HL 21: Heterostructures, Interfaces and Surfaces I

Time: Tuesday 9:30–11:45 Location: EW 561

HL 21.1 Tue 9:30 EW 561

Surface passivation and detrimental heat-induced diffusion effects in RbF-treated Cu(In,Ga)Se_2 solar cell absorbers — •Amala Elizabeth[1], Sudhir K. Sahoo[2], Tim Kodalle[3], Thomas D. Kühne[2], Christian A. Kaufmann[3], Hossein Mirhosseini[2], and Harry Mönig[1] — [1]University of Münster, Münster, Germany — [2]University of Paderborn, Paderborn, Germany — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany

Recent efficiency gains by Cu(In,Ga)Se_2 (CIGS)-based thin film solar cells (> 23%) are largely attributed to post-deposition treatments (PDTs) using alkali metal compounds like RbF and CsF. Consequently, comprehending the impact of alkali PDTs on the electronic defect physics of these absorber surfaces is crucial for understanding p/n junction formation and further device optimization.

Here we present a combined analytical study of the RbF-CIGS surface using scanning tunneling spectroscopy (STS) and X-ray photoelectron spectroscopy (XPS). STS results reveal the effectiveness of RbF PDT in preventing surface oxidation and consequently passivating electronic defect levels at the absorber surface. Ab-initio density functional theory (DFT) calculations corroborate this passivating effect. However, heat treatment at temperatures as low as 100°C was found to induce Rb diffusion, leading to increased electronic defect levels at the surface and potential deterioration of the p/n-junction interface. This study emphasizes the dual impact of RbF PDT, with its advantages and potential drawbacks, especially during subsequent device fabrication steps at elevated temperatures.

HL 21.2 Tue 9:45 EW 561

Depth profiling of defects with nanometer resolution at semiconductor interfaces using low-energy muons — •Thomas Prokscha[1], Maria Martins[1,2], Piyush Kumar[2], Marianne Bathen[2], Xiaojie Ni[1], Judith Wörle[2], and Ulrike Grossner[2] — [1]Laboratory for Muon Spin Spectroscopy, Paul Scherrer Institute, 5232 Villigen PSI, Switzerland — [2]Advanced Power Semiconductor Laboratory, ETH Zurich, 8092 Zurich, Switzerland

Defects and structural changes at semiconductor interfaces are of fundamental importance for the performance of semiconductor devices. While a variety of characterization methods exists for the investigation of process-induced defects, most of these techniques cannot resolve the depth distribution of defects close to the interfaces, an information which is important to better understand the relation between these defects and the observed limitations in device performance. Here we use low-energy muon spin spectroscopy as a powerful tool to study the distribution of defects in semiconductors with unprecedented nanometer depth resolution. The technique is based on studying the effect of defects on the formation probability of hydrogen-like muonium states in semiconductors and semiconductor-oxide interfaces. We used proton irradiated Si and 4H-SiC to measure the effect of well-defined defect concentrations profiles on the formation of muonium states, and apply this new technique to the study of technologically relevant SiO2/Si and SiO2/SiC interfaces [1,2].

[1] M. Martins et al., Adv. Mat. Inter. 10, 2300209 (2023).
[2] P. Kumar et al., Phys. Rev. Appl. 19, 054025 (2023).

HL 21.3 Tue 10:00 EW 561

Investigation Of Dielectric Parameters Of ZnO/p-Si Diode At Room Temperature — •Ali Orkun Çağırtekin, Ahmad Ajjaq, Özlem Barin, Pinar Oruç, and Selim Acar — Department of Physics, Faculty of Science, Gazi University, Ankara, Turkey

In this study; ZnO/p-Si nanostructure was obtained with a two-step process. First, a ZnO nucleating layer was produced on p-type silicon substrate by the dip coating method. Then, the core-coated sample was exposed to a 95 * and 3-hour hydrothermal reaction and the production of ZnO nanostructures was achieved. Finally, silver contact was applied to the produced structure by thermal evaporation. SEM analysis results show that ZnO nanostructures are coated homogeneously on the silicon substrate without gaps. It was aimed to investigate the performance properties of the produced diode under different conditions for different applications. Current-voltage, capacitance-frequency and conductance-frequency measurements of the ZnO/p-Si diode were measured at room temperature between 2 kHz and 1 MHz. As a result of these measurements, the obtained diode displays a rectification of about seven orders of magnitude at a bias voltage of 4 V. The dielectric constant of the diode at 2 kHz at room temperature was calculated as 13, dielectric loss as 10, and dielectric loss tangent as 0.79. It was also observed that there was a peak in the imaginary part of the electrical modulus. Finally, in the conductivity parameter, it was observed that the conductivity increased as the frequency increased. According to the results obtained, it was seen that the ZnO surface layer was suitable for capacitor applications.

HL 21.4 Tue 10:15 EW 561

Realization of the Topological Pseudospin-Hall Effect in an Exciton-Polariton Elliptical Micropillar Chain — •Simon Widmann, Jonas Bellmann, Johannes Düreth, Siddhartha Dam, Christian G. Mayer, Philipp Gagel, Simon Betzold, Monika Emmerling, Sven Höfling, and Sebastian Klembt — Julius-Maximilians-Universität Würzburg, Physikalisches Institut and Würzburg-Dresden Cluster of Excellence ct.qmat, Lehrstuhl für Technische Physik

We realize the topological pseudospin-Hall effect in a chain of elliptical exciton-polariton micropillars, using the different circular polarizations $\sigma_\pm$ as a pseudospin [1]. Elliptical micropillars are fabricated by fully etching a GaAs microcavity, creating a large confinement potential. The ellipticity of the micropillars leads to a linear polarization splitting along the semi-minor and major axis of the individual elliptical micropillars. In combination with a suitable placement into a lattice, this produces a system in which positive and negative momentum states have opposing circular polarizations. This experimental demonstration is a step towards the realization of the non-Hermitian skin effect in a chain of coupled elliptical micropillars.

[1] S. Mandal et al., ACS Photonics 9, 527-539 (2022)

15 min. break

HL 21.5 Tue 10:45 EW 561

Effectiveness of an AlSb dislocation filter layer in the epitaxy of GaSb on Si(001) — •Karl Graser[1], Audrey Gilbert[2], Steffen Richter[1], Jean-Baptiste Rodriguez[2], Eric Tournié[2], and Achim Trampert[1] — [1]Paul-Drude Institut für Festkörperelektronik, Leibnitz-Institut im Forschungsverbund Berlin e.V., Berlin, Germany — [2]Institut d'Electronique et des Systèmes , University of Montpellier, CNRS, F- 34000, France

The direct epitaxial growth of III-V semiconductors on Si (001) opens the door to the integration of III-V-based photonic devices with Si integrated circuits. Especially for the epitaxial growth of GaSb on Si with its high lattice mismatch, methods must be found to reduce the resulting huge number of threading dislocations which negatively affect the device performance. In the present study, the impact of a strained AlSb filter layer on the dislocation reduction for GaSb-on-Si epitaxy is investigated by transmission electron microscopy techniques. The site-specific measurements of dislocation density at different positions along the growth direction are used to calculate the filter efficiency, which is clearly related to the formation of misfit dislocation networks at the interfaces between AlSb and GaSb. It is shown that the nature of the dislocation networks, their line directions and Burgers vectors, is governed by epitaxial strain relief and complex dislocation reactions in the interfaces, and finally determines the effectiveness of threading dislocation reduction process.

HL 21.6 Tue 11:00 EW 561

Implementation of polaritonic lattices using patterning and oversputtering techniques — •David Laibacher, Johannes Düreth, Simon Betzold, Siddhartha Dam, Monika Emmerling, Sven Höfling, and Sebastian Klembt — Julius-Maximilians-Universität Würzburg, Physikalisches Institut and Würzburg-Dresden Cluster of Excellence ct.qmat, Lehrstuhl für Technische Physik, Am Hubland, 97074 Würzburg, Deutschland

Exciton-Polaritons have been a focus of study during recent years due to their ability to form a driven-dissppative Bose-Einstein-Condensate in two dimensions at finite temperatures. One way to study them accesibly is using a laser to generate exitons in an active material located between two distributed Bragg reflectors (DBR), confining the photon

in one direction. In this work, the polaritonic potential landscape is manipulated due to confinement of it's photonic part by manipulating the length of the cavity layer in order to create different structures with components in the order of microns. The length of the cavity is manipulated by either etching a few tens of nanometers into (Etch and Oversputter) or depositing a similar thickness of TiO_2 discs onto (Deposition and Oversputter) the cavity layer. This enables the creation of polariton lattices with features in the order of nanometers, which was not possible using previously established techniques such as etching micropillars. The top DBR is deposited using sputtering, aiming to achieve a similar quality when compared to growing it using molecular beam epitaxy, thus allowing easier sample-generation and faster structural optimization.

HL 21.7 Tue 11:15 EW 561

Realization of Higher Order Topological Insulators in Hybrid Dielectric-Semiconductor Microcavities — •Johannes Düreth, Philipp Gagel, Simon Betzold, Siddhartha Dam, Christian G. Mayer, David Laibacher, Monika Emmerling, Sven Höfling, and Sebastian Klembt — Technische Physik, Wilhelm-Conrad-Röntgen-Research Center for Complex Material Systems, and Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

Since its introduction to the polariton community by El Daïf and coworkers in 2006 [1], the etch-and-overgrowth method has been a very versatile technique for the generation of photonic confinement. It is perfectly suited to manufacture large, uniform and complex potential landscapes since the confinement as well as its coupling can be finely tuned by controlling the etch-depth. Here, we improve on this method by using a dielectric top mirror consisting of SiO_2/TiO_2 layers instead of an epitaxially grown one. In recent years, topological photonics has emerged as a powerful tool to engineer traits of optoelectronic applications. We implement 0-dimensional higher order topological defects in a *breathing* Kagome lattice, as well as a 2-D Su-Schrieffer-Heeger (SSH) lattice. Additionally, we show polariton lasing from the corner defect of the breathing Kagome lattice and the 0-D defect of the 2D-SSH lattice, as well as their coherence properties [2].

[1] O. El Daïf et al., Appl. Phys. Lett. 88, 061105 (2006)
[2] P. Gagel, J. Düreth et al., in preparation (2023)

HL 21.8 Tue 11:30 EW 561

Chemical and energetical structure at P-rich InP(100)/TiO_2 heterointerface — •Agnieszka Paszuk[1], Jennifer Velázquez Rojas[2], Mohammad Amin Zare Pour[1], David Ostheimer[1], Christian Höhn[2], Roel van de Krol[2], and Thomas Hannappel[1] — [1]Fundamentals of Energy Materials, Technische Universität Ilmenau — [2]Institute for Solar Fuels, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Germany

In the photoelectrochemical cells with the highest solar-to-hydrogen conversion efficiencies, III−V photoabsorbers are integrated with a metal oxide passivation layer and a catalyst. Such devices require preparation of ideal (buried)interfaces to minimize the losses of the photogenerated charge carriers. Here, we study atomic layer deposition (ALD) of TiO_2 on phosphorus terminated (P-rich) InP(100) surfaces prepared in a metalorganic vapor phase epitaxy reactor. Samples were transferred in ultra-high vacuum to an ALD chamber. Titanium tetrachloride and water were used as the titanium and oxygen precursors, respectively. The preparation of P-rich InP(100) and the deposition of the TiO_2 were monitored *in situ* by ellipsometry and optical spectroscopy, respectively. After selected precursor pulses, the surface chemical composition and the electronic structure were determined by photoemission spectroscopy. We observed a nucleation delay of TiO_2 and during the first deposition cycles, a limited interaction of the water and the Ti precursor due to stable P-P bonds on the InP(100) surface. The TiO_2 layers show +4 oxidation state and we find no evidence of the presence of Ti^{3+} state, which might act as trap centres.