378-382

Nagarkar V, Entine G, Stoppel P

Abstract

A major impediment to the accurate measurement of neutron dose experienced by astronauts arises from the sensitivity of most neutron dosimeters to the large fluxes of protons which occur during a typical space mission. As a result, measurement of the neutron dose has remained largely an unsolved problem. Under NASA sponsorship, we have developed a special PIN diode that has good response to neutrons while being relatively insensitive to other forms of ionizing radiation. This new sensor has been incorporated into a very compact flight instrument to provide high quality real time measurement of neutron dose. The dosimeter is capable of measuring and periodically recording fast neutron dose (E sub(n) greater than or equal to 140 keV) from 50 microgray to tens of milligrays (5 mRads to several Rads) over a flight of up to 14 days with an accuracy of plus or minus 17.5 micrograys (plus or minus 1.75 mRads) or better. The latest measurements of the PIN diode performance, with a detailed description of the overall instrument, are presented.

320) **Lead sulfate scintillator crystal growth for pet applications**

1994 IEEE NUCL SCI SYMP MED IMAGING CONF Vol.Part 1 Pages 76-80

Zhang JG, Lund JC, Cirignano L, Shah KS, Squillante MR, Moses WW

Abstract

It has recently been shown that lead sulfate (PbSO sub(4)) is a promising scintillator material for use in PET detector systems. However, for lead sulfate scintillators to be useful in such an application a technique must be developed to grow large optical quality crystals of this material. This paper describes our research into the high-temperature solution growth of PbSO sub(4) crystals. We report on the systematic selection of solvent materials including KCl, LiCl, PbCl sub(2), Na sub(2)SO sub(4) and Li sub(2)SO sub(4). Our studies indicate that Na sub(2)SO sub(4) is the best solvent. In the high-temperature solvent growth, we employed ACRT (Accelerated Crucible Rotation Technique) to resolve the constitutional supercooling problem. Use of this technique has increased the crystal yield by 17 percent and reduced the number of grains. Finally, we report on the scintillation properties of the PbSO sub(4) crystals we grew.

319) **Lead sulfate scintillator crystal growth for pet applications**

1994 IEEE TRANS NUCL SCI Vol.41 Pages 669-674

Zhang JG, Lund JC, Cirignano L, Shah KS, Squillante MR, Moses WW

Abstract

It has recently been shown that lead sulfate (PbSO sub(4)) is a promising scintillator material for use in PET detector systems. However, for lead sulfate scintillators to be useful in such an application, a technique must be developed to grow large optical quality crystals of this material. This paper describes our research into the high-temperature solution growth of PbSO sub(4) crystals. We report on the systematic selection of solvent materials including KCl, LiCl, PbCl sub(2), Na sub(2)SO sub(4) and Li sub(2)SO sub(4). Our studies indicate that Na sub(2)SO sub(4) is the best solvent. With Na sub(2)SO sub(4) as the flux, we obtained PbSO sub(4) single crystals of several millimeters in size by Bridgman crystal growth method. We employed ACRT (Accelerated Crucible Rotation Technique), to resolve the constitutional supercooling problem, thus increased the crystal yield and reduced the number of grains. Finally, we compared the scintillation properties of synthetic PbSO sub(4) crystals we grew with previous measurements on natural anglesite and other synthetic crystals, and found them nearly identical.

318) **Solid state tritium detector for biomedical applications**

1994 IEEE TRANS NUCL SCI Vol.41 Pages 1494-1499

Gordon JS, Farrell R, Daley K, Oakes CE

Abstract

Radioactive labeling of proteins is a very important technique used in biomedical research to identify, isolate, and investigate the expression and properties of proteins in biological systems. In such procedures, the preferred radiolabel is often tritium. Presently, binding assays involving tritium are carried out using inconvenient and expensive techniques which rely on the use of scintillation fluid counting systems. This traditional method involves both time-consuming laboratory protocols and the generation of substantial quantities of radioactive and chemical waste. We have developed a novel technology to measure the tritium content of biological specimens that does not rely on scintillation fluids. The tritiated samples can be positioned directly under a large area, monolithic array of specially prepared avalanche photodiodes (APDs) which record the tritium activity distribution at each point within the field of view of the array. The 1 mm super(2) sensing elements exhibit an intrinsic tritium beta detection efficiency of 27% with high gain uniformity and very low cross talk.

317) **Performance characteristics of CdTe gamma-ray spectrometers**

1994 MATER RES SOC SYMP PROC Vol.299 Pages 259-264

Squillante MR, Cole H, Waer P, Entine G

Abstract

The use of cadmium telluride (CdTe) semiconductor nuclear detectors is continuing to expand into new areas because of their unique properties which include room temperature operation and high detection efficiency. In addition, they remain the material of choice in many critical applications such as nuclear medicine and power plant monitoring because of their reputation for reliability and long term stability. CdTe is by far the most developed of the compound semiconductors used in nuclear detector applications and it offers a number of significant benefits to researchers, clinicians and engineers who have special requirements relating to size, sensitivity and operating temperature. Recently, there have been improvements in the growth of the crystalline material and in the fabrication procedures which have resulted in better performance and in the ability to produce arrays. This article describes the physical and electronic properties of CdTe nuclear detectors, discusses how the crystal growth and device fabrication procedures can affect these properties, and compares the performance to CdZnTe detectors.

316) **Solid state tritium detector for biomedical applications**

1994 IEEE NUCL SCI SYMP MED IMAGING CONF Vol.Part 3 Pages 1523-1527

Gordon JS, Farrell R, Daley K, Oakes CE

Abstract

Radioactive labeling of proteins is a very important technique used in biomedical research to identify, isolate, and investigate the expression and properties of proteins in biological systems. In such procedures, the preferred radiolabel is often tritium. Presently, binding assays involving tritium are carried out using inconvenient and expensive techniques which rely on the use of scintillation fluid counting systems. This traditional method involves both time-consuming laboratory protocols and the generation of substantial quantities of radioactive and chemical waste. We have developed a novel technology to measure the tritium content of biological specimens that does not rely on scintillation fluids. The tritiated samples can be positioned directly under a large area, monolithic array of specially prepared avalanche photodiodes (APDs) which record the tritium activity distribution at each point within the field of view of the array. The 1 mm super(2) sensing elements exhibit an intrinsic tritium beta detection efficiency of 27% with high gain uniformity and very low cross talk.

315) **Lead sulfate scintillator crystal growth for pet applications**

1994 IEEE NUCL SCI SYMP MED IMAGING CONF Vol.Part 1 Pages 76-80

Zhang JG, Lund JC, Cirignano L, Shah KS, Squillante MR, Moses WW

Abstract

It has recently been shown that lead sulfate (PbSO sub(4)) is a promising scintillator material for use in PET detector systems. However, for lead sulfate scintillators to be useful in such an application a technique must be developed to grow large optical quality crystals of this material. This paper describes our research into the high-temperature solution growth of PbSO sub(4) crystals. We report on the systematic selection of solvent materials including KCl, LiCl, PbCl sub(2), Na sub(2)SO sub(4) and Li sub(2)SO sub(4). Our studies indicate that Na sub(2)SO sub(4) is the best solvent. In the high-temperature solvent growth, we employed ACRT (Accelerated Crucible Rotation Technique) to resolve the constitutional supercooling problem. Use of this technique has increased the crystal yield by 17 percent and reduced the number of grains. Finally, we report on the scintillation properties of the PbSO sub(4) crystals we grew.

314) **A combined video and gamma ray imaging system for robots in nuclear environments**

1994 Nuclear Instruments and Methods in Physics Research, Section A (Netherlands) Vol.353 Pages 324-327

Redus R, Squillante MR, Gordon J, Knoll G, Wehe D

Abstract

An integrated imaging sensor system is being developed to enhance operations of robots and telerobotic systems used in nuclear industry. This system combines a gamma ray image of the distribution of radioactivity with a video image of the area, allowing a rapid and intuitive determination of the source location. The gamma ray imaging system is based upon a position sensitive photomultiplier tube, a segmented scintillator, and a pinhole collimator which provides high quality images in the energy range of 0.1 to 1.5 MeV. The design and measured performance of a prototype of this system will be discussed.

313) **High resolution CdTe detector systems**

1994 Nuclear Instruments and Methods in Physics Research, Section A (Netherlands) Vol.353 Page 59

Redus R, Squillante MR, Lund J, Cirignano L, Waer P, Pantazis J, Huber A

312) **Electronic noise in lead iodide X-ray detectors**

1994 Nuclear Instruments and Methods in Physics Research, Section A (Netherlands) Vol.353 Pages 85-88

Shah KS, Lund JC, Olschner F, Bennett P, Zhang J, Moy LP, Squillante MR

Abstract

Lead iodide (PbI sub 2) is a wide bandgap semiconductor (E sub g =2.32 eV) and has been studied over the past several years as a semiconductor material for use in solid state X-ray and gamma-ray detectors. Small lead iodide detectors have been found to operate with low noise and good energy resolution (500 eV FWHM for 5.9 keV sup 55 Fe X-rays). In the interest of reducing the electronic noise in lead iodide detection systems we have characterized the measured noise in the lead iodide detectors, and have compared the measurements with known noise models. It has been assumed that the noise sources in the lead iodide detectors would take form of a combination of series thermal noise, detector shot noise, and 1/f noise. Detectors with differing areas and thicknesses were analyzed by measuring their noise as a function of the amplifier integration time. A computer fitting program was used to obtain the magnitude of each noise source. Based on this analysis, 1/f noise was found to be the dominant noise source in most detectors at larger integration times of 4 mu s to 12 mu s, in which range the detectors are normally operated. The 1/f noise was also found to be proportional to the input capacitance, indicating that it is dominated by the series 1/f noise. The 1/f noise magnitude appears to be dependent on the detector fabrication procedures, and may be reduced in future detectors by using more suitable fabrication procedures. ((orig.))

311) **Radiation detection performance of very high gain avalanche photodiodes**

1994 Nuclear Instruments and Methods in Physics Research, Section A (Netherlands) Vol.353 Pages 176-179

Farrell R, Cirignano L, Squillante MR, Entine G

Abstract

Large area silicon avalanche photodiodes (APDs) have been fabricated with maximum avalanche gains exceeding 10 000 and with relatively flat signal-to-noise performance from gains of a few hundred to gains of a few thousand. Gain and noise performance as well as detector speed of response is presented for APDs with active areas of 4 mm sup 2 and 64 mm sup 2 . An overview of the performance of these devices as radiation detectors includes pulse height spectra using the APD as a scintillation spectrometer coupled to CsI(Tl) and to plastic scintillator, and also for direct detection of low energy X-rays.

310) **Observation of Rydberg wavepacket dynamics in coulomb and magnetic potentials**

1994 Phys Rev Lett Vol.72 Page 3783

Wals J, Fielding HH, Christian JF, Snoek LC, van der Zande WJ, van Linden van den Heuvell HB

309) **Experimental investigation of rubidium atoms above the field-ionization limit using a time-resolved wavepacket approach**

1994 Phys Rev Vol.A49 Page 2498

Broers B, Christian JF, van Linden van den Heuvell HB

308) **Ion beam studies of atomic ion collisions with C60: Chemistry at surface, substitutional, and endohedral sites**

1994 Int J Mass Spectrom Ion Processes Vol.138 Page 173

Basir Y, Wan Z, Christian JF, Anderson SL

307) **Time-resolved studies of electron motion in atomic rubidium using a phase sensitive technique**

1994 14th Intl Conf on Atomic Physics, Boulder, CO Vol.July 31-Aug. 5

Christian JF, Broers B, Snoek LC, Hoogenraad JH, van der Zande WJ, Noordam LD, Wals J, Fielding HH, van Linden van den Heuvell HB