HL 18: Photonic crystals I

Time: Tuesday 10:45–12:45 Location: H13

HL 18.1 Tue 10:45 H13

Photonic Crystal functional elements based on optically anisotropic materials and large-scale devices — •Patrick Mack[1,2], Daniel Hermann[1], Matthias Schillinger[1], Sergei Mingaleev[1,3], and Kurt Busch[1] — [1]Institut für Theoretische Festkörperphysik, Universität Karlsruhe (TH), Germany — [2]Institut für Nanotechnologie, Forschungszentrum Karlsruhe, Germany — [3]Bogolyubov Institute for Theoretical Physics, Kiev, Ukraine

We present device designs in macroporous silicon photonic crystals based on the infiltration of individual pores with liquid crystals which yield actively tunable photonic devices. These designs have been developed via a photonic Wannier function approach that allows the characterization of such devices via complex transmittance and reflectance coefficients. As a result, individual devices may be represented by small frequency-dependent scattering matrices. In turn, these scattering matrices form the basis of a quantitative circuit theory that allows to design complex functional elements that are very hard to handle with other simulation techniques.

HL 18.2 Tue 11:00 H13

Fabrication of 3D photonic crystal structures by two-photon polymerization technique — •Aleksandr Ovsianikov and Boris Chichkov — Hollerithallee 8

Two-photon polymerization technique can be considered as an enabling technology for the fabrication of 3D photonic crystals, especially those with introduced defects. Here, we report on our recent progress in the fabrication of 3D polymeric photonic crystals and investigation of their optical properties. Most of the materials used for 2PP were developed for lithographic applications and have a refractive index of the order of 1.6. We have investigated many of such materials and their structurability by 2PP technique. Further prospects of 2PP technology will be discussed.

HL 18.3 Tue 11:15 H13

Plasmon hybridization in stacked cut-wire metamaterials near metal films — •na liu[1], hongcang guo[1], liwei fu[1], heinz Schweizer[1], stefan kaiser[2], and harald giessen[1] — [1]4. Physikalisches Institut,Universitaet Stuttgart, Pfaffenwaldring 57, 70500, stuttgart, Germany — [2]1. Physikalisches Institut,Universitaet Stuttgart, Pfaffenwaldring 57, 70500, stuttgart, Germany

Abstract: We introduce a simple and convenient method to stack artificial units for metamaterials in the third dimension. Cut-wires and cut-wire pairs are placed above a metal film so that image cut-wires or cut-wire pairs are induced by the metal mirror when illuminated by light [1], which is equivalent to stacking two or four layers of cut-wires. The optical properties of cut-wires and cut-wire pairs above metal mirrors are investigated experimentally and numerically. The resonant plasmon modes are interpreted utilizing directly stacked cut-wire structures according to the method of plasmon hybridization [2]. Furthermore, the frequencies of different plasmon modes as a function of cut-wire separation are explored numerically. This method should pave the road towards a fundamental understanding of the electronic and optical properties of 3D metamaterials.

[1] V. A. Podolskiy, A. K. Sarchev, and V. M. Shalaev, Opt. Express 2003, 11, 735. [2] E. Prodan, C. Radloff, N. J. Halas, and P. Norlander, Science 2003, 302, 419.

HL 18.4 Tue 11:30 H13

Wasserstoffsensor auf Basis metallischer photonischer Kristalle — •Regina Orzekowsky, Andreas Seidel und Harald Giessen — 4. Physikalisches Institut, Universität Stuttgart, Germany

Aus Sicherheitsgründen sind günstige Wasserstoffsensoren Voraussetzung für die marktreife Umsetzung von wasserstoffbetriebenen Fahrzeugen oder elektronischen Geräten. Bisher sind Wasserstoffsensoren sehr teuer und benötigen elektrische Leitungen in einer potentiell explosionsgefährdeten Umgebung. Wir stellen einen optischen Wasserstoffsensor auf Basis eines metallischen oder dielektrischen photonischen Kristalls vor. Wir verwenden dabei eine Wolfram-Trioxid-Wellenleiterschicht unter einem Gitter aus metallischen oder dielektrischen Nanodrähten. Die Nanostrukturen werden mit Interferenzlithographie oder Elektronenstrahllithographie hergestellt. Die optischen Eigenschaften der Wellenleiterschicht und somit die Polaritonresonanzen des metallischen photonischen Kristalls werden durch den gasochromen Effekt verändert. Das Detektionsprinzip wird erklärt und die Funktionsweise des Wasserstoffsensors experimentell nachgewiesen. Da unser Detektionsprinzip auf einem optischen Effekt beruht, kann das sensitive Element von der Elektronik isoliert und dadurch sicherer werden. Wir erwarten, daß dieser Sensor sowohl billiger in der Herstellung als herkömmliche Wasserstoffsensoren sein wird, als auch gleichzeitig robust, klein und wiederverwendbar.

HL 18.5 Tue 11:45 H13

Fabrication of silicon inverse woodpile photonic crystals — •Martin Hermatschweiler[1], Martin Wegener[1,2], Geoffrey Allen Ozin[3], Alexandra Ledermann[2], and Georg von Freymann[2] — [1]DFG-Center for Functional Nanostructures (CFN) and Institut für Angewandte Physik, Universität Karlsruhe (TH), 76131 Karlsruhe — [2]Institut für Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft, 76021 Karlsruhe — [3]Department of Chemistry, University of Toronto, Toronto, Ontario M5S 3H6, Canada

We fabricate silicon inverse woodpile structures for the first time. Direct laser writing of polymeric templates and a novel silicon-single-inversion procedure [1] lead to structures with gap/midgap ratios of 14.2% centered at 2.5 μm wavelength.

First, polymer templates are fabricated by direct laser writing or other means. Next, we deposit a thin silica coating via atomic layer deposition (ALD) on the polymer and - without removing the polymer - infiltrate the composite structure with Si via Si chemical vapor deposition (CVD). The silica shell provides sufficient and reliable stabilization for the high temperature CVD process. Finally, the silica is etched out and the polymer is calcined in air, leading to a Si inverse woodpile structure. Optical measurements and comparison to band-structure and scattering-matrix calculations reveal a gap/midgap ratio of 14.2% centered at 2.5 μm. An optimized structure could open a band gap with a gap/midgap ratio of up to 20.5%.

[1] M. Hermatschweiler et al., submitted (2006).

HL 18.6 Tue 12:00 H13

Strong Circular Dichroism from Chiral 3D Photonic Crystals — •Michael Thiel[1], Manuel Decker[2], Martin Wegener[1], Stefan Linden[2], and Georg v. Freymann[2] — [1]Institut für Angewandte Physik, Universität Karlsruhe (TH), Wolfgang-Gaede-Straße 1, D-76131 Karlsruhe — [2]Institut für Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft, D-76021 Karlsruhe

Chiral photonic crystals allow for photonic stop bands for circularly polarized light connected with pronounced circular dichroism[1] which can potentially be used for applications, e.g., as compact *thin-film* optical diodes[2]. We have fabricated high-quality polymeric 3D spiral photonic crystals[3] via direct laser writing[4]. The measured transmittance spectra of these low-index contrast structures reveal spectral regions where the transmittance is below 5 % for one circular polarization and larger than 95 % for the other – for just eight lattice constants along the propagation direction[1]. These polarization stop bands occur if the pitch of the light spiral matches the pitch of the dielectric spiral. As expected from the symmetry, the transmittance spectra are closely similar if both the sense of rotation of the dielectric spirals and that of the incident light field are changed simultaneously. Our experimental results agree well with theory. Additionally, we present a novel chiral 3D layer-by-layer structure as an alternative to the discussed circular dichroitic 3D spiral photonic crystals.

[1]*M. Thiel et. al., Adv. Mater., in press (2006). [2]*J. Hwang et. al., Nature Mater., 4, 383 (2005). [3]*K. K. Seet et. al., Adv. Mater., 17, 541 (2005). [4]*M. Deubel et. al., Nature Mater., 3, 444 (2004).

HL 18.7 Tue 12:15 H13

Silicon-based Photonic Crystal Gas Sensors — •Stefan Schweizer[1], Torsten Geppert[1], Andreas von Rhein[1], Susanne Hartwig[2], Jürgen Wöllenstein[2], Armin Lambrecht[2], and Ralf Wehrspohn[1] — [1]Institut für Physik, Universität Halle-Wittenberg, 06099 Halle — [2]Fraunhofer Institut Physikalische Messtechnik, Heidenhofstr. 8, 79110 Freiburg

The bandstructure of photonic crystals offers intriguing possibilities for the manipulation of electromagnetic waves. We suggest utilization of photonic crystals as an optical sensor in the infrared spectral region for qualitative and quantitative gas analysis. Taking advantage of the low group velocity and certain mode distributions for some k-points in the bandstructure of a photonic crystal should enable the realization of very compact sensor devices for mobile applications. We prepared sensing elements based on macroporous silicon photonic crystals consisting of up to 1000 of pore rows and measured the transmission with and without gas through the porous sensing element. We observed an enhancement in sensitivity of about 3 to 4 compared to a gas cell without a photonic crystal. Limitations of this technology being based on low group velocity modes inside photonic crystals are discussed.

HL 18.8 Tue 12:30 H13

GaAs pyramids as alternative micro-cavities — •Matthias Karl[1], Frank M. Weber[1], Jaime Lupaca-Schomber[1], Wolfgang Löffler[1], Shunfeng Li[1], Thorsten Passow[1], Jacques Hawecker[2], Dagmar Gerthsen[2], Heinz Kalt[1], and Michael Hetterich[1] — [1]Institut für Angewandte Physik and Center for Functional Nanostructures (CFN), Universität Karlsruhe (TH), 76128 Karlsruhe, Germany — [2]Laboratorium für Elektronenmikroskopie and CFN, Universität Karlsruhe (TH), 76128 Karlsruhe, Germany

Pyramidal resonators are promising optical micro-cavities since they have great potential as small-mode volume resonators to enhance light-matter interaction.

Our resonators are fabricated from a molecular-beam epitaxy-grown layer structure containing an AlAs/GaAs distributed Bragg reflector as the bottom mirror. The pyramidal resonators on top are achieved by a combination of electron-beam lithography and wet chemical etching utilizing an AlAs sacrificial layer. The pyramids contain In(Ga)As quantum dots which – excited by a 532 nm cw laser – serve as a broad-band light source in the spectral range from 900 nm to 1000 nm. Optical cavity modes in these pyramids are identified and investigated using temperature-dependent measurements in a confocal micro-photoluminescence set-up.