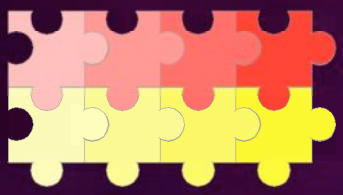
UNIVERSITÄT DUISBURG ESSEN

2nd International Workshop on Semiconducting Nanoparticles

CeNIDE
CENTER FOR NANOINTEGRATION DUISBURG-ESSEN



Photovoltaics and Optoelectronics

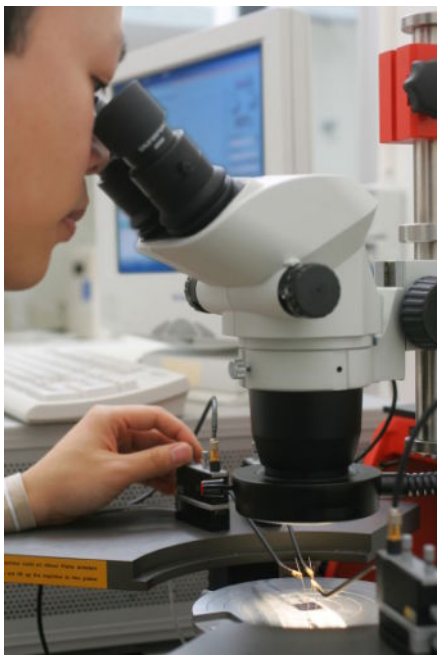
Deutsche Forschungsgemeinschaft
DFG

Duisburg, Germany

December 10th to 12th 2008

Evonik Industries AG
Creavis Technologies & Innovation

Evonik Industries ist der kreative Industriekonzern aus Deutschland mit den Geschäftsfeldern Chemie, Energie und Immobilien. Als strategische Forschungs- und Entwicklungseinheit des Geschäftsfelds Chemie von Evonik Industries hat die Creavis Technologies & Innovation den Auftrag, neue, nachhaltige Geschäfte für Evonik aufzubauen und zukunftsweisende Technologieplattformen zu entwickeln. Die Arbeit der Creavis konzentriert sich dabei auf neue Technologien, Anwendungen und Systemlösungen für Zukunftsmärkte, die überdurchschnittliche Wachstumsraten versprechen. Forschungsthemen, die völlig neue Gebiete für Evonik darstellen, werden in den Science-to-Business Centern (S2B Center) der Creavis bearbeitet. Das Konzept dieser Center beruht auf der Integration aller F&E-Aktivitäten entlang der Wertschöpfungskette unter einem Dach – von der Grundlagenforschung über die Produktentwicklung bis hin zur Pilotproduktion. Ziel ist die schnelle Entwicklung neuer Geschäfte bis hin zur Produktion fertiger Systeme für den Endanwender. Dazu unterhält Creavis zahlreiche Kooperationen mit Hochschulen und Forschungsinstituten sowie kleinen und mittelständischen Unternehmen. Als einen Schritt hin zu Systemlösungen für die Elektronikindustrie hat Evonik im Jahr 2005 in Marl das Science-to-Business Center Nanotronics mit dem Schwerpunkt auf der Integration von Nanotechnologie und Elektronik eröffnet. Ziel der Forschung ist es, auf Nanomaterialien basierende neue Systemlösungen für die Elektronikindustrie zu entwickeln. Das Projekt „Druckbare Elektronik“ des S2B Centers Nanotronics entwickelt mit druckbaren leitenden und halbleitenden Materialien die technischen Voraussetzungen für zukünftige Anwendungsmöglichkeiten in der Elektronik. Ziel ist die Bereitstellung eines Produktportfolios für die kostengünstige gedruckte Elektronik. Projekte des Science-to-Business Center Nanotronics werden vom Land Nordrhein-Westfalen gefördert und von der Europäischen Union kofinanziert.



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Chairmen:

Markus Winterer and Gerd Bacher

Local Organizing Committee:

Markus Winterer, Udo Dörfler, Gerd Bacher, Peter Entel, Dieter Jäger, Tilmar Kümmell, Axel Lorke, Hartmut Wiggers, Dietrich Wolf

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date	time	topic	speaker	title	chair
Wednesday, 10.12.					
	08:00	registration			
	08:45	Welcome	**Prorektor Michael Farle**	*Welcome*	Winterer
	09:00	invited lecture p. 2	**Jochen Feldmann (LMU München)**	*Semiconductor Nanocrystals as Building Blocks in Hybrid Nanosystems*	Bacher
	09:45	coffee break			
	10:15	invited lecture p. 4	**Jörg Amelung (IPMS Dresden)**	*Large area OLED lighting and organic solar cell fabrication*	Winterer
	11:00	short oral contribution p. 6	**Ludger Weisser (Atomic Force Mannheim)**	*Advanced Local Probe Techniques for Electro-Optical Characterization*	Winterer
	11:20	short oral contribution p. 8	**Peter Gnauck (Zeiss Oberkochen)**	*CrossBeam: A tool for high resolution investigation of Nanostrucutres*	Winterer
	11:40	lunch break			
	13:00	invited lecture p. 10	**Oliver Hayden (Siemens Erlangen)**	*Near-Infrared Imaging with Quantum Dot Sensitized Organic Photodiodes*	Wolf
	13:45	invited lecture p. 12	**Juan Carlos Cuevas (U Madrid)**	*Electronic and thermal transport in single-molecule junctions*	Wolf
	14:30	coffee break			
	15:00	invited lecture p. 14	**Konstantin Efetov (U Bochum)**	*Coulomb blockade and transport in granular metals*	Entel
	15:45	short oral contribution p. 16	**Matias Zilly (U Duisburg-Essen)**	*Statistical model for the effects of dephasing on transport properties of large samples*	Entel
	16:05	short oral contribution p. 18	**Sanjeev Kumar Nayak (U Duisburg-Essen)**	*Theoretical perspective of magnetism in Co doped ZnO*	Entel
	16:25	invited lecture p. 20	**Dietmar Borchert (Fraunhofer ISE Gelsenkirchen)**	*Thin films used in solar cell technology*	Entel
	17:10 - 19:00	**poster session / snack**			

date	time	topic	speaker	title	chair
Thursday, 11.12.					
	08:00	registration			
	08:45	invited lecture p. 22	**Mark Swihart** **(U Buffalo)**	*Photoluminescent Silicon Nanocrystals: Aerosol Synthesis, Functionalization, and Applications*	Schmechel
	09:30	coffee break			
	10:00	invited lecture p. 24	**Wayne Gladfelter** **(U Minnesota)**	*Synthesis, Characterization and Surfactant Bonding of Monodispersed Zinc Oxide Nanocrystals*	Schmechel
	10:45	oral contribution p. 26	**Norman Mechau** **(FZ Karlsruhe)**	*Effect of the interface roughness on the performance of nanoparticulate Zinc Oxide FETs*	Schmechel
	11:30	short oral contribution p. 28	**Simon Bubel** **(FZ Karlsruhe)**	*Changes in FET Mobility Due to the Amount of Stabilizer in Nano-Particulate ZnO Transistors*	Schmechel
	11:50	lunch break			
	13:00	**informal labtours to be arranged individually**			
	14:30	invited lecture p. 30	**Lubomir Spanhel** **(U Rennes)**	*Sol-Gel Derived $Zn_xTi_yO_z$ Nanostructures for Solar and Photonic Technologies*	Tegude
	15:15	short oral contribution p. 32	**Ruzica Djenadic** **(U Duisburg-Essen)**	*Chemical Vapor Synthesis and Characterization of Co-doped ZnO nanoparticles*	Tegude
	15:35	short oral contribution p. 34	**Moazzam Ali** **(U Duisburg-Essen)**	*ZnO nanocrystals in solid phase: Surprisingly alive*	Tegude
	15:55	coffee break			
	16:30	invited lecture p. 36	**Uwe Rau** **(FZ Jülich)**	*Perspectives of nano-technology in photovoltaics*	Jäger
	17:15	short oral contribution p. 38	**Anoop Gupta** **(U Duisburg-Essen)**	*Influence of etching and surface functionalization on the visible photoluminescence of Si-NCs*	Jäger
	17:35	short oral contribution p. 40	**Vinit Sharma** **(Agrawal College)**	*Unusual electronic properties of InN*	Jäger
	17:55 - 19:30	**poster session / snack**			

date	time	topic	speaker	title	chair
Friday, 12.12.					
	08:00	registration			
	08:45	invited lecture p. 42	**Zahid Durrani** **(Imperial College London)**	*Electron conduction and charging effects in silicon nanocrystals*	Lorke
	09:30	coffee break			
	10:00	invited lecture p. 44	**Shunri Oda** **(Tokyo Institute of Technology)**	*Electron transport and photonic properties of Si nanocrystals prepared by VHF plasma processes*	Lorke
	10:45	invited lecture p. 46	**Hartmut Wiggers** **(U Duisburg-Essen)**	*Functional structures based on semiconducting silicon nanoparticles*	Lorke
	11:30	lunch break			
	12:45	invited lecture p. 48	**Knut Deppert** **(U Lund)**	*Aerosol nanoparticle for the creation of innovative nanostructures*	Wiggers
	13:30	invited lecture p. 50	**Bernd Günther** **(Fraunhofer IFAM Bremen)**	*Nanoparticle Synthesis by Sputtering Methods*	Wiggers
	14:15	coffee break			
	14:45	invited lecture p. 52	**Wolfgang Peukert** **(U Erlangen-Nürnberg)**	*Linear and non-linear optical analysis of early stages of particle formation: a case study for ZnO*	Kümmell
	15:30	invited lecture p. 54	**Andreas Klein** **(TU Darmstadt)**	*Electronic Surface and Interface Properties of TCOs*	Kümmell
	16:15	short oral contribution p. 56	**Libo Ma** **(FSU Jena)**	*Photoluminescence study of Si_xGe_{1-x} nanocrystals fabricated by laser-induced pyrolisis*	Kümmell
	16:35	coffee break			
	17:05	invited lecture p. 58	**Tilmar Kümmell** **(U Duisburg-Essen)**	*All-inorganic light emitting devices based on ZnO nanoparticles with UV and white emission*	Prost
	17:50	invited lecture p. 60	**Klaus Attenkofer** **(Argonne NL)**	*Dynamics of dye/nano particle systems*	Prost
	18:35	**transfer to and dinner at Faktorei Duisburg (19:00 - open end)**			

Oral / Invited Presentations

Semiconductor Nanocrystals as Building Blocks in Hybrid Nanosystems

Jochen Feldmann

Photonics and Optoelectronics Group, Ludwig-Maximilians-Universität München, Germany

I will report on our efforts to utilize semiconductor nanocrystals for light harvesting and for separation of optically excited charge carriers. Cascaded energy transfer in nanocrystal heterolayers [1] as well as electrically controlled energy transfer in core-shell nanorods [2] will be addressed. Hybrid structures in combination with fullerenes [3] and type II aligned nanocrystal layers [4] show efficient charge separation and add to our understanding, whether semiconductor nanocrystals could be used in optoelectronic applications such as photovoltaics.

[1] T. Franzl, T. A. Klar, S. Schietinger, A. L. Rogach, and J. Feldmann, „Exciton Recycling in Graded Gap Nanocrystal Structures", Nano Letters **4**, 1599 (2004)

[2] K. Becker, J. M. Lupton, J. Müller, A. L. Rogach, D. V. Talapin, H. Weller, and J. Feldmann, „Electrical Control of Förster Energy Transfer", Nature Mat. **5**, 777 (2006)

[3] A. Biebersdorf, R. Dietmüller, A. Susha, A. Rogach, S. Poznyak, D. Talapin, H. Weller, T. Klar, and J. Feldmann, „Semiconductor Nanocrystals Photosensitize C60 Crystals", Nano Letters **6**, 1559-1563 (2006)

[4] D. Gross, A. S. Susha, T. A. Klar, E. Da Como, A. L. Rogach, and J. Feldmann, „Charge Separation in Type II Tunneling Structures of Close-packed CdTe and CdSe Nanocrystals", Nano Lett., **8**, 1482 (2008)

Notes

Large area OLED lighting and organic solar cell fabrication

Jörg Amelung

Fraunhofer IPMS Dresden, Germany

For a next generation of solid state light with high efficiency, low operating voltage and long life time, organic light emitting diodes (OLED) are promising candidates. The fabrication of large emission area OLEDs for lighting application at reasonable costs is essential to achieve a large market penetration. To reach this target an improved combination of fabrication principle and OLED device has to be established. Organic solar cells (OSC) are potential low cost alternatives for next generation solar cell technologies. Up to now organic solar cells are mainly investigated and prepared only in laboratory scale and areas. The fabrication principle is similar to OLED lighting, so both systems need highly efficient large area fabrication technology. Inside the talk some aspects for large area fabrication technology will be covered.
First all actual technologies are based on glass or other transparent substrate types covered by ITO (Indium-tin-Oxide). Based on the limiting conductivity of ITO improved current distribution aspects has to be developed to achieve homogeneous large area lighting. In the paper improved metal support line structures will be presented to achieve a large area lighting capability. Highly efficient large area white lighting modules with 25 lm/W efficacy and more than 120 cm^2 active area will be shown.
The cost for the OLED lighting fabrication has to be reduced drastically to achieve large market segments. ITO is the most common electrode material but the cost for ITO constantly rises over the last years. ZAO (aluminum doped zinc oxide) and PEDOT:PSS are candidates as an alternative transparent anode for OLEDs which is widely used because of its high conductivity and transparency in the visual range. In this work, the OLED devices with ZAO and PEDOT:PSS were prepared and the performance of the device were compared to ITO based OLEDs. Finally, up scaled white OLEDs on ZAO and PEDOT were successfully demonstrated on 10 x 10 cm^2 substrates.
For low cost large area production the structuring technique for the substrates has to be improved, both for OLED lighting and Organic solar cells. Printing techniques for the structuring are potential techniques to reduce the overall cost of fabrication. Inside the talk a process flow for such structuring technique will be shown and large area integration aspects will be discussed.

Notes

Advanced Local Probe Techniques for Electro-Optical Characterization

Ludger Weisser, S. Vinzelberg, M. Viani, R. Proksch, J. Cleveland

Atomic Force GmbH Mannheim , Germany

The ability to image, probe and manipulate nano-objects has brought the Scanning Probe Microscope into the lab of many nano-particle researchers. In addition to topographical information like size, shape and distribution of nano-particles the SPM can probe mechanical, electrical and magnetic properties of small objects thus helping to gain a more comprehensive understanding of nano-systems. Advanced experiments beyond simple imaging require superior positioning accuracy, control over contact forces and a very flexible control system with deep access to the instruments hard- and software. Some examples of advanced electrical probing experiments will be presented and the combination of SPM with optical techniques is discussed.
Recent development of a fast scanning, small cantilever SPM increases the dynamic range of SPM techniques into the MHz region without compromising ease of use, accuracy and flexibility.

Notes

CrossBeam: A tool for high resolution investigation of Nanostructures

Peter Gnauck

Carl Zeiss NTS Oberkochen, Germany

In recent years focused ion beam (FIB) systems were routinely used for site specific cross sectioning and sample preparation for the transmission electron microscope (TEM). A wide range of different materials such as metals, semiconductors, ceramics and even biological substances can be covered. By combining the technique of focused ion beam and field emission scanning electron microscopy FESEM into an integrated CrossBeam system the accuracy of TEM sample preparation and cross sectioning and nano-analytics is significantly extended.

In a standard FIB cross sectioning the sample surface is imaged with the FIB before cutting to determine the area of interest. After this the sample is milled and polished with predefined milling patterns. Without the possibility of monitoring the milling process directly the area of interest is easily destroyed.

The capability of CrossBeam tools to image the sample in real time at high resolution during the ion milling process gives the operator direct control to the ion milling process. This results in an interactive process that leads to an extended accuracy on site specific cross sections and three dimensional nano-analytics.

Notes

Near-Infrared Imaging with Quantum Dot Sensitized Organic Photodiodes

Oliver Hayden

Siemens AG Erlangen, Germany

Solution processable photodiodes with infrared sensitivities at wavelengths beyond the bandgap of silicon (corresponding to a wavelength of ~1100 nm) would be a significant advancement for cost-effective imaging. Colloidal quantum dots represent highly suitable infrared absorbers for photodetection, yet high quantum yields were only reported with photoconductors. For imaging, photodiodes are required to ensure low-power operation and compatibility to active matrix backplanes. Organic bulk-heterojunctions are attractive as solution processable diodes but limited to the visible spectrum.
Here, we report the fabrication and application of hybrid bulk-heterojunction photodiodes containing PbS nanocrystalline quantum dots as sensitizer for the near infrared. These diodes with rectification ratios >5000, having a minimum lifetime of one year, can be applied for infrared detection up to a wavelength of 1.8 μm, with external quantum efficiencies as high as 18%. By integration of the solution processed devices on amorphous silicon active matrix backplanes, we demonstrate for the first time near infrared imaging with organic/inorganic hybrid photodiodes at a wavelength of 1310 nm and a frame rate of 5 Hz. Furthermore, we observe low crosstalk between the pixels, which allows us to record infrared videos with a backplane-limited resolution of ~150 μm.

Notes

Electronic and thermal transport in single-molecule junctions

Juan Carlos Cuevas

Universidad Autonoma de Madrid, Spain

Recent advances in nanofabrication techniques have made possible to contact individual molecules between metallic electrodes and measure their electronic and thermal transport properties. This fact has triggered the hope that single molecules could be used as electronically active elements in a variety of applications. Apart from the potential technological relevance, the recent experimental achievements have posed a fundamental theoretical challenge, namely the understanding of the mechanisms that control the transport at the molecular scale.

In my talk, I will present our recent efforts to describe theoretically the transport through single-molecule junctions. Our work is based on the combination of ab initio quantum chemistry calculations and Green functions techniques. Such an approach allows us to elucidate the relation between the electronic structure of individual molecules and the conduction through the circuits in which they are embedded. This fact will be illustrated in my talk with the discussion of the following basic topics motivated by recent experiments: (i) High conductance of molecular junctions based on direct binding of benzene to platinum electrodes, (ii) the relation between molecular conformation and conductance in single-molecule contacts, (iii) thermoelectricity in molecular junctions and (iv) photoassisted transport in organic molecular wires.

Notes

Coulomb blockade and transport in granular metals

Konstantin Efetov

Ruhr-Universität Bochum, Germany

Transport properties of granular metals are discussed taking into account effects of Coulomb interaction and magnetic field. An important region of temperatures is identified where the behavior of the granular metals is drastically different from that of homogeneously disordered metals. In this region of not very low temperatures that can easily be reached experimentally the resistivity logarithmically depends on temperature in all dimensions of the array of the grains. Both the longitudinal and Hall resistivity are calculated. Although the longitudinal resistivity is very sensitive to intergrain tunneling, the Hall resistivity does not depend on this parameter giving a direct information about the carrier concentration and other quantities inside the grains.

Notes

Statistical model for the effects of dephasing on transport properties of large samples

Matias Zilly

Theoretical Physics, University of Duisburg-Essen, and Center for NanoIntegration Duisburg-Essen, CeNIDE, Germany

We present a statistical model for the effects of dephasing on the transport properties of large samples. The physical picture differs from earlier models which assume that dephasing happens uniformly throughout the sample, whereas we model the dephasing in a statistical sense, assuming a distribution of completely phase randomizing regions, between which the transport is coherent and described by the non-equilibrium Green's function method. In this way, the sample is effectively divided into smaller parts making the numerical treatment more efficient. As a first application, the conductances of ordered and disordered linear tight-binding chains are calculated and compared to the strong dephasing limit results of other phenomenological models in the literature.

Notes

Theoretical perspective of magnetism in Co doped ZnO

Sanjeev Kumar Nayak

Theoretical Physics, University of Duisburg-Essen, and Center for NanoIntegration Duisburg-Essen, CeNIDE, Germany

Transition metal (TM) doped binary semiconductors are of current interest for the light emitting properties; especially ZnO which is relatively easier to grow as thin-films and nano-particles and is economically viable. In addition to this, dilutely doped TM elements in ZnO is anticipated to give necessary ferromagnetism, along with the semiconducting properties, to successfully act as a diluted magnetic semiconductor (DMS). In experiments both ferromagnetism and no spontaneous magnetism is observed, making it difficult to conclude straightforwardly about any possible underlying mechanism for the magnetic properties in this system. From a combination of first-principles and Monte Carlo studies, we show that the absence of spontaneous magnetization is more probable for low doping concentrations of Co in ZnO.

Notes

Thin films used in solar cell technology

Dietmar Borchert

Fraunhofer ISE, Labor- und Servicecenter Gelsenkirchen, Auf der Reihe 2, 45884 Gelsenkirchen
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The conversion efficiency of crystalline or multicrystalline silicon solar cells mainly depends on the wafer material quality. Nevertheless nowadays it is possible to reach efficiencies up to 16% even with lower quality material. This is due to a much better understanding of the interaction of the solar cell production process with the material. It is possible to tune the material quality by some process steps. An important role in this process play multi functional silicon nitride films which are commonly used as antireflection layers. The introduction of these films led to a major increase in solar cell efficiencies.
Very thin amorphous silicon layer are used in so called heterojunction solar cells. These films are used to create an artificial pn-junction. At the same time they provide excellent surface passivation. The temperature during the whole manufacturing process remains below 250 °C and efficiencies about 20% can be achieved with this cell concept.

Notes

Photoluminescent Silicon Nanocrystals: Aerosol Synthesis, Functionalization, and Applications

Mark Swihart

University at Buffalo, USA

Photoluminescent silicon nanocrystals, or quantum dots (QDs) have great potential for use in applications ranging from low-cost flexible photovoltaics and light emitters to biological imaging and diagnostic applications, where they provide an attractive alternative to fluorescent organic dyes or potentially toxic heavy-metal-containing quantum dots. However, because of challenges related to the synthesis and surface modification of free-standing Si QDs, they have been much less studied than more easily prepared QDs of compound semiconductors such as CdSe. In all of their potential applications, stability and tunability of optical and electronic properties are important. In electronic device applications, transport of electrons and holes to and from the particles is also key, and the ability to incorporate dopants may be necessary. In biological systems, the QDs must remain stably dispersed in water and biological fluids, over a wide range of pH and salt concentration.

Meeting these requirements requires engineering both the crystalline silicon core and its interface with the surroundings. This talk will outline our efforts in developing scalable, economical methods of preparing and modifying Si QDs for such applications. This includes high-rate laser driven aerosol synthesis, solution phase etching and surface modification, and encapsulation of surface-modified nanocrystals within phospholipid micelles for bioimaging. We will also briefly introduce aerosol methods we are using to produce other semiconductor nanocrystals, including ZnS nanocrystals produced by spray pyrolysis.

Notes

Synthesis, Characterization and Surfactant Bonding of Monodispersed Zinc Oxide Nanocrystals

Wayne Gladfelter

University of Minnesota, USA

The overall energy conversion efficiency of solar cells depends on the combined efficiencies of light absorption, charge separation, charge and ion transport. Although zinc oxide is emerging as a potential semiconducting component in dye sensitized solar cells, there is less known about the factors controlling charge separation across the dye/ZnO interface. The lack of site homogeneity in binding dye molecules to TiO_2 films and nanoparticles (NPs) has been widely acknowledged as an impediment to extracting details about the electron transfer across the interface. The overarching goal of this research is to study the relationship between structure, energetics, and dynamics in a set of synthetically controlled donor-acceptor dyads and triads. Our approach begins with the construction of extremely well-defined dye-NP dyads that will be sufficiently dispersible to allow the use state of the art pulsed laser spectroscopic and kinetic methods to understand the charge transfer events at a fundamental level.

Monodispersed, spherical ZnO nanocrystals were synthesized from the reaction of an amide precursor, $[Zn(NiBu_2)_2]_2$, with hexylamine followed by exposure of the as-formed solution to an air flow maintained at constant humidity. The room temperature reactions led to 2.8-5.3 nm nanocrystals with the nanocrystal diameter exhibiting a linear increase as a function of humidity. Purification afforded free-flowing powders of nanocrystals that were dispersible in nonpolar or weakly polar solvents. The nanocrystals were characterized using elemental analysis, XRD, TEM, TGA, XPS, solution and solid-state NMR, IR , UV-Vis absorption and photoluminescence spectroscopies. The ZnO surfaces were protected by a combination of hexylamine and hexylcarbamate, $[CH_3(CH_2)_5NC(O)O]$-. The carbamate was derived from the reaction of hexylamine with atmospheric CO_2 and was bound to surface zinc ions as a bidentate ligand. The hexylamine was bound to the surface OH groups. The total number of surface molecules for a 3.7 nm nanocrystal was 200. Nanocrystals up to 7.3 nm in diameter were obtained by heating smaller nanocrystals in a mixture of hexylamine and toluene at 119°C. Preliminary studies of the excited state behavior of transition metal dyes bound the zinc oxide will be presented.

Notes

Effect of the interface roughness on the performance of nanoparticulate Zinc Oxide FETs

Norman Mechau

FZ Karlsruhe, Germany

Field-effect transistors (FETs) based on nanocrystalline zinc oxide (ZnO) have been attracting great interests for printable electronics. The FETs mostly work in the n-channel enhancement mode, which has rarely been accomplished by organic FETs. Furthermore, they can be fabricated in a solution spin coating process. Spin-coating suspension of nanocrystals has the advantage in terms of low temperature and high throughput processing, leading to low-cost and large-area device fabrications. However, the critical parameter of FETs fabricated from spin-coating nanocrystals is the interface roughness between the nanocrystalline semiconducting layer and insulating layer. Since the nanocrystalline semiconducting layer consists of nanocrystals and their agglomerates in the range of a few tens of nm, the roughness at the interface, where the channel of the FET is formed, has a significant influence on the FET characteristics. Therefore, nanoparticulate ZnO FETs are taken as a model system of nanocrystalline FETs, and the effect of the interface roughness on the field-effect mobility is investigated in conjunction with the film roughness and the capacitance analyses.
ZnO nanoparticles, produced by Evonik, Germany, were dispersed in 2-methoxyethanol with a small amount of copolymeric stabilizer, and were processed by ultrasonic treatments. The agglomerate sizes were changed by the duration of the process, so that the resulting films have different roughness at the interface to the insulating layer. The FETs in the bottom-gate configuration were fabricated from the suspensions, consisting of a lightly doped p-type Si substrate, a thermally grown SiO_2 layer of 200nm, a spin-coated nanoparticulate ZnO layer and Al top source and drain electrodes. The FET with the lowest average roughness of 47.4 nm showed the best mobility of 8.4x10-3 cm^2/Vs. In contrast, the FET with the highest roughness of 70.6 nm showed two orders of magnitude lower mobility of 8.7x10-5 cm^2/Vs. These results indicate that the roughness at the interface between a nanoparticulate layer and an insulating layer is a key parameter for the performance of nanoparticulate FETs.

Notes

Changes in FET Mobility Due to the Amount of Stabilizer in Nano-Particulate ZnO Transistors

Simon Bubel

FZ Karlsruhe, Germany

In order to build printable electrical devices, a semiconducting suspension which can be processed at low cost and low temperature is needed. From this perspective nano-particulate zinc oxide dispersions were used to build field-effect transistors. By the application of different fractions of a stabilizer to the dispersions, the influence on the morphological and the electrical properties of the prepared films was shown. The field-effect mobility of the nano-particulate ZnO layers could be altered for more than one order of magnitude by changing the stabilizer fraction from 3 to 13 weight percent.

Notes

Sol-Gel Derived ZnxTiyOz Nanostructures for Solar and Photonic Technologies

Ludomir Spanhel

Université de Rennes, France

Nanocolloidal sol-gel chemistry allows to elaborate nano-structured $Zn_xTi_yO_z$ films and to functionalize them with foreigner species such as nitride anions, rare-earth cations as well as metallic nanostructures. These coatings on glass can also be easily be micro-patterned employing RIBE techniques. We studied the resulting properties of xerogels and coatings in photo-catalytic experiments, optical spectroscopic investigations as well as structural and thermal analytical measurements. An overview about this recent work will be given.

Notes

Chemical Vapor Synthesis and Characterization of Co-doped ZnO nanoparticles

Ruzica Djenadic[1], T. Kammermeier[2], A. Ney[2], G. Akgul[3], K. Attenkofer[3], M. Winterer[1]

[1] Nanoparticle Process Technology, and Center for NanoIntegration Duisburg-Essen, CeNIDE, University of Duisburg-Essen, Germany
[2] Experimental Physics, and Center for NanoIntegration Duisburg-Essen, CeNIDE, University of Duisburg-Essen, Germany
[3] Advanced Photon Source, Argonne National Laboratory, USA

Co-doped ZnO nanoparticles with the different cobalt concentration were synthesized by chemical vapor synthesis (CVS). Solid anhydrous acetate precursors were evaporated using a laser flash evaporator [1], transported by the helium gas stream into the hot wall reactor where the precursor are decomposed and nanoparticles are formed at 20 mbar and 1100°C. The as-synthesized particles were separated from the gas stream by thermophoresis. The materials were structurally characterized by X-ray diffraction (XRD), ultraviolet-visible spectroscopy (UV-VIS), electron paramagnetic resonance spectroscopy (EPR), and extended X-ray absorption fine structure spectroscopy (EXAFS). Magnetic properties were investigated using a superconducting quantum interference device (SQUID). The Rietveld refinement of the XRD data shows that nanocrystalline, single phase wurtzite powders were synthesized. The crystallite size is increasing and the lattice constant ratio, *c/a*, is decreasing slightly with increasing cobalt concentration. EXAFS data analysis shows that zinc is successfully replaced by cobalt. However, no ferromagnetism is observed in as-synthesized Co-doped ZnO powders.

[1] M. Winterer, V. V. Srdic, R. Djenadic, A. Kompch, T. E. Weirich, *Rev. Sci. Instr.,* **78** (2007) 123093.

Notes

ZnO nanocrystals in solid phase: Surprisingly alive

Moazzam Ali, M. Winterer

Nanoparticle Process Technology, and Center for NanoIntegration Duisburg-Essen, CeNIDE, University Duisburg-Essen, Germany

Nanocrystalline ZnO has been a material of interest, commercially as well as for fundamental research, for last few decades. In order to materialize the specific properties of ZnO nanomaterials into practical applications, it has always been assumed that ZnO nanomaterials are inert towards surface oxidation. Contrary to general, but not fully substantiated, belief we show that the ZnO nanocrystals are very much active in ambient condition in solid phase. We observed that ZnO nanocrystals – synthesized by Chemical Vapor Synthesis in the size range of 10-20 nm – in powder form grow in presence of moisture at room temperature. The size of ZnO nanocrystal was determined by XRD and TEM at regular time intervals. In order to observe the influence of water vapor, ZnO nanocrystals were placed in different water vapor pressure and growths were recorded. We observed that the growth rate is directly influenced by water vapor pressure.

Notes

Perspectives of nano-technology in photovoltaics

Uwe Rau

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Nano-technology plays no role whatsoever within the basic concept of photovoltaics. Even present day high-efficiency solar cells contain no component that could be related to nano-technology. Nevertheless, nano-technological approaches are getting increasingly popular in the literature on advanced solar cell concepts. The reason for this trend is the possibility to overcome limitations of present-day photovoltaic bulk materials by the design possibilities offered by nano-technology. Thus, any nano-concept in photovoltaics should be looked at as an auxiliary tool to solve a specific and well-defined problem within the chain of photovoltaic actions of a solar cell. The contribution reviews and categorizes the perspectives of nano-technology in photovoltaics. The *first* category is given by nano-composites of different materials. These composites are often used as absorber materials for solar cells, like organic bulk heterojunction devices or dye-sensitized cells. Here the typical length scale is given by the diffusion length of photogenerated excitons which usually is of the order of 10 nm. The first step of charge separation in these devices is therefore necessary within this length scale. The *second* category of nano-concepts concerns the optics of solar cell where light trapping, or more generally light management, is enabled by structures that are in the order of the wavelength of the light in the specific medium. In this field spectrally and/or directionally selective filters are especially interesting. The *third* category comprises structure sizes enabling electronic quantum effects. These effects are, e.g., used to design photovoltaic materials with a desirable band gap that, within a given material system, cannot be achieved otherwise. In addition, electronic quantum effects have the possibility to avoid or to minimize losses by thermalization or transmission that are unavoidable when using bulk materials. The contribution will give examples for all three categories and discuss their potential.

Notes

Influence of etching and surface functionalization on the visible photoluminescence of Si-NCs

Anoop Gupta

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In this study, we have investigated the photoluminescence (PL) properties of silicon nanocrystals (Si-NCs) after etching and functionalization processes. The synthesis of Si-NCs was carried out in a low pressure microwave plasma reactor via pyrolysis of silane (SiH_4). The surface of Si-NCs was stain etched in a mixture of hydrofluoric acid (HF) and nitric acid (HNO_3). The etched Si-NCs show a continuous blue shift in the emission spectrum with increasing etching time. Hence, we were able to obtain the full visible spectrum of Si-NCs. We observed that the air oxidation of etched Si-NCs profoundly affects their optical property, which causes a blue shift in the emission spectrum and a diminished intensity. In order to stabilize their PL, surface functionalization of etched Si-NCs was endeavored with various alkenes using photoinitiated hydrosilylation technique. We observed that the emission spectrum of functionalized Si-NCs was shifted compared to that of etched Si-NCs. The nature of the shift (red/blue) is dependent on the size of the etched Si-NCs. Furthermore, we found that the amount of shift depends on the UV exposure time and the type of ligands on the surface of the Si-NCs.

Notes

Unusual electronic properties of InN

Vinit Sharma

Agrawal PG College, India

Electronic structure of zinc-blende and wurtzite InN using linear combination of atomic orbitals and the latest approach of generalised gradient approximation within full potential linearised augmented plane wave schemes is reported. An unusual small band gap and real space analysis of our first ever experimental Compton profile are discussed.

Notes

Electron conduction and charging effects in silicon nanocrystals

Zahid Durrani

Imperial College London, UK

Si nanocrystal films and one-dimensional nanochains of Si nanocrystals, prepared by material synthesis, provide a means to define nanometre-scale electronic devices using growth techniques. In principle, these nanostructures can form building blocks to assemble nanodevices in a 'bottom-up' approach, removing the need for high-resolution lithography. The electronic conduction process in these systems is influenced strongly by single-electron charging and quantum-confinement effects, and by the grain boundary regions between the nanocrystals. This paper discusses various conduction processes in Si nanocrystal materials, e.g. the thermionic emission of electrons across the grain boundaries, space charge limited current, hopping conduction, and the single-electron charging of nanocrystals isolated by tunnel barriers formed at the grain boundaries. The paper also discusses the fabrication of single-electron devices in Si nanocrystals. In particular, devices operating at room-temperature are considered, e.g. single-electron devices fabricated on single Si nanochains, where the single-electron charging energy ~ 0.32 eV ~$12k_BT$ at 300 K.

Notes

Electron transport and photonic properties of Si nanocrystals prepared by VHF plasma processes

Shunri Oda

Tokyo Institute of Technology, Japan

Quantum dot structures, where electrons are confined three-dimensionally in the sub-10 nm scale, show characteristics quite different from conventional bulk structures. Recent progress in the fabrication technology of silicon nanostructures has made possible observations of novel electrical and optical properties of silicon quantum dots, such as single electron tunneling, ballistic transport, visible photoluminescence and electron emission. Electron transport and photonic properties of silicon nanocrystals prepared by plasma processes will be presented with particular emphasis on the fabrication of monodispersed silicon nanocrystals, high-density assembly of silicon quantum dots. I will also discuss applications of silicon quantum dots to nanodot memory for future Tera bit non-volatile memory devices, and silicon photonic devices for future ULSI interconnections.

Notes

Functional structures based on semiconducting silicon nanoparticles

Hartmut Wiggers

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Nanoscale materials like nanoparticles, especially those who show specific, nanoscale-dependent properties, will capture the market with their ability to be incorporated into functional devices and structures. To provide such functional structures of nanoparticles, it is necessary to develop technologies which preserve the size and the specific characteristics of the nano-scaled materials and which also also able to yield devices with long-term stability with respect to their electronic, optical and mechanical properties. There are a couple of technologies which can be used or have been developed to meet these requirements like printing, laser sintering and sparc plasma sintering.

Using the example of silicon nanoparticles, it will be shown how the electronic properties of this material can be adjusted by p- and n-type doping and how the electronic properties of the nanoscale silicon differs from the bulk. Furthermore, first devices prepared from nanoscale silicon will be shown and some nano-specific future applications of silicon nanoparticles in photovoltaic devices will be discussed**.**

Notes

Aerosol nanoparticle for the creation of innovative nanostructures

Knut Deppert

Lund University, Sweden

During the last decade there has been a tremendous research interest in semiconductor nanowires. Nanowires are one-dimensional, rod-shaped nanostructures with two dimensions in the size range of tens of nanometers and a longer third dimension, typically in the range of micrometers. Due to this specific structure, nanowires possess unique properties such as a large surface-to-volume ratio and the ability to laterally quantum confine electrons in discrete energy levels. These properties make the nanowires highly promising as building blocks for the next generation of electronic and optoelectronic devices. Several applications utilizing nanowires, such as light emitting diodes, single electron transistor, and nanobiosensors have already been demonstrated.

The most common approach to fabricate perfect nanowires, a bottom up method, uses self assembly to build up the structure atom by atom. The success of nanowires in future applications lies in the degree of control that can be achieved for their growth down to the atomic level. To initiate the epitaxial growth of a highly perfect nanowire a nanometer-sized metal seed particle, usually gold, is used. Here, aerosol nanoparticles exhibit the most excellent properties in order to create advanced nanowires.

In this talk, I will discuss the advantages of using aerosol nanoparticles over other methods and will demonstrate the creation of innovative nanostructures starting from size-selected aerosol nanoparticles for generation and harvesting of light.

Notes

Nanoparticle Synthesis by Sputtering Methods

Bernd Günther

Fraunhofer IFAM Bremen, Germany

Thermal evaporation/vapor condensation in inert gases is a well-known process to synthesize nanoscale particulate metals and semiconductors. However, for many alloys and composite materials, stoichiometry is difficult to achieve due to temperature/composition dependent activities of the constituents in the respective liquid precursor. In contrast laser ablation and sputtering from solid precursor material are preferred techniques to prepare nanoparticle deposits with stoichiometric composition and various material combinations.
In this contribution the underlying principles and technical realisation of sputtering at elevated pressures are outlined. It is shown that particle formation in the gas phase and the resulting coating morphologies depend critically on the target-substrate distance and the sputtering gas pressure in the sub-mb range. As a specialty gas flow sputtering from hollow cathodes allows preparing a fairly focused flow of nanoparticles and is particularly useful for deposition on porous substrates. A range of possible applications is outlined including joining via in-situ compaction of nanoporous interlayers, preparation of nanoporous catalytic coatings and synthesis of low-vapour-pressure colloidal liquids.

Notes

Linear and non-linear optical analysis of early stages of particle formation: a case study for ZnO

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ZnO is an interesting semiconductor for applications in opto-electronic devices, sensors and UV-absorption. Suspensions of ZnO nanoparticles, made from gas phase (EVONIK) or by chemical synthesis in liquids, are being investigated for printable electronics. In an integrated and interdisciplinary approach, the whole process chain from particle formation to functional opto-electronic devices is being investigated. In this contribution, we study specifically the precipitation of ZnO nanoparticles in the size range below 10 nm by linear and non-linear optical techniques.
Incoherent nonlinear Hyper-Rayleigh Scattering (HRS) has been applied to monitor the different stages in the synthesis of sub-10nm ZnO nanoparticles. During long-term HRS investigations of the ripening process, supplemented by size sensitive optical absorbance measurements and TEM analysis, we found an increase in the particle hyperpolarizability ZnO with increasing particle size. Time-resolved measurements with a resolution down to 20 ms revealed regions of prevalent nucleation, growth and ripening. During nucleation a strong signal increase attributed mainly to the increasing number of particles was observed. Using the size-dependent hyperpolarizability, nucleation, growth and ripening rates could be determined. The results show the unique capability of HRS to characterize fast precipitation processes, which have so far been experimentally elusive.

Acknowledgement: This work is supported by DFG within the priority program “Colloid process technology”, by the Cluster of Excellence “Engineering of Advanced Materials – Hierarchical structure formation for functional devices” and by the RTG “Disperse systems for electronics” (in cooperation with EVONIK).

Notes

Electronic Surface and Interface Properties of TCOs

Andreas Klein

TU Darmstadt, Germany

Electronic properties of transparent conducting oxide surfaces and their interfaces in different thin film solar cells and organic light emitting devices are investigated using photoelectron spectroscopy (XPS, UPS). The TCO films and interfaces are mainly prepared in integrated surface analysis and preparation systems, allowing for analysis of contamination-free surfaces. With XPS and UPS, it is possible to assess chemical as well as electronic properties of surfaces and interfaces. Results will be presented for magnetron sputtered films of doped and undoped ZnO, In_2O_3, and SnO_2. The variation of surface properties with deposition parameters is presented, highlighting the influences affecting the work function and the importance of non-equilibrium conditions for the carrier concentration of magnetron sputtered films. Noticeable differences between the different TCO materials are emphasized.
The second part of the talk will present results on interface properties between CdS and magnetron sputtered ZnO films, which is the window layer contact in $Cu(In,Ga)Se_2$ thin film solar cells.

Notes

Photoluminescence study of Si_xGe_{1-x} nanocrystals fabricated by laser-induced pyrolisis

Libo Ma

FSU Jena, Germany

Series of Si_xGe_{1-x} nanocrystals (NCs) with different Germanium concentrations were produced by laser-induced pyrolysis. Single-crystalline Si_xGe_{1-x} NCs of high quality and their microstructural features were revealed by high-resolution TEM investigation. The chemical composition of the as-deposited Si_xGe_{1-x} samples were determined by using Rutherford Back Scattering (RBS) technique. Photoluminescence emissions in the range of red-IR band were observed in as-prepared samples, in which the aging effect survived nearly two weeks. Decay-time measurements were also carried out correspondingly at various wavelengths. Finally, the oxides of Si_xGe_{1-x} were investigated without/after annealing.

Notes

All-inorganic light emitting devices based on ZnO nanoparticles with UV and white emission

Tilmar Kümmell

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Luminescent semiconducting nanoparticles are highly attractive for future large-area devices: Compared to commercially available organic light emitting devices, a better robustness against degradation is expected.
We report on room-temperature, white color electroluminescence from an all-inorganic light emitting device, based on spin-coated ZnO nanoparticles. A tight sub-?m thick layer was fabricated using commercially available ZnO nanoparticles from the gas phase and fluorine doped tin oxide (FTO) glass as a substrate. An Aluminum layer is evaporated as a top electrode. The light emitting device is driven at low voltages below 10 V. In electroluminescence, an excitonic peak at around 390 nm and a broad defect-related signal in visible range were observed. The device showed stable operation at ambient air conditions. The whole fabrication process is easy and suitable for low-cost printable large-area emitting devices.

Notes

Dynamics of dye/nano particle systems

Klaus Attenkofer

Argonne National Lab, USA

Notes

Poster Presentations

In-Situ Time-of-Flight Mass Spectrometry of High Temperature Chemical Vapour Deposition of Silicon Carbide

Erdal Akyildiz, H. Piest, M. Winterer

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A high temperature chemical vapour deposition reactor (HTCVD-reactor) has been built, in which silicon carbide (SiC) crystals are grown homoepitaxially on silicon carbide substrates using silane and propane as precursors. To date it is assumed that in this HTCVD process SiC nanoparticles are formed in the gas phase. These are proposed as precursor for epitaxial growth of SiC. The processes of nanocrystal formation and film deposition, and how they relate to each other as function of process parameters are unknown. A better understanding about the HTCVD-process is possible using TOF mass spectrometry. The HTCVD process is probed in-situ using a chopped molecular beam which is generated from an orifice where normally the substrate for SiC layer deposition is mounted. We expect that in the HTCVD process a substantial number of thermal ions are generated at temperature where the SiC growth occurs. Neutral reaction products can be photoionized with the 248 nm output of an excimer laser. These ions can be mass selected and detected via the TOF mass spectrometer, with which we are able to record a mass spectra at different settings of temperature, precusor flow or precusor mixing. The results may contribute to a better understanding, online control and optimization of SiC film fabrication.

Notes

Thin film field effect transistors based on nanoparticulate semiconductors

Claudia Busch

Nanostrukturtechnik, University of Duisburg-Essen, and Center for NanoIntegration Duisburg-Essen, CeNIDE, Germany

Transparent semiconducting oxides in the nanoparticulate form are currently studied for the application of printable electronics. Processing of thin film transistors from oxide nanoparticles is inexpensive and at the same time it has benefit in terms of air stability and non-toxicity. Therefore, different deposition methods and different oxide semiconductors are used to realize thin film field effect transistors. The thin film transistors in the bottom gate configuration are fabricated either by direct deposition of indium oxide particles from the gas phase or using the spin coating method for dispersions of zinc oxide. Both oxides show n-type behaviour in the current-voltage characteristics. Using the direct deposition technique, a thickness of few monolayers of particles, in the best case one single particle layer can be achieved.

Notes

Surface energies of Fe, Co, Mn, Pt and their alloys: An ab initio study

Antje Dannenberg

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L10-ordered FePt and CoPt nanoparticles are considered as promising materials for ultra-high density magnetic recording applications. Since the energies of surfaces and internal interfaces play an important role in determining the equilibrium shape of the particles, their analysis is of fundamental interest. We here show the results of a systematic study of the energies and magnetism of low-indexed surfaces for the monoatomic systems Fe, Co, and Pt, as well as for the binary alloys FePt, CoPt, and MnPt. For L10-ordered, stoichiometric alloys we present a method which is based on surface energy phase diagramms in order to evaluate the surface energy contributions of the single material components. For transition metals this has not been done before. We find, that especially platinum covered {111} facets show extraordinary low surface energy while the (001) surface, which is needed for the desired L10-cuboctahedron, lays higher in energy. This gives rise to the appearance of multiply twinned icosahedra in gas phase experiments. The energies are calculated within density functional theory using the VASP code and the surfaces were modeled within the slab approach.

Notes

Electronic and transport properties of semiconductoring nanoparticles

Andreas Gondorf

Experimental Physics, University of Duisburg-Essen, and Center for NanoIntegration Duisburg-Essen, CeNIDE, Germany

Semiconductor nanoparticles, especially based on silicon or germanium, are of great interest due to their possible applications in (opto)electronic devices. On one hand Si and Ge nanoparticles can be easily integrated into nowadays semiconductor bulk electronics, on the other hand, they promise new routes of fabrication in printable electronics. The electronic properties that determine the conductivity are crucial characteristics for future opto-electronic devices based on Si or Ge nanoparticles. Therefore in this work we investigate the charge carrier concentration and mobility in Ge and Si nanoparticles. We use current- voltage (I-V) and Hall-measurements and find a very weak but measurable Hall-effect in compressed powder pellets. In these pellets based on Si nanoparticles a very low charge carrier concentrations of about 10^{12} cm^{-3} was measured at 250°C while Ge nanoparticles showed at room temperature two order of magnitude higher concentration of about and $4*10^{14}cm^{-3}$. Surprisingly in Si nanoparticles we find mobilities of up to 100 cm^2/Vs at 250°C. In contrast Ge nanoparticles have a very small mobility of 0,1 cm^2/Vs 25°C. In comparison, the charge carrier mobilities of intrinsic undoped Si are of the order of 1000 cm^2/Vs at 250°C, while undoped bulk Ge has values of the order of 1000-4000 cm^2/Vs respectively. The reason for the lower conductivity and mobility in nanoparticles is the high amount of grain boundaries and the isolating SiO_2/GeO_2 shell of the particles.

Notes

Structure and magnetism of free and decorated binary transition metal nanoparticles

Markus Gruner

Theoretical Physics, University of Duisburg-Essen, and Center for NanoIntegration Duisburg-Essen, CeNIDE, Germany

Arrays of L1_0 ordered nanoparticles of near-stoichiometric FePt and CoPt with diameters down to 4 nm are considered as promising material for future ultra-high density recording media. However, with decreasing particle size, also multiply twinned structures like decahedra and icosahedra are frequently encountered in experiment (e.g., [1]). These structures, however, will not posses the required hard magnetic properties due to the different crystallographic orientations of the individual twins. In recent large scale ab initio calculations of FePt clusters [2,3] considering up to 923 atoms (~3 nm in diameter), it was shown that ordered multiply twinned structures are energetically preferred over L1_0 cuboctahedra. Within this contribution, we discuss the influence of chemical trends on the structural stability of the L1_0 phase obtained by variation of the 3d and the 5d element. In a further step, first studies of decorated clusters will be presented, giving insight how the embedding of the clusters into metallic or organic matrices may affect their properties.

[1] R. Wang, O. Dmitrieva, M. Farle, G. Dumpich, H. Poppa, R. Kilaas and C. Kisielowski, Phys. Rev. Lett. 100, 017205 (2008).
[2] M. E. Gruner, G. Rollmann, P. Entel and M. Farle, Phys. Rev. Lett. 100, 087203 (2008).
[3] M. E. Gruner and P. Entel, Psi-k Newsletter 89, 36 (2008).

Notes

Imaging measurements of atomic iron concentration in a nano-particle synthesis flame reactor

Christian Hecht

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Nanosized semiconducting metal particles are widely used for gas-sensing devices, photocatalysis and (opto)electronic devices. A promising route for the synthesis of such material is the low-pressure premixed-flame reactor.
In this reactor, Fe_2O_3 nano particles are produced by adding $Fe(CO)_5$ to the fresh gases of the burner. This precursor is destroyed in the flame and Fe atoms are oxidized to form Fe_2O_3. Accordingly, all oxidation states of iron between 0 and +III are found in the flame. At 225 nm iron atoms and ions can be excited by laser radiation inducing fluorescence in the 250 - 400 nm range. Elastically-scattered light is suppressed with long-pass filters (UG 5) and signal is detected with an intensified CCD camera. Fluorescence images show the 2D-distribution of these species. The fluorescence can be attributed to defined transitions of e.g. iron (I), but this technique can also be applied to other oxidation states and to other species.
Temperature imaging measurements based on multi-line NO LIF in the same zone were used for correcting for the temperature-dependend variation in ground-state population. The local variation of fluorescence quenching was determined for different areas within the flame based on fluorescence lifetime measurements. Signal intensities were calibrated based on laser attenuation measurements. A strong transition was chosen at 248 nm that leads to strong laser attenuation and the LIF signal relative to the LIF signal at 225 nm, where the laser attenuation is negligible, was used to determine the local concentration using the Beer-Lambert law. The influence of $Fe(CO)_5$ concentrations higher than 70 ppm on the flame structure has been observed as the flame moves closer to the burner surface.

Notes

Stable Aqueous Dispersion of ZnO Nanocrystals for ink-jet printing

Ahmed S. G. Khalil

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Zinc oxide (ZnO) nanomaterials have attracted great interest due to their unique properties and applications in electronics, optics and photonics. Different preparation methods have been reported to synthesize ZnO nanoparticles (ZnO NP). Here, the ZnO NP have been synthesized by chemical vapor synthesis (CVS), which is a modified chemical vapor deposition (CVD) process. By using this method, highly crystalline, less aggregated and narrow-sized distribution ZnO NP can be obtained. The prepared particles have been characterized by XRD, TEM, and some other techniques. As-prepared particles have a primary size of about 20 nm as measured by XRD.

For the fabrication of printable devices based on nanoparticles, stable colloidal dispersions of these materials are highly desirable. In this work, aqueous dispersions of ZnO NP have been prepared successfully after the addition of new stabilizers. The prepared dispersions are stable for several weeks without observable sedimentation. The Zeta potential and the size of the ZnO NP in these dispersions have been monitored for several weeks and showed quite invariable values. In addition, it has been found that the optimization of the ultrasonic treatment of the dispersion is very important, leading to less-aggregated particles with sizes near to the size of the primary particles. The realization of these stable dispersions has given the opportunity to form ZnO NP films for different applications on glass and silicon substrates by ink-jet printing.

Notes

Low pressure gas phase synthesis of monodisperse, high-purity silicon nanoparticles

Richard Körmer

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Silicon nanoparticles were synthesised from mixtures of silane in argon in hot-wall reactor. The reactor design was optimised for the production of high-purity particles by the use of 6.0 grade Argon and a cleaned quartz glass tube. A mixture of silane in argon was injected in the middle of the pipe and in the outer region a sheath flow of pure argon was additionally added. We found that it is possible to obtain almost monodisperse primary particles. The size of the primary particles is 29 nm with a narrow standard deviation of only 4 nm calculated from image analysis of SEM pictures. The primary particles are interconnected in larger open-structured aggregates. Dispersion experiments did clearly show that hard and soft agglomerates can be produced by choosing the proper time-temperature profile. XRD analysis gives the typical diffraction pattern for crystalline silicon and the average crystallite size was calculated to 29 nm using Rietveld refinement. This value is in excellent agreement with image analysis by SEM and implies that the primary particles are monocrystalline. The specific surface area of the silicon particles was determined by nitrogen gas adsorption technique (BET method) to 82,7 m^2/g. This corresponds to a mean particle diameter of 31,6 nm, if spherical and monodisperse particles are assumed. Population balance modelling results show that the very narrow distribution is obtained because the particle synthesis process is dominated by surface growth in contrast to typical aerosol processes which are dominated by agglomeration and sintering. The homogeneous gas phase pyrolysis kinetics is decreased by the reduced pressure which corresponds to a reduced amount of collision partners for the precursor. The surface growth kinetics remains unattached and leads to the growth of a narrow particle size distribution. For determination of the contamination level Si powder was dissolved in a mixture of electronic grade nitric acid and hydrofluoric acid and analyzed with AAS and TXRF. In both measurements, copper was found to be the principal contaminant with a concentration of about 1 μg/g. The silicon particles can be dispersed in organic solvents (e.g. ethanol) and be used as inks for printable electronics.

Notes

Controlled doping of GaAs nanowires for pn-diode applications

Andrey Lysov

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In the recent past, III-V semiconductor nanowires have attracted great research interest. The vapour-liquid-solid (VLS) growth mode in a metal-organic vapor phase apparatus (MOVPE) is a powerful tool for the fabrication of semiconductor nanowires with outstanding structural, transport, and optical properties. Doping is an essential issue for the fabrication of nanowire based devices such as pn-junctions used in the light emitting devices. In this contribution we report about controlled p-type doping of GaAs nanowires via diethylzinc (DEZn) during the growth. The nanowires were grown by metal-organic vapor phase epitaxy (MOVPE) using tertiarybutylarsine (TBAs) as group-V and trimethylgallium (TMGa) as group-III sources. Using DEZn an increased conductance was measured, giving evidence, that doping was successful. By adjusting the II/III ratio, controlled doping concentrations from $4.6*10^{18}$ cm^{-3} up to $2.3*10^{19}$ cm^{-3} could be achieved. The doping concentrations were estimated from electrical conductivity measurements applied to single nanowires with different diameters. Electroluminescence measurements on pn-diodes, built by zinc doped GaAs nanowires grown on n-type GaAs substrate yielded an additional proof of successful p-type doping of the nanowires via VLS-mechanism.

Notes

Theoretical perspective of magnetism in Co doped ZnO

Sanjeev Kumar Nayak

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Transition metal (TM) doped binary semiconductors are of current interest for the light emitting properties; especially ZnO which is relatively easier to grow as thin-films and nano-particles and is economically viable. In addition to this, dilutely doped TM elements in ZnO is anticipated to give necessary ferromagnetism, along with the semiconducting properties, to successfully act as a diluted magnetic semiconductor (DMS). In experiments both ferromagnetism and no spontaneous magnetism is observed, making it difficult to conclude straightforwardly about any possible underlying mechanism for the magnetic properties in this system. Form a combination of first-principles and Monte Carlo studies, we show that the absence of spontaneous magnetization is more probable for low doping concentrations of Co in ZnO.

Notes

Optoelectronic emitters based on ZnO nanoparticles

Ekaterina Neshataeva

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Cost-effective large area devices based on luminescent nanoparticles have been in the focus of interest for the last years: Compared to commercially available organic light emitting devices they promise to be more robust against degradation. However, in order to access a low voltage operation regime most concepts still use organic matrices or support layers.

We present a device concept without any organic support layers, which is based on inorganic, non-toxic nanoscaled materials from the gas phase as active material and a glass substrate coated with indiumtinoxide (ITO) as back electrode. The particle fabrication process is suited for mass production. The nanoparticles are dispersed in a water-based suspension and spin coated onto the ITO-substrate. We achieve a densely packed, homogeneous layer with a thickness of 300-500 nm. A metal contact is deposited by electron beam evaporation as a top contact.

The light emitting device is driven in the low voltage range. At an operation voltage of only 4 V, we detect a broad visible electroluminescence (EL) signal with a maximum at 650 nm indicating an efficient carrier injection. While in this operation regime the signal can be attributed to defect states, the EL maximum shifts to the blue spectral range if one increases the voltage. Thus, our findings open a path to an all-inorganic, non-toxic particle based luminescent device.

Notes

Photoluminescence of extremely dilute Si nanoparticle films

Matthias Offer[1], M. Geller[1], A. Lorke[1], C. Meier[2], H. Wiggers[3]

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Light-emitting silicon nanoparticles are attractive candidates for future optoelectronic applications. For the realization of such devices, a detailed knowledge of the recombination dynamics is an important prerequisite. The photoluminescence of silicon nanoparticles exhibits an interesting exitonic fine structure with a bright and a dark state, which, surprisingly, have very similar radiative recombination lifetimes [1]. To elucidate the intriguing excitonic properties of Si nanoparticles, it is highly desirable to investigate single particles or few-particle ensembles to answer questions regarding homogeneous line broadening and Zeeman shift. We have dispersed Si nanoparticles in organic solvents and deposit extremely dilute films of Si particles on arbitrary surfaces. These can be covered by metallic micro-apertures (! 1 µm in diameter), which make it possible to study the optical properties of ensembles of about 100 particles and below. Furthermore, a scanning micro-photoluminescence setup was designed and realized to map out the local optical properties of nanoscopic semiconductor structures. First results of spatially resolved photoluminescence on nanoparticles will be presented and compared to spectra of large-scale ensembles.

[1] S. Lüttjohann, C. Meier, M. Offer, A. Lorke, and H. Wiggers, Europhys. Lett. **79**, 37002 (2007)

Notes

Magnetic anisotropy studies for transition metal clusters

Sanjubala Sahoo

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Magnetic properties of 3d-transition metal clusters are studied using density functional theory. In the present work, the magnetic anisotropy of 13 atom icosahedral Fe, Co and Ni clusters are calculated and compared with respect to bulk. Spin and orbital moments for the corresponding clusters are also studied, which is observed to be larger relative to bulk. In addition, the spin and orbital moments for some specific binary 55 atom transition metal clusters will be presented.

Notes

Dispersing and stabilizing semiconducting nanoparticles

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In this work dispersions of zinc oxide nanoparticles in aqueous and non-aqueous media with different stabilizers were studied. The dispersed nanoparticles were spin coated on Si/SiO_2-wafers to produce semiconducting thin layers. The effect of the electrostatic, electrosteric and steric stabilization mechanisms on the ZnO on the electrical properties of the ZnO films was studied. Also the effect of different annealing temperatures between 200 °C and 600 °C on the electrical properties of the ZnO films was investigated. Zinc oxide nanoparticles were obtained from Evonik Industries. Field effect transistors were prepared in the top contact geometry in order to characterize the electrical performance of the thin ZnO layers. Source and drain electrodes were prepared by thermal evaporation of Al through a shadow mask on top of the ZnO layers. The Si substrate was used as the gate electrode. The characterization of the dispersions and ZnO layers was done with the following standard methods: DLS, AFM, TGA, SEM and mechanical profilometry. Dispersions with a stability against sedimentation and agglomeration of several weeks were achieved with the additives $Y(NO_3)_3$, TODS and TEGO 715 W in ethanol and water. A volume based particle size distribution could be achieved in the range of 100 nm for the stable dispersions. Based on the stable dispersions densely packed thin layers with a rms surface roughness of about 20 nm and film thicknesses in the range from 400 nm to 100 nm could be produced. At annealing temperatures of 400°C for 1h the organic compounds in the layer were removed. Characteristic FET curves with mobilities of 4×10^{-3} Vs/cm_ with an I_{on}/I_{off} ratio of 105 could be measured with layers based on the dispersions stabilized with TODS in ethanol. Layers based on the dispersions with the other stabilizers showed high charging effects in the characteristic FET curves. This might be due to the additionally charge transport of the ions of the electrostatic and electrosteric stabilizeres. At the annealing temperature of 200 °C no characteristic FET curves were observed due to charging effects and dense trap states in the layers. At 600 °C annealing temperature the characteristic curves showed a high off current due to the occurring of sinter necks. Considering the morphological issues of the thin layers, all the stable dispersions led to densely packed thin films with a very low surface roughness. But considering the electrical performance of the layers, the stabilizing additives in the dispersions showed highly influencing effects on the characteristic curves. In this work we could realise the whole process chain from the raw material to the electronic device such as a TFT.

Notes

Luminescence studies on single silicon nanoparticles synthesized by laser-induced pyrolysis

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Light-emitting silicon nanocrystals with lateral dimensions between 2 and 8 nm are attractive candidates for future applications not only in micro- and optoelectronic devices, but also in the field of biology and medicine. The quantum confinement effect is responsible for the fact that, in contrast to their bulk counterparts, these low-dimensional systems can emit very efficiently visible light when they are illuminated with UV radiation. Especially bio-imaging and drug-delivery are in the focus of current research. For these kinds of applications, optical and microstructural properties of single silicon nanocrystals are of major interests.The purpose of this poster presentation is to briefly introduce the basics of laser-induced pyrolysis of silane for synthesis of luminescent silicon nanoparticles. The method of employing a cluster beam apparatus for extracting silicon nanoparticles according to their size for thin film as well as for single nanoparticle deposition is described. In the aim of investigating optical properties of single silicon nanocrystals and hollow single silicon dioxide nanoparticles confocal microscopy was applied. Recorded photoluminescence spectra of these single nanoparticles are presented. Also excitation patterns of silicon and silicon dioxide particles, indicating orientation of the transition dipole moment, obtained by using confocal microscopy in combination with higher order laser modes, are shown.

Notes

Influence of Powder Geometry on Impedance

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We present a correlation between a microscopic model of the impedance of nanoparticles and the resulting macroscopic impedance of a powder made of these particles. To verify this correlation we use numerical calculations of the impedance of a system of particles in a two dimensional grid with random holes and different aspect ratio of the grid. We show an easy method to characterize the powder with the information from the macroscopic impedance. We also present effective equations to predict the influence of the geometry and the porosity of the grid on the macroscopic impedance.

Notes

Chemical Vapor Synthesis of Fluorine-doped SnO2 Nanoparticles

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Among the wide band-gap oxides tin dioxide (SnO_2) is a very promising candidate for electronic applications as it combines good transparency and excellent chemical stability. To utilize SnO_2 as transparent conductive oxide (TCO) material in e.g. optoelectronics, doping with fluorine or antimony is necessary to increase the conductivity. Nanoparticles of these oxides are interesting as printable materials for electronic structures in low-cost electronic devices. We present the preparation of nanoscale SnO_2 powders by Chemical Vapor synthesis (CVS) starting from tetramethyltin (TMT, $(CH_3)_4Sn$). Doping the particles with fluorine has been obtained by feeding difluoromethane (DFM, CH_2F_2) together with the oxide precursor to the hot wall reactor. The particles formed are well crystalline, owing an average particle size of about 5-7 nm as obtained from XRD line broadening, transmissions electron microscopy, and Brunauer-Emmett-Teller (BET) surface area analysis. The Sn/F ratio can easily be adjusted by controlling the mass flow rate of DFM. XPS indicates the formation of a second fluorine component at high DFM flow rates. In addition, we conclude that an enrichment of fluorine towards the particle surface takes place.

Notes

Growth and photoluminescence properties of ZnO nanorods in methanol

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ZnO nanoparticles were prepared by precipitation from a solution of zinc acetate dihydrate and potassium hydroxide in methanol. Subsequent refluxing of the ZnO dispersion led to the formation of ZnO nanorods, as formerly reported by Harnack et al. In order to investigate the growth mechanism of the ZnO nanorods we used HRTEM, SEM, XRD, and photoluminescence (PL) spectroscopy. The growth of the nanorods occurs in three consecutive stages. In stage I nucleation and growth of nearly spherical particles of 5-10 nm diameter is observed. In stage II oriented aggregation (OA) of a limited number of the spheres along the c-axis occurs, which leads to nanorods with an aspect ratio of 2.5. In stage III further increase of the aspect ratio is observed, which is explained by ripening. A sharp and strongly intense emission band is recorded at 366 nm for the sample taken in stage I, which can be attributed to the intrinsic emission of ZnO. This band slightly shifts to higher wavelengths with increasing growth time, which can be attributed to the formation of shallow trap states in stage II and stage III. Beside this two broad emission bands are observed at 375 nm (blue emission) and 560 nm (yellow emission). The blue and the yellow emission band are attributed to different types of deep trap states, as formerly reported in the literature. Significant changes of the blue emission band are observed during stage II and stage III. These changes can be explained by the formation and healing of the different types of defects during the formation of the ZnO nanorods.

Notes

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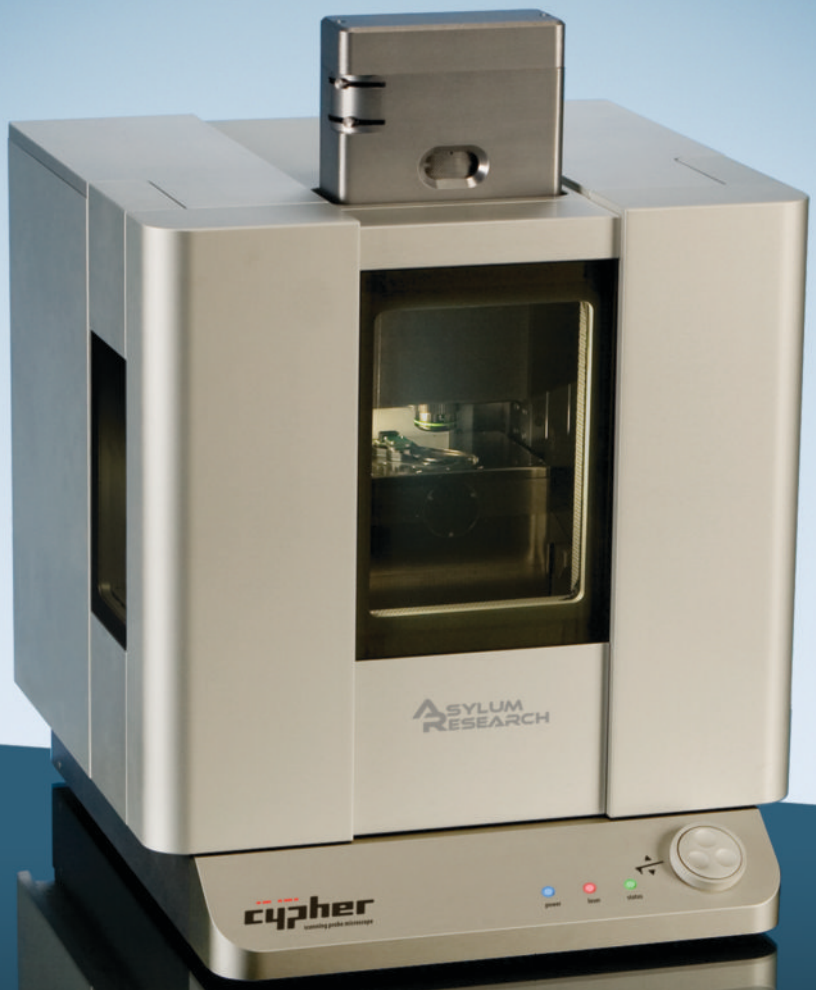

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- Thermal control for optimum imaging/measurement stability
- Integrated acoustic isolation
- Asylum's legendary support and money-back guarantee

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