SLALOM 2022
Poster session

	Name	Poster title
1	**Artem Larin**	Perfect metasurface absorber for the silicon up-conversion luminescence
2	**Anna Vedernikova**	Optical properties of carbon dots from o-phenylenediamine depending on the polarity and pH of the medium
3	**Pavel Demakov**	Tuning efficient and multi-colored light emission in rare earth metal-organic framework series with aliphatic linkers
4	**Maria Egorova**	Investigation of conditions for laser-plasma recording of micro-optical elements arrays in glass
5	**Rodion Eresko**	Numerical Simulations of The Gallium Phosphide Nanowires and 2D Transition Metal Dichalcogenides Based Hybrid System Optical Properties
6	**Alisher Ibragimov**	Light modulation using semiconductor metasurfaces upon electrical signal
7	**Leonid Leites**	Optical elements fabrication by using microstereolithography 3D-printing method
8	**Timofei Antipov**	Optical coupling of interlayer excitons in thin films with resonant silicon nanostructures
9	**Ekaterina Deribina**	Droplet Molecular Beam Epitaxy and Optical Properties of Quantum Dots GaAs/AlGaAs
10	**Maksim Aparin**	Fabrication of optical microstructures with gradient refractive index by two-photon laser lithography
11	**Emil Chiglintsev**	Nonlinear Terahertz Generation of Carbon Nanotubes
12	**Polina Shaban**	Skyrmions in Moire magnets
13	**Elizaveta Arkhipova**	Ultrafast laser-induced dynamics of magneto-optical response in layered van der Waals antiferromagnets NiPS3 and FePS3
14	**Artem Polushkin**	Slot-die coating deposition method for perovskite green light-emitting chemical cell fabrication
15	**Anastasiia Efimova**	Monolayers of Zn-based metal-organic framework for vapor polarity sensing
16	**Mikhail Miruschenko**	Developing of pH sensors based on carbon dots from o-phenylenediamine
17	**Andrey Dotsenko**	Peculiarities of optical response of 3D alumina photonic crystals
18	**Ekaterina Agafonova**	Star spectra: screening of star-shaped hole transporting materials towards 20% perovskite solar cell efficiency
19	**Stanislav Colari**	Transfer of the Orbital Momentum of Light to the Spin System in a Ferrite Garnet Film
20	**Anna Obraztsova**	Bifacial perovskite solar cell improved by a highly efficient light-trapping electrode
21	**Alexey Kuznetsov**	GaP/GaPxAs1-x epitaxial nanowires based directed radiation sources

SLALOM 2022

POSTER SESSION PROGRAM

1

ARTEM LARIN | ITMO UNIVERSITY

PERFECT METASURFACE ABSORBER FOR THE SILICON UP-CONVERSION LUMINESCENCE

The perfect metasurface absorber gained its popularity for its high resonant absorption and large field localization values in very small volumes. Such features are useful for the design of silicon-based up-conversion broadband light sources that suffer from low absorbance at wavelengths greater than 1100 nm. This work presents the design of a hybrid Au-Si metasurface with an emitting material in the nanogap based on numerical simulation and demonstrates experimental results on the emissivity of such a planar structure. The results of this work have prospects for expanding the practical application of silicon as a radiation source, and also paves the way for the study of the dynamics of a dense electron-hole plasma in semiconductors.

2

ANNA VEDERNIKOVA | ITMO UNIVERSITY

OPTICAL PROPERTIES OF CARBON DOTS FROM O-PHENYLENEDIAMINE DEPENDING ON THE POLARITY AND PH OF THE MEDIUM

Today, the development of nanomaterials with sensing properties attracts much scientific interest because of the demand for low-cost nontoxic colloidal nanoprobes with high sensitivity and selectivity for various biomedical and environment-related applications. Carbon dots (CDs) are promising candidates for these applications as they demonstrate unique optical properties with intense emissions, biocompatibility, and ease of fabrication. Herein, we developed synthesis proto cols to obtain CDs based on o-phenylenediamine with a variety of optical responses depending on additional precursors and changes in the reaction media. The obtained CDs are N-doped (N,S-doped in case of thiourea addition) less than 10 nm spherical particles with emissions observed in the 300–600 nm spectral region depending on their chemical composition. These CDs may act simultaneously as absorptive/fluorescent sensing probes for solvent polarity with ΔS/ΔE(T N) up to 85, for ΔE (T N) from 0.099 to 1.0 and for pH values in the range of 3.0–8.0, thus opening an opportunity to check the pH in non-pure water or a mixture of solvents. Moreover, CDs preserve their optical properties when embedded in cellulose strips that can be used as sensing probes for fast and easy pH checks. We believe that the resulting dual-purpose sensing nano probes based on CDs will have high demand in various sensing applications.

3

PAVEL DEMAKOV | NIKOLAEV INSTITUTE OF INORGANIC CHEMISTRY, SB RAS

TUNING EFFICIENT AND MULTI-COLORED LIGHT EMISSION IN RARE EARTH METAL-ORGANIC FRAMEWORK SERIES WITH ALIPHATIC LINKERS

Metal-organic frameworks (MOFs) represent an emerging class of hybrid functional materials. In particular, optical properties of such class of highly crystalline polymeric networks are of great interest due to the possible applications in light emitters, sensors and data processing devices. Aliphatic-backboned ligands are quite rare in MOF chemistry, however, unusual structural dynamics, surface nature and UV/vis transparency inherent to the saturated linker core put them onto a unique place in the design of optical materials.
Lanthanide-based metal-organic frameworks are extensively studied owing to their remarkable magnetic properties and easily photosensitized luminescence. A two-ligand approach has been applied in our group to synthesize several series of rare earth-based MOFs combining aliphatic functionalities and highly intensive luminescence. Structure tuning by synthetic conditions as well as excitation energies were revealed to be crucial factors driving the emission features of these series. As a result, a diversity of even single-metal compound luminescence is represented by white (Sm3+, Yb3+ or Y3+), yellow (Gd3+, Sm3+ or Y3+), blue (Y3+, Sm3+ or Lu3+), green (Tb3+) and red (Eu3+) colors with quantum yields up to 63%, while isomorphic metal center mixing allowed to achieve a single-phase white emitter with 20% quantum yield under a soft UV excitation. This report summarizes our data on the luminescence properties of the obtained compounds and further prospects in this field.
This work was supported by Russian Science Foundation, project № 22-23-20179

4

MARIA EGOROVA | ITMO UNIVERSITY

INVESTIGATION OF CONDITIONS FOR LASER-PLASMA RECORDING OF MICRO-OPTICAL ELEMENTS ARRAYS IN GLASS

In this work was studied the energy density and the pulse repetition frequency influence on geometric dimensions such as diameter and depth of microlens formed in fused silica glass.
The study was carried out on two setups that differ in the method of positioning radiation from a pulsed fiber laser source with a wavelength of 1 μm. In one case, through a mirror optical system, the radiation fell on an 8x microobjective, and then it was focused on the target-sample interface, which were located on motorized sliders. In another case, the radiation was applied to a galvanometric scanning system, which directed the radiation through an F-theta lens focusing the radiation at the interface. Laser exposure parameters were varying among arrays. The fused silica surface was studied by the optical profilometer Zemetrics ZeScope. Obtained values were compared with the measuring results of the microlenses arrays made using F-theta lens.

5

RODION ERESKO | ALFEROV UNIVERSITY

NUMERICAL SIMULATIONS OF THE GALLIUM PHOSPHIDE NANOWIRES AND 2D TRANSITION METAL DICHALCOGENIDES BASED HYBRID SYSTEM OPTICAL PROPERTIES

The object of this work is a hybrid system based on gallium phosphide NNW (GaP) and 2D transition metal dichalcogenides (TMDC). The prospects for the study of these materials are due to the radiative properties of MoSe2 and MoS2 monolayers, as well as the waveguide and resonator properties of GaP NNW associated with low absorption in almost all visible and IR ranges. The use of GaP-based NNW as submicron waveguides makes it possible to significantly increase the directivity of photoluminescence output from MoSe2 and MoS2 monolayers, which makes it possible to integrate this hybrid system into optical chips. In this paper, a system with the following geometries and parameters was investigated by numerical modeling methods: on a Si substrate with a 300 nm thick SiO2 layer, there is a 0.7 nm thick MoS2 monolayer (MoSe2), on top of which there is a 6 micron long GaP part. The calculations were carried out for the NNW's diameters of 300, 250, 200, 150 nm. A model Gaussian beam with a wavelength of 532 nm was used to analyze the interaction of the pump laser with the system under consideration. Photoluminescence (PL) from TMDC monolayers was modeled using dipole sources which spectral emission range was 625-725 nm and 740-860 nm for MoS2 and MoSe2, respectively. Analysis of model data shows: 1) There is a decrease in the localization of the wave field inside the GaP NNW and localization at the NNW/TMDC interface increases with a decrease in the diameter of the NNW and an increase in the wavelength, and for better penetration of TMDC radiation into the GaP NNW, it is necessary to use NNW with a diameter of more than 200 nm; 2) localization of the PL field in the volume of the NNW is higher in the case of polarization in a plane perpendicular to NNW's axis that in the case of polarization in the direction of the parallel axis; 3) the Q-factor decreases with a decrease in the diameter of the GaP NNW, which indicates a stronger delocalization of e/m waves inside it.

6

ALISHER IBRAGIMOV | LOMONOSOV MOSCOW STATE UNIVERSITY

LIGHT MODULATION USING SEMICONDUCTOR METASURFACES UPON ELECTRICAL SIGNAL

Chalcogenide phase-change materials (PCMs) are a promising platform for the development of non-volatile memory and computing devices, including those inspired by brain principles. One of the key challenges in these devices is the high energy consumption for the crystallization (writing) and amorphization (erasing) processes when switching between different states. In this paper, we propose to combine PCMs with a sub-wavelength chain of variable-sized silicon nanoantennas, varying according to a parabolic reflectance profile. Numerical simulation results using FDTD as well as FEM show that such a chain of nanoparticles requires orders of magnitude less energy for writing and erasing compared to a conventional silicon waveguide due to the deceleration of light near the edge of the photonic band gap which leads to the enhancement of the local electromagnetic fields in the structure. The results obtained can be used to create more efficient devices for silicon neuromorphic photonics.

7

LEONID LEITES | LOMONOSOV MOSCOW STATE UNIVERSITY

OPTICAL ELEMENTS FABRICATION BY USING MICROSTEREOLITHOGRAPHY 3D-PRINTING METHOD

Nowadays, the industry has a need for the development of the technology of custom optical elements as part of prototyping or small-scale manufacturing. For example, such need arises, when it's necessary to develop augmented reality glasses or photonic integrated circuits.
An interesting additive approach to solving such problems is the use of projection microstereolithographiy 3D-printing (PμSL). The resolution of this approach can reach a few microns. At the same time, the printed samples have a layer-by-layer structure, that does not allow to achieve the optical quality of the surface. In order to solve this problem, authors developed post-processing technology which allowed to smooth out the surface. This approach has a few drawbacks: 1) The fabricated optical elements cannot be used to work with high-intensity light due to the properties of existing photopolymers. 2) Existing photopolymers have low transparency in the UV range.
For the fabrication of UV transparent structures with high chemical and temperature resistance, the technology of quartz 3D-printing has been developed, namely the one with a high aspect ratio including manufacturing of a composite photoresin, polymerization, and sintering in a vacuum furnace. High transmittance with wavelengths from 190 nm to 1100 nm for polymerized samples has been demonstrated. Lightguides with a diameter of 2 mm and length of 12 mm were obtained by 3D printing and the effect of total internal reflection was demonstrated.
Another interesting application of the above mentioned technology is the fabrication of custom active media in solid-state lasers. As seen in work of Moore et al [1], phase separation phenomena can be used to fabricate complex glass parts containing lanthanide salts and displaying light-controlled porosity. Thus, it is possible to change the concentration of rare-earth metals in glass in a scale of several microns, which can, for example, make it possible to fabricate laser arrays and other active media with unique properties.
References:
1. Moore, D.G., Barbera, L., Masania, K. et al. Three-dimensional printing of multicomponent glasses using phase-separating resins. Nat. Mater. 19, 212–217 (2020).

8

TIMOFEI ANTIPOV | LOMONOSOV MOSCOW STATE UNIVERSITY

IALL-OPTICAL MODULATION BASED ON THE PHASE-CHANGE MATERIALS

The creation of efficient light sources on a chip is one of the most important problems of modern integrated photonics. In this work, as such a source, we proposed an InSe film combined with a waveguiding chain of resonant silicon nanoparticles, in which Mie resonances can be excited. It was experimentally shown that the photoluminescence of the InSe film is enhanced by 45 times as compared to the case when the film is combined with a standard rib waveguide. This and other results can be useful in various applications of integrated photonics.

EKATERINA DERIBINA | SAINT-PETERSBURG STATE UNIVERSITY

DROPLET MOLECULAR BEAM EPITAXY AND OPTICAL PROPERTIES OF QUANTUM DOTS GAAS/ALGAAS

Unlike quantum wells, where the movement of electrons is limited along one axis, the spatial limitation of the movement of quantum dots takes place for all three dimensions. Thus, a quantum dot corresponds to an almost zero-dimensional motion of electrons. The energy spectrum of such quantum structures is purely discrete in all three directions. In practice, they can serve as the basis for creating devices, primarily for opto- and nanoelectronics.

There are two methods for quantum dot epitaxy. Traditionally, they are grown according to the Stranski-Krastanov method: a ternary solution of indium arsenide is collected on the surface of gallium arsenide into islands, then again covered with gallium arsenide. However, indium dots are highly stressed due to the large difference in lattice constants and are considered to be of lower quality.

In this work, we used the method of droplet epitaxy, in which aluminum arsenide is used as an energy barrier. There are no stress in such quantum dots, since the lattice constants are almost the same, which significantly improves the quality of such semiconductor structures.

For epitaxially grown samples, the photoluminescence and reflection spectra from grown samples with quantum dots were studied. The surface structure at different stages of growth was also studied.""Unlike quantum wells, where the movement of electrons is limited along one axis, the spatial limitation of the movement of quantum dots takes place for all three dimensions. Thus, a quantum dot corresponds to an almost zero-dimensional motion of electrons. The energy spectrum of such quantum structures is purely discrete in all three directions. In practice, they can serve as the basis for creating devices, primarily for opto- and nanoelectronics.

There are two methods for quantum dot epitaxy. Traditionally, they are grown according to the Stranski-Krastanov method: a ternary solution of indium arsenide is collected on the surface of gallium arsenide into islands, then again covered with gallium arsenide. However, indium dots are highly stressed due to the large difference in lattice constants and are considered to be of lower quality.

In this work, we used the method of droplet epitaxy, in which aluminum arsenide is used as an energy barrier. There are no stress in such quantum dots, since the lattice constants are almost the same, which significantly improves the quality of such semiconductor structures.

For epitaxially grown samples, the photoluminescence and reflection spectra from grown samples with quantum dots were studied. The surface structure at different stages of growth was also studied.

10

MAKSIM APARIN | LOMONOSOV MOSCOW STATE UNIVERSITY

FABRICATION OF OPTICAL MICROSTRUCTURES WITH GRADIENT REFRACTIVE INDEX BY TWO-PHOTON LASER LITHOGRAPHY

The method of two-photon lithography is used to fabricate GRIN microstructures. Test rectangular structures with sizes 25x25x3 micrometers were used with varying laser intensity by linear or gaussian distribution in one dimension. The resulting refractive index has been tuned in the range of 0.03. The suggested method can be applied to produce arbitrarily-shaped 3D GRIN micro-optical elements.

11

EMIL CHIGLINTSEV | MOSCOW INSTITUTE OF PHYSICS AND TECHNOLOGY

NONLINEAR TERAHERTZ GENERATION OF CARBON NANOTUBES

In this paper, the transport of free charge carriers of various CNTs in terahertz fields of different power was studied. Regardless of the length of CNTs and their diameter, a change in the behavior of delocalized charge carriers was detected with an increase in the power of terahertz radiation (the appearance of Drude), while the plasmon contribution remained unchanged for all measured samples. This behavior may indicate the generation of additional free charge carriers in powerful terahertz fields. To study the effect of interline scattering, the ratio of the concentration of charge carriers to their effective mass (N/m*) was estimated depending on the field strength (from 15 to 60 kV/cm). A change in energy levels under the influence of a strong electric field, leading to an increase in the number of free carriers, may be a qualitative mechanism explaining the change in conductivity in CNTs. The behavior of free charge carriers in CNTs of various types was also investigated. At the maximum amplitude of the terahertz field, the ratio N/m* increases 1.5 times for long nanotubes with a large diameter, and 6 times for short ones with a smaller diameter at an electric field strength of about 60 kV/cm.

12

POLINA SHABAN | ITMO UNIVERSITY

SKYRMIONS IN MOIRE MAGNETS

We consider a twisted magnetic bilayer. The interplay of induced by elctric field Dzyaloshinskiy Moriya interaction and spatially varying Moire exchange potential results in complex non-collinear magnetic phases in these structures. We numerically demonstrate the coexistence of intralayer skyrmions and bound interlayer skyrmion pairs and show that they are characterized by distinct dynamics under the action of electric current. Specifically we demonstrate the railing behaviour of skyrmions along the domain walls which could find applications in spintronic devices based on van der Waals magnets.

13

ELIZAVETA ARKHIPOVA | PETER THE GREAT ST.PETERSBURG POLYTECHNIC UNIVERSITY THE IOFFE PHYSICAL-TECHNICAL INSTITUTE OF THE RUSSIAN ACADEMY OF SCIENCES

ULTRAFAST LASER-INDUCED DYNAMICS OF MAGNETO-OPTICAL RESPONSE IN LAYERED VAN DER WAALS ANTIFERROMAGNETS NIPS3 AND FEPS3

Exfoliation of graphene and demonstration of its unique properties laid the foundation for an active search and study of other types of two-dimensional and quasi-two-dimensional materials. The modification of the magnetic properties of materials in the 2D limit also attracts a lot of interest, as such materials may find application in the creation of ultrathin spintronic and magnetic memory devices, and also be used to create heterostructures with unique properties.

This work is devoted to revealing the features of the ultrafast laser-induced dynamics of the magneto-optical response in van der Waals magnetically ordered materials. Layered van der Waals antiferromagnets FePS3 and NiPS3 from the family of transition metal thiophosphates were chosen as the object of study. The measurement of ultrafast laser-induced dynamics was carried out using the femtosecond pump-probe technique.

The magnitude of the laser-induced magneto-optical signal changes with temperature as a derivative of the order parameter L. For the MPS3 (M=Ni, Fe) below the transition temperature to the antiferromagnetic state, the laser pulse induces an ultrafast partial decrease in the antiferromagnetic vector (demagnetization). The temperature dependences of laser-induced demagnetization in in NiPS3 and FePS3 was found to be qualitatively similar. For FePS3, characteristic times of demagnetization appeared to be longer then in the NiPS3 sample, and increase noticeably as the Néel temperature is approached

14

ARTEM POLUSHKIN | ITMO UNIVERSITY

SLOT-DIE COATING DEPOSITION METHOD FOR PEROVSKITE GREEN LIGHT-EMITTING CHEMICAL CELL FABRICATION

Nowadays halide perovskites demonstrate high potential for solar cell and light-emitting devices. Laboratory-made devices show significant results, however, fabrication methods used in the laboratory, like spin-coating, are not applicable for mass production. Slot-die coating is one of the scalable methods that can be used for the mass production of perovskite devices. This work is dedicated to CsPbBr3 perovskite bright green light-emitting chemical cell fabricated by slot-die coating with gas-assisted crystallization.

15

STANISLAV COLARI | MOSCOW INSTITUTE OF PHYSICS AND TECHNOLOGY
RUSSIAN QUANTUM CENTER
TRANSFER OF THE ORBITAL MOMENTUM OF LIGHT TO THE SPIN SYSTEM IN A FERRITE GARNET FILM

The control of spin dynamics with the help of light opens up new possibilities for creating various logical devices and circuits. In this study, we considered how the orbital angular momentum of light affects the precession of magnetization in a ferrite garnet film. To do this, we used Laguerre-Gaussian light beams with different orbital numbers. The dependence of the amplitude and phase of spin waves on the orbital number was discovered, and the cause of the influence of structured light on the magnetization precession was studied.
The work was supported by the Russian Science Foundation grant No. 21-12-00316.

16

ANASTASIIA EFIMOVA | ITMO UNIVERSITY
MONOLAYERS OF ZN-BASED METAL-ORGANIC FRAMEWORK FOR VAPOR POLARITY SENSING

Metal-organic frameworks (MOFs) are a class of hybrid materials where metallic centers are bound with organic ligands. These materials are perfect candidates for sensing as their optical properties change under external stimuli such as radiation, gas, or temperature. 2D-MOFs could be exfoliated into monolayers as graphene or transition metal dichalcogenides. But the creation of applications based on 2D-MOFs is challenging as achieving the high aspect ratio of the layers and MOF's flakes is a non-trivial task.

Here we present 2D MOF based on zinc ions and H4TBAPy (1,3,6,8-tetrakis(p-benzoic-acid)pyrene) ligand. MOF was exfoliated using the thaw-freeze technique: first crystals were dipped into dimethylformamide (DMF) and afterward frozen in liquid nitrogen and melted in water 15 times. The obtained layers have an extremely high aspect ratio (1:21333) with a lateral size of which is equal to 60 um and a height equal to 3 nm.

The photoluminescence of bulk zinc-based MOF increases in presence of guest DMF molecules and decreases while UV-eradiation as the solvent evaporates. Exfoliated material is more sensitive to solvent presence as the interacting area is bigger due to the high aspect ratio so the solvent evaporation process goes rapidly. Based on exfoliated layers detector of solvent polarity was made. A similar effect of changing the luminescence intensity will make it possible in the future to create sensitive and efficient gas sensors based on two-dimensional frameworks.

17

MIKHAIL MIRUSCHENKO | ITMO UNIVERSITY

DEVELOPING OF PH SENSORS BASED ON CARBON DOTS FROM O-PHENYLENEDIAMINE

The main problem in the use of pH sensors is the possibility of other solvents or metal salts in water. The effect of pH changes in a mixture of ethanol and water in equal proportions on the position of the maxima in the absorption and luminescence spectra of carbon dots from o-phenylenediamine was studied, and the effect of additions of Ca, Co, Cu, and Fe salts on the optical properties of these dots was studied. The obtained results are compared with the changes occurring in pure water. The possibility of developing pH sensors based on carbon dots from o-phenylenediamine is considered. The introduction of dots into paper and cellulose strips was carried out. The optical properties were studied when solutions with a known pH were added to the strips. The obtained results were compared with commercial samples of paper test strip.

18

ANDREY DOTSENKO | LOMONOSOV MOSCOW STATE UNIVERSITY

PECULIARITIES OF OPTICAL RESPONSE OF 3D ALUMINA PHOTONIC CRYSTALS

Artificial optical materials are the cornerstone of photonics serving unusual optical properties. The wealth of functionalities is offered by photonic crystals (PhCs), which are periodical dielectric structures supporting photonic band gaps (PBG), that are the frequency ranges, in which light cannot propagate through the PhC. In spite of the variety of PhCs fabrication methods, the formation of 3D structures remains a challenging problem.

In this work we studied the optical properties of 3D PhCs made of anodic aluminum oxide (AAO) obtained by the electrochemical anodization. The key point here is the perfect periodic ordering of the structure consisting of the hexagonal array of air pores with the diameter of hundred of nanometres. Periodical arrangement of the pores with spacing of 400 nm was achieved by pre-patterning of aluminum foil by focused ion beam processing. To obtain the 3D modulation of the refractive index, harmonic modulation of the pores' diameter along their direction with a period of several hundred nanometers was applied.

We revealed multiple PBGs in the angle-wavelength transmission spectrum of 3D PhCs and found that the 3D periodicity results in the appearance of additional PBGs as compared to analogous structures with random pore arrangement. The latter structure exhibits PBGs intrinsic to 1D PhC, which can be considered as layered structure with periodical distribution of the effective refractive index. The performed analysis demonstrates that PBGs of 3D PhCs result from the lateral umklapp PBGs process driven by the in-plane hexagonal pores' arrangement. The obtained experimental results are confirmed by numerical calculations carried out using the rigorous coupled-wave analysis.

We believe that found optical properties of 3D PhCs opens the way for the light manipulation with advanced AAO structures and makes alumina PhCs promising for sensing applications harnessing open-end pores of the structures. Work is supported by RSF grant № 19-73-10176.

19

ANNA OBRAZTSOVA | ITMO UNIVERSITY

BIFACIAL PEROVSKITE SOLAR CELL IMPROVED BY A HIGHLY EFFICIENT LIGHT-TRAPPING ELECTRODE

Perovskite materials possess excellent optical and electrical characteristics, and hence, their use for solar cells attracts rising interest [1]. One of the common designs for solar cells is a one-sided structure with front traditional electrodes based on transparent conducting oxides, such as FTO and ITO, and a non-transmitting metallic contact. Such solar cells exhibit a high photovoltaic efficiency up to 25.7% [2]. However, bifacial perovskite solar cells (PSCs) consist of two transparent electrodes and have recently drawn growing attention [3]. The bifacial structure increases the solar cell efficiency by a harvesting of the reflected light, but the development of such PSCs is prevented by their low light absorption in the active layer due to high optical losses, which leads to a photocurrent reduction and, as a result, a decrease in the power conversion efficiency. In addition, ITO and FTO have a high sheet resistance, which reduces the power conversion efficiency. To increase the generation rate in the perovskite photoactive layer and enhance the energy conversion efficiency of PSCs, light-trapping structures improving the light absorption in the active layer can be introduced.

In our work, we have introduced a method involving a light-trapping electrode, which presents a perforated metal electrode with densely packed dielectric nanospheres. We have performed an optical and electrical calculations of our PSCs and have shown that these structures significantly improve the efficiency of light conversion and current generation. We have observed an 15% improvement in the light absorption for the bifacial PSCs. The best theoretical results of efficiency for our PSCs is 33.4% at the input power is Pin = 50 mW. Thus, the modified electrode based with the light-trapping function is one of the best candidates to replace the classic transparent conducting oxides such as ITO or FTO. We show that our structure has excellent characteristics, improving the efficiency of light conversion and current generation.

References

[1] Zhang, Hailin, et al. ""Review on efficiency improvement effort of perovskite solar cell."" Solar Energy 233 (2022): 421-434

[2] www.nrel.gov

[3] Song, Zhaoning, et al. ""Perovskite Solar Cells Go Bifacial—Mutual Benefits for Efficiency and Durability."" Advanced Materials 34.4 (2022): 2106805

20

EKATERINA AGAFONOVA | SKOLKOVO INSTITUTE OF SCIENCE AND TECHNOLOGY

STAR SPECTRA: SCREENING OF STAR-SHAPED HOLE TRANSPORTING MATERIALS TOWARDS 20% PEROVSKITE SOLAR CELL EFFICIENCY

The organic p-type semiconductors gained extensive attention due to their low-temperature solution processability and tunable optoelectronic properties. However, as soon as the amount of parameters for structure-property tailoring grows exponentially, one needs the guidelines towards rational design of these materials. In particular, the issue remains acute in the field of perovskite solar cells (PSCs), where the strict criteria should be met by the hole transporting material (HTM).
Our goal was to provide a solid strategy towards design of the state-of-the-art HTM for PSCs. In order to accomplish that, we have performed a systematic performance screening in devices and characterisation of 14 compounds incorporating triphenylamine (TPA), triazatruxene (TAT) and quinolizine acridine (QA). With the extensive research on side wing substituents, we were able to deduce the complex structure-property relationships and prioritise the effect of core and side parts of the star-shaped small molecule.
To reveal the figures of merit for HTM quality evaluation the surface potential and morphology were examined by Kelvin probe force and atomic force microscopies. It is found that the triazatruxenes employing dithiophene moiety as π-bridge reveal wired surface assembly distinguishing them from their counterpart with three thiophenes. Furthermore, it is shown that the optimal highest occupied molecular orbital (HOMO) level favouring enhanced open circuit voltages (Voc) ranges from -5.4 to -5.2 eV for $MAPbI_3$.
Another preliminary parameter to consider is the photoluminescence (PL) quenching in perovskite/HTL sandwiches. In the absence of the intrinsic luminescence of the compound the PL quenching is directly related to the resulting device efficiency. For instance, the highest value of PL quenching (~95%) for TAT2 accounts for the low recombination rate leading to the impressive device performance of 20.0%. It means that one may use the photoluminescence quenching as the figure of merit to evaluate the perovskite/HTM interface quality.

21

ALEXEY KUZNETSOV | ALFEROV UNIVERSITY

GAP/GAPXAS1-X EPITAXIAL NANOWIRES BASED DIRECTED RADIATION SOURCES

Precisely controlled synthesis of axially heterostructured epitaxial nanowires (NWs) with a properly selected set of materials makes it possible to fabricate new photonic devices, such as submicron resonators with an integrated nanosized emitter. An example of such a structure is the GaP NW studied in this work with 50 nm direct-gap inserts based on the GaPxAs1-x ternary solid solution and a droplet of Ga catalyst at the end tip. By using photoluminescence microspectroscopy and numerical simulations, the optical response from single horizontally oriented heterostructured NWs was studied experimentally and theoretically. Due to the high refractive index and almost zero absorption within the emission band of the GaPxAs1-x inserts act as a Fabry-Perot cavity. Near each insert, a weak radiation propagating perpendicular to the nanowire axis occurs. Thus, both amplitude and spectrally anisotropic photoluminescent signals can be obtained inside a heterostructured NW. Numerical simulation of the PL of direct-gap inserts, demonstrates a decrease in the directivity of radiation. Spectral and spatial features of the PL excited in GaPxAs1-x inserts in GaP NWs were experimentally and theoretically analyzed. Inserts provide anisotropic radiation, which can be output both in their vicinity and at the edge. Due to the resonant properties of the NWs, the radiation extracted from the tip is strongly spectrally modulated, while the radiation detected in the vicinity of the inserts is unmodulated and less intense. The Ga droplet, which, on the one hand, acts as an effective reflector that increases the quality factor of the resonator, and, on the other hand, as an optical antenna that allows an electromagnetic wave polarized along the NW axis to penetrate more efficiently. Additional modeling of NWs with IR emitters demonstrates the effects of changing the field pattern, leading to a weaker radiation directivity along the NW axis.