the electronic states at the interface are of special interest. We present ab initio calculations of ZnO/ZnS interfaces in wurzite structure for different boundary conditions based on a pseudopotential method. We calculate the equilibrium positions of the atoms at the interface and the coupling between them.(SPP 1386)

DS 9.49 Mon 15:00 Poster D1

Thermoelectric properties of silicon nano pillars — •Andrej Stranz, Ünsal Sökmen, Andreas Waag, and Erwin Peiner — Institute of Semiconductor Technology, Braunschweig, Germany

In order to establish silicon as a efficient thermoelectric material, its high thermal conductivity has to be reduced which is feasible, e.g., by nano structuring. Therefore, in this study Si-based sub-micron pillars of various dimensions were investigated. Using anisotropic etching followed by thermal oxidation we could fabricate pillars of diameters $<$ 500 nm, about 25 *m in height with aspect ratios of more than 50. The distance between the pillars was varied from 500 nm to 10 micron. Besides the fabrication and structural characterization of sub-micron silicon pillars, and adequate metrology for measuring their thermoelectric properties was implemented. Commercial tungsten probes and self-made gold probes, as well as Wollaston wire probes were used for electrical and thermal conductivity, as well as Seebeck voltage measurements on single pillars in a scanning electron microscope equipped with nano manipulators.

DS 9.50 Mon 15:00 Poster D1

Thermoelectric properties of hot wall deposited thin SnS films — •Dzianis M. Unuchak[1], Vasil A. Ivanov[2], Valeriy F. Gremenok[2], and Klaus Bente[1] — [1]Institut für Mineralogie, Kristallographie und Materialwissenschaft, Universität Leipzig, Scharnhorststr. 20, 04275 Leipzig, Germany — [2]State Scientific and Production Association "Scientific-Practical Materials Research Centre of the National Academy of Sciences of Belarus", P. Brovka str., 19, 220072 Minsk, Belarus

Polycrystalline ingots of SnS was directly synthesized from a stoichiometric mixture of 99.999 % purity Sn and S in a vacuum-sealed quartz ampoule. Thin SnS films were deposited by hot wall technique on glass and molybdenum substrates under an ambient pressure of 5*10^{-6} mbar. The elemental composition of the obtained films was determined to be stoichiometric (SEM-EDX). The crystal structure and crystalline phases of the samples were studied by X-ray diffraction (Siemens D-5000 diffractometer with CuK_α radiation). The obtained films were polycrystalline, monophase in nature and had orthorhombic crystal structure. The films on glass were highly oriented along (001) plane whereas films on molybdenum showed SnS phase with different orientation. The as-prepared films show *p*-type electrical conductivity confirmed by the thermoelectric probe measurement. The value of Seebeck coefficient was about 1000 and 400 μV/K for films on glass and Mo, respectively.

DS 9.51 Mon 15:00 Poster D1

Properties of thin films and bulk of $Pb_{1-x}Sn_{1+x}X_2$ (X=S, Se) mixed crystals — •Vera Lazenka[1], Klaus Bente[1], and Valery Gremenok[2] — [1]Institut für Mineralogie, Kristallographie und Materialwissenschaft, Universität Leipzig, Scharnhorststr. 20, 04275 Leipzig, Germany — [2]State Scientific and Production Association "Scientific-Practical Materials Research Centre of the National Academy of Sciences of Belarus", P. Brovka str., 19, 220072 Minsk, Belarus

Mixed crystals of the galena-herzenbergite-system implying intermediate $PbSnS_2$ are perspective for thermoelectric, photovoltaic etc. materials. In addition to the Pb-Sn-substitution the replacement of S by Se and Te is studied, taking in account that thermoelectrical properties of e.g. PbX are improved by the substitution of S for Se and Te. The work aims to investigate the effect of anionic and metal atom substitutions in SnX - $PbSnX_2$ on structure and optical and electrical properties. For target synthesis Sn, Pb, S and Se (99.998 %) were reacted in vacuum-sealed quartz ampoules. Because of the thermoelectrical properties improvement caused by metal impurities in galena, also natural PbS is used. Thin films were prepared from powder material by hot wall evaporation method at 7*10^{-6} mbar on glass substrates at 200-350 °C. $Pb_{1-x}Sn_{1+x}X_2$ (X=S, Se) characterized by XRD and EPMA and effects of Pb-Sn and S-Se ratios on the thermopower are presented.

DS 9.52 Mon 15:00 Poster D1

Thermoelectric properties of ball-milled and subsequent short-term sintered $In_xCo_4Sb_{12}$ skutterudites — •Andreas Sesselmann, Ralf Hassdorf, Lothar Böttcher, Christian Stiewe, Andreas Schmitz, and Eckard Müller — German Aerospace Center (DLR), Institute of Materials Research, 51170 Cologne, Germany

For more than a decade, $CoSb_3$ has been widely studied as a promising thermoelectric (TE) material at intermediate temperatures. High thermoelectric figure of merit (ZT) in this material system can be achieved by filling guest atoms known as rattlers. One of the best improvements in ZT is reported when In is used as a filler atom leading to a ZT_{max} of about 1.2 at 575 K [1]. Another approach to lower the lattice thermal conductivity is by nano-structuring which leads to increased phonon scattering at the grain boundaries. The approach in this study is based on planetary ball milling, which allows for grain sizes on the nanometer scale and subsequent compaction by short-term sintering in favour of grain growth confinement. Phase homogeneity of the bulk material has been probed by XRD and EDX. TE properties (i.e. electrical conductivity, Seebeck coefficient, thermal conductivity) have been analyzed in the temperature range from 300 K to 700 K. The functional homogeneity of the samples was checked by Potential-Seebeck Microprobe (PSM). Based on these results, the combined effect of In filling and nano-structuring on the TE properties will be discussed.
[1] T. He *et al.*, Chemistry of Materials, 2006, 18, 759-762

DS 9.53 Mon 15:00 Poster D1

Complex Chalcogenides for Thermoelectrics: Microstructural-Property Relationship — •Susanne Perlt and Thomas Höche — Leibniz Institute of Surface Modification, Permoserstrasse 15, D-04318 Leipzig, Germany

The quaternary compound $AgPb_{18}SbTe_{20}$ (LAST) is a typical high-temperature thermoelectric material. The manufactoring process needs to be controlled in such a way, that the figure of merit, ZT [1], gets maximized. In this respect, a high electronic conductivity σ, a high thermopower S, and a low thermal conductivity κ are crucial. The high thermoelectric performance of LAST is assumed to be caused by the nanoscale precipitates formed by spinodal decomposition [2]. Based on properties monitored by a Seebeck probe, structure-property relationships are studied by SEM and TEM analysis. Site-specific lift-out of TEM lamellae from thermoelectrically characterised samples is made by focused ion beam (FIB) machining. Composition analyses, phase analyses (via electron diffraction) and element distributions are done by energy-dispersive X-ray spectrometry.
[1] D. Bilc et al., Phys. Rev. Lett. **93**, 146403 (2004)
[2] M.-K. Han et al., Chem. Mater. **20**, 3512 (2008)

DS 10: Plasmonics and Nanophotonics I (Joint Session DS/O/HL)

Time: Tuesday 10:30–13:00 Location: H2

DS 10.1 Tue 10:30 H2

Electrochemically tunable photonic metamaterial — •Lihua Shao, Stefan Linden, Matthias Ruther, Jörg Weissmüller, and Martin Wegener — Institut für Nanotechnologie and DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

We report experiments to combine two approaches for designing functional nanomaterials. Photonic metamaterials provide a strategy for obtaining unconventional optical response - in the extreme, negative refractive indices - by lithographically structured elements like arrays of split-ring resonators (SRR). Nanomaterials with tunable electronic structure exploit large specific surface area of metal nanostructures to tune the surface properties through the controlled space-charge regions for tuning macroscopic properties. The combination is a photonic metamaterial in which the space-charge at the surface of SRR is controlled via an applied potential, leading to a tunable optical resonance. We report first results support this concept. SRR structures with resonance frequencies in the near infrared are immersed into aqueous electrolytes as working electrode in an electrochemical experiment.

Varying the electrode potential, E, induces a space-charge layer at the metal surface as part of the electrochemical double-layer. We find the resonance frequencies vary linearly, reversibly, and reproducibly with E, with a blue shift for negative potential. A tentative explanation is based on the effective thickening of the SRR by the excess electrons, which changes the SRR aspect ratio. The observation of larger frequency shift for thinner SRR's is compatible with this scenario.

DS 10.2 Tue 10:45 H2

Mixing colours like nature — •Mathias Kolle, Maik Scherer, Pedro Cunha, Fumin Huang, Jeremy Baumberg, and Ullrich Steiner — Cavendish Laboratories, University of Cambridge, UK

Biomimetic attempts to produce novel photonic structures have attracted increasing research interest in recent years. Nature offers us an enormous amount of multifunctional micro- and nanostructures, that provide outstanding, distinctive, dynamic and tailored colouration. A "brilliant" example is the indonesian butterfly *papilio blumei*, whose wing scales are covered with 5-10μm wide concavities, that are cladded with a perforated cuticle multilayer. The regularly shaped multilayer structure gives rise to very impressive colour mixing effects, accompanied by controlled change in light polarisation.

We have successfully replicated the intricate photonic structure of *papilio blumei* on the cm^2-scale in four simple steps involving colloidal templating, electrochemical growth and atomic layer deposition. A small conceptual modification of the original photonic structure leads to a completely different optical effect. Any freely chosen colour and its complementary hue can be separated and reflected into different directions while conserving a particular polarisation effect.

Since the procedures are easily up-scaleable, these biomimetic photonic structures have a huge potential for industrial applications in security printing, encoding of information, non-emissive display technology and other fields where distinct colours play an important role.

DS 10.3 Tue 11:00 H2

Optical properties of carpets of randomly grown silicon nanowires on glass — •Gerald Brönstrup and Silke Christiansen — Institut für Photonische Technologien e.V., Abt. Halbleiter-Nanostrukturen, 07745 Jena

Silicon Nanowires [SiNWs] have attracted much attention in the recent years as possible future building blocks for field effect transistors, sensors, photo detectors and solar cells. For the latter SiNWs grown on a cheap substrate like glass is of special interest. To build solar cells with high efficiencies a high absorption is mandatory. We present a study of the influence of the diameter on the reflection, transmission and absorption spectra of carpet like assembly of SiNWs grown on glass.

We grew SiNWs on glass using gold colloids of different fixed diameters to achieve a control over the diameter of the SiNWs. Then we measured the reflection R and transmission T using an integrating sphere. The absorption A was calculated using the simple formula A=1-T-R.

For a better understanding of the underlying physics of the absorption happening in SiNWs with diameters much smaller than the wavelength of the visible light we present a statistical model based on scattering cross sections calculated for single SiNWs using Mie-theory.

DS 10.4 Tue 11:15 H2

Suppressed transmission through ultrathin metal films by subwavelength hole arrays — •Julia Braun[1], Bruno Gompf[1], Uwe Huebner[2], and Martin Dressel[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart — [2]IPHT Jena, Albert-Einstein-Straße 9, 07745 Jena

If an opaque metal film is periodically perforated by tiny subwavelength holes, extraordinary high transmission is observed [1]. We investigate the transmission through subwavelength hole arrays (SWHA) in ultrathin semitransparent Au films with various periodicities and hole diameters and observe the opposite behavior: less light is transmitted through the pierced metal compared to the closed film. The samples were fabricated by optical interference and electron beam lithography in 12 nm and 20 nm thick Au films with periodicities between 250 nm and 400 nm, and than characterized in the frequency range 4400 cm^{-1} to 37000 cm^{-1} (0.6 eV to 4.6 eV). The optical properties of SWHA cannot be explained by a pure dielectric function, but show a strong $\vec{k}$-dependent behavior. In ultrathin Au films it is marked by the excitation of strongly damped antisymmetric short range surface plasmons. The obtained dispersion curves perfectly agree with this explanation when the altered dielectric function of the ultrathin Au films is taken into account [2].

[1] T.W. Ebessen, H.J. Lezec, H.F. Ghaemi, T. Thio, and P.A. Wolff, *Nature* **391**, 667 (1998).

[2] J. Braun, B. Gompf, G. Kobiela, M. Dressel, *Physical Review Letters* **103**, 203901 (2009)

DS 10.5 Tue 11:30 H2

Manipulation of fluorescence resonance energy transfer in single plasmonic nanoresonators — •Valerie Faessler, Calin Hrelescu, Sergiy Mayilo, Frank Jäckel, and Jochen Feldmann — Photonics and Optoelectronics Group, Department of Physics and Center for Nano Science (CeNS), Ludwig-Maximilians-Universität München, Amalienstrasse 54, 80799 München, Germany;

We show that fluorescence resonance energy transfer (FRET) between two organic chromophores can be manipulated in plasmonic nanoresonators consisting of two spherical gold nanoparticles.The nanoresonators can be tuned by varying the inter-particle distance or the nanoparticle size. This allows us to selectively modify the decay channels of the chromophores. FRET can be supressed if the molecules are placed in the nanoresonator at a certain distance from the nanoparticle surface. Furthemore we observe spectral shaping and intensity modulation of the fluorophore emision in the nanoresonators [1]. Correlated whitelight Rayleigh scattering and fluorescence microscopy data of the hybrid system are discussed in the framework of generalized Mie theory.

[1] M. Ringler, A. Schwemer, M. Wunderlich, A. Nichtl, K. Kürzinger, T. A. Klar, J. Feldmann Phys. Rev. Lett., 100, 203002 (2008)

DS 10.6 Tue 11:45 H2

Optical antenna thermal emitters — •Jon Schuller[1], Thomas Taubner[1,2], and Mark Brongersma[1] — [1]Stanford University, Stanford, CA, USA — [2]1. Physikalisches Institut, RWTH Aachen, Germany

Optical antennas are a critical component in nanophotonics research[1] and have been used to enhance nonlinear and Raman cross-sections and to make nanoscale optical probes [2]. In addition to their receiving properties, optical antennas can operate in broadcasting mode, and have been used to modify the emission rate[3] and direction [4] of individual molecules.

In these applications the antenna must operate at frequencies given by existing light emitters. Using thermal excitation of optical antennas, we bypass this limitation and realize emitters at infrared frequencies where sources are less readily available [5].

Specifically, we show that the thermal emission from a single SiC whisker antenna is attributable to well-defined, size- tunable Mie resonances. Furthermore, we derive a fundamental limit on the antenna emittance and argue theoretically that these structures are nearly ideal black-body antennas.

1. Schuck, P. J. et al., PRL 94, 017402 (2005).
2. Farahani, J. N., et al., PRL 95, 017402 (2005).
3. Kuhn, S., et al., PRL 97, 017402 (2006).
4. Taminiau, T. H., et al, Nature Photon. 2, 234-237 (2008).
5. Schuller, J.A. et al., Nature Photon. 3, 658-661 (2009).

DS 10.7 Tue 12:00 H2

Spatial Resolved Near Field Interference on Nanooptical Bowtie Antennas — •Pascal Melchior, Daniela Bayer, Christian Schneider, Martin Rohmer, Alexander Fischer, and Martin Aeschlimann — Fachbereich Physik and Research Center OPTIMAS, Technische Universität Kaiserslautern, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern, Germany

The response of metallic nanostructures is responsible for interference effects of the electric near field in the vicinity of the structure surface. While the incoming electric field vectors are independent in the far field, spectral interference in the near field can occur since the resulting field vectors are not necessarily perpendicular. On the nanostructure configuration of a Bowtie antenna, we show how the superposition of different plasmonic excitation modes leads to a local enhancement of the effective near field depending on the phase relation between the incoming electric field vectors. Via an interferometric superposition of two laser pulses with cross polarized electric fields the near field interference can be directly observed by means of a photoemission electron microscope (PEEM). Spatial switching of the photoemission yield depending on the relative phase between the two superposed laser pulses will be demonstrated.

DS 10.8 Tue 12:15 H2