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2001 PHOTONIC NANOSTRUCTURES - Advancing Materials to Control Light

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Overview

The Photonic Nanostructures conference will take place as scheduled.

Our deepest sympathy's go out to the people involved in the widespread tragedy of Tuesday, September 11, 2001. There are no words to describe the senselessness of this horrible act. Our thoughts are with the families at this time.

Sincerely,
Craig Wohlers
President

The discovery of novel PBG nanostructures and implementing nanofabrication processing will enable photonics to advance the technology of light localization, optics miniaturization, and production of smaller, less expensive, highly integrated optical devices and components. This conference bridges the gap between physics, chemistry and engineering in an effort to explore the impact of these PBG materials on the production of products that depend on lightwave technology. In addition, advances in commercialization and critical breakthroughs in ***photonic nanocomposite*** materials and ***silicon-based photonic structures*** will be addressed.

An international panel of experts will provide you with the latest developments with special emphasis on:

- Materials and technologies for photonic band gap materials
- Micro- and nanofabrication and self assembly methods for photonic systems
- The race for the photonic chip
- On-chip assembly of silicon inverted opals
- Photonic band-gap materials: the "semiconductors" of the future?
- Colloidal self-assembly and photonic crystals
- Panoscopic approach to new architectures of photonic crystals
- Inorganic vs. organic and bio photonic nanostructures
- Trends in developing photonic materials in/on/with silicon
- 2-D, 3-D, multilayer, and composite photonic crystals/coatings/films

Don't miss the opportunity to participate in this outstanding gathering with the most comprehensive coverage of this emerging field of materials technology - ***REGISTER TODAY!***

RELATED LINKS
Applied Physics Letter, American Institute of Physics
The University of Arizona Optical Sciences Center
The Society for Information Display International Display
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Photonics
IOP Journal of Optics A: Pure and Applied Optics

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Thursday, October 11, 2001

8:00 Registration, Poster/Exhibit Setup, Coffee and Pastries

SYNTHESIS & DESIGN

8:50 Chairperson's Opening Remarks
David J. Norris*, PhD, Research Scientist, NEC Research Institute*

9:00 Colloidal Self-Assembly and Photonic Crystals
Pierre Wiltzius*, PhD, Director, Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana Champaign*
Colloids have the interesting property of self-assembling into 3-dimensional periodic structures. These colloidal crystals can be made from suspensions of monodisperse, low-index of refraction (n ~ 1.5) silica or polystyrene spheres. If the lattice constants of the crystals are comparable to the wavelength of visible or near-infrared light they act like three-dimensional gratings. We will review our progress towards making photonic band gap structures and switchable gratings by introducing high-dielectric constant materials and liquid crystals into the

microperiodic assemblies.

9:45 Fabrication and Application of One- and Two-Dimensional Photonic Bandgap Structures Made on Silicon Wafers

Philippe M. Fauchet*, PhD, Professor and Chair, Department of Electrical and Computer Engineering; Director, Center for Future Health, University of Rochester*

One- and Two-dimensional photonic bandgap structures can be fabricated on silicon wafers using several techniques. We report on the state-of-the-art of such structures made via electrochemical etching and other processes compatible with silicon microelectronics technology. Examples of application include microphotonics, optical interconnects, and biosensing.

10:15 Fabrication of Organic Nanocrystals and Their Dispersion Systems for Some New Applications

Hidetoshi Oikawa*, Dr, Associate Professor, Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, Japan*

The "reprecipitation method" is available for fabrication of well-defined organic nanocrystals by controlling the reprecipitation conditions. These nanocrystals prepared are stable when dispersed in a medium. By utilizing this property, we can prepare the layered nanocrystals films with high optical quality. In addition, we confirmed the transmittance changes through the electric field-induced orientation of dispersed ionic chromophore nanocrystals. The nanocrystal dispersions are regarded as a novel "Liquid and Crystals" system.

10:45 Refreshment Break, Exhibit / Poster Viewing

11:15 Protein Photonic Crystals

Bernard Kress*, PhD, Scientist, Photonics Systems Laboratory, API Center Louis Pasteur University; and Founder, Diffractive Solution Company, France**

We will explain and demonstrate how some proteins molecules doped with specific mineral material can constitute 2D or 3D photonic crystals. We use a photonic method for organizing the proteins molecule for them to have a band gap effect on light. The prcise basic photonic molecular phenomena are unknown. But we formulate some modeling, explanations, and comments that constitute a reasonable approach of these phenomena. We will introduce our experimental set up and describe and discuss the band gap effect that we have obtained on several wavelength. We will present a method that could lead to a 1.5 micron wavelength band gap use. We tested the life duration of the protein photonic crystal once realized and we found this as being excellent. We precise the limitation in temperature and other physical parameters that we have investigated. We will conclude by a prospective view of what could be a photonics band gap technology on proteins by some first demonstrations of an effective system for media applications.

**In collaboration with: P.Meyrueis, R.Grzymala, I.El-Hafidi, and R.Kiefer, Photonics Systems Lab, API*

11:45 Designing Crystal Structures for the Manipulation of Light

Shanhui Fan*, PhD, Assistant Professor of Electrical Engineering, Stanford University*

With strong index contrast at the wavelength scale, photonic crystals exhibit many novel optical effects and present us with new opportunities for manipulating light. Large-scale computations, which exactly solve the underlying equations, provide important insights into the properties of photonic crystals. Moreover, these computations allow us to design structures for specific applications. In this talk, we will present some of our recent works in computational studies of photonic crystal structures.

12:15 Photonic Bandgap Enhanced Infrared Emitters

Martin U. Pralle*, PhD, Senior Research Scientist, Ion Optics, Inc.**

The use of photonic crystals as a medium for enhanced spontaneous emission is a growing area of research. We report the use of 2-D photonic crystals in silicon as a novel surface for enhanced thermal emission of infrared radiation. The emitted spectrum is of narrow bandwidth defined by the symmetry and periodicity of the photonic crystal. Furthermore, the peak emission is tunable throughout the infrared by varying the dimensions of the lattice parameter. In-band, the emission intensity is enhanced up to the theoretical limit of the black body envelope, but out-of-band the emission is suppressed to <10% of the black body spectrum. We report measured emission intensities comparable to conventional glow-bar sources at a band-width comparable to LEDÕs. These infrared emitters have broad applicability as stand alone infrared sources as well as for use in IR sensing and spectroscopy.

**In collaboration with: E.Johnson, J.Daly, A.Greenwald, N.Mölders, and M.McNeal, Ion Optics, Inc.; D.Choi and T.George, NASA Jet Propulsion Lab; R.Biswas and I.El-Kady, Ames Lab, Iowa State University*

12:45 Speaker Power Luncheon Sponsored by The Knowledge Foundation
Don't miss the opportunity to meet one-on-one with our conference faculty. Delegates are invited to join participating speakers over luncheon to discuss today's "hot topic" photonic bandgap crystal issues

SELF ASSEMBLY & FABRICATION

1:55 Chairperson's Remarks
Ghassan E. Jabbour*, PhD, Professor, Optical Sciences Center, University of Arizona*

2:00 The Race for the Photonic Chip
Geoffrey A. Ozin, PhD, Professor, Materials Chemistry Research Group, Chemistry Dept, University of Toronto, Canada
A global race is underway for the "holy grail" of the photonics revolution - a photonic chip constructed from integrated 3-D photonic crystals that display a complete photonic band gap at 1.5 microns, the wavelength of choice for optical telecommunications. Will the winner be an engineering physics fabrication approach or through self-assembly chemistry? In this lecture we will take you to the frontier of this rapidly moving and expanding field and describe methods, materials and nanostructures to beat in order to stay in the race for the photonic chip. The goal is to discover a facile, quick, reproducible and inexpensive chemistry or physics strategy to micron scale patterned single crystal 3-D photonic crystal chips, that are easy to integrate into existing chip fabrication facilities and amenable to mass production. This breakthrough could be of the disruptive kind and may pave the way to future all-optical integrated microphotonic circuits, computers and telecommunication systems.

2:30 Self-Organized High Dielectric Contrast Photonic Crystals
Paul V. Braun*, PhD, Professor, Dept of Materials Science and Engineering, University of Illinois at Urbana-Champaign*
The formation of low dielectric contrast three-dimensionally microperiodic structures is relatively straightforward, but fabrication of high refractive index structures as required for many PBG applications remains quite challenging. To address this problem, we have developed a range of materials chemistry routes which operate within the three-dimensional void space of a colloidal template to form high refractive index contrast structures. These include imbibing of melt imbibing of chalcogenide glasses, electrodeposition of II-VI semiconductors and electrodeposition of conducting polymers.

3:00 Self-Assembly Approaches to Photonic Bandgap Crystals and Other Types of Optical Devices
Younan Xia*, PhD, Assistant Professor, Department of Chemistry, University of Washington*
We have recently demonstrated several strategies for self-assembling spherical colloids into complex structures for various types of applications. In one example, spherical colloids have been organized into uniform clusters with well-controlled structures. In another example, spherical colloids have been assembled into three-dimensionally ordered lattices that exhibit interesting photonic bandgap properties. In this presentation, I am going to briefly discuss the procedure, capability, advantages, disadvantages, and potential application of each approach.

3:30 Refreshment Break, Exhibit / Poster Viewing

4:00 Emulsion and Colloidal Templating of Photonic Crystals
David J. Pine*, PhD, Professor of Chemical Engineering, University of California, Santa Barbara*
A variety of new kinds of photonic crystals can be fabricated by combining emulsion and colloidal templating. One such structure, which we call supraballs, consists of macroporous colloidal particles that have very high scattering cross sections and may be useful as high contrast pigments. Other structures are possible too and may be useful in constructing diamond and other colloidal crystal structures.

4:30 Colloidal Photonic Crystals: Novel Structures for Diffractive Optics
***Daniel Mittleman**, PhD, Professor, Dept of Electrical & Computer Engineering, Rice University*
The gemstone opal exhibits a brilliant visible iridescence due to the regular spacing of sub-micron colloids which comprise its structure. This natural motif can be replicated in the laboratory, and artificial opals can be cast as thin films of controlled thickness using colloidal assembly techniques. Numerous solids, ranging from polymers to metals, can be cast around the colloidal network and the colloids subsequently removed. The macroporous materials that result have arrays of spherical cavities interconnected by smaller windows. Diffractive properties of these inside-out structures are even stronger than the host opal, and in some cases can possess nearly complete photonic band gaps at visible wavelengths. The monodisperse cavities of macroporous polymers are ideal environments for growing many types of more complex colloidal architectures, with more tunable band gap behavior.

5:00 Inverse Opals Made of Silicon and Germanium
***Francisco J. Meseguer Rico**, PhD, Professor, Unidad Asociada CSIC-UPV Edificio de Institutos II, Universidad Politécnica de Valencia, Spain**
Synthetic opals templating has proven to be an easy and cheap route to the fabrication of photonic band gap materials. Optical properties of the opal-like photonic devices can also be tuned through the control of the mesoscopic opal length scale. The main goal is the synthesis of inverse opals made of materials with a high refractive index that can allow the opening of an omnidirectional band gap. An inverted opal can be envisaged as the negative replica of an opal with a periodic distribution of interconnected spherical cavities in a high refractive index medium. Here we will report on the fabrication of inverted opals made of type IV semiconductors (Silicon and Germanium). Firstly, we have infiltrated Si and Ge into the opal void volume of large sphere silica opal templates (above around 0.9 microns in diameter). Chemical Vapor Deposition technique allows a layer-by-layer semiconductor growth and also a control on the semiconductor-filling fraction. Secondly, when loading is finished, we remove the silica to obtain a semiconductor-inverted opal. SEM and optical properties allow to characterise the structures obtained. The optical features that appear at different frequencies, in the NIR, are explained by theoretical photonic band calculations.
**In collaboration with: Instituto de Ciencia de Materiales de Madrid (CSIC), Spain, and University of Toronto, Canada*

5:30 Open Discussion

6:00 End of Day One

Friday, October 12, 2001

8:00 Exhibit / Poster Viewing, Coffee and Pastries

8:55 Chairperson's Remarks
***Geoffrey A. Ozin**, PhD, Professor, Materials Chemistry Research Group, Chemistry Dept, University of Toronto, Canada*

9:00 *REVIEW*
Photonic Band Gap Materials: The "Semiconductors" of the Future?
***Costas M. Soukoulis**, PhD, Professor, Ames Laboratory and Department of Physics and Astronomy, Iowa State University*
In analogy to electrons in a crystal, electromagnetic waves propagating in a structure with a periodically modulated dielectric constant are organized into photonic bands. For certain crystal structures that have high enough dielectric contrast ratios, these photonic bands are separated by photonic gaps in which propagating states are forbidden. Spontaneous emission is suppressed for photons in the photonic band gap, offering novel approaches in manipulating the electromagnetic field. There have already been proposals for novel applications of these photonic band gap crystals, with operating frequencies ranging from the microwave to optical wavelengths. These include zero-threshold lasers, low-loss resonators and cavities, and efficient microwave antennas.

We review the search of for three-dimensional periodic dielectric structures that possess a photonic band gap and in addition, are easily fabricated experimentally. A new dielectric structure constructed with simple layers of dielectric rods is introduced. This new structure has a full three-dimensional photonic band gap of appreciable frequency width. It was first built in the microwave regime by stacking alumina rods, with a photonic band gap around 13 GHz. Crystals with photonic band gaps around 100 GHz and 500 GHz were fabricated using silicon wafers. Recently both the Sandia group and the University of Kyoto have fabricated this structure at the micron wavelength range. The experimental results are in excellent agreement with theoretical calculations of the transmission coefficient. At midgap, an attenuation of 21 dB per unit cell is obtained. Defect states of "donor" and "acceptor" type can be easily introduced by the addition and removal of dielectric material, respectively. Results for the propagation of the EM energy around an L-shaped photonic crystal waveguide gives a transmission efficient of more than 90%.
This new layer-by-layer structure is superior to previously suggested photonic gap structures as it can be easily fabricated at smaller scales to achieve photonic band gaps in the millimeter wave regime, and offers the promise of photonic band gaps at optical wavelengths.

FABRICATION & CHARACTERIZATION

9:30 Semiconductor Nanocrystals for Photonic Applications
***Axel Schülzgen**, PhD, Professor, Optical Sciences Center, University of Arizona*
Glasses doped with semiconductor nanocrystals are inexpensive and robust materials compatible with communication components. Recent improvements in fabrication of quantum dots embedded in glassy matrices have resulted in more uniform sizes and fewer defects. As in epitaxial grown nanostructures, linear and nonlinear optical properties of these materials can be tailored for specific applications utilizing the quantum confinement effect. We report on steady-state and time-resolved spectroscopy and also discuss applications.

10:00 Design Fabrication and Properties of Silicon Photon Crystals
***Jim G. Fleming**, PhD, Distinguished Member of Technical Staff, Sandia National Laboratories**
The photonic band structure results when light encounters a well-defined repeating arrangement of materials with differing refractive indexes. Advances in silicon processing technology, especially chemical mechanical polishing, have enabled rapid progress in the fabrication of well-behaved and controllable layer-by-layer structures. This has enabled us to demonstrate cavity fabrication, waveguiding, modification of thermal emissivity and the modification of Er emissivity.
**In collaboration with: Shawn-Yu Lin, Sandia National Labs*

10:30 Refreshment Break, Exhibit / Poster Viewing

11:00 Photonic Bandgap Properties of Opal Templated Systems
***Cefe López**, PhD, Tenure Scientist, Instituto de Ciencia de Materiales de Madrid (CSIC), Spain**
Opal templating is nowadays a well-developed technique apt to produce photonic band gap systems functioning in the optical regime. In this contribution the fabrication of inverse opals of different materials (polymers, semiconductors) is reviewed. In particular, the synthesis of the spheres for the templating opal and the formation of the template itself is described. So is that of various materials on opals templates. Finally, the characterization of the different stages of production (bare opal, composite, and inverse opal) and the comparison of the optical properties, (transmission and reflectance) with photonic band structure provides a good understanding of the parameters governing the formation and characteristics of the photonic bands. Resin inverted opals are an example of high fidelity replication the precursor of the infiltrated material being a liquid that thoroughly impregnates the template. Maximum dielectric contrast is achieved with Germanium. Semiconductor materials with lucent ability (such as CdS) are also studied.
**In collaboration with: Unidad Asociada CSIC-UPV, Universidad Politécnica de Valencia, Spain*

11:30 Metal Nanoshells: Manipulating Light at Nanoscale Dimensions
***Naomi J. Halas**, PhD, Professor, Dept of Electrical and Computer Engineering, and Dept of Chemistry, Rice University*
Metal Nanoshells are a new class of nanoparticles with highly frequency agile optical resonances and light

scattering properties, which depend on the relative thickness of the nanoparticles constituent layers. Thus Metal Nanoshells can be used to manipulate light "from the bottom up", independent of the long-range periodicity required by traditional photonic crystalline structures. This allows for the high-precision enhancement of local fields and their resultant nonlinear optical properties, as well as the development of unique new optical materials based on incorporating Metal Nanoshells into other materials and structures.

12:00 Scanning Probe Microscopy: A Tool for Fabrication and Characterization
***Dror Sarid**, PhD, Professor, Optical Sciences Center, University of Arizona**
Since their invention in 1982 and 1986, the scanning tunneling microscope and atomic force microscope have spawned a huge number of applications and is unmatched by any other technique in resolution and sensitivity. From atomic resolution imaging of conducting and non conducting surfaces, to measuring single electronic charge and electron interference effects, to manipulation of single atoms, naming only a few examples. In this talk we will present applications of these technologies to the fabrication and testing of nanostructures that can be used in optics and photonics.
**In collaboration with: C.A.Peterson, University of Arizona*

12:30 Selected Oral Poster Presentation

12:50 Lunch on your own

PHOTONIC APPLICATIONS

1:55 Chairperson's Remarks
***Pierre Wiltzius**, PhD, Director, Semiconductor Physics Research, Lucent Technologies - Bell Labs*

2:00 On-Chip Assembly of Silicon Inverted Opals
***David J. Norris**, PhD, Research Scientist, NEC Research Institute**
Colloidal assembly can now achieve 3D semiconductor photonic crystals (inverted opals) that theory predicts should exhibit a complete photonic band gap. However, serious skepticism remains whether in practice these materials will 1) actually have a band gap and 2) be useful in any real device. Here, these issues will be addressed by exploring high-quality silicon inverted opals that are assembled directly "on-chip". These structures are useful both for understanding their photonic properties and potential applications.
**In collaboration with: Yu.A.Vlasov, NEC Research Institute*

2:30 Nanowire Photonics
***Peidong Yang**, PhD, Assistant Professor, Dept of Chemistry, University of California, Berkeley*
Nanowires are important building blocks for organizing complex nanostructures with potential electronic and photonic applications. A gas phase process was used to synthesize semiconductor nanowires in our lab. These nanowires have unique optical properties due to their anisotropic nature. We will discuss several new concepts using nanowires for photonic applications, including nanowire nanolasers and nanowire array as 2-dimensional photonic crystals.

3:00 Refreshment Break, Exhibit / Poster Viewing

3:30 Processing of Nanothick Layers for Organic LEDs and Photovoltaic Applications
***Ghassan E. Jabbour**, PhD, Professor, Optical Sciences Center, University of Arizona*
Organic light-emitting devices (OLEDs) in display applications have progressed rapidly from the research stage to the commercial market, in an impressive short period of time. Features such as wide viewing angle, low power consumption, ease of processing, mechanical flexibility, and sunlight readability make these displays ever attractive to the consumer. The active layers in these devices are only several tens of nanometer in thickness. Spin coating and vacuum deposition have been the dominant techniques in the fabrication of such devices. There have been several demonstrations regarding the deposition of the active polymer materials using ink-jet printing. However, versatile, fast, more efficient, and roll-to-roll adaptable techniques are needed in the processing of these devices for numerous applications ranging from lighting and signage, to low information content displays. In this presentation, we demonstrate the use of screen printing (SP) in the processing of ultra

thin organic layers for OLEDs fabrication. For the first time, layers on the order of 20 nm can be printed and patterned using SP technology. The technique was also extended to the fabrication of the first screen-printed organic solar cell. Initial results will be presented and demonstration will be shown.

4:00 Silicon-Based Photonic Crystal Structures
Greg J. Parker*, PhD, Professor of Photonics, Department of Electronics & Computer Science, The University of Southampton, United Kingdom*
It is likely that the commercialisation of Photonic Crystal (PC) technology will require the high-volume capabilities provided by semiconductor nanofabrication processes. To this end, a Silicon-compatible PC waveguide could form the basic building block of an all-optical circuit. This presentation will discuss the development of PC research at Southampton University (UK) which began with deep photoelectrochemically etched holes in single-crystal Silicon. This initial work progressed to an all dielectric waveguide structure on a Silicon substrate, with the materials utilised being compatible with a CMOS process. PC nanofabrication and optical characterisation using these waveguiding structures will be described in detail.

4:30 Panel Discussion

Moderator:

Pierre Wiltzius

Panelists:

Ghassan E. Jabbour
Greg J. Parker

5:00 Closing Remarks / End of Conference

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The Knowledge Foundation, Inc.
18 Webster Street
Brookline, MA 02446-4938, USA
Knowledge Press is a division of Knowledge Foundation, Inc.

E-mail: custserv@knowledgefoundation.com
Telephone: (617) 232-7400
Fax: (617) 232-9171