1st International Workshop on Advanced Materials for Medicine and Environment

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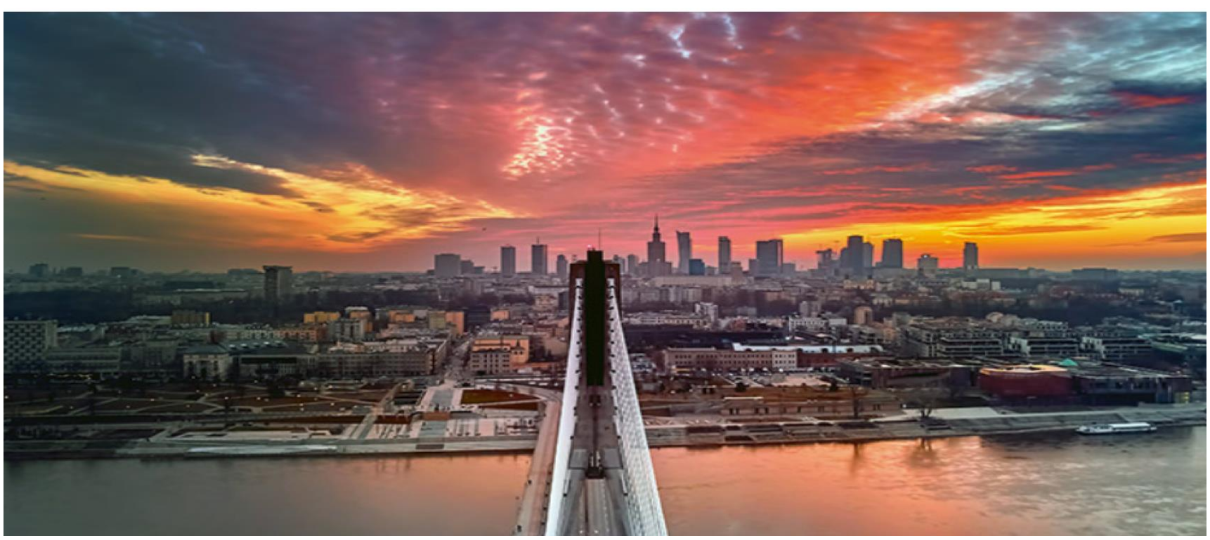

1st International Workshop on Advanced Materials for Medicine and Environment

IWAMME 2022
June, 24-25

The present edition of the 1st IWAMME is under the auspices of the Institute of the Fundamental Technological Research of the Polish Academy of Sciences in Warsaw, the University of Warsaw, and the Warsaw University of Technology

The book of Abstracts

Warsaw, June 24-25

Introduction to the International Workshop on Advanced Materials for Medicine and Environment

Dear Colleagues,

On behalf of the Organizing and Scientific Committees of the "1st International Workshop on Advanced Materials for Medicine and Environment", IWAMME2022, I have the great pleasure of inviting you to participate in this event on June 24-25, 2022, in Warsaw, Poland.

The IWAMME2022 will be organized for the first time by the interdisciplinary scientific community of the city of Warsaw under the patronage of the Institute of the Fundamental Technological Research of the Polish Academy of Sciences in Warsaw, the University of Warsaw, and the Warsaw University of Technology. During this event, we would like to initiate among experts the forum discussions on advanced materials and technologies applicable to the fields of Bio-medicine and Electronics.

We are looking forward to meeting you in person in Warsaw!

Yours sincerely,

Michał Giersig
(Institute of Fundamental Technological Research of Polish Academy of Sciences)
Chairman of the Scientific Committee

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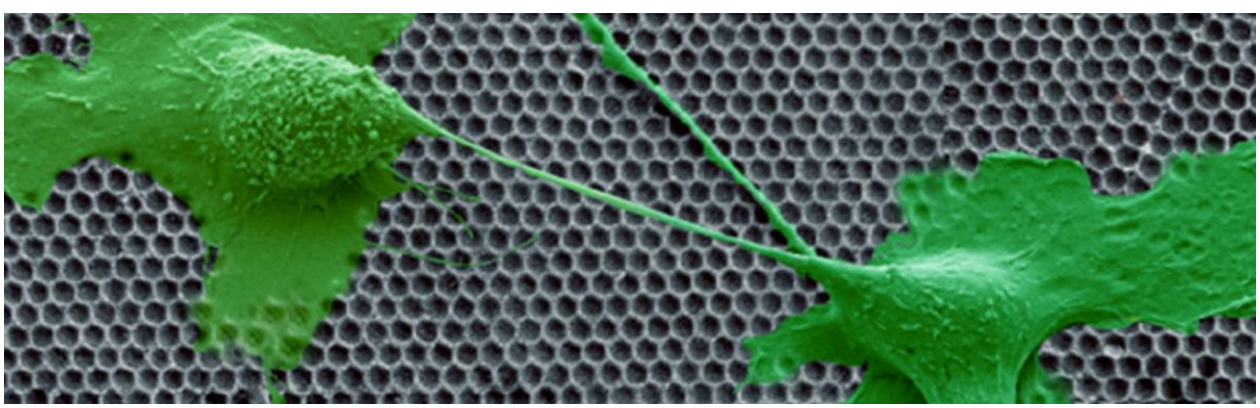

Many-body theory of collective modes to describe nanostructures and low-dimensional materials

Piotr Chudzinski

Department of the Theory of Continuous Media and Nanostructures, Institute of Fundamental Technological Research, Polish Academy of Sciences, Pawinskiego 5B Str., 02–106 Warsaw, Poland

Corresponding author: ***pchudzin@ippt.pan.pl***

In the first part of the talk, we shall introduce the many-body theory of collective modes, known as Tomonaga-Luttinger liquid, and clarify the regimes when it is applicable. We shall focus on nanostructures created by the method of nano-sphere lithography, indicating when the collective phenomena may play an important role. The motivation of our interest in such theories, is because they can provide us with solutions hosting exotic orders, when charge and spin are separable and order independently. We will then move to theoretical progress recently achieved at IPPT in Warsaw. This includes a specific problem of field emission from nano-engineered surfaces described by power law potential. Another interesting solved problem is the existence of an exact analytical solution for soliton-type excitations in a curved space. In the last part of the talk, we will move on to the question whether such theories can be realized in real materials.

We shall describe in detail one material, lithium molybdenum purple bronze, where not only we have experimental evidences of Tomonaga-Luttinger liquid, but also we were able to show an emergence of new type of order – an incomplete Mott-Peierls insulator. The talk will be concluded with some future perspectives, in particular embedding quasi-1D materials in nanostructures.

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Surface modifications and mechanical characterization – accelerated way for development of new materials and systems for the green future.

Dariusz M. Jarząbek, *Piotr Jenczyk*, and *Michał Milczarek*

Institute of Fundamental Technological Research, Polish Academy of Sciences, Pawinskiego 5B Str., 02–106 Warsaw, Poland

*Corresponding author:**djarz@ippt.pan.pl***

Sustainable development requires on the one hand new environmentally-friendly energy sources and on the other hand durable and/or recyclable devices. Unfortunately, many mechanical moving components for energy production or harvesting operate in extremely harsh environments. Due to the surface friction and wear at high temperatures, in a corrosive environment and/or under significant radiation the service life and reliability of these components are still suffering serious technical challenges. Hence, there is an urgent need to develop new materials, which can provide this reliability, and much recent research of our group has focused on this topic.

Among the new materials we deal with, high-entropy alloys and ceramics (HEAs and HECs) have recently played an important role. Unlike conventional alloys, which contain one and rarely two base elements, HEAs comprise multiple principal elements, with the possible number of HEA compositions extending considerably more than conventional alloys. Furthermore, HECs represent a new type of high-entropy materials that can have unique compositions and structures that differ distinctly from any other existing materials, as well as great possibilities of tailoring their properties via an extremely-large compositional engineering space. Compared with conventional materials, many HEAs and HECs have considerably better strength-to-weight ratios; enhanced tensile strength; and improved fracture, corrosion, and oxidation resistance [1]. However, it would be difficult to use them commercially in most structural engineering applications, where much cheaper, yet still suitable materials—such as steels or aluminum or magnesium alloys—are currently used. Hence, one should pursue applications in which HEAs are still attractive, that is, applications in which all other materials fail to function properly. For example, interactions with irradiation or high-energy particles usually induce severe and challenging structural changes of conventional materials and initial research shows that HEAs and HECs may be significantly more resistant to this effects [2]. This topic is of particular importance for future nuclear and fusion power plants and space applications.

In this workshop we present our approach to this problem and our recent results. To study the phase stability of HEAs, we use ion implantation and nanoindentation. This approach provides much faster results than conventional neutron irradiation of the whole sample. Furthermore, ion implantation combined with thermal treatment may lead to the creation of new materials. As an example we present nitrogen ion implantation of $AlCoCrFeNiTi_{0.2}$, an alloy in which the σ phase is dominant [3]. We applied high-fluence nitrogen ion implantation and observed not only the σ-to-BCC phase transformation, but also a hardening of both phases.

Furthermore, X-ray powder diffraction (XRD) results of the implanted samples revealed an unexpected crystallographic structure that could not be assigned to any simple nitride. We have tentatively attributed these changes to the creation of new high- or medium-entropy ceramics, with interesting and promising properties. The ion-irradiated surface exhibited enhanced ductility and increased wear resistance, both of which are very beneficial for applications in mechanical engineering and tribology.

It should be noted that creation of thin layers of new or modified materials introduces the problem of their characterization and extrapolation of their properties at the nano/microscale to the macroscale. Hence, in our group we also develop the measurement methods and tools which are helpful in solving this issue [4]. For example, there is a big gap in experimental tribology on the boundary between the nano- and microscale caused by a limited selection of tools for such precise measurements. Atomic force microscopes could be used in this range; unfortunately, they are limited by the types of probes available on the market. Probes for atomic force microscopy are commonly made of silicon or silicon nitride with a stiffness in the range of 0.01 to 100 N/m. At the same time, a proper friction experiment requires materials and loads carefully selected, as they greatly influence the results. We strive to solve this problem by designing all-metal probes and fabricating them using a novel method. Our probes allow previously impossible experiments to be conducted for a better understanding of the mechanics of friction at the microscale. It can lead to the new approaches of reduction of friction at the macroscale and therefore, saving of energy and increased durability of the mechanisms.

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ZnO- and ZrO_2-based fluorescent nanoparticles for cancer detection and treatment

Marek Godlewski[1,*], *Jarosław Kaszewski*[1], *Julita Rosowska*[1], *Paula Kiełbik*[2], and *Michał M. Godlewski*[2]

[1]Institute of Physics, Polish Academy of Sciences, Al. Lotników 32/46, 02–668 Warsaw, Poland
[2]Department of Physiological Sciences, Faculty of Veterinary Medicine, Warsaw University of Life Sciences – SGGW, Nowoursynowska 159, 02–776 Warsaw, Poland
Corresponding author: ***godlew@ifpan.edu.pl***

Nanoparticles (NPs) of selected wide band gap oxides (ZnO, ZrO_2) are tested by us for early detection of cancer. These NPs are used as so-called fluorescent markers (FMs). This new generation of FMs is based on NPs doped with rare earth ions. ZnO and ZrO_2 are selected due to their bio-neutrality. Rare earth doping of the markers results in relatively efficient and spectrally sharp photoluminescence (PL) in a visible light spectral region. Importantly, a stable PL is observed, without any blinking and photo-bleaching. We tested a new method of FMs introduction – Intra-gastric (IG). This innovative method of introducing of markers to organisms was developed by us. After IG introduction FMs penetrate and gradually accumulate in tumors, including the difficult to diagnose and treat lungs tumor. An effective trafficking of FMs to the areas of lung cancer was observed, whereas surrounding tissue was impermeable for nanoparticles. The data obtained confirm 100% selectivity of the method. FMs developed by us can also be used as MRI contrast agents. Moreover, we performed tests of using developed FMs as transport agents. FMs were used to selectively introduce a given medicine to area of tumor. A directed therapy is thus possible.

Properties of nematic liquid crystals for linear and nonlinear optics

Mirosław A. Karpierz

Faculty of Physics, Warsaw University of Technology, Koszykowa 75 Str., 00-662 Warsaw, Poland

Corresponding author: ***karpierz@if.pw.edu.pl***

Liquid crystals are unique materials for optics, applicable not only in commonly used displays or phase modulators. Their unique properties result from transparency in a wide spectral range (especially for visible and near infrared light), high birefringence and the possibility of creating complex structures that can be easily reoriented with external fields. To the above advantages, it is necessary to add the unique properties of optical nonlinearity mechanisms, in particular reorientational and thermal nonlinearities and their combination. These are extremely strong nonlinearities, nonlocal, incoherent, controlled by outer fields, giving unique properties of focusing and defocusing competition.

The above features of nematic liquid crystals will be illustrated in this presentation on experimental phenomena and systems such as elements for forming vortex beams of any (tunable) polarization or switching systems in channels produced by spatial optical solitons (called nematicons).

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Interaction of biomolecules and cells with nonionizing electromagnetic radiation I: Theory

Kris Kempa and *Michael J. Naughton, Boston College*

Department of Physics, Boston College, Chestnut Hill, MA 02467, USA
Corresponding authors: ***kris.kempa@bc.edu,*** and ***naughton@bc.edu***

While molecular spectra are highly characteristic (identifiable) at low excitation level, this property is lost at very high excitation levels due to nonlinear effects. We show that by following the progression of a characteristic resonance maximum while gradually increasing intensity of radiation, one must necessarily arrive at a dissociation point, where ultra-high spectral selectivity is retained. This is a general property of all systems that belong to the class of the *fold catastrophe* of Catastrophe Theory. Our simulations of DNA molecules confirm this finding. This strategy might lead to novel medical therapies (cancer, anti-bacterial, anti-viral, etc.). A modification of this idea is to employ “Trojan horse” strategy, by application of nanoparticles with designed, characteristic absorption spectra, attached to or engulfed by the target biospecies. We demonstrate that such a targeted strategy, with melanin nanoparticles as the radiation target, can be used to overheat circulating tumor cells, responsible for cancer metastasis. Further extension of this idea includes employing nanoparticles producing dc voltage, and extending the class of cells to macrophages.

Microfluidics as a tool for chemical and biological research

Piotr Korczyk

Institute of Fundamental Technological Research, Polish Academy of Sciences, Pawinskiego 5B Str., 02–106 Warsaw, Poland

Corresponding author: ***piotr.korczyk@ippt.pan.pl***

Since its very beginning microfluidics has expanded rapidly as a multidisciplinary area of scientific and technical research, covering the fluid dynamics at the microscale and its various applications in biology, chemistry, and medical diagnostics. One of the attracting aspects of microfluidics is the precise control and manipulation of fluids. The high precision is commonly seen as a result of small dimensions of microfluidic channels, laminarity of the flows and dominant role of interfacial tension in two-phase flows (low capillary numbers).

The Microfluidic Laboratory of the Institute of Fundamental Technological Research aims to develop microfluidic techniques toward the increase of their precision and applicability for chemical and biological research and the elaboration of customized microfluidic devices for meeting the requirements of particular biological research. Here we show some recent examples of our activities.

Our interest area encompasses both single-phase and two-phase flows. The use of more than one immiscible phase allows for the controlled formation and then manipulations on droplets. Each such droplet in the microfluidic channel is equivalent to a tiny reactor that can include samples, reagents, or biological components for chemical synthesis, analytical assays, biological processes, drug discovery, and more. In these and other applications, obtaining the concentration of a given component in a precise, accurate, and above all, reproducible manner is paramount.

We developed unique microfluidic geometries for the passive manipulation of droplets and sequential logic devices for the controlled permutations of droplets within the sequence. Then we used digital algorithms that ensure superior accuracy, repeatability, and flexibility in concentration settings through a series of operations of the selective merging of droplets and splitting of droplets into equal parts.

Confined geometry of microfluidic chambers and superior flow control renders this technology suitable for mimicking physiological conditions for culturing cells. One of our microfluidic laboratory's main goals is to develop microfluidic devices toward the customization to the requirements of particular biological research. A successful example of the development of such biological-oriented design is our microfluidic system enabling spatial and temporal control over the formation of tension gradients arising from epithelial monolayer deformation. Our approach, in which mechanical variables of a tissue such as in-plane strain and curvature are well characterized, allowed for observations of the response of an epithelium subjected to a controlled deformation. By combining our microfluidic system with high-resolution microscopy, the local deformations of cells arising from either positive or negative folding of the epithelial layer could be observed and described.

***Acknowledgements**: grant First TEAM/2017-3/22 of the Foundation for Polish Science co-financed by the EU with the support of the Smart Growth Operational Programme (The project operated within the First Team grant (POIR.04.04.00-00-3FEF/17-00).*

Chirality and Complexity of Nanostructures

Nicholas A. Kotov

Department of Chemical Engineering, University of Michigan, Ann Arbor, USA
Corresponding author: ***kotov@umich.edu***

Nanoscale chirality is a rapidly emerging field in science and engineering. The early observation of strong circular dichroism for individual nanoparticles (NPs) and their assemblies have developed into a rapidly expanding research area on chiral inorganic nanostructures. They encompass a large family of mirror-asymmetric constructs from metals, semiconductors, ceramics, and nanocarbons with multiple chiral geometries with characteristic scales from Ångströms to microns (**Figure 1**).

Versatility in, scales, dimensions and polarizability of the inorganic materials enables their multiscale engineering to attain a broad range of optical and chemical properties. These capabilities as chiral materials enabled their fast technological translation for biosensing and optoelectronics, which, in turn, opened new venues for scientific inquiry into the unifying role chirality at the interface of materials science, biology, chemistry, and physics.

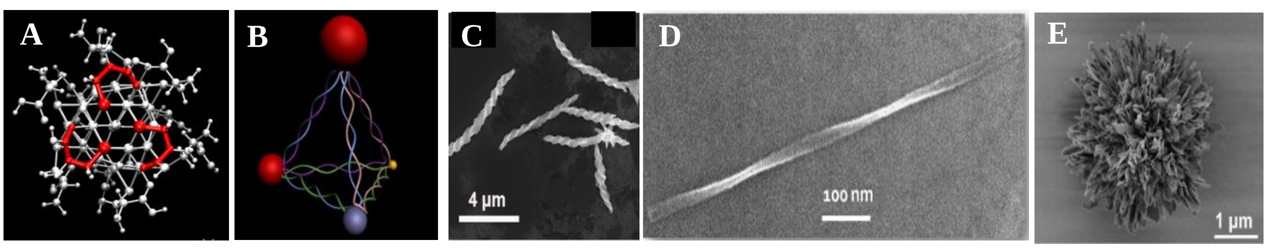

Figure 1. **Chiral inorganic nanostructures at multiple scales**. (A) Co_3O_4 NPs with twisted crystal lattice ; (B) tetrahedral assembly of four different NP; (C) mesoscale helices and (D) twisted ribbons self-assembled from CdTe NPs; (E) chiral hedgehog particles self-assembled from Au-S nanoplatelets.

Some of the latest directions in this field is understanding the fascinating relationships between multiscale chirality and structural/functional complexity of biomimetic nanomaterials forming from the spontaneous hierarchical ordering of inorganic building blocks over multiple scales. Empirical observations of complex nanoassemblies are abundant, but physicochemical mechanisms leading to their geometrical complexity remain puzzling, especially for non-uniformly sized components. These mechanisms are discussed in this talk taking an example of hierarchically organized particles with twisted spikes and other morphologies from polydisperse Au-Cys nanoplatelets [1]. The complexity of these supraparticles is higher than biological counterparts or other complex particles as enumerated by graph theory (GT). Complexity Index (*CI*) and other GT parameters are applied to a variety of different nanoscale materials to assess their structural organization. As the result of this analysis, we determined that intricate organization Au-Cys supraparticles emerges from competing chirality-dependent assembly restrictions that render assembly pathways primarily dependent on nanoparticle symmetry rather than size. These findings open a pathway to a large family of colloids with complex architectures and unusual chiroptical and chemical properties. The design principles elaborated for nanoplatelets have been extended to engineering of other complex nanoassemblies. They include polarization-based drug discovery platforms for Alzheimer syndrome,[2] biomimetic composites for energy and robotics [3,4], materials for chiral photonics [5], CO_2-dispersable catalysis [6] chiral antiviral vaccines [7], and pharmaceutical quality control [8]. Yet, the work on the generalization of the engineering principles for chiral biomimetic nanostructures is incomplete; further directions of these efforts will be discussed.

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The importance of lanthanide-doped nanoluminophores as excellent optical sensors and anti-counterfeiting materials

Stefan Lis

Department of Rare Earths, Faculty of Chemistry, Adam Mickiewicz University in Poznań, Uniwersytetu Poznańskiego 8, 61–614 Poznań, Poland
Corresponding author: ***blis@amu.edu.pl***

Luminescent nanomaterials doped with lanthanide ions have attracted considerable attention and due to their unique properties allow for applications in various areas, e.g. optoelectronics, display panels, solar cells, forensic materials. This lecture presents selected nanomaterials based on inorganic matrices (e.g.: fluorides, vanadates, borates, phosphates, silicates, etc.) doped with luminescent lanthanide (Ln) ions, characterized by efficient emission properties. As application materials, they should show: phase purity, high crystallinity and homogeneity, small particle size and narrow particle size distribution, and should not be agglomerated. Examples of effective nanoluminophores (NL) and up-converting (UCNL) doped with Ln^{3+} (or Ln^{2+}) ions and their surface functionalized, by coting with organic compounds, hybrid systems for sensor and analytical applications are discussed in detail. We show that the luminescence of selected Ln3+ or Ln/2+-doped NLs can be successfully used in (nano)-manometry as optical pressure sensors [1], capable of measuring pressure and multifunctional optical sensors for (nano)- manometry & (nano)-thermometry, [2] high-pressure and temperature upconversion luminescence of Ln^{3+} doped NLs [3]. Novel luminescent–magnetic cellulose microfibers, based on Ln^{3+}-doped fluorides and magnetite nanoparticles ($Fe_3O_4/SiO_2/NH_2$/PAA/LnF_3) [2] and $CeF_3:Tb^{3+}$ NPs and $CePO_4:Tb^{3+}$ nanorods [4] used as nanomodifiers of the fibers are presented. Such multifunctional NLs are excellent materials for textile and documents protection against counterfeiting [4,5].

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Wind Energy System (WES) - universal source of energy

Jacek Michalczuk

MG-ECOPOWER GmbH, Hirschwechsel 7a, Kleinmachnow 14532, Brandenburg Germany
Corresponding author: ***ecopower@gmail.com***

The Wind Energy System (WES) is our proposal/response to the market demand for a highly efficient, cheap, light, scalable and ecological source of energy.
Our knowledge of the combined aero-engine gas turbine technology with the new materials made with nanotechnology methods is the basis of our concept (see, **Figure 1**), which guarantees the improvement of the following important parameters of the new wind turbine:

- Increased mechanical strength, corrosion and erosion resistance and better heat transfer of rotating parts
- Removal of ice deposits on turbine blades and air ducts
- increased aerodynamic and mechanical efficiency
- Reduction in dimensions and weight
- Optimizing safe and effective work
- Reduction of noise emissions and exclusion of negative environmental impact caused by "shadow flicker"

The new turbine enables operation in all geographic and agglomeration conditions for individual and industrial users on water and on land. The construction of the WES and the technology of creating new composites has been patented and we are in the prototyping phase.

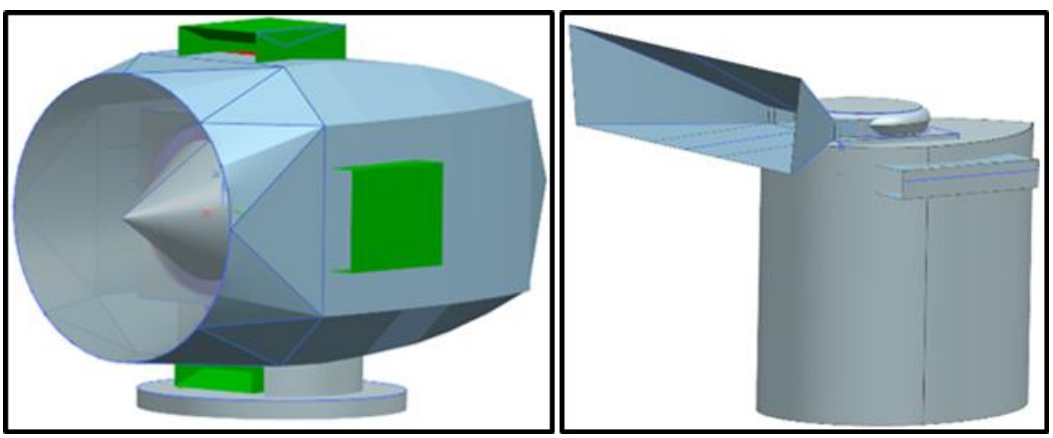

Figure 1. Horizontal and vertical view of our gas turbine.

Interaction of biomolecules and cells with nonionizing electromagnetic radiation II: Experiment

Michael J. Naughton, and *Krzysztof Kempa*

Department of Physics, Boston College, Chestnut Hill, MA 02467, USA
*Corresponding authors**: naughton@bc.edu***, and ***kris.kempa@bc.edu***

We report on our recently demonstrated selective optical destruction of cancer cells [1]. Melanin nanoparticles are known to be biologically benign to human cells for a wide range of concentrations in a high glucose culture nutrition. We have recently shown show cytotoxic behavior at high nanoparticle and low glucose concentrations, as well as at low nanoparticle concentration under exposure to (nonionizing) visible radiation. To study these effects in detail, we developed highly monodispersed melanin nanoparticles (both uncoated and glucose-coated). In order to study the effect of significant cellular uptake of these nanoparticles, we employed three cancer cell lines: VM-M3, A375 (derived from melanoma), and HeLa, all known to exhibit strong macrophagic character, *i.e.*, strong nanoparticle uptake through phagocytic ingestion. Our main observations are: (i) metastatic VM-M3 cancer cells massively ingest melanin nanoparticles (mNPs); (ii) the observed ingestion is enhanced by coating mNPs with glucose; (iii) after a certain level of mNP ingestion, the metastatic cancer cells studied here are observed to die—glucose coating appears to slow that process; (iv) cells that accumulate mNPs are much more susceptible to killing by laser illumination than cells that do not accumulate mNPs; and (v) non-metastatic VM-NM1 cancer cells also studied in this work do not ingest the mNPs, and remain unaffected after receiving identical optical energy levels and doses. Results of this study could lead to the development of a therapy for control of metastatic stages of cancer. We also discuss a similar, sublethal method that may be possible with macrophages. Possessing the ability to electrically modulate the pro- and anti-inflammatory behavior of macrophages *in vivo*, with temporal and spatial control, could have significant impact on a number of human diseases and ailments, such as rheumatoid arthritis, Alzheimer's, cancer tumorigenesis, obesity, acute lung injury, spinal cord injury, cystic fibrosis, insulin resistance, acute respiratory distress syndrome, tissue repair/wound healing, and many others.

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Nanocomposites based on superparamagnetic iron oxide nanoparticles for cancer treatment

Magdalena Osial

Department of the Theory of Continuous Media and Nanostructures, Institute of Fundamental Technological Research, Polish Academy of Sciences, Pawinskiego 5B Str., 02–106 Warsaw, Poland

Corresponding author: ***mosial@ippt.pan.pl***

Despite the recent development in anticancer therapies, the scale of the cancer diseases and their varieties is challenging. Therefore, new treatment solutions are deeply needed. Besides the various therapeutic approaches like surgery, radiotherapy, chemotherapy, hyperthermia, and coupling of different methods, nanotechnology offers individual approaches to treating particular cancers. Much research has been done in the nanomaterials for anticancer therapy leading to the development of various nanocarriers like metal liposomes, mesoporous particles, carbon-based materials, polymer particles, hydrogels, metal, and metal oxide particles. However, nanomaterials can change their functionality for promising biomedicine applications depending on their morphology, size, surface area, and surface chemistry. One of the groups of materials bringing tremendous attention is superparamagnetic (SPIONs) particles and their composites [1-4]. Iron oxide-based nanoparticles can be fabricated within the low-cost methods offering large volume-to-surface area, controllable shape and size, and superparamagnetism for magnetic hyperthermia application. Due to their surface chemistry, they can be easily modified within porous inorganic materials like hydroxyapatite for the anticancer drug or other biologically active compounds. They can also be easily modified within the different organic compounds directly within the chemical bonds. So far, depending on their further application, they can release these substances in a controllable way. SPIONs treated within the alternating magnetic field increase their temperature, making them possible to be used towards the cancer cells to induce apoptosis within the magnetic hyperthermia (**Figure 1**). Moreover, applying hyperthermia leads to the enhanced release of anticancer drugs.

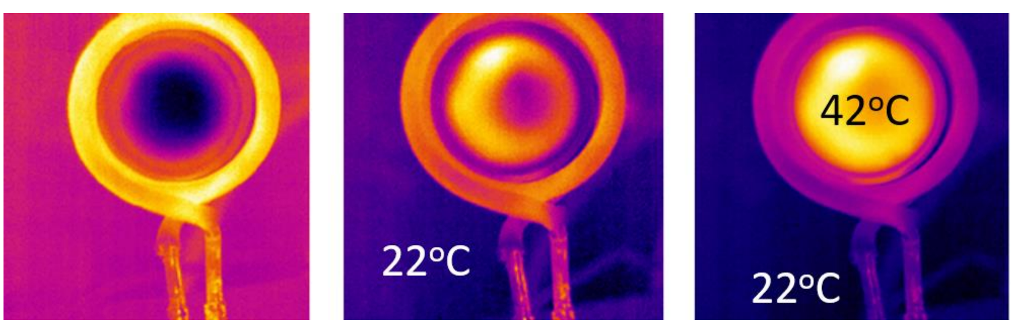

Figure 1. Heating of the superparamagnetic suspension under the alternating magnetic field (AMF). Images from the left: with no AMF, after 30 s of AMF, after 90 s of AMF

We will present our recent studies on the SPION-based nanocomposites for active targeting of cancer cells and multimodal action by simultaneous magnetic hyperthermia of specific cancer cells. Cytotoxicity studies demonstrated that fabricated nanocomposites reduced the metabolic activity of SKOV-3 cells in a dose-dependent manner. Moreover, they exhibited slightly higher toxicity when two different substances were loaded in the drug carrier. Thus, nanocomposites are stable when applying an alternating magnetic field, which is a significant feature for their possible medical applications.

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The Laboratory of Applied Biotechnology – from 3D bioprinted meniscus to COVID–19 immunodiagnostics

Adam A. Mieloch[1]*, Tomasz Szymanski*[1,2]*, Julia Semba*[1,3]*, Filip Porzucek*[1]*,* and *Jakub D. Rybka*[1]

[1] Center for Advanced Technology, Adam Mickiewicz University in Poznań, Uniwersytetu Poznańskiego 10, 61–614 Poznań, Poland

[2] Faculty of Chemistry, Adam Mickiewicz University in Poznań, Święty Marcin 78 Str., 61–809 Poznań, Poland

[3]Faculty of Biology, Adam Mickiewicz University in Poznań, Umultowska 89 Str., 61–614 Poznań, Poland

Corresponding author: ***jrybka@amu.edu.pl***

The topics of our research revolve around tissue engineering, 3D bioprinting, meniscus regeneration, and most recently, COVID-19 diagnostics. We are also actively participating in efforts directed towards the automation and robotization of biotech laboratories. Our mission is to venture beyond the boundaries of basic science and bridge academic discoveries with real-life applications. We strive to establish meaningful partnerships with both scientific and industrial entities to drive innovation in biotechnology. 3D bioprinting allows mimicking spatial characteristics of biological structures with the use of bioinks, composed mainly of biocompatible hydrogels. 3D bioprinting enables precise cell deposition while providing optimal conditions for cellular growth and proliferation. This technology is suitable for the creation of various models, reflecting tissue environment more precisely in comparison to monolayer cell cultures. Additionally, 3D bioprinting as a part of novel tissue engineering approaches offers a possibility to restore the physiological functions of an organ without resorting to artificial implants. Our main focus is to utilize 3D bioprinting for meniscus regeneration.

The main diagnostic tool utilized to detect ongoing infection with SARS-CoV-2 is based on the real-time polymerase chain reaction (RT-PCR), which detects viral genetic material in patients. It is a precise and reliable method to determine the carriers of the infection. Immunodiagnostics of COVID-19 is a crucial supplement for RT-PCR diagnostics, as the gradual development of herd immunity may affect policies employed to countermeasure the effects of the ongoing pandemic. Additionally, it will be crucial for the evaluation of the vaccines, including long-term immunity, and their efficacy against novel strains of the virus. Our team is focused on developing an in-house, high-throughput system for COVID-19 diagnostics, utilizing a robotic station and optimized ELISA.

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Advanced Nonlinear Optical Materials for Biological Applications

Marek Samoć

Institute of Advanced Materials, Wrocław University of Science and Technology, Wybrzeże Wyspiańskiego 27, 50–370 Wrocław, Poland
Corresponding author: ***marek.samoc@pwr.edu.pl***

The focus of the research carried out in my group is on novel materials, especially nanomaterials, exhibiting interesting nonlinear optical (NLO) properties that can lead to various practical applications. In particular, bio-related applications such as those in diagnostics and therapy are always very much in demand. Among the NLO phenomena that occur at high light intensities, nowadays readily obtainable from short-pulse lasers, such as frequency conversion, nonlinear refraction and nonlinear absorption, the most researched are those of two-photon absorption and various types of photon energy upconversion. Such effects can be exploited e.g. in photodynamic therapy carried out at relatively longer wavelengths than those at which typical photosensitizers operate [1].

From the materials engineering point of view, recent years have brought reports on a number of various "emerging" materials and nanomaterials that show promising NLO properties [2]. While not all of these reports are entirely reliable, certain patterns appear that may indicate attractive directions of the future research. We are especially interested in effects that appear to be due to aggregation of chromophores, even in the case of relatively short wavelength transitions such as those in proteins without aromatic residues. Indeed, aggregated proteins such as amyloids, appear to show much enhanced NLO properties leading, among others, to efficient two-photon induced autofluorescence [3]. A similar aggregation effect is likely the reason of enhanced two-photon absorption and two-photon induced emission observed by us in certain polymer nanoparticles [4].

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Non-hermitean optics

Marek Trippenbach

Institute of Theoretical Physics, University of Warsaw
Pasteura 5 Str., 02-093 Warsaw, Poland
Corresponding author: ***matri@fuw.edu.pl***

Recent years have seen a tremendous progress in the theory and experimental implementations of non-Hermitian photonics, including all-lossy optical systems as well as parity-time symmetric systems consisting of both optical loss and gain. This progress has led to a host of new intriguing results in the physics of light–matter interactions with promising potential applications in optical sciences and engineering. In this comment, we present a brief perspective on the developments in this field and discuss possible future research directions that can benefit from the notion of non-Hermitian engineering.

The notion of non-Hermitian parity-time (PT) reversal symmetric Hamiltonians having real spectra was first conceived within the context of quantum physics. The introduction of this concept later in optics, has led to an explosion of research activities aimed to explore some of the exotic features displayed by such non-conservative systems. In general, such configurations can be synthesized by establishing an even distribution in the real part of the refractive index while imposing an antisymmetric gain/loss profile, associated with the imaginary part of the refractive index. For example, despite being non-Hermitian, PT symmetric photonic structures can exhibit either entirely real spectra or complex conjugate eigenvalue pairs. In the first regime, the eigenstates also respect PT symmetry (i.e., the system is in an exact PT phase) while in the latter, PT symmetry is broken with the optical intensities associated with the eigenstates being more concentrated either in the gain or in the loss region. The ability to design and implement photonic systems operating in these domains has led to new light-wave dynamics and unusual optical effects such as unidirectional invisibility, laser self-termination and complex Bloch oscillations just to mention a few. Beyond scientific curiosity, PT symmetric photonics is also paving the way towards new technological innovations. For example, PT symmetry can be used to engineer the spectral or the spatial properties of laser emission.

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Materials design for medical application – from clinical need to product ready for implementation

Olga Urbanek-Świderska

Institute of Fundamental Technological Research, Polish Academy of Sciences, Pawinskiego 5B Str., 02–106 Warsaw, Poland
Corresponding author: ***ourbanek@ippt.pan.pl***

The clinical need is a strong trigger for scientists all over the world to transfer their scientific idea into ready to use product. At the begging of this path, the deep understanding of specific clinical need is crucial for proper material design. Both, chemical composition and morphological structure need to carefully thoughtful in order to meet the specific application requirements. For this purpose the biomimetic approach is also used nowadays. The use of electrospinning as a method of material formation is the example of biomimetic approach. Moreover, this method let to prepare materials from broad spectrum of components, additionally bringing closer to solutions coming from nature. Using high voltage applied to the spinning nozzle through which polymer solution is extruded, the (nano)fibres may be easily formed. So obtained fibres may be a part of various medical products such as stents, wound dressings, drug delivery systems or cell scaffolds for tissue regeneration. What is important, the translation of electrospinning to the clinic, including the need to produce materials at large scale and the requirement to do so under Good Manufacturing Practice conditions is currently available [1].

The researchers from Laboratory of Polymers and Biomaterials (IPPT PAN) are strongly focused on developing materials for medical applications. The designed medical products are mostly combination of electrospun fibres with other type of materials, formed from both natural and synthetic materials. The materials for application in tendon and ligaments regeneration were one of the first developed in the Laboratory. The aligned fibres, also covered with hydroxyapatite were produced in order to prepare cells scaffolds with gradient structure [2]. Also the hydrogels containing the nanofibers are developed as a proposition for nerve regeneration or scaffolds for cartilage [3]. Moreover, the innovative drug delivery system is developed, based on electrospun nanofiber carriers for the controlled delivery of brinzolamide for glaucoma treatment [4]. One of the mostly explored topics related to nonwovens, concern its application as a wound dressings. In the Laboratory the nonwovens modified with novel enzybiotic (*AuresinePlus*) were developed for treatment of *E.coli* contaminated wounds [5]. What is important, the *in vitro* experiments are translated into *in vivo*. The researchers from Laboratory of Polymers and Biomaterials have started the *in vivo* experiments on their vascular stents using big animal model.

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Biocompatible materials for medical application

Sara Targońska, Adam Watras and Rafal J. Wiglusz

Institute of Low Temperature and Structure Research, PAS, Okolna 2,
50-422 Wroclaw, Poland
Corresponsing author: r.wiglusz@intibs.pl

The main aim of our research is to obtain a novel multifunctional biomaterial based on nanosized phosphate compounds with apatite structure doped with different ions closed in the biodegradable polymers for tissue regeneration including critical bone and nerve defects as well as drug delivery system. In the system, the biodegradable polymer serves as a supporting base that could be adjusted to the size and/or volume of a defect site. The obtained materials are biodegradable polymer matrix in which phosphate compounds modified with their surface can be closed, giving opportunity for application in personalized medicine. Bioactive factors as nanosized phosphate compounds with apatite structure doped with different ions can be delivered to the damaged tissue locally to promote regeneration. Moreover, it is studied a comprehensive development of medical device – the 3rd generation of the hydrogel, which would be a kind of "hybrid" of biodegradable polymers i.e. hyaluronic acid, nanohydroxyapatite and chitosan. Such biomaterial is characterized by biocompatibility, which accelerates the healing and regeneration process, allowing a painless supply of the wound resulting. The three-dimensional structure of the hydrogel supports the formation of a protective barrier against infection and prevent bacteria coming from the wound inside. Such biomaterial allows absorbing the overtake along with contaminants, so that tissue change is constantly cleaned. In addition, it is a permeable layer for oxygen, which facilitates cell regeneration and protects against the development of dangerous anaerobic. In addition, it is non antigenic, nonallergenic, easy to use and fabrication.

Smart nature-inspired biomaterials for light-activated nanomedicine

Yasamin Ziai, Paweł Nakielski, Chiara Rinoldi, Anna Zakrzewska, and *Filippo Pierini*

Department of Biosystems and Soft Matter, Institute of Fundamental Technological Research Polish Academy of Sciences, Pawińskiego 5B Str., 02–106 Warsaw, Poland

Corresponding author: ***fpierini@ippt.pan.pl***

Through thousands of years of evolution, materials designed by nature have achieved extraordinary properties and functionalities that are still challenging for manufactured engineered materials. Biomimetic nanomaterials are anthropogenic materials, which, thanks to the assistance of nanotechnology-based tools and features, can partially replicate the properties of natural materials.

Hydrogel-based multifunctional and smart materials with nature-inspired structure and unique physical properties as responsiveness to external stimuli play a key role in developing a next-generation of biomaterials. Hybrid materials made of electrospun nanofibers, hydrogels, and plasmonic nanomaterials allow for manipulating light at the nanoscale, thus enabling a cascade-like series of responses and new functionalities. Light-responsive soft material fabrication represents a breakthrough approach thanks to the possibility of using light to activate nanoplatforms for biomedical applications. Stimuli-responsive polymeric structures have recently gained a lot of interest due to their contribution to developing platforms for drug delivery systems and biosensing.

Here we show the development of two different biomimetic multifunctional light-responsive nanostructured platforms based on electrospun and plasmonic hydrogels for advanced biomedical applications. The first material is a biosensor, inspired by the unique features of the chameleon skin, able to detect glucose in human urine samples [1]. The development of this accurate biosensor having innovative functionalities such as reusability, self-sterilization, bendability, wearability, and the ability to respond to external stimuli is crucial to revolutionizing the biosensing field. The second material is a multifunctional platform inspired by the mesoglea structure of jellyfishes for drug delivery applications [2]. The fabricated nanostructured pillow can be activated using a cascade of stimuli by near-infrared (NIR) light, releasing bioactive molecules on demand. During the presentation, all the material fabrication, nanoplatform characterization, and their applicability will be shown. Finally, an overview of future applications of light-responsive materials in the biomedical field will be presented.

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