Unusual photoanisotropic alignment in amorphous azobenzene polymers: Photoanisotropy

It is well known that irradiation of azobenzene polymer films between 490 and 530nm results in alignment of molecules perpendicular to the polarization of the incident beam. I have recently found that irradiation of amorphous azobenzene polymers with linearly polarized light at wavelengths between 560 and 630nm, where the absorption is minimal, results in a possible uniaxial hedgehog arrangement of the molecules. Experiments performed with a dye laser, which can be tuned continuously between 560 and 630nm, are described. Not only azobenzene but also another photosensitive molecule, bacteriorhodopsin, seems to exhibit this behavior.

The still unknown azobenzene - Wavelength dependent photoanisotropy in amorphous azobenzene polymers.

We demonstrate a new type of anisotropy in thin films of amorphous azobenzene polymers induced between 570 and 633 nm, where the absorbance in the film is on the order of 0.05. The anisotropy has a pronounced radial contribution. This observation points to an additional mechanism for the alignment of azobenzene molecules.
Can colour be measured?
Colour is a sensation. While wavelength can be measured with a spectrometer consisting of dispersive elements and colour insensitive detectors, detection of colour is accomplished by the eye, equipped with a lens, colour sensitive detectors, and a powerful processor in the form of brain. Sometimes this process results in unexpected phenomena. Different theories of colour vision have been proposed, such as the retinex theory of Land. In this lecture, we shall explore the land of colour vision.

Materials through light, light through materials: interaction of light and matter
Polarization holography
Current research into holography is concerned with applications in optically storing, retrieving, and processing information. Polarization holography has many unique properties compared to conventional holography. It gives results in high efficiency, achromaticity, and special polarization properties. This book reviews the research carried out in this field over the last 15 years. The authors provide basic concepts in polarization and the propagation of light through anisotropic materials, before presenting a sound theoretical basis for polarization holography. The fabrication and characterization of azobenzene based materials, which remain the most efficient for the purpose, is described in detail. This is followed by a description of other materials that are used in polarization holography. An in-depth description of various applications, including display holography and optical storage, is given, and the book concludes with perspectives for the future. This book is an important reference for researchers.

Acridizinium-Substituted Dendrimers As a New Potential Rewritable Optical Data Storage Material for Blu-ray
A second-generation (acridizinium)12-dendrimer based on a poly(2,2-bis(hydroxymethyl)propionic acid) [bis-MPA] scaffold which can undergo photoinduced (4n + 4n) cycloaddition reactions on exposure to blue-violet light at 405 nm, and be reversed upon irradiation at 257 nm, has been synthesized. This provides an alternative chromophore for rewritable optical data storage media to the existing dye materials such as azo, cyanine, and phthalocyanine dyes for Blu-ray recording. The compound was initially tested in ethanol, showing good reversible properties and photoinduced degree of dimerization. The (acridizinium) 12-bis-MPA dendrimer was cast on a quartz plate, using poly(vinylpyrrolidone) as a matrix, in order to simulate conditions found in DVD discs for existing dyes. The film showed good transmission, stability, and mechanical properties. Through gray scale recording it may be possible to store more than 75 GB on a single-layer disk of a conventional-sized 5.25 in. disk, using existing Blu-ray disc technology.
Azobenzene Polyesters for Polarization Holographic Storage. Part I: Materials and Characterization

General information
Publication status: Published
Organisations: The Danish Polymer Centre, Department of Chemical and Biochemical Engineering, Optical Microsensors and Micromaterials, Department of Photonics Engineering, Kaleido Technology ApS, Budapest University of Technology and Economics, University of York, Bulgarian Academy of Sciences
Contributors: Holme, N., Hvilsted, S., Lörincz, E., Matharu, A., Nedelchev, L., Nikolova, L., Ramanujam, P.
Pages: 183-211
Publication date: 2008

Holographic recording in thiophene-based polyester
The synthesis and optical data storage properties of a side-chain thiophene-phenyl azopolyester ThPhAzoP.ol is reported. The polyester is derived from diphenyl tetradecanedioate and a thiophene-based liquid crystalline diol which exhibits a short-lived enantiotropic SmA phase (Cryst 177.7 SmA 180.4 I). The polyester ThPhAzoPol exhibits amorphous (Tg, 78.6 DC), crystalline and liquid crystalline character as evidenced by differential scanning calorimetry and thermal polarising microscopy. A grainy texture, which is thermally reversible, with increasing birefringence on cooling from the isotropic melt is observed. The polyester is amenable to optical data storage, showing efficient induced anisotropy, which is stable at room temperature. Polarisation gratings can be inscribed using orthogonally linear and circularly polarised light to good effect (>10/0) and surface relief gratings are formed in addition as evidenced by atomic force microscopy.

General information
Publication status: Published
Organisations: The Danish Polymer Centre, Department of Chemical and Biochemical Engineering, Optical Microsensors and Micromaterials, Department of Photonics Engineering
Contributors: Matharu, A. S., Chambers-Asman, D., Jeeva, S., Hvilsted, S., Ramanujam, P.
Pages: 3011-3016
Publication date: 2008
Peer-reviewed: Yes

Publication information
Journal: Journal of Materials Chemistry
Volume: 18
Issue number: 25
ISSN (Print): 0959-9428
Ratings:
BFI (2008): BFI-level 1
Azobenzene polyesters for polarization holographic storage. Part 1. Materials and characterization

General information
Publication status: Published
Organisations: Laser Systems and Optical Materials, Optics and Plasma Research Department, Risø National Laboratory for Sustainable Energy
Contributors: Holme, N., Hvilsted, S., Lorincz, E., Matharu, A., Nedelchev, L., Nikolova, L., Ramanujam, P.
Pages: 184-211
Publication date: 2007

Host publication information
Title of host publication: Handbook of organic electronics and photonics
Volume: Vol. 2
Place of publication: Valencia, CA
Publisher: American Scientific Publishers
Editor: Nalwa, H.
Source: orbit
Source ID: 215490

Azobenzene polyesters for polarization holographic storage. Part 2. Technology and system

General information
Publication status: Published
Organisations: Laser Systems and Optical Materials, Optics and Plasma Research Department, Risø National Laboratory for Sustainable Energy
Pages: 213-234
Publication date: 2007

Host publication information
Title of host publication: Handbook of organic electronics and photonics
Volume: Vol. 2
Place of publication: Valencia, CA
Publisher: American Scientific Publishers
Editor: Nalwa, H.
Source: orbit
Source ID: 215489

Liquid crystals for holographic optical data storage
A tutorial review is presented to inform and inspire the reader to develop and integrate strong scientific links between liquid crystals and holographic data storage, from a materials scientist's viewpoint. The principle of holographic data storage as a means of providing a solution to the information storage demands of the 21st century is detailed. Holography is a small subset of the much larger field of optical data storage and similarly, the diversity of materials used for optical data storage is enormous. The theory of polarisation holography which produces holograms of constant intensity, is discussed. Polymeric liquid crystals play an important role in the development of materials for holographic storage and photoresponsive materials based on azobenzene are targeted for discussion due to their ease of photo- reversion between trans- and cis- states. Although the final polymer may not be liquid crystalline, irradiation can induce ordered domains. The mesogens act in a co-operative manner, enhancing refractive indices and birefringences. Surface relief gratings are discussed as a consequence of holographic storage. Cholesteric polymers comprising azobenzene are briefly highlighted. Irradiation causing cis - trans-isomerisation can be used to control helix pitch. A brief mention of liquid crystals
is also made since these materials may be of future interest since they are optically transparent and amenable to photo-induced anisotropy.

**General information**
- Publication status: Published
- Contributors: Matharu, A., Jeeva, S., Ramanujam, P.
- Pages: 1868-1880
- Publication date: 2007
- Peer-reviewed: Yes

**Publication information**
- Journal: Chemical Society Reviews
- Volume: 36
- Issue number: 12
- ISSN (Print): 0306-0012
- Web of Science (2007): Indexed yes
- Original language: English
- DOIs: 10.1039/b706242g
- Source: orbit
- Source ID: 215650

Self-Assembly of Uracil-PAMAM Dendrimer Systems into Domains of Micrometer Length Scale

**General information**
- Publication status: Published
- Organisations: Risø National Laboratory for Sustainable Energy, Solar Energy Programme, The Danish Polymer Centre, Department of Chemical and Biochemical Engineering, University of California at Santa Barbara
- Pages: 1779-1781
- Publication date: 2007
- Peer-reviewed: Yes

**Publication information**
- Journal: Macromolecules
- Volume: 40
- Issue number: 6
- ISSN (Print): 0024-9297
- Scopus rating (2007): SJR 3.1 SNIP 1.59
- Web of Science (2007): Indexed yes
- Original language: English
- DOIs: 10.1021/ma062703s
- Source: orbit
- Source ID: 197479

Synthesis and optical storage properties of a thiophene-based holographic recording

The results of the fabrication and optical data storage characteristics of a novel azothiophene polyester 9 for potential holographic storage are reported. The polyester is derived from an azothiophene diol 1 and diphenyl phthalate 8 via in vacuo melt transesterification. Inclusion of a 5-methoxy-2-thienyl moiety generates a trans pi-pi* transition centered close to 405 nm. An investigation of the optical data storage characteristics of a solution cast film of azopolyester with a thickness of 65 nm is summarised. The optical anisotropy induced by a 532 nm frequency doubled YAG laser and probed at a wavelength of 633 nm outside the absorption band with a polarimeter reveals a very high induced anisotropy of 7 rad (laser intensity, 250 mW cm(-2)). The calculated birefringence of the film is 0.02 per micron. Maximum anisotropy is reached after approximately 70 s of irradiation. The induced anisotropy disappears at approximately 90 degrees C. Room temperature stable gratings can be inscribed with high diffraction efficiency.
UV-Photodimerization in Uracil-substituted dendrimers for high density data storage

Two series of uracil-functionalized dendritic macromolecules based on poly (amidoamine) PAMAM and 2,2-bis(hydroxymethyl)propionic acid bis-MPA backbones were prepared and their photoinduced (2π+2π) cycloaddition reactions upon exposure to UV light at 257 nm examined. Dendrimers up to 4th generation were synthesized and investigated as potential materials for high capacity optical data storage with their dimerization efficiency compared to uracil as a reference compound. This allows the impact of increasing the generation number of the dendrimers, both the number of chromophores, as well as the different steric environments, on the performance of each series of dendrimers to be investigated. The (uracil)(12)-[G-2]-bis-MPA and (uracil)(8)-[G-1]-PAMAM were observed to have high dimerization efficiency in solution with different behavior being observed for the PAMAM and bis-MPA dendrimers. The dendrimers with the best dimerization efficiency in solution were then examined in the solid state as thin films cast on quartz plates, and their film qualities along with their photodimerization performance studied. High quality films with a transmission response of up to 70% in 55 s. when irradiated at 257 nm with an intensity of 70 mW/cm² could be obtained suggesting future use as recording media for optical data storage. (c) 2007 Wiley Periodicals, Inc.

Cycloaddition in peptides for high-capacity optical storage

Photodimerization of chromophores attached to a short peptide chain is investigated for high-capacity optical digital storage with UV lasers. The length and rigidity of the peptide chain assure an optimal distance and orientation of the
chromophores for effective photodimerization. Using a theory developed by Tomlinson, the absorption cross section for the dimerization process in a uracil-ornithine-based hexamer is determined to be $9 \times 10^{-20}$ cm$^2$. A large change in the transmission due to irradiation in the UV area may make it possible to realize multilevel storage in a thin film of the peptides.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, The Danish Polymer Centre, Department of Chemical and Biochemical Engineering
Contributors: Lohse, B., Berg, R. H., Hvilsted, S., Ramanujam, P.
Pages: 488-492
Publication date: 2006
Peer-reviewed: Yes

Publication information
Volume: 45
Issue number: 1B
ISSN (Print): 0021-4922
Ratings:
Scopus rating (2006): SJR 0.829 SNIP 0.969
Original language: English
DOIs:
10.1143/JJAP.45.488
Source: orbit
Source ID: 188796
Research output: Contribution to journal › Journal article – Annual report year: 2006 › Research › peer-review

Dendrimes for high capacity optical data storage

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Lohse, B., Vestberg, R., Berg, R. H., Hvilsted, S., Ramanujam, P., Hawker, C.
Publication date: 2006
Peer-reviewed: No
Event: Abstract from Nordic Polymer Days 2006, Copenhagen, Denmark.
Source: orbit
Source ID: 309065
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2006 › Research

Holographic recording in a series of conjugated polymers

General information
Publication status: Published
Organisations: Solar Energy Programme, Risø National Laboratory for Sustainable Energy
Contributors: Krebs, F. C., Ramanujam, P.
Pages: 350-354
Publication date: 2006
Peer-reviewed: Yes

Publication information
Volume: 28
Scopus rating (2006): SJR 0.917 SNIP 1.326
Web of Science (2006): Indexed yes
Original language: English
DOIs:
10.1016/j.optmat.2005.01.021
Source: orbit
Source ID: 308988
Research output: Contribution to journal › Journal article – Annual report year: 2006 › Research › peer-review
N-1-Alkylated Pyrimidine Films as a New Potential Optical Data Storage Medium

We investigate several compounds of the type 1,1′-(a,w-alkanediyl)bis[pyrimidine] and 1-(w-bromoalkyl)uracil, which can undergo photoinduced (2μ + 2n) cycloaddition reactions on exposure to UV light at 254 and 257 nm, which have been synthesized for application in high capacity optical data storage. Their dimerization efficiency was compared, in solution, with uracil as a reference, and as films, to investigate the correlation between solution and film. Films of good quality displaying excellent thermal and optical stability can be fabricated. A significant optical contrast between the irradiated and nonirradiated medium was observed. 1,1′-(1,3-Propanediyl)bis[uracil], 1,1′-(1,8-octanediyl)bis[uracil], and 1-(6-bromoheptyl)uracil showed remarkably good dimerization efficiency and are a significant improvement compared to previously reported similar systems. Gray scale and holographic grating storage are also demonstrated in the films. Writing and reading of the gray scale can be performed at the same wavelength.

General information
Publication status: Published
Organisations: The Danish Polymer Centre, Department of Chemical and Biochemical Engineering, Risø National Laboratory
Contributors: Lohse, B., Hviilsted, S., Berg, R. H., Ramanujam, P.
Pages: 4808-4816
Publication date: 2006
Peer-reviewed: Yes

Publication information
Journal: Chemistry of Materials
Volume: 18
Issue number: 20
ISSN (Print): 0897-4756
Ratings: Scopus rating (2006): SJR 3.198 SNIP 1.934
Web of Science (2006): Indexed yes
Original language: English
DOIs: 10.1021/cm061092f
Source: orbit
Source ID: 202213
Research output: Contribution to journal » Journal article – Annual report year: 2006 » Research » peer-review

Photoinduced processes and holographic storage in stilbene and stilbenecarboxaldehyde in a polymethylmethacrylate matrix

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ilieva, D., Nedelchev, L., Petrova, T., Dragostinova, V., Todorov, T., Nikolova, L., Ramanujam, P.
Pages: 221-224
Publication date: 2006
Peer-reviewed: Yes

Publication information
Volume: 8
ISSN (Print): 2040-8978
Ratings: Scopus rating (2006): SJR 1.078 SNIP 1.275
Web of Science (2006): Indexed yes
Original language: English
DOIs: 10.1088/1464-4258/8/2/019
Source: orbit
Source ID: 309102
Research output: Contribution to journal » Journal article – Annual report year: 2006 » Research » peer-review
Polarisation-sensitive optical elements in azobenzene polyesters and peptides

In this article, we describe fabrication of polarisation holographic optical elements in azobenzene polyesters. Both liquid crystalline and amorphous side-chain polyesters have been utilised. Diffractive optical elements such as lenses and gratings that are sensitive to the polarisation of the incident light have been fabricated with polarisation holography. Computer-generated optical elements and patterns have also been written with a single polarised laser beam. Recording of polarisation defects enabling easy visualisation is also shown to be feasible in azobenzene polyesters.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Physics, The Danish Polymer Centre, Department of Chemical and Biochemical Engineering, Bulgarian Academy of Sciences
Contributors: Ramanujam, P., Dam-Hansen, C., Berg, R. H., Hvilsted, S., Nikolova, L.
Pages: 912-925
Publication date: 2006
Peer-reviewed: Yes

Publication information
Journal: Optics and Lasers in Engineering
Volume: 44
Issue number: 9
ISSN (Print): 0143-8166
Ratings:
Scopus rating (2006): SJR 0.506 SNIP 1.377
Web of Science (2006): Indexed yes
Original language: English
Keywords: Polarisation defects, Computer-generated holograms, Holographic optical elements, Surface relief, Azobenzene polymer
DOIs:
10.1016/j.optlaseng.2005.06.015
Source: orbit
Source ID: 198287
Research output: Contribution to journal – Journal article – Annual report year: 2006 – Research – peer-review

Cycloaddition in dipeptides for high capacity optical storage (invited talk)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P., Berg, R.
Publication date: 2005
Peer-reviewed: No
Source: orbit
Source ID: 308909
Research output: Contribution to conference – Conference abstract for conference – Annual report year: 2005 – Research

Nanotechnological initiatives in Denmark

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P.
Publication date: 2005
Peer-reviewed: No
Event: Abstract from Meeting at John Welch Technology Center, Bangalore (IN), 27 Jan, .
Source: orbit
Source ID: 308906
Research output: Contribution to conference – Conference abstract for conference – Annual report year: 2005 – Research

Optical fabrication of nano-structured biopolymer surfaces

General information
Publication status: Published
Photodimerization in pyrimidine-substituted dipeptides

Ten N-epsilon-glycylornithineamide derivatives have been synthesized containing various N-alpha-linked pyrimidine-1-ylacetetyl groups which can undergo (2 π + 2 π) photodimerization on irradiation with UV light at 254 nm. The dimerization efficiency of the free and bound pyrimidine groups was compared in aqueous solution; it was dependent on the substitution of the pyrimidine ring. N-alpha,N-alpha’-bis-(uracil-1-ylacetetyl)-(N-epsilon-glycylornithineamide) and N-alpha,N-alpha’-bis-(5-bromouracil-1-ylacetetyl)-(N-epsilon-glycylornithineamide) were identified as possible candidates for optical data storage.
Contributors: Ramanujam, P.
Publication date: 2005
Peer-reviewed: No
Event: Abstract from Meeting at Indian Institute of Technology, Department of Physics, Chennai, India.
Source: orbit
Source ID: 308907
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2005 › Research

**Photoinduced phenomena in azobenzene polymers (invited talk)**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P.
Publication date: 2005
Peer-reviewed: No
Event: Abstract from International conference on nonlinear optics (ICONO 8), Matsushima (JP), 10 Mar, .
Source: orbit
Source ID: 308910
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2005 › Research

**Photoresponsive azobenzene polymers (invited talk)**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P.
Publication date: 2005
Peer-reviewed: No
Source: orbit
Source ID: 308912
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2005 › Research

**Structural dynamics of the competing forces of light and matter**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Andreasen, J., Breiby, D., Hansen, S., Ramanujam, P., Drews, M., Nielsen, M.
Publication date: 2005
Peer-reviewed: No
Event: Abstract from 20. IUCr congress and general assembly, Florence (IT), 23-31 Aug, .
Source: orbit
Source ID: 308620
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2005 › Research

**Photodimerization in dipeptides for high capacity optical digital storage**
We have developed peptide materials with chromophores that undergo cycloaddition, suitable for terabit optical digital storage in a 5.25 in. disc. The rationale behind this design is that the length and rigidity of the backbone can be adjusted to facilitate the formation of a photodimer without large physical movements of the chromophores on exposure to UV light. Initially strongly absorbing films transmit up to 50% of light on irradiation at dimerizing wavelengths. This property can be utilized to record grey levels. An intensity-dependent transmission behavior has been observed that may enable data to be written and read at the same wavelength. (C) 2004 American Institute of Physics.

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P., Berg, R.
Pages: 1665-1667
Publication date: 2004
Peer-reviewed: Yes
Description of photoinduced anisotropy in azobenzene side-chain polyesters

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Sajti, S., Kerekes, A., Lorincz, E., Ramanujam, P.
Pages: 79-83
Publication date: 2003
Peer-reviewed: Yes

Effect of heat and film thickness on a photoinduced phase transition in azobenzene liquid crystalline polyesters

The liquid crystal to isotropic phase transition induced with 488 nm light in films of liquid crystalline azobenzene polyesters has been studied as a function of temperature, light intensity, and film thickness. That phase transition is associated with the photoinduced trans-cis-trans isomerizations of azobenzene molecules and it has been found that the 488 nm light power needed to induce the transition to the isotropic state increases when the film thickness decreases. The irradiation with the laser beam heats the film up and this seems to be responsible for the observed thickness dependence. Optical absorption measurements show that azobenzene aggregates present in one of the polymers are broken down in the photoinduced phase transition. The birefringence induced with low power 488 nm light in films before and after undergoing that photoinduced phase transition has also been studied. Birefringence shows a faster growing rate in films which have undergone the transition.

General information
Publication status: Published
Organisations: The Danish Polymer Centre, Department of Chemical and Biochemical Engineering, Risø National Laboratory for Sustainable Energy, University of Zaragoza
Contributors: Sanchez, C., Alcala, R., Hvilsted, S., Ramanujam, P.
Pages: 4454-4460
Publication date: 2003
Peer-reviewed: Yes
Evanescent polarization holographic recording of sub-200-nm gratings in an azobenzene polyester

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P.
Pages: 2375-2377
Publication date: 2003
Peer-reviewed: Yes

Publication information
Journal: Optics Letters
Volume: 28
ISSN (Print): 0146-9592
Ratings:
Scopus rating (2003): SJR 3.725 SNIP 2.609
Web of Science (2003): Indexed yes
Original language: English
Source: orbit
Source ID: 306186
Research output: Contribution to journal › Journal article – Annual report year: 2003 › Research › peer-review

Optical data storage using peptides (invited lecture)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Berg, R., Ramanujam, P.
Publication date: 2003
Peer-reviewed: No
Event: Abstract from 10th Congress of the European Society for Photobiology (ESP 2003), Vienna, Austria.
Source: orbit
Source ID: 306379
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2003 › Research

Photoinduced anisotropy in a family of amorphous azobenzene polyesters for optical storage

We investigate parameters associated with optical data storage in a variety of amorphous side-chain azobenzene-containing polyesters denoted as E1aX. The polyesters possess a common cyano-substituted azobenzene chromophore as a side chain, but differ in their main-chain polyester composition. Seventeen different polymers from the E1aX family divided into four classes, depending on the type of the main-chain substituent (one-, two-, and three-ring aromatic or alicyclic) have been thoroughly investigated. Various parameters characterizing the photoinduced birefringence in these materials, such as the response time, thermal and light stability, and long-term stability under ambient light at room temperature have been measured. Each of these parameters is quantitatively represented and therefore it is possible to make a clear comparison between the properties of the polymers. The results indicate that the long-term stability at ambient temperature is closely related to the thermal stability of the photoinduced birefringence. A strong correlation has also been found between the response time and the stability of the induced anisotropy toward illumination with unpolarized
white light. One of the classes of E1aX polymers characterized by two-ring aromatic substituent in the main chain is a good candidate for optical data storage media. A recording energy of approximately 2 J/cm(2) is sufficient to induce high refractive-index modulations of Delta n = 0.13 in these materials, which is retained even at elevated temperatures (>130 degreesC). Long-term stability of greater than one year for the induced anisotropy has also been achieved.

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, The Danish Polymer Centre, Department of Chemical and Biochemical Engineering, Nottingham Trent University
Contributors: Nedelchev, L., Matharu, A. S., Hvilsted, S., Ramanujam, P.
Pages: 5918-5927
Publication date: 2003
Peer-reviewed: Yes

**Publication information**
Journal: Applied Optics
Volume: 42
Issue number: 29
ISSN (Print): 1559-128X
Ratings:
Scopus rating (2003): SJR 1.205 SNIP 1.653
Web of Science (2003): Indexed yes
Original language: English
DOIs: 10.1364/AO.42.005918
Source: orbit
Source ID: 181609
Research output: Contribution to journal › Journal article – Annual report year: 2003 › Research › peer-review

**Azobenzene Polyesters for Optical Information Storage and Other Optical Applications**

**General information**
Publication status: Published
Organisations: The Danish Polymer Centre, Department of Chemical and Biochemical Engineering, Risø National Laboratory for Sustainable Energy
Contributors: Hvilsted, S., Ramanujam, P.
Pages: 21-24
Publication date: 2002

**Host publication information**
Title of host publication: 9th International Conference on Radiation Curing 2003
Source: orbit
Source ID: 181605
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2002 › Research › peer-review

**Light scattering of thin azobenzene side-chain polyester layers**
Light scattering properties of liquid crystalline and amorphous azobenzene side-chain polyester layers used for optical data storage were examined by means of transmissive scatterometry. Comparative experiments show that the amorphous polyester has significantly lower light scattering characteristics than the liquid crystalline polyester. The amorphous samples have negligible polarization part orthogonal to the incident beam. The liquid crystalline samples have relative high orthogonal polarization part in light scattering. The light scattering results can be used to give a lower limit for the domain size in thin liquid crystalline polyester layers being responsible for the dominant light scattering. The characteristic domain sizes obtained from the Fourier transformation of polarization microscopic Pictures confirm these values.

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, The Danish Polymer Centre, Department of Chemical and Biochemical Engineering, Optilink Hungary Ltd., Budapest University of Technology and Economics
Contributors: Kerekes, Á., Lörincz, E., Ramanujam, P., Hvilsted, S.
Pages: 57-65
Publication date: 2002
Peer-reviewed: Yes
Photoinduced macroscopic chiral structures in a series of azobenzene copolyesters
A study of the propagation of elliptically polarized light and the resulting formation of macroscopic chiral structures in a series of azobenzene side-chain copolyesters, in which the morphology is varied from liquid crystalline to amorphous, is reported. Real-time measurements are presented, showing the dynamic behavior of the photoinduced rotation of the polarization ellipse in the different samples. The relationship between the ellipticity of the recording light and the linear birefringence induced is studied. A numerical solution that takes into account the influence of the photoinduced linear dichroism on the light propagation through the samples is presented.

Physically Functional Materials
The invention relates to novel monodisperse or polydisperse compounds, in general named DNO (diamino acid Nalpha-substituted oligopeptides), preferably low molecular weight polypeptides, e.g., based on ornithine, lysine, diaminobutyric acid, diaminopropionic acid, aminoethylglycine or other amino acids or peptides having azobenzenes or other physically functional groups, e.g., photoresponsive groups, as side chains. These compounds may be synthesized using solid phase peptide synthesis techniques. Materials, e.g., thin films, comprising such compounds may be used for optical storage of information (holographic data storage), nonlinear optics (NLO), as photoconductors, photonic band-gap materials, electrically conducting materials, electroluminescent materials, piezoelectric materials, magnetic materials, ferromagnetic materials, ferroelectric materials, photoelectronic materials, or materials in which light-induced conformational changes can be produced. Optical anisotropy may reversibly be generated with polarized laser light whereby a hologram is formed. First order diffraction efficiencies of up to around 80% have been obtained.

Physically Functional Materials
The invention relates to novel monodisperse or polydisperse compounds, in general named DNO (diamino acid Nalpha-substituted oligopeptides), preferably low molecular weight polypeptides, e.g., based on ornithine, lysine, diaminobutyric acid, diaminopropionic acid, aminoethylglycine or other amino acids or peptides having azobenzenes or other physically functional groups, e.g., photoresponsive groups, as side chains. These compounds may be synthesized using solid phase peptide synthesis techniques. Materials, e.g., thin films, comprising such compounds may be used for optical storage of information (holographic data storage), nonlinear optics (NLO), as photoconductors, photonic band-gap materials, electrically conducting materials, electroluminescent materials, piezoelectric materials, magnetic materials, ferromagnetic materials, ferroelectric materials, photoelectronic materials, or materials in which light-induced conformational changes can be produced. Optical anisotropy may reversibly be generated with polarized laser light whereby a hologram is formed. First order diffraction efficiencies of up to around 80% have been obtained.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Nedelchev, L., Nikolova, L., Matharu, A., Ramanujam, P.
Pages: 671-676
Publication date: 2002
Peer-reviewed: Yes
Propagation of polarized light through azobenzene polyester films

When elliptically polarized light of appropriate wavelength corresponding to trans-cis-trans isomerisation process is incident on thin films of azobenzene polyesters, a helical structure is induced. We investigate the propagation of the exciting light beam (self-induced) as well as a probe light beam outside the absorption band through the polyester films. Investigations are carried out in one amorphous and one liquid crystalline polyester. We show that amorphous polyester after irradiation behaves like classical helical material.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, The Danish Polymer Centre, Department of Chemical and Biochemical Engineering, Optilink A/S
Contributors: Nedelchev, L., Matharu, A., Nikolova, L., Hvilsted, S., Ramanujam, P.
Pages: 563-575
Publication date: 2002
Peer-reviewed: Yes

Response function for the characterization of photo-induced anisotropy in azobenzene containing polymers

A response function is derived for the description of photo-induced birefringence and dichroism in case of materials where the underlying process is photo-isomerization. Our result explains the usefulness of the theoretical formulae derived earlier by Kakichashvili for photo-anisotropic materials of another kind, which are widely used in polarization holographic models. The expression proposed by us depends on the exposure time for a given intensity, and describes the saturation of the anisotropy with time and intensity. The material constants introduced in our approach are expressed by proper microscopic quantities. The results are verified by numerical simulation and also by experiments.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Sajti, S., Kerekes, Á., Ramanujam, P., Lorincz, E.
Pages: 677-685
Publication date: 2002
Peer-reviewed: Yes
Fabrication of narrow surface relief features in a side-chain azobenzene polyester with a scanning near-field microscope

We show that it is possible to fabricate topographic submicron features in a side-chain azobenzene polyester with a scanning near-field optical microscope, through irradiation at a wavelength of 488 nm at intensity levels of 12 W/cm², topographic features as narrow as 240 nm and as high as 6 nm have been reproducibly recorded in a thin film of the polyester. These observations are consistent with the fact that at low intensities peaks are produced evolving into formation of trenches at high intensities in the case of amorphous side-chain azobenzene polyesters. This may find applications in high-density optical storage and high-resolution lithography.

High diffraction efficiency polarization gratings recorded by biphotonic holography in an azobenzene liquid crystalline polyester

High diffraction efficiencies have been achieved with polarization gratings recorded in thin films of an azobenzene side-chain liquid crystalline polyester by means of biphotonic processes. Efficiency values up to 30% have been reached after an induction period of 300 s and subsequent evolution with the sample in darkness. These values are at least two orders
of magnitude higher than those previously reported for biphotonic recording. The gratings can be erased with unpolarized blue light and partial recovery of the diffraction efficiency has been observed after the erasure process when the sample is kept in darkness. Red light illumination of the erased film increases the recovered efficiency value and the recovery rate.

**General information**
Publication status: Published
Organisations: The Danish Polymer Centre, Department of Chemical and Biochemical Engineering, Risø National Laboratory for Sustainable Energy, University of Zaragoza
Contributors: Sánchez, C., Alcalá, R., Hvilsted, S., Ramanujam, P.
Pages: 3944-3946
Publication date: 2001
Peer-reviewed: Yes

**Publication information**
Volume: 78
Issue number: 25
ISSN (Print): 0003-6951
Ratings:
Web of Science (2001): Indexed yes
Original language: English
Keywords: SPECTROSCOPY, DATA-STOREAGE, MOIETIES, POLYMER-FILMS, SIDE-CHAIN
Electronic versions:
Hvilsted.pdf
DOIs:
10.1063/1.1379791
URLs:
http://link.aip.org/link/?APPLAB/78/3944/1

**Bibliographical note**
Copyright (2001) American Institute of Physics. This article may be downloaded for personal use only. Any other use requires prior permission of the author and the American Institute of Physics.
Source: orbit
Source ID: 181623
Research output: Contribution to journal › Journal article – Annual report year: 2001 › Research › peer-review

**Influence of structures of polymer backbones on cooperative photoreorientation behavior of p-cyanoazobenzene side chains**
Photoinduced orientational behavior of a polymethacrylate (CN6) and a polyester (p6a12) with p-cyanoazobenzene side chains was studied to reveal the structural effect of the liquid crystalline polymer backbones. Irradiation with linearly polarized W light resulted in the reorientation of the azobenzene for both polymers toward the direction perpendicular to the electric vector of the incident light. The induced orientation can be slowly amplified by thermal Z-to-E isomerization and be facilitated by irradiation with visible light. For p6a12 with the long alkylene and carbonyl groups in main-chain cooperative orientation of main chains with p-cyanoazobenzene side chains was confirmed using FT-IR spectroscopy, contrary to the case of CN6. Furthermore, in-situ observation of changes in photoinduced birefringence by ellipsometry revealed that thermal treatment plays a significant role in levels of molecular orientation in polymer matrices.

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, The Danish Polymer Centre, Department of Chemical and Biochemical Engineering, Tokyo Institute of Technology
Contributors: Han, M., Kidowaki, M., Ichimura, K., Ramanujam, P., Hvilsted, S.
Pages: 4256-4262
Publication date: 2001
Peer-reviewed: Yes

**Publication information**
Journal: Macromolecules
Volume: 34
Issue number: 12
ISSN (Print): 0024-9297
Ratings:
Scopus rating (2001): SJR 2.863 SNIP 1.716
Light propagation through photoinduced chiral structures in azobenzene-containing polymers

We investigate light propagation through azobenzene-containing polymers with photoinduced chiral structures. The structures have large pitch but the Mauguin condition is not fulfilled. The eigenmodes are shown to be elliptical and their ellipticity is determined by the ellipticity $e(o)$ of the exciting light. In amorphous azopolymers, light induces a macroscopic chiral structure comprising the whole illuminated region. The pitch depends on the value of $e(o)$: no chirality is induced if $e(o) = 1$ (circular polarization). In liquid-crystalline azopolymers circularly polarized light induces the formation of many microscopic spirals, which makes the material equivalent to the classical optically active media.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, The Danish Polymer Centre, Department of Chemical and Biochemical Engineering, Bulgarian Academy of Sciences
Pages: 304-310
Publication date: 2001
Peer-reviewed: Yes

Publication information
Volume: 3
Issue number: 4
ISSN (Print): 2040-8978
Ratings:
Scopus rating (2001): SJR 0.776 SNIP 1.184
Web of Science (2001): Indexed yes
Original language: English
DOIs:
10.1088/1464-4258/3/4/313
Source: orbit
Source ID: 181622
Research output: Contribution to journal › Journal article – Annual report year: 2001 › Research › peer-review

Physics and technology of optical storage in polymer thin films

We discuss different strategies for optical storage of information in polymeric films. An outline of the existing trends is given. The synthesis and characterization of side-chain azobenzene polyester films for holographic storage of information is described. A compact holographic memory card system based on polarization holography is described. A storage density of greater than 10MB/cm2 has been achieved so far, with a potential increase to 100MB/cm2 using multiplexing techniques and software correction. Finally the role of surface relief in azobenzene polymers on irradiation with polarized light is mentioned. (C) 2001 Elsevier Science BN. All rights reserved.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, The Danish Polymer Centre, Department of Chemical and Biochemical Engineering, Budapest University of Technology and Economics, Optilink Hungary Ltd.
Pages: 145-150
Publication date: 2001
Peer-reviewed: Yes

Publication information
Journal: Synthetic Metals
Volume: 124
Issue number: 1
ISSN (Print): 0379-6779
Ratings:
Polymer scaffolds bearing azobenzene - Potential for optical information storage

The fundamental optical storage mechanism of the laser light addressable azobenzene moiety is briefly introduced. A modular and flexible synthesis design furnishes polyester matrices covalently integrating cyanobenzene in regularly spaced side chains. Thin films of these materials are particularly well suited for holographic storage. Notable figures of merit of liquid crystalline polyesters are response time to blue-green laser light of the order of nanoseconds, storage capacity expressed as 5000 lines/mm, and high, permanent (almost nine years) diffraction efficiency of the order of 50% or greater, and erasability. The implications of the main chain nature for polyester morphology and for the permanency of the induced anisotropy are discussed. The design and methods of preparation of other significantly different polymer scaffolds supporting cyanobenzene are elaborated. Oligopeptides always result in amorphous materials, whereas copolymethacrylates and dendritic or hyperbranched polyesters provide some materials that exhibit liquid crystallinity. However, none of these scaffolds affords materials that result in permanent anisotropy when exposed to interfering laser light.

General information
Publication status: Published
Organisations: The Danish Polymer Centre, Department of Chemical and Biochemical Engineering, Risø National Laboratory for Sustainable Energy
Contributors: Hvilsted, S., Ramanujam, P.
Pages: 147-153
Publication date: 2001
Peer-reviewed: Yes

Publication information
Journal: Chinese Journal of Polymer Science
Volume: 19
Issue number: 2
ISSN (Print): 0256-7679
Ratings:
Scopus rating (2001): SJR 0.102 SNIP 0.098
Web of Science (2001): Indexed yes
Original language: English
Keywords: Azobenzene side-chain polymers, Copolymethacrylates, Dendrimers, Holographic storage, LC and amorphous polyesters, Morphology, Oligopeptides
Source: orbit
Source ID: 181627
Research output: Contribution to journal › Conference article – Annual report year: 2001 › Research › peer-review

Read/write Demonstrator of rewritable holographic memory card system

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, Risø National Laboratory for Sustainable Energy, Department of Chemical and Biochemical Engineering, The Danish Polymer Centre
Pages: 166-168
Publication date: 2001

Host publication information
Title of host publication: Technical Digest, Optical Data Storage Topical Meeting
Place of publication: Bellingham, WA
Publisher: International Society for Optical Engineering
Source: orbit
Source ID: 182125
Side-chain Azobenzene Polyesters for Optical Information Storage

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, Risø National Laboratory for Sustainable Energy, Department of Chemical and Biochemical Engineering, The Danish Polymer Centre
Contributors: Ramanujam, P., Hvilsted, S.
Pages: 82-85
Publication date: 2001

Host publication information
Title of host publication: Extended Abstracts: 4 NIMC International Symposium on Photoreaction Control and Photofunctional Materials
Place of publication: Ibaraki
Publisher: National Institute of Materials and Chemical Research
Source: orbit
Source ID: 182130

Simulation of erasure of photoinduced anisotropy by circularly polarized light
The temporal evolution of photoinduced birefringence is investigated on the basis of a model proposed by Pedersen and co-workers. This model is extended for the case of elliptically polarized light, and used to describe the erasure of photoinduced birefringence by circularly polarized light. It is shown that the anisotropy is not erased, only the direction of the optical axis is changed, and this is measured as erasure. The computed results are compared with measurements and show good agreement for several intensities.

General information
Publication status: Published
Organisations: The Danish Polymer Centre, Department of Chemical and Biochemical Engineering, Risø National Laboratory for Sustainable Energy, Optilink Hungary Ltd., Budapest University of Technology and Economics
Contributors: Sajti, S., Kerekés, Á., Barabás, M., Lorincz, E., Hvilsted, S., Ramanujam, P.
Pages: 435-442
Publication date: 2001
Peer-reviewed: Yes

Publication information
Journal: Optics Communications
Volume: 194
Issue number: 4-6
ISSN (Print): 0030-4018
Ratings:
Scopus rating (2001): SJR 1.305 SNIP 1.263
Web of Science (2001): Indexed yes
Original language: English
Keywords: Photoanisotropic polymers, Polarization holography
DOIs:
10.1016/S0030-4018(01)01308-6
Source: orbit
Source ID: 181620

Surface relief measurements in side-chain azobenzene polyesters with different substituents
Light-induced surface modification of a series of liquid-crystalline side-chain azobenzene polyesters which have the same main- and side-chain structure but eleven different substituents on the azobenzene is investigated. Using a transmission mask as well as single focused beams we show that the formation of the surface relief is dependent on the substituents. In both experiments irradiation with p-polarized light generates peaks for the CN, CF3, CH3 and F substituents, while for a Cl substituent valleys are observed. Also s-polarized light is found to produce surface deformations. An amorphous azobenzene polyester was included in the study for comparison. The results point to a mechanism of the surface relief phenomenon, in which the architecture of the polyesters plays a crucial role.
The azobenzene optical storage puzzle - Demands on the polymer scaffold?
The basic mechanism of optical information storage utilizing the azobenzene photoaddressable moiety will briefly be introduced. A synthetically flexible polyester matrix covalently integrating cyanoadzobenzene in regularly spaced side chains is particularly well suited for holographic storage. Notable figures of merits of thin film materials of liquid crystalline polyesters are: response time to laser light in the order of ns, storage capacity of 5000 lines/mm, high permanent (more than eight years) diffraction efficiency in the order of 50% or higher, and erasability. The implications of the nature of the main chain on polyester morphology and on the permanency of the induced anisotropy are discussed. Arguments for the design and methods of preparation of other very different polymer scaffolds supporting the cyanoadzobenzene are elucidated. Whereas oligopeptides invariably form amorphous materials, both copolymethacrylates and dendritic or hyperbranched polyesters provide some materials that exhibit liquid crystallinity. However, none of these other scaffolds offer materials that allow long-lasting anisotropy to be laser Light induced.
Determination of the Response Time of Photoanisotropy in Azobenzene Side-Chain Polyesters

We present a method which allows the determination of the response time to polarized light of an azobenzene side-chain polyester. This method is based on the measurement of intensities in dependence on the delay time between a pump and a probe pulse. The described method does not need a very sophisticated time resolving measuring equipment. The time resolution is in the order 10 ps and is comparable with the laser pulse duration. The response time of the azobenzene side-chain polyester E1aP has determined to be about 40 ps. (C) 2000 Elsevier Science B.V. All rights reserved.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Chemical and Biochemical Engineering
Pages: 155-160
Publication date: 1 Aug 2000
Peer-reviewed: Yes

Publication information
Journal: Optics Communications
Volume: 182
Issue number: 1-3
ISSN (Print): 0030-4018
Ratings:
Scopus rating (2000): SJR 1.035 SNIP 0.919
Web of Science (2000): Indexed yes
Original language: English
Keywords: photoanisotropic polymers, azo-dye doped polymers
DOI:
10.1016/S0030-4018(00)00797-5
Source: orbit
Source ID: 176811
Research output: Contribution to journal › Journal article – Annual report year: 2000 › Research › peer-review

Ab initio calculation of the electronic spectrum of azobenzene dyes and its impact on the design of optical data storage materials

Electronic excitation energies of 16 azobenzene dyes have been calculated by ab initio methods within the second-order polarization propagator approximation (SOPPA). Good agreement with experiment is found for the lowest singlet and triplet states for both the trans- and cis-azobenzene molecules. The differences are in the range of ±0.3 eV, with the exception of the lowest n → π* transition in trans-azobenzene, where a deviation of −0.64 eV is found. The lowest τ → π* transition in trans-azobenzene, on the other hand, is particularly well represented with a deviation of only −0.15 eV. Furthermore, the experimental singlet τ → π* transitions are reproduced for a set of azobenzene dyes with different electron donor and acceptor groups and the correct shifts in excitation energy are obtained for the different substituents. It has also been demonstrated that ab initio methods can be used to determine suitable candidates for azo components used in materials for data storage.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Chemical and Biochemical Engineering, The Danish Polymer Centre
Contributors: Åstrand, P., Ramanujam, P., Hvilsted, S., Bak, K., Sauer, S.
Pages: 3482-3487
Publication date: 2000
Peer-reviewed: Yes

Publication information
Journal: Journal of the American Chemical Society
Volume: 122
Issue number: 14
ISSN (Print): 0002-7863
Ratings:
Scopus rating (2000): SJR 3.589 SNIP 2.146
Web of Science (2000): Indexed yes
Original language: English
DOI:
10.1021/ja993154r
Source: orbit
An improved method for separating the kinetics of anisotropic and topographic gratings in side-chain azobenzene polyesters

The induction of anisotropy gratings in side-chain azobenzene polyesters is accompanied by the formation of surface relief. We introduce an improved holographic method to separate the contributions of the anisotropic and the topographic part to the diffraction efficiency by analyzing the polarization of the first-order diffracted beam. The main advantage of this method is that both parts can be determined simultaneously by only one measurement. Furthermore the displacement between both gratings can be determined in a similar manner. Experimental results obtained with two different polyesters are presented.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Helgert, M., Fleck, B., Wenke, L., Hvilsted, S., Ramanujam, P.
Pages: 803-807
Publication date: 2000
Peer-reviewed: Yes

Publication information
Journal: Applied Physics B-Lasers and Optics
Volume: 70
Issue number: 6
ISSN (Print): 0946-2171
Ratings:
Scopus rating (2000): SJR 1.508 SNIP 1.23
Web of Science (2000): Indexed yes
Original language: English
Source: orbit
Source ID: 302056

Biphotonic holographic gratings in azobenzene polyesters: Surface relief phenomena and polarization effects

Biphotonic holographic gratings have been recorded in a side-chain azobenzene liquid crystalline polyester using a blue incoherent source and a He-Ne laser. Intensity gratings and the appearance of surface relief have been observed when two linearly polarized beams from a He-Ne laser are made to interfere on a film illuminated with blue light. Polarized holographic gratings are also created with two orthogonally circularly polarized He-Ne beams. All these gratings are stable in darkness but can be erased with blue light. (C) 2000 American Institute of Physics.

General information
Publication status: Published
Organisations: The Danish Polymer Centre, Department of Chemical and Biochemical Engineering, Risø National Laboratory for Sustainable Energy, University of Zaragoza
Contributors: Sánchez, C., Alcalá, R., Hvilsted, S., Ramanujam, P.
Pages: 1440-1442
Publication date: 2000
Peer-reviewed: Yes

Publication information
Volume: 77
Issue number: 10
ISSN (Print): 0003-6951
Ratings:
Scopus rating (2000): SJR 4.137 SNIP 1.997
Web of Science (2000): Indexed yes
Original language: English
Keywords: SPECTROSCOPY, DIFFRACTION, POLYMER-FILMS, LIQUID-CRYSTALLINE POLYESTER, SIDE-CHAIN, REVERSIBLE OPTICAL STORAGE
Electronic versions:
Søren.pdf
DOIs:
Five-membered rings as diazo components in optical data storage devices: An ab initio investigation of the lowest singlet excitation energies

The two lowest singlet excitation energies of 18 azo dyes have been studied by ab initio quantum-chemical methods within the second-order polarization propagator approximation (SOPPA). Various combinations of five-membered rings (furan, thiophene, pyrrole, oxazole, thiazole, and imidazole) have been investigated as diazo components for a potential use in optical data storage materials. It is found that the diazo compounds with two heterocyclic five-membered rings have π → π* excitation energies corresponding to laser wavelengths in the region 450-500 nm whereas one five-membered ring and a phenyl group as diazo components results in wavelengths in the region 400-335 nm. (C) 2000 Published by Elsevier Science B.V.
Photoinduced Deformation of Azobenzene Polyester Films

We investigate two types of azobenzene side-chain polyesters which have shown opposite behaviour in light-induced surface grating formation experiments. Thin films of these polymers prepared on a water surface undergo opposite changes of shape under the influence of polarized light. We propose this deformation to be responsible for the surface relief gratings.

General information
Publication status: Published
Organisations: Department of Chemical and Biochemical Engineering, Risø National Laboratory for Sustainable Energy
Contributors: Bublitz, D., Helgert, M., Fleck, B., Wenke, L., Hvilsted, S., Ramanujam, P.
Pages: 863-865
Publication date: 2000
Peer-reviewed: Yes

Publication information
Journal: Applied Physics B-Lasers and Optics
Volume: 70
Issue number: 6
ISSN (Print): 0946-2171
Ratings:
Scopus rating (2000): SJR 1.508 SNIP 1.23
Web of Science (2000): Indexed yes
Original language: English
DOIs: 10.1007/PL00021146
Source: orbit
Source ID: 176812
Research output: Contribution to journal › Journal article – Annual report year: 2000 › Research › peer-review

Self-Induced Light Polarization Rotation in Azobenzene-Containing Polymers

We report here a light-induced phenomenon—a self-induced rotation of the azimuth of elliptically polarized light passing through photobirefringent azopolymers. The experiments are carried out with films of amorphous and liquid-crystalline polymers. It has been shown that the induced rotation angle depends on the ellipticity of the input light. A theoretical analysis of the phenomenon has been done and it has been shown that light induces chiral structure in the polymer films.

(C) 2000 American Institute of Physics. [S0003-6951(00)02731-5].

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Pages: 657-659
Publication date: 2000
Peer-reviewed: Yes

Publication information
Volume: 77
Issue number: 5
ISSN (Print): 0003-6951
Ratings:
Scopus rating (2000): SJR 4.137 SNIP 1.997
Web of Science (2000): Indexed yes
Original language: English
DOIs: 10.1063/1.127076
Source: orbit
Source ID: 176815
Research output: Contribution to journal › Journal article – Annual report year: 2000 › Research › peer-review
Accelerated optical holographic recording using bis-DNO
The design, synthesis and optical holographic recording properties of bis-DNO are reported. Bis-DNO is composed of two identical azobenzene oligoornithine segments (DNO) connected via a dipeptide linker. The two segments were assembled in a parallel fashion at the two amino groups of the dipeptide linker by Merrifield synthesis. Surprisingly, the response time of films of bis-DNOs was found to be much faster than that of their linear counterparts. (C) 1999 Elsevier Science Ltd. All rights reserved.

A nonlinear optical element for incoherent image processing based on photoanisotropy

Azobenzene polymers for optical information storage
Azobenzene side-chain LC polyesters for optical information storage

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hvilsted, S., Ramanujam, P.
Publication date: 1999
Peer-reviewed: No
Event: Abstract from SICL '99 workshop: Applications of liquid crystals, Portonovo di Ancona, Italy.
Source: orbit
Source ID: 300247
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1999 › Research

Azobenzene side-chain liquid crystalline polyesters - A prodigious potential for optical information storage

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hvilsted, S., Ramanujam, P.
Publication date: 1999

Host publication information
Title of host publication: Abstract book and general information
Place of publication: Bayreuth
Publisher: Universität Bayreuth
Source: orbit
Source ID: 300398
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 1999 › Research

Combined Main- and Side-Chain Azobenzene Polyesters: A potential for Photoinduced Nonlinear Waveguides

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Sahién, F., Geisler, T., Hvilsted, S., Holme, N., Ramanujam, P., Petersen, J.
Pages: 57-62
Publication date: 1999

Host publication Information
Title of host publication: Materials Research Society Symposium Proceedings
Volume: 561
Place of publication: Warrendale, PA
Publisher: MRS
Editors: Kippelen, B., Lackritz, H., Claus, R.
ISBN (Print): 1-55899-468-8
(Materials Research Society symposium proceedings, 561).
Source: orbit
Source ID: 182004
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 1999 › Research

Holographic Gratings in Azobenzene Side-Chain Polymethacrylates

Optical storage properties of thin unoriented liquid crystalline and amorphous side-chain azobenzene polymethacrylate films are examined by polarization holographic measurements. The investigated materials are free radical copolymers derived from two photochromic monomers, 6-(4-oxy-4'-cyanoazobenzene)hex-1-yl methacrylate and 8-(4-oxy-4'- cyanoazobenzene)oct-1-yl methacrylate, and a nonphotochromic optically active comonomer, (-)-menthyl methacrylate. The thermal behavior and phase transitions of the polymers have been investigated in detail through differential scanning calorimetry and polarizing optical microscopy. Atomic force microscopy investigations have been carried out on the polarization holographic gratings recorded in the polymethacrylate films. A surface relief grating has been found to appear in all films after irradiation. The copolymers with 50-75% dye content exhibit the largest surface relief. The stored information seems to be stable up to approximately 70 degrees C, except in the case of polymers with low dye content.
Holographic memories

A two-dimensional holographic memory for archival storage is described. Assuming a coherent transfer function, an A4 page can be stored at high resolution in an area of 1 mm². Recently developed side-chain liquid crystalline azobenzene polyesters are found to be suitable media for holographic storage. They exhibit high resolution, high diffraction efficiency, have long storage life, are fully erasable and are mechanically stable.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P., Holme, N., Berg, R., Hvilsted, S.
Pages: 611-617
Publication date: 1999
Host publication information
Title of host publication: Selected papers from Photonics India '98
ISBN (Print): 0-8194-3479-5
DOIs:
10.1117/12.347985
Source: orbit
Source ID: 182005
Light-induced circular birefringence in cyanoazobenzene side-chain liquid-crystalline polyester films

We report the inducement of large circular birefringence (optical activity) in films of a cyanoazobenzene side-chain liquid-crystalline polyester on illumination with circularly polarized light. The polyester has no chiral groups and is initially isotropic. The induced optical rotation is up to 5 degrees m(-1) at 633 nm and three to four times larger at 488 nm. The effect is explained through photoinduced changes in the structure of the polymer films due to reorientation of the rod-like chromophores and angular momentum transfer from the circularly polarized light to the azobenzene side chains.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Chemical and Biochemical Engineering, The Danish Polymer Centre, Bulgarian Academy of Sciences
Contributors: Naydenova, I., Nikolova, L., Ramanujam, P., Hvilsted, S.
Pages: 438-441
Publication date: 1999
Peer-reviewed: Yes

Light induced surface relief in azobenzene materials

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hvilsted, S., Ramanujam, P.
Publication date: 1999

Host publication information
Title of host publication: 2. Symposium on phthalocyanines and related compounds. Abstracts
Place of publication: Madrid
Publisher: Cost Action 518
Source: orbit
Source ID: 300322
Research output: Chapter in Book/Report/Conference proceeding – Annual report year: 1999 – Research

Optical holographic data storage using peptides

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Berg, R., Rasmussen, P., Hvilsted, S., Ramanujam, P.
Pages: 88-90
Publication date: 1999

Host publication information
Title of host publication: Peptides. Frontiers of peptide science. Proceedings
Place of publication: Dordrecht
Publisher: Kluwer Academic Publishers
Editors: Tam, J., Kaumaya, P.
ISBN (Print): 0-7923-5160-6
Source: orbit
Optically induced surface relief phenomena in azobenzene polymers
Azobenzene polymers and oligomers show intriguing surface relief features when irradiated with polarized laser light. We show through atomic force microscopic investigation of side-chain azobenzene polymers after irradiation through an amplitude mask that large peaks or trenches result depending on the architecture of the polymer. Extensive mass transport over long distances has been observed, paving the way for easy replication of nanostructures. We also show that it is possible to store microscopic images as topographic features in the polymers just through polarized light irradiation. (C) 1999 American Institute of Physics.

Physical processes in azobenzene polymers on irradiation with polarized light
Azobenzenes can serve as model compounds for the study of trans-cis isomerization in more complex molecules. We have performed time-resolved spectroscopy in solutions containing free azobenzene chromophores and diols with a view to obtaining the energy levels and lifetimes of the excited states. A transition route based on experimental results for the theoretically calculated energy level scheme is proposed. Physical observations of surface relief in thin films of azobenzene polymers when irradiated with polarized light are reported. These include two beam polarization holographic observations and single beam transmission measurements through a mask, followed by atomic force microscope and profiler investigations. It is concluded that none of the prevalent theories can explain all the observed facts.
Mean-field theory of photoinduced formation of surface reliefs in side-chain azobenzene polymers

A mean-field model of photoinduced surface reliefs in dye containing side-chain polymers is presented. It is demonstrated that photoinduced ordering of dye molecules subject to anisotropic intermolecular interactions leads to mass transport even when the intensity of the incident light is spatially uniform. Theoretical profiles are obtained using a simple variational method and excellent agreement with experimental surface reliefs recorded under various polarization configurations is found. The polarization dependence of both period and shape of the profiles is correctly reproduced by the model.

Processes of importance for the holographic storage in azobenzene side-chain LC polyesters

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hvilsted, S., Holme, N., Ramanujam, P.
Publication date: 1998
Peer-reviewed: No
Source: orbit
Source ID: 182159

Prodigious optical storage polyesters - The matrix-integrated azobenzene puzzle

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hvilsted, S., Ramanujam, P.
Publication date: 1998
Peer-reviewed: No
Source: orbit
Source ID: 182169

Quantum theory and experimental studies of absorption spectra and photoisomerization of azobenzene polymers

The microscopic properties of azobenzene chromophores are important for a correct description of optical storage systems based on photoinduced anisotropy in azobenzene polymers. A quantum model of these properties is presented and verified by comparison to experimental absorption spectra for trans and cis isomers of cyano methoxy azobenzene. In addition, the trans \rightarrow cis quantum efficiency is measured, and hence the combined experimental and theoretical work allows one to determine the essential molecular properties, including magnitude and anisotropy of the absorption cross section and various components of the polarizability tensor for both trans and cis isomers. It is shown that the trans isomer
is almost perfectly anisotropic, whereas the cis isomer is approximately isotropic in the plane containing the central C-N=N-C azobridge. The implications for models of the storage mechanism are discussed.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, The Danish Polymer Centre
Contributors: Pedersen, T. G., Ramanujam, P., Johansen, P., Hvilsted, S.
Pages: 2721-2730
Publication date: 1998
Peer-reviewed: Yes

Publication information
Journal: Optical Society of America. Journal B: Optical Physics
Volume: 15
Issue number: 11
ISSN (Print): 0740-3224
Original language: English
DOIs:
10.1364/JOSAB.15.002721
Source: orbit
Source ID: 181958
Research output: Contribution to journal › Journal article – Annual report year: 1998 › Research › peer-review

Selectively deuterated liquid crystalline cyanoazobenzene side-chain polyesters. 3. Investigations of laser induced segmental mobility by Fourier transform infrared spectroscopy
The laser-induced anisotropy in thin films of an extensive number of cyanoazobenzene sidechain liquid crystalline polytetradecanedioates, -dodecanedioates, and -adipates selectively deuterated at different positions have been investigated with polarized FTIR spectroscopy. The analysis of the segmental orientation based on dichroic ratios of characteristic absorption bands shows that, in polyesters with long main-chain spacing (tetradecanedioates and dodecanedioates), not only the light sensitive azo chromophore but also the main-chain methylene segment and to a smaller extent the flexible spacer are preferentially oriented perpendicular to the laser light polarization. The extent of orientation increases with increasing spacer length. On the other hand, in the shorter adipates only the chromophore and the spacer are likewise oriented. Rapid-scan FTIR analysis performed on-line with the laser irradiation reveals that the alignment of the aliphatic segments arises simultaneously with the chromophore orientation. Temperature dependent infrared investigations of the laser-induced orientation shows that the preservation of the photoinduced anisotropy directly relates to the polyester phase behavior.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Risø National Laboratory, University of Duisburg-Essen
Contributors: Kulinna, C., Hvilsted, S., Hendann, C., Siesler, H. W., Ramanujam, P.
Pages: 2141-2151
Publication date: 1998
Peer-reviewed: Yes

Publication information
Journal: Macromolecules
Volume: 31
Issue number: 7
ISSN (Print): 0024-9297
Original language: English
DOIs:
10.1021/ma970967w
Source: orbit
Source ID: 181962
Research output: Contribution to journal › Journal article – Annual report year: 1998 › Research › peer-review

The importance of the substituent on azobenzene side-chain polyester optical storage materials

General information
Publication status: Published
Organisations: Department of Chemical and Biochemical Engineering, The Danish Polymer Centre, Department of Photonics Engineering, Optical Microsensors and Micromaterials, Risø National Laboratory for Sustainable Energy
Contributors: Hvilsted, S., Pedersen, M., Holme, N., Ramanujam, P.
Pages: 298-299
Theoretical model of photoinduced anisotropy in liquid-crystalline azobenzene side-chain polyesters

A theoretical framework for the temporal behavior of photoinduced anisotropy in liquid-crystalline azobenzene side-chain polyesters is constructed. The domain structure of the material is taken into account and inter molecular interactions are included through a mean-field description. Photoinduced trans cis isomerization is taken as the dominating source of chromophore reorientation events, and it is demonstrated how this mechanism in conjunction with the multidomain picture is able to account for the long-term stability of the anisotropy. The photoinduced birefringence is calculated by means of a truncated basis method, and in addition the photostationary solution is obtained. Comparison between theory and experiment shows excellent agreement in the entire range of intensities used experimentally.
An analysis of the anisotropic and topographic gratings in a side-chain liquid crystalline azobenzene polyester

We have examined in detail the formation of surface relief structures in azobenzene polyesters formed by polarization holography with orthogonally circularly polarized laser beams. We show that it is possible to separate the contribution to the diffraction efficiency into an anisotropic part and a surface relief part by examining the polarization content of the first order diffracted beam. By studying the dynamics of the growth of the grating, we show that the gratings due to anisotropy and surface relief appear at the same time. Atomic force microscopic investigations of the film after irradiation reveal a strongly polarization dependent surface relief pattern. (C) 1997 American Institute of Physics.

Azobenzene Side-Chain Liquid Crystalline Polyesters with Outstanding Optical Storage Properties

Peptides for Holographic Data Storage
Photoinduced Circular Anisotropy in Side-Chain Azobenzene Polyesters

We report for the first time the inducing of large circular anisotropy in previously unoriented films of side-chain azobenzene polyesters on illumination with circularly polarized light at a wavelength of 488 nm. The circular dichroism and optical activity are measured simultaneously in real time at two wavelengths, 488 nm and 633 nm. The photoinduced optical activity has been measured to be > 10(4) deg/cm and the circular dichroism has been found to be on the order of 0.3. (C) 1997 Elsevier Science B.V.

Polarimetric investigation of materials with both linear and circular anisotropy

We investigate light propagation through materials with both linear and circular anisotropy and find the relation of the amplitude and polarization transfer functions to the four anisotropic characteristics: linear circular birefringence, and linear and circular dichroism. We determine these four characteristics of anisotropic samples by measuring the output intensity and polarization corresponding to different input polarization azimuths and fitting the theoretical and experimental results. In our experiments we have used films of side-chain azobenzene polyesters in which optical anisotropy had been previously induced on illumination with elliptically polarized light.
**Time-Resolved FTIR-Polarization Spectroscopy of the Laser-Induced Anisotropy in Side-Chain Liquid Crystalline Polyesters**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Publication date: 1997
Peer-reviewed: No
Event: Abstract from 11th International Conference on Fourier Transform Spectroscopy, Athens, GA, United States.
Source: orbit
Source ID: 182179
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1997 › Research

**Atomic force and optical near-field microscopic investigations of polarization holographic gratings in a liquid crystalline azobenzene side-chain polyester**

Atomic force and scanning near-field optical microscopic investigations have been carried out on a polarization holographic grating recorded in an azobenzene side-chain liquid crystalline polyester. It has been found that immediately following laser irradiation, a topographic surface grating structure appears. The time development of the grating structure was followed by atomic force microscopy for 20 h by repeatedly scanning the same area of the film. The grating structure disappears after a few hours and a pronounced increase of surface roughness has been found to take place. A near-field optical microscopic scanning of the grating reveals, however, that the bulk of the film remains optically anisotropic. (C) 1996 American Institute of Physics.

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P., Holme, N., Hvilsted, S.
Pages: 1329-1331
Publication date: 4 Mar 1996
Peer-reviewed: Yes
Publication information
Volume: 68
Issue number: 10
ISSN (Print): 0003-6951
Original language: English
DOIs: 10.1063/1.115924
Source: orbit
Source ID: 182029
Research output: Contribution to journal › Journal article – Annual report year: 1996 › Research › peer-review

**10,000 optical write, read, and erase cycles in an azobenzene sidechain liquid-cristalline polyester**

We show far what is believed to be the first time that it is possible to generate 10,000 rapid write, read, and erase cycles optically in an azobenzene sidechain liquid-crystalline polyester. We do this by exposing the film alternately to visible light from an argon laser at 488 nm and ultraviolet light from a krypton laser at 351 nm. The efficiency of the system shows several exponential decays, presumably associated with the azobenzene chromophores' aligning out of the plane of the film and the lifetime of the cis state of the azobenzene. A local temperature increase may also play a role. However, there is enough contrast even after 10,000 cycles to permit a clear distinction between the maximum and the minimum anisotropy. As the anisotropy is stable between erasures, this method could have immediate applications for optical storage.

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Risø National Laboratory
Laser Induced Segmental Orientation of Side-Chain Liquid Crystalline Polyesters Investigated by FTIR

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hvilsted, S., Kulinna, C., Ramanujam, P.
Number of pages: 18
Publication date: 1996

Host publication information
Title of host publication: 12th European symposium on polymer spectroscopy. Program. Book of abstracts
Place of publication: Lyon
Publisher: Université Claude Bernard
Source: orbit
Source ID: 182188
Research output: Chapter in Book/Report/Conference proceeding – Conference abstract in proceedings – Annual report year: 1996 – Research

Near-Field Microscopy on Liquid Crystalline Side-Chain Polyesters

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Holme, N., Ramanujam, P., Hvilsted, S., Pedersen, M.
Publication date: 1996
Peer-reviewed: No
Source: orbit
Source ID: 182190
Research output: Contribution to conference – Conference abstract for conference – Annual report year: 1996 – Research

New Polymer Materials for Erasable Holographic Storage

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P., Hvilsted, S., Berg, R.
Pages: 2-3
Publication date: 1996
Peer-reviewed: No

Publication information
Journal: Holography, SPIE Int. Techn. Working Group Newsletter
Volume: 6
Issue number: 2
Original language: English
Source: orbit
Source ID: 182030
Research output: Contribution to journal – Journal article – Annual report year: 1996 – Research
Novel Azobenzene Polyesters and Peptides for Erasable Holographic Storage

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Berg, R. H., Hvilsted, S., Ramanujam, P.
Pages: 191-192
Publication date: 1996

Host publication information
Title of host publication: Conference on Communication Technologies
Source: orbit
Source ID: 182186
Research output: Chapter in Book/Report/Conference proceeding – Article in proceedings – Annual report year: 1996

Peptide oligomers for holographic data storage
SEVERAL classes of organic materials (such as photoanisotropic liquid-crystalline polymers and photorefractive polymers) are being investigated for the development of media for optical data storage. Here we describe a new family of organic materials-peptide oligomers containing azobenzene chromophores-which appear particularly promising for erasable holographic data storage applications. The rationale for our approach is to use the structural properties of peptide-like molecules to impose orientational order on the chromophores, and thereby optimize the optical properties of the resulting materials. Here we show that holographic gratings with large first-order diffraction efficiencies (up to 80%) can be written and erased optically in oligomer films only a few micrometres thick. The holograms also exhibit good thermal stability, and are not erased after heating to 180 degrees C for one month. Straightforward extension of this peptide-based strategy to other molecular structures should allow the rational design of a wide range of organic materials with potentially useful optical properties.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Berg, R. H., Hvilsted, S., Ramanujam, P.
Pages: 505-508
Publication date: 1996
Peer-reviewed: Yes
Peptide oligomers for optical holographic storage of information

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Berg, R. H., Hvilsted, S., Ramanujam, P.
Publication date: 1996
Peer-reviewed: No
Source: orbit
Source ID: 294316
Research output: Contribution to conference ➔ Conference abstract for conference – Annual report year: 1996 ➔ Research

Photoinduced anisotropic measurements in liquid-crystalline azobenzene side-chain polyesters

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Holme, N., Ramanujam, P., Hvilsted, S.
Pages: 4622-4627
Publication date: 1996
Peer-reviewed: No

Publication information
Volume: 35
Original language: English
Source: orbit
Source ID: 295311
Research output: Contribution to journal ➔ Journal article – Annual report year: 1996 ➔ Research

Photoinduced anisotropy measurements in liquid-crystalline azobenzene side-chain polyesters
Reversible photoinduced anisotropy in a series of Liquid-crystalline azobenzene side-chain polyesters is investigated as a function of intensity of the write beam and the sample temperature. Measurements reveal that the erasing takes place at a temperature much higher than the glass transition temperature. induced anisotropy can be erased by heating the polyesters to approximately 80 degrees C.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Holme, N., Ramanujam, P., Hvilsted, S.
Pages: 4622-4627
Publication date: 1996
Peer-reviewed: No

Publication information
Journal: Applied Optics
Volume: 35
Issue number: 23
Original language: English
Source: orbit
Source ID: 182026
Polarization holographic gratings in side-chain azobenzene polyesters with linear and circular photoanisotropy

We investigate thin phase polarization holographic gratings recorded with two waves with orthogonal linear polarizations in materials in which illumination with linearly/circularly polarized light gives rise to linear/circular birefringence. The theoretical analysis shows that the presence of circular photoanisotropy changes significantly the diffraction characteristics of the gratings. The intensities of the waves diffracted in the +1 and -1 orders of diffraction and their ratio depend substantially on the reconstructing-wave polarization. Experiments with films of side-chain liquid-crystalline azobenzene polyester that is a photoanisotropic material of the considered type confirm the unusual polarization properties. It is shown that polarization holography may be used for real-time simultaneous measurement of photoinduced linear and circular birefringence.

Selective deuterium labeling as a tool for the investigation of laser induced segmental orientation in cyanoazobenzene side-chain polyesters

Selective Deuterium Labelling as a Tool for the Investigation of Laser-Induced Segmental Orientation in Cyanoazobenzene Side-Chain Polyesters

Selective Deuterium Labelling as a Tool for the Investigation of Laser-Induced Segmental Orientation in Cyanoazobenzene Side-Chain Polyesters
Side-Chain Liquid Crystalline Azobenzene Polyesters with Unique Reversible Optical Storage Properties

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hvilsted, S., Ramanujam, P.
Pages: 53-63
Publication date: 1996
Peer-reviewed: No

Publication information
Journal: Current Trends in Polymer Science
Volume: 1
ISSN (Print): 0972-446X
Original language: English
Source: orbit
Source ID: 182024
Research output: Contribution to journal › Journal article – Annual report year: 1996 › Research

Side-chain liquid crystalline polyesters for optical information storage
Azobenzene side-chain liquid crystalline polyester structures suitable for permanent optical storage are described. The synthesis and characterization of the polyesters together with differential scanning calorimetry and X-ray investigations are discussed. Optical anisotropic investigations and holographic storage in one particular polyester are described in detail and polarized Fourier transform infrared spectroscopic data complementing the optical data are presented. Optical and atomic force microscope investigations point to a laser-induced aggregation as responsible for permanent optical storage.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Risø National Laboratory, CNR, Università di Pisa, University of Duisburg-Essen
Pages: 768-776
Publication date: 1996
Peer-reviewed: Yes

Publication information
Journal: Polymers for Advanced Technologies
Volume: 7
Issue number: 9
ISSN (Print): 1042-7147
Original language: English
Keywords: Azobenzene polymers, Holography, Optical information storage, Liquid crystals
DOIs:
10.1002/(SICI)1099-1581(199609)7:9<768::AID-PAT587>3.0.CO;2-E
Source: orbit
Source ID: 182025
Research output: Contribution to journal › Journal article – Annual report year: 1996 › Research › peer-review

The Research Group on New Materials for Optical Information Storage at Risø National Laboratory

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Publication date: 1996
Peer-reviewed: No
Event: Abstract from NorFA Nordic-Baltic workshop on molecular electrooptic materials, Göteborg (SE), 17-18 Jun.,
Source: orbit
Source ID: 295504
A compact holographic storage system based on novel polyesters

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P., Holme, N., Hvilsted, S., Pedersen, M.
Publication date: 1995

Host publication information
Title of host publication: Optics and information
Place of publication: Mulhouse
Publisher: Cercle SFO/SEE d’Opto-Informatique (European Optical Society Topical Meetings Digests Series, 6).
Source: orbit
Source ID: 293516
Research output: Chapter in Book/Report/Conference proceeding – Annual report year: 1995 – Research

Bacteriorhodopsin - a model material for studies in spatial nonlinear optics

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P.
Publication date: 1995

Host publication information
Title of host publication: Copenhagen conference on complex dynamics in spatially extended systems. Book of abstracts
Place of publication: Roskilde
Publisher: Risø National Laboratory
Source: orbit
Source ID: 293674
Research output: Chapter in Book/Report/Conference proceeding – Conference abstract in proceedings – Annual report year: 1995 – Research

Caratterizzazione de polipropilenadipati liquido-cristallini contenenti gruppi laterali azobenzenici

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Tassi, E., Paci, M., Magagnini, P., Yang, B., Rustichelli, F., Andruzzi, F., Hvilsted, S., Ramanujam, P., Pedersen, M., Zebger, I., Hendann, C., Siesler, H.
Pages: 164-167
Publication date: 1995

Host publication information
Title of host publication: 12. Convegno Italiano di scienza e tecnologia delle macromolecole
Place of publication: Palermo
Publisher: Associazione Italiana di Scienza e Tecnologia delle Macromolecole
Source: orbit
Source ID: 293617
Research output: Chapter in Book/Report/Conference proceeding – Article in proceedings – Annual report year: 1995 – Research

Fourier-transform infrared spectroscopy of side-chain liquid crystalline polyesters under external fields

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Holographic storage in side-chain azobenzene polyesters

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Number of pages: 52
Publication date: 1995

Host publication information
Title of host publication: Third international symposium on polymers for advanced technologies. Conference programme
Place of publication: Pisa
Publisher: CNR
Source: orbit
Source ID: 293939
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 1995 › Research

New azobenzene polymers for optical information storage

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hvilsted, S., Kulinna, C., Ramanujam, P.
Number of pages: 46
Publication date: 1995

Host publication information
Title of host publication: 45th Finnish chemical congress and exhibition and Nordic polymer meeting. Abstracts
Place of publication: Helsinki
Publisher: Association of Finnish Chemical Societies
Source: orbit
Source ID: 293381
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 1995 › Research

New side-chain liquid crystalline polyesters for optical storage

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Pedersen, M., Hvilsted, S., Andruzzi, F., Ramanujam, P.
Pages: 57-58
Publication date: 1995
Peer-reviewed: No

Publication information
Journal: Materialenyt
Issue number: 2
Original language: English
Source: orbit
Source ID: 294059
Research output: Contribution to journal › Journal article – Annual report year: 1995 › Research
Novel side-chain liquid crystalline polyester architecture for reversible optical storage

New side-chain liquid crystalline polyesters have been prepared by melt transesterification of diphenyl tetradecanedioate and a series of mesogenic 2-[omega-[4-(4-cyanophenyl)azo]phenoxyl] alkyl]-1,3-propanediols, where the alkyl spacer is hexa-, octa-, and decamethylene in turn. The polyesters have molecular masses in the range 5000-89 000. Solution C-13 NMR spectroscopy has been employed to identify carbons of polyester repeat units and of both types of end groups. Polyester phases and phase transitions have been investigated in detail by polarizing optical microscopy and differential scanning calorimetry for the hexamethylene spacer architecture with different molecular masses. Using FTIR polarization spectroscopy, the segmental orientation in unoriented polyester films induced by argon ion laser irradiation has been followed and an irradiation-dependent order parameter for the cyanazoazobenzene mesogens calculated. FTIR is also utilized to follow the temperature-dependent erasure of the induced orientation. Optical storage properties of thin unoriented polyester films are examined through measurements of polarization anisotropy and holography. A resolution of over 5000 lines/mm and diffraction efficiencies of about 40% have been achieved. Lifetimes greater than 30 months for information stored have been obtained, even though the glass transition temperatures are about 20 degrees C. Complete erasure of the information can be obtained by heating the films to about 80 degrees C, and the films can be reused many times without fatigue.

On the explanation of the biphotonic processes in polyesters containing azobenzene moieties in the side chain

An explanation for the recently observed biphotonic transitions in side-chain polyesters with azobenzene moieties is given on the basis of experimental observations from optical and Fourier-Transform infrared absorption spectra. We present for the first time experimental evidence that a red laser beam at 633 nm causes cis-trans (Z-E) transitions in azobenzene.

Optical near-field studies of liquid crystalline side-chain azobenzene polyesters
Photoanisotropic incoherent to coherent converter using a bacteriorhodopsin thin film

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Imam, H., Lindvold, L., Ramanujam, P.
Pages: 225-227
Publication date: 1995
Peer-reviewed: Yes

Publication information
Journal: Optics Letters
Volume: 20
ISSN (Print): 0146-9592
Original language: English
Source: orbit
Source ID: 293999
Research output: Contribution to journal › Journal article – Annual report year: 1995 › Research › peer-review

Spatial frequency response and transient anisotropy in bacteriorhodopsin thin films

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Lindvold, L., Imam, H., Ramanujam, P.
Pages: 32-38
Publication date: 1995
Peer-reviewed: No

Publication information
Volume: 2
Original language: English
Source: orbit
Source ID: 293863
Research output: Contribution to journal › Journal article – Annual report year: 1995 › Research

The diagnostic value of exercise echocardiography in ischemic heart disease in relation to quantitative coronary arteriography

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Pages: 1-7
Publication date: 1995
Peer-reviewed: Yes

Publication information
Journal: International Journal of Cardiovascular Imaging
Volume: 11
Issue number: 1
ISSN (Print): 1569-5794
Original language: English
Source: orbit
The influence of substituents on the orientational behaviour of novel azobenzene side-chain polyesters

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Zebger, I., Kulinna, C., Siesler, H., Andruzzi, F., Pedersen, M., Ramanujam, P., Hvilsted, S.
Pages: 159-170
Publication date: 1995
Peer-reviewed: Yes

Publication information
Journal: Macromolecular Symposia
Volume: 94
ISSN (Print): 1022-1360
Original language: English
Source: orbit
Source ID: 293380
Research output: Contribution to journal › Journal article – Annual report year: 1995 › Research › peer-review

The use of bacteriorhodopsin in optical processing: A review

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Lindvold, L., Ramanujam, P.
Pages: 55-66
Publication date: 1995
Peer-reviewed: No

Publication information
Volume: 54
Issue number: 1
Original language: English
Source: orbit
Source ID: 293894
Research output: Contribution to journal › Journal article – Annual report year: 1995 › Research

Array illuminator based on transverse self-phase modulation in bacteriorhodopsin thin film

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Glückstad, J., Ramanujam, P.
Pages: 318-319
Publication date: 1994

Host publication information
Title of host publication: LEOS '94. Conference proceedings. Vol. 2
Place of publication: New York
Publisher: Institute of Electrical and Electronics Engineers
Source: orbit
Source ID: 294000
Research output: Contribution to journal › Journal article – Annual report year: 1995 › Research

Assessment of coronary artery stenosis pressure gradient by quantitative coronary arteriography in patients with coronary artery disease

General information
Bacteriorhodopsin: A holographic material assessment. POPAM ESPRIT project 6863

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Lindvold, L., Imam, H., Ramanujam, P.
Number of pages: 23
Publication date: 1994

Publication information
Place of publication: Roskilde
Publisher: Risø National Laboratory. Optics and Fluid Dynamics Department
Original language: English
Source: orbit
Source ID: 291780

Characterisation of the orientational behaviour of liquid-crystalline side-chain polymers for reversible optical data storage by Fourier-Transform-IR-Spectroscopy

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Kulina, C., Zebger, I., Siesler, H., Hvilsted, S., Ramanujam, P.
Pages: 476-477
Publication date: 1994

Host publication information
Title of host publication: Fourier transform spectroscopy
Place of publication: Bellingham, WA
Publisher: The International Society for Optical Engineering
Editors: Bertie, J., Wieser, H.
Source: orbit
Source ID: 291479
Research output: Chapter in Book/Report/Conference proceeding – Article in proceedings – Annual report year: 1994 – Research

Characterization of the segmental mobility of liquid-crystalline side-chain polyesters by Fourier-Transform infrared spectroscopy

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Kulina, C., Zebger, I., Hvilsted, S., Ramanujam, P., Siesler, H.
Pages: 169-181
Publication date: 1994
Peer-reviewed: Yes
Dynamic contrast reversal due to self-phase modulation in bacteriorhodopsin thin film

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P., Glückstad, J., Lindvold, L., Juul Rasmussen, J.
Pages: 321-327
Publication date: 1994
Peer-reviewed: No

Erasable optical storage in azobenzene side-chain polyesters

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hvilsted, S., Pedersen, M., Ramanujam, P., Andruzzi, F.
Publication date: 1994

Influence of the length of flexible spacers on the optical storage properties of side-chain liquid crystalline polyesters

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P., Andruzzi, F., Hvilsted, S.
Number of pages: 176
Publication date: 1994
New side-chain liquid crystalline polyesters for optical storage

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Pedersen, M., Hvilsted, S., Andruzzi, F., Ramanujam, P.
Publication date: 1994

Host publication information
Title of host publication: Nordiske polymerdage 1994. Programme and abstracts
Place of publication: Copenhagen
Publisher: H.C. Ørsted Institute
Source: orbit
Source ID: 292664
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 1994 › Research

Optical storage in side-chain liquid crystalline polyesters

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P., Andruzzi, F., Hvilsted, S.
Pages: 30-32
Publication date: 1994
Peer-reviewed: No

Publication information
Volume: 1
Issue number: 1
Original language: English
Source: orbit
Source ID: 292918
Research output: Contribution to journal › Journal article – Annual report year: 1995 › Research

Spatial frequency response and transient anisotropy of bacteriorhodopsin thin films

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Lindvold, L., Imam, H., Ramanujam, P.
Number of pages: 277
Publication date: 1994

Host publication information
Title of host publication: Frontiers in information optics
Place of publication: Kyoto
Publisher: ICO
Source: orbit
Source ID: 292719
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 1994 › Research

The influence of substituents on the orientational behaviour of novel azobenzene side-chain polyesters

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Zebger, I., Siesler, H., Andruzzi, F., Pedersen, M., Ramanujam, P., Hvilsted, S.
Number of pages: 86
Publication date: 1994

Host publication information
The sensitometric properties of chemically modified bacteriorhodopsin films

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Lindvold, L., Imam, I., Ramanujam, P.
Pages: 22-33
Publication date: 1994

Host publication information
Title of host publication: Optical memory
Place of publication: Bellingham, WA
Publisher: The International Society for Optical Engineering
Editor: Mikaelian, A.
(Source Proceedings, 2429).
Source: orbit
Source ID: 291779
Research output: Chapter in Book/Report/Conference proceeding – Article in proceedings – Annual report year: 1994

60.000 A4-sider på én kvadratcentimeter

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hvilsted, S., Ramanujam, P.
Pages: 8-9
Publication date: 1993
Peer-reviewed: Unknown

Publication information
Journal: Elteknik
Volume: 10
Issue number: 6/7
Original language: Danish
Source: orbit
Source ID: 291174
Research output: Contribution to journal – Journal article – Annual report year: 1993

Arbejdet med materialer for optisk lagring

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P.
Publication date: 1993
Peer-reviewed: No
Event: Abstract from Besøg af Professorforeningen fra DTH, Risø, Denmark.
Source: orbit
Source ID: 290739
Research output: Contribution to conference – Conference abstract for conference – Annual report year: 1993

Dark spatial solitons in bacteriorhodopsin thin films

General information
Holographically recorded transient gratings in retinylidene films

Influence of new architecture for side-chain liquid crystalline polyesters on holographic behaviour

Materials for optical storage
Novel biphotonic holographic storage in a side-chain liquid crystalline polyester

We report novel biphotonic holographic storage of text and gratings on unoriented films of a side-chain liquid crystalline polyester capable of high density storage and complete erasure. The holograms have a typical size of 1 mm. The recording utilizes unusual photochemistry involving azo dye molecules. We believe that this technique would have a great potential in the recording of thousands of holograms in a two-dimensional plane, as for instance in text retrieval systems and in the fabrication of high density interconnects in optical neural networks.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P., Hvilsted, S., Andruzzi, F.
Pages: 1041-1043
Publication date: 1993
Peer-reviewed: No

Publication information
Volume: 62
Issue number: 10
ISSN (Print): 0003-6951
Original language: English
DOIs:
10.1063/1.108788
Source: orbit
Source ID: 291176
Research output: Contribution to journal › Journal article – Annual report year: 1993 › Research

Nye materialer husker med laserlys

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hvilsted, S., Ramanujam, P.
Pages: 36-38
Publication date: 1993
Peer-reviewed: Unknown

Publication information
Journal: PC World
Issue number: 6
Original language: Danish
Source: orbit
Source ID: 291313
Research output: Contribution to journal › Journal article – Annual report year: 1993 › Communication

Nye materialer husker med laserlys

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hvilsted, S., Ramanujam, P.
Pages: 12-13
Publication date: 1993
Peer-reviewed: Unknown

Publication information
Journal: Risønyt
Issue number: 1
Original language: Danish
Source: orbit
Source ID: 291362
Research output: Contribution to journal › Journal article – Annual report year: 1993 › Communication
Nye polymermaterialer til optisk hukommelse

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hvilsted, S., Ramanujam, P.
Pages: 19-20
Publication date: 1993
Peer-reviewed: Unknown

Publication information
Journal: DOPS-Nyt
Volume: 8
Issue number: 3
Original language: Danish
Source: orbit
Source ID: 290986
Research output: Contribution to journal › Journal article – Annual report year: 1993 › Communication

Optical storage

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P.
Publication date: 1993
Peer-reviewed: No
Event: Abstract from Danish-Indian Society, Copenhagen (DK), 29 Apr, .
Source: orbit
Source ID: 290711
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1993 › Research

Optical storage

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P.
Publication date: 1993
Peer-reviewed: No
Event: Abstract from Institution of Electronic Engineers, Bangalore (IN), 10 Aug, .
Source: orbit
Source ID: 290716
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1993 › Research

Optical storage in side-chain liquid crystalline polyester

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P.
Publication date: 1993
Peer-reviewed: No
Event: Abstract from National Physical Laboratory, New Delhi (IN), 29 Jun, .
Source: orbit
Source ID: 290713
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1993 › Research

Optisk informationslagring

General information
Optisk informationslagring

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hvilsted, S., Ramanujam, P.
Publication date: 1993
Peer-reviewed: No
Event: Abstract from Polymerteknisk Selskab, København (DK), 26 Oct.
Source: orbit
Source ID: 290984
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1993 › Research

Optisk lagring

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P., Hvilsted, S.
Publication date: 1993
Peer-reviewed: No
Event: Abstract from Folkeuniversitetet i Roskilde, Risø, Denmark.
Source: orbit
Source ID: 290985
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1993 › Research

Photochemistry of azobenzenes - still an unsolved problem

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P.
Publication date: 1993
Peer-reviewed: No
Source: orbit
Source ID: 290712
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1993 › Research

Side-chain liquid crystalline polyesters for optical storage

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P.
Publication date: 1993
Peer-reviewed: No
Event: Abstract from NORDITA, Copenhagen, Denmark.
Source: orbit
Source ID: 290709
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1993 › Research
Side-chain liquid crystalline polyesters with unusual optical information storage properties

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P., Hvilsted, S., Andruzzi, F., Kulinna, C., Siesler, H.
Pages: 244-247
Publication date: 1993

Host publication information
Title of host publication: Organic thin films for photonic applications. Conference edition
Place of publication: Washington, DC
Publisher: Optical Society of America
(Technical Digest Series, 17).
Source: orbit
Source ID: 291012
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 1993 › Research

The use of bacteriorhodopsin as a dynamic holographic media. Esprit basic research programme. Project no. 6863, POPAM

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Lindvold, L., Ramanujam, P.
Number of pages: 24
Publication date: 1993

Publication information
Place of publication: Roskilde
Publisher: Risø National Laboratory. Optics and Fluid Dynamics Department
Original language: English
Source: orbit
Source ID: 290829
Research output: Book/Report › Book – Annual report year: 1993 › Research › peer-review

Generation of sub-poisson distribution of light

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ramanujam, P.
Pages: 206-208
Publication date: 1992

Host publication information
Title of host publication: Emerging optoelectronic technologies
Place of publication: New Delhi
Publisher: McGraw-Hill
Editors: Selvarajan, A., Sonde, B., Shenai, K., Tripathi, V.
Source: orbit
Source ID: 289989
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 1992 › Research

Intercomparison of Northern European I-127(2) stabilized He-Ne lasers at Lambda=633 nm

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Pages: 331-339
Novel side-chain liquid crystalline polyesters for optical information storage

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hvilsted, S., Ramanujam, P., Andruzzi, F.
Publication date: 1992

Second harmonic generation in anisotropic Langmuir-Blodgett films of N-docosyl-4-nitroaniline

Langmuir-Blodgett (LB) films of N-docosyl-4-nitroaniline have been made and their nonlinear optical properties studied by second harmonic generation (SHG) measurements. A significant enhancement of the intensity of the second harmonic of the 1.064-μm YAG was observed when a two layer Y-type film rather than a monolayer was used. Also, the dependence of the second harmonic signal on the polarization of the fundamental beam suggests that the nonlinear chromophores are lying nearly flat with respect to the substrate and are oriented along the dipping direction resulting in a noncentrosymmetric structure. Both of these observations are not common for Y-type LB films and the usual assumption of C(∞v) symmetry is therefore not valid. The results make us suggest that these LB films possess C(s) and C2-v symmetry for mono- and multilayers, respectively. Theoretical expressions for the envelope functions of the SHG for these symmetries are derived and compared with the experimental results.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Geisler, T., Rosenkilde, S., Ramanujam, P., Wijekoon, W., Prasad, P.
Pages: 127-133
Publication date: 1992
Peer-reviewed: No

Second harmonic generation in Langmuir-Blodgett films of N-docosyl-4-nitroaniline

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Side-chain liquid-crystalline polyesters for optical information storage
We report erasable holographic recording with a resolution of at least 2500 lines/mm on unoriented films of side-chain liquid-crystalline polyesters. Recording energies of approximately 1 J/cm² have been used. We have obtained a diffraction efficiency of approximately 30% with polarization recording of holograms. The holograms can be erased by heating them to approximately 80-degrees-C for approximately 2 min and are available for rerecording.

General information
Publication status: Published
Organisations: Rise National Laboratory for Sustainable Energy, University of Pisa
Contributors: Hvilsted, S., Andruzzi, F., Ramanujam, P.
Pages: 1234-1236
Publication date: 1992
Peer-reviewed: Yes

Publication information
Journal: Optics Letters
Volume: 17
Issue number: 17
ISSN (Print): 0146-9592
Original language: English
DOIs:
10.1364/OL.17.001234
Source: orbit
Source ID: 290141

Generation of sub-Poissonian photon number distribution
An optimization of a nonlinear Mach-Zehnder interferometer to produce sub-Poissonian photon number distribution is proposed. We treat the system quantum mechanically and estimate the mirror parameters, the nonlinearity of the medium in the interferometer, and the input power to obtain minimal output uncertainty in the photon number. The power efficiency of the system is shown to be high.

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, Technical University of Denmark
Contributors: Grønbech-Jensen, N., Ramanujam, P. S.
Pages: 2906-2909
Publication date: 1990
Peer-reviewed: Yes

Publication information
Journal: Physical Review A
Volume: 41
Issue number: 5
ISSN (Print): 2469-9926
Original language: English
Electronic versions:
Groenbech.pdf
DOIs:
Bibliographical note
Copyright (1990) by the American Physical Society.
Source: orbit
Source ID: 251150
Research output: Contribution to journal › Journal article – Annual report year: 1990 › Research › peer-review

Projects:

Fotodimerisering i peptider til optisk lagring
Hvilsted, S., Main Supervisor, Department of Chemical and Biochemical Engineering
Berg, R. H., Supervisor, Risø National Laboratory for Sustainable Energy
Ramanujam, P. S., Supervisor, Risø National Laboratory for Sustainable Energy
Vigild, M. E., Examiner, Department of Chemical and Biochemical Engineering
Jonsson, E. E. M., Examiner
Matharu, A. S., Examiner
Lohse, B., PhD Student, Department of Chemical and Biochemical Engineering
Risø (Løn)
01/09/2003 → 30/04/2007
Award relations: Fotodimerisering i peptider til optisk lagring
Project: PhD

Spectroscopic Studies of Cytochrome P450 Enzymes by Application of Optical Spectroscopic Techniques Combined with QM/MM Calculations
Johannessen, C., PhD Student, Department of Physics
Bohr, H., Main Supervisor
Abdali, S., Supervisor
Rottwitt, K., Examiner
Blanch, E. W., Examiner
Ramanujam, P. S., Examiner
DTU stipendium
01/02/2004 → 01/08/2007
Award relations: Spectroscopic Studies of Cytochrome P450 Enzymes by Application of Optical Spectroscopic Techniques Combined with QM/MM Calculations
Project: PhD

Light engine V8 - a green revolution for colored light
Dam-Hansen, C., Project Manager, Department of Photonics Engineering, Diode Lasers and LED Systems
Ramanujam, P. S., Project Participant, Department of Photonics Engineering, Optical Microsensors and Micromaterials
Hansen, S. G., Project Participant, Department of Photonics Engineering, Optical Sensor Technology
Pedersen, H. C., Project Participant, Department of Photonics Engineering, Optical Microsensors and Micromaterials
Jensen, O. B., Project Participant, Department of Photonics Engineering, Diode Lasers and LED Systems
Plesner, P., Project Participant, Brother, Brother & Sons ApS
Brockmann, T., Project Participant, Brother, Brother & Sons ApS
Poulten, C., Project Participant, Brother, Brother & Sons ApS
Flensburg, H., Project Participant, Brother, Brother & Sons ApS
Thorseth, A., Project Participant, Department of Photonics Engineering, Diode Lasers and LED Systems
Chakrabarti, M., Project Participant, Department of Photonics Engineering, Diode Lasers and LED Systems
Project ID: 70710
Innovationsfonden: DKK3,962,840.00
01/09/2011 → 30/06/2014
Collaborators: Brother, Brother & Sons ApS
Award relations: Light engine V8 - a green revolution for colored light
Project: Research