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Editorial

Science in 2025-2027 and the SPQEO journal

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Abstract. Relevance of recent research is important for scientists and journals reporting research results. There are many sources of prognoses and one of them is the Report of European Commission "Looking into the R&I future priorities 2025-2027". It predicts the importance of the following areas for users: healthcare, energy, climate, sustainability and digitalization. The Ukrainian journal Semiconductor Physics, Quantum Electronics and Optoelectronics (SPQEO) actually focuses on these areas and contributes to the development of related knowledge. Monitoring of last SPQEO issues shows some interesting results: (i) the effect of local field amplification, which causes emergence of ponder motive forces acting on viruses until destruction of viral envelopes; (ii) the methods of malignant tumors treatment taking into account their genesis mechanisms and focusing on correction of definite pathogenesis components, while being nontoxic for other organs and tissues; and (iii) manipulation of the spectral characteristics of a "polycarbonate matrix – gold nanostructures – HTTH dye" system due to influence of gold nanostructures. SPQEO paid attention to the improvement of solar cells (SCs) by considering physical effects such as the effect of space charge region (SCR) recombination on the key characteristics of high-efficiency silicon solar cells, such as photovoltaic conversion efficiency and open-circuit voltage, is not only dependent on the charge-carrier lifetime in the SCR, but also on the ratio of hole-to-electron-capture cross section, $\sigma p/\sigma n$. Non-traditional SCs were also considered: SCs with perovskite thin films, SCs comprising CdS/CIGS heterojunctions, and vitamin B12-patterned silicon hybrids based SCs. Moreover, SPQEO also covers research results in the fields of quantum devices, diamond-like and oxide films, and light-emitting diodes.

Keywords: SPQEO journal, healthcare, energy, climate, sustainability, biosensor, solar cell, quantum devices, diamond-like film, oxide film, LED.

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1. The main challenges in science for the world society

Politicians, scientists, businessmen and smart citizens still continue to discuss further development of the global science. For example, the European Commission launched the report "Looking into the R&I future priorities 2025-2027" [1]. In particular, the report outlined future priorities and societal challenges based on the opinions of 1,105 experts on the most important R&D decisions that will improve their lives during the next 10 years. The experts identified such thematic areas as health, energy, climate, sustainable development, and digitalization. Over 90% of them emphasized climate change and energy. Another independent expert, T.T. Reinhardt also supports some of these trends, calling for climate change to be made a major focus of all research programs [2].

In this paper, we compare the main scientific challenges facing the international community in the near future with the articles on semiconductor physics, quantum electronics and optoelectronics published in the SPQEO journal, especially in its latest issues.

2. Health and food

According to the report [1], the healthcare issues most relevant to SPQEO are as follows:

- Cancer (prevention, cure, treatment, personalized medicine, vaccine development, targeted therapies, aggressive cancers);
- Infectious diseases (prevention, cure, viral control);

- Development of new diagnostics, vaccines, and therapeutics against the diseases being neglected;
- Antimicrobial resistance;
- Food security.

At a first glance, the healthcare topics and SPQEO seem to be far apart. We will show, however, that there can actually be a lot of common approaches and solutions.

The review [3] reflects the unique physical properties of nanoscale materials and the ideas, materials and structures of nanophysics, and demonstrates wide range of their applications in modern science-related fields such as biology and medicine. Use of nanoparticles as nanocontainers for targeted drug delivery is also briefly discussed. It is also demonstrated how the effects of nanophysics can be used to develop new non-conventional methods of antiviral therapy. These methods are based on the idea of a physical (field) action of nanoparticles on viruses, namely the effect of local field amplification, which causes emergence of ponder motive forces acting on viruses until destruction of viral envelopes. Plasmonic resonance in metal nanoparticles is the basis of plasmonic photothermal therapy (PPT) for the treatment of tumors. The method is used for laboratory and clinical treatment of cancerous tissues. Research on the antiviral activity of nanoparticles of various nature, sizes and shapes is widely applied. Small nanoparticles made from various materials have antiviral activity against multiple DNA and RNA viruses (i.e. influenza virus, herpes simplex virus, adenovirus, etc.). This fact suggests that the effect of nanoparticles on these viruses is generalized and related not only to chemical interaction.

In [4], one of the promising directions in oncology is stated to be development of methods for treatment of malignant tumors taking into account the mechanisms of their genesis and focusing on correction of definite pathogenesis components, while being nontoxic for other organs and tissues. In this work, the possibility of using surface plasmon resonance (SPR) to analyze blood characteristics of patients with glioma of different malignancy degrees by studying the level of aggregation of blood cells was investigated. The correlation between the SPR characteristics and the condition of patient was ascertained as well as the drug efficient concentrations were determined.

In this issue, the green route to prepare zinc oxide nanoparticles (NPs) using leaf extracts of *Moringa Oleifera Leaf* is proposed [5]. NPs were synthesized from zinc acetate dehydrate [$(CH_3COO)_2$ Zn $2H_2O$], sodium hydroxide pellets [NaOH] and leaf extract of Moringa Oleifera. The Powder XRD pattern of the ZnO NPs showed definite line broadening of the XRD peaks, evidencing the prepared NP sizes between 1 and 100 nm. The NPs exhibited absorption peak in the range of 323–440 nm with maximum at 396 nm. The NP synthesis method from plant leaf extracts is easy to use [6]. Plants do not release pollution into the environment and are non-toxic themselves. The NP synthesis method is exhaustive with most applications in medicine. These molecules not only help in bio reduction of the ion to the nano-range, but also play an important role in capping the NPs, which is pivotal for stability and bio-compatibility.

Earlier, another method of ZnO nanoparticles preparation was highlighted in SPQEO [7]. Nanocrystalline ZnO films were deposited by sol-gel method on glass substrates. The crystalline grain size was found to be close to 16 nm.

The article [8] is devoted to the spectral and microscopic study of phytosynthesized plasmonic gold nanoparticles. Aqueous extracts of peppermint (M. piperita, cv. ‘Perpeta’) were obtained by maceration of crushed and dried leaves collected in the Botanical Garden of the Prešov University (Prešov, Slovak Republic). Nanocolloidal solutions of gold nanoparticles were obtained by direct interaction of a 1 mM HAuCl4 aqueous solution with an aqueous solution of plant extract under continuous stirring at room temperature (23 °C). Nanocolloidal solutions containing M. piperita-mediated Au NPs were obtained at the extract concentrations ranging from 0.125 to 1.0 mg/ml and initial Au3+ concentrations ranging from 0.025 to 0.9750 mmol. Both large and small gold nanoparticles with different morphologies, including spherical, triangular and hexagonal shapes, were obtained. This is a simple and environmentally friendly synthesis method of gold nanoparticles. Due to their high transparency at 650 - 1350 nm within the bio-transparent window with strong light absorption, and thus promising for nanomedicine, such as photothermal therapy.

Furthermore, optical and luminescent properties of Ag NPs and SdS nano-crystals, as well as Si nanoclusters were studied [10-13]. In [14], influence of gold nanostructures on the spectral characteristics of a “polycarbonate matrix – gold nanostructures – HTTH” system was studied using thiazole dye HTTH as an example. Presence of gold nanostructures in the vicinity of the HTTH molecules was found to change the ratio of the luminescence peak intensities for the enol and keto form of these molecules. This phenomenon opens up the possibility of additional manipulation of the spectral characteristics.

3. Energy R&I

The energy part includes the following relevant to SPQEO topics:

- Solutions for clean, sustainable and affordable energy production;
- Development of renewable energy solutions.

There is a series of articles devoted to improving conventional silicon solar cells [15-20]. In particular, it has been shown that the effect of space charge region (SCR) recombination on the key characteristics of high-efficiency silicon solar cells, such as photovoltaic conversion efficiency and open-circuit voltage, depends not only on the charge carrier lifetime in the SCR but also on the hole-to-electron-capture cross section ratio, $\sigma p/\sigma n$. This effect is significantly enhanced when $\sigma p/\sigma n$

< 1, and, conversely, weakened when σp/σn > 1 [15]. The article [16] provides theoretical modeling of the optical and photovoltaic characteristics (including short-circuit current, open-circuit voltage, and photovoltaic conversion efficiency) of high-efficiency textured silicon solar cells (SCs). Non-radiative exciton recombination mechanisms relative to the Auger mechanism, as well as deep recombination and space charge region recombination were also considered in the modeling. The following six recombination mechanisms in Si are considered while solving the generation-recombination equilibrium equations [17]: Shockley-Reed-Hall recombination, radiative recombination, interband Auger recombination, surface recombination, nonradiative exciton recombination, and SCR recombination. The latter two recombination terms were not considered in the study of the key characteristics and simulation of the properties of Si solar cells. Therefore, in the cited work, the mentioned characteristics and properties are correctly defined, and their contributions are compared with those of other recombination mechanisms. The obtained results show that the properties and key parameters of Si solar cell cannot be sufficiently correctly characterized without taking them into account.

Non-Si solar cells were also considered, namely with perovskite thin films [21] and CdS/CIGS heterojunctions [22]. In [21], the properties of organic-inorganic clad-crystalline CH3NH3PbI3 thin films synthesized at different ratios of the starting reagents (PbI2 and CH3NH3I) were studied. The results showed that, regardless of the starting reagents ratio, single-phase crystalline inclusions form and the film microstructure significantly changes.

A ZnO (200 nm)/CdS (50 nm)/CIGS (350 nm)/Mo (CIGS) thin solar cell is modeled using the auxiliary design software (TCAD Silvaco) [22]. The simulated conversion efficiency (η) is 20.10% and the other characteristic parameters are as follows: open circuit voltage (Voc) is 0.68 V, short circuit current density (Jsc) is 36.91 mA/cm2, and form factor (FF) is 0.80.. The simulation results show that the optimum value of the molar fraction x of the CIGS layer is about 0.31, which corresponds to the band gap value of 1.16 eV, which is in a good agreement with the experimental data. The article [23] discussed application of vitamin B12/Si hybrids in solar cells. Such structures were obtained by chemical deposition of vitamin B12 from an aqueous solution onto a patterned silicon substrate at room temperature. The solar conversion efficiency of these hybrid materials was close to 3.75%. Optimization of the deposition time and the corresponding surface morphology of these low-cost hybrid materials is a promising way to improve the photovoltaic characteristics of the investigated hybrid cells.

4. Circular economy and climate R&I

The next area of circular economy and climate includes R&I solutions: (i) for waste management and recycling, (ii) for sustainable agriculture, (iii) for water management and purification from pollutants, and (iv) for preparedness to respond to threats and disasters. SPQEO mainly deals with sensors for these areas or sensor applications. In [24], an optical biosensor capable of detecting mycotoxins in the field has been proposed. The optical mycosensor implements the mycotoxin fluorescence method. Structurally, it consists of a quartz tube, aluminum body, LED, sensor, filters, control board, operational amplifier, analog-to-digital converter, and cooling radiator. The test results show that it can detect the mycotoxin concentrations in the range of 0..100 ppb and has a fluorescence intensity with satisfactory linearity (relative error less than 2% at high concentrations). The developed sensor may be used for rapid detection and assessment of mycotoxin contamination in agriculture.

In [25], a method for rapid detection and subsequent identification of explosives was developed using arrays of two types of sensor elements - quartz crystal microweights and chemoresistive electrodes. Thin layers of chalcogenides and conductive polymer composites were used as sensitive coatings. Several volatile nitroaromatic compounds from the nitrotoluene family, namely o-nitrotoluene (2-MNT) and nitrobenzene (MNB) at concentrations of 10 to 100 ppm, were chosen as explosive simulators. Depending on the analyzed type of explosive, the detection thresholds for the quartz sensor and calixarene sensor film ranged from 1 to 10 ppm, the response time for the quartz sensor was greater than 10...20 seconds, and for the chemoresistive sensor - up to 1 minute. The possibility of qualitative identification of explosives at relatively low concentrations using statistical methods of chemical pattern recognition (the so-called "electronic nose") was demonstrated.

In [26], a novel optoelectronic sensor based on the chromatic mode spectral surface plasmon resonance (SPR) effect has been proposed and tested for detecting gas molecules and colorimetric registration of the R, G, and B components of reflected light. The optical sensing element is a 40-nm silver film on the base of the prism. The SPR is excited in the Krechman geometry, which allows to fully realize the SPR effect in the entire visible spectral range from 450 to 700 nm. A laboratory version of a portable gas sensor based on the SPR-RGB effect was created.

An alternative method to ELISA and PCR for diagnosing bovine leukemia based on the SPR phenomenon was proposed in [27]. This study demonstrated for the first time that the SPR method enables detection of the antibodies to bovine leukemia virus in diluted solutions (1 vol.%) of slightly positive blood serum taken from diseased animals.

5. Technology

This area is the closest to SPQEO and includes photonics technologies, electric battery technologies, quantum technologies, and microelectronics. We have already mentioned sensors for medical monitoring, environmental protection, converting sunlight into electricity, and more [14-27]. As an example, quantum technologies are presented in [28]. A voltmeter based on a single-electronic device (SED) is considered. It consists of three elements: (i) a digital control word, (ii) a digital-to-

analog converter, and (iii) a comparator. The time delays of the CMOS/TTL logic and SET-based logic are investigated and these logics are found to be at least three times faster than the classical CMOS/TTL logic. The switching power of SET-based devices is about 10^{-17} W, which is a very low value. Single-electron devices have become an important tool for research in science and technology. In engineering and science, single-electronic devices are characterized by fast operation, low power consumption, and high integration density. As S-devices, which consume very low power and require a small number of nodes, they have attracted attention because they provide higher-order population integrity (i.e., large-scale integration) and enable performance much better than 10^6.

The following research areas in the field of microelectronics, which are also covered by SPQEO: diamond films [29, 30], oxides films [31-36], and light emitting diodes [37-41], should be pointed out as well.

6. Conclusion

The SPQEO journal follows the mainstream trends of the global scientific development. According to the report "Looking into the R&I future priorities 2025-2027" published by the European Commission based on the opinions of 1,105 experts, the future priorities and societal challenges include health, energy, climate, sustainable development and digitalization.

In particular, in recent years, SPQEO has focused on the following results: (i) the local field amplification effect, which leads to the emergence of a modest driving force that acts on virus until the viral envelope is destroyed; and (ii) the methods for treating malignant tumors that take into account the mechanisms of tumor genesis and aim at correcting certain aspects of the pathogenesis, while being non-toxic to other organs and tissues. By considering physical effects, SPQEO focuses on improvements in solar cells. In particular, it considers impact of space-charge recombination on key characteristics of high-efficiency Si solar cells such as photovoltaic conversion efficiency and no-load voltage, and takes into account six recombination mechanisms in Si when solving the equations for power generation-recombination equilibrium. The latter mechanisms include Shockley Reed-Hall recombination, radiative recombination, interband Auger recombination, surface recombination, nonradiative exciton recombination, and space charge region recombination. Moreover, non-conventional SCs such as SCs with perovskite films and CdS/CIGS heterojunctions as well as SCs based on silicon-vitamin B12 hybrids are considered. This suggests that SPQEO also encompasses the research results in the fields of quantum devices, diamond-like and oxide films, and light-emitting diodes.

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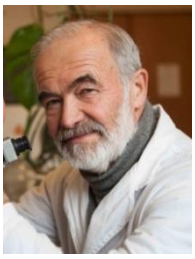

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Authors' contributions

Belyaev A.: supervision, conceptualization, writing - review & editing.
Smertenko P.: formal analysis, investigation, data curation, writing – original draft, writing - review & editing.

Наука в наступних 2025-2027 роках та SPQEO журнал

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Анотація. Актуальність новітніх досліджень важлива для науковців та журналів, які публікують результати досліджень. Існує багато джерел прогнозів, і одним з них є Звіт Європейської Комісії "Погляд на майбутні пріоритети досліджень і розробок 2025-2027". У ньому прогнозується важливість для користувачів таких сфер: охорона здоров'я, енергетика, клімат, сталий розвиток та діджиталізація. Український журнал "Semiconductor Physics, Quantum Electronics and Optoelectronics" (SPQEO) фактично фокусується на цих напрямках і робить свій внесок у розвиток відповідних знань. Моніторинг останніх випусків SPQEO показує кілька цікавих результатів: (i) ефект локального підсилення поля, який спричиняє виникнення сил помірних рушійних сил, що діють на віруси аж до руйнування вірусної оболонки; (ii) методи лікування злоякісних пухлин з урахуванням механізмів їх генезису, спрямовані на корекцію певних ланок патогенезу, при цьому нетоксичні для інших органів і тканин; (iii) керування спектральними характеристиками системи "полікарбонатна матриця – золоті наноструктури – барвник НТТН" за рахунок впливу наноструктур золота. SPQEO приділив увагу вдосконаленню сонячних елементів (СЕ) шляхом урахування фізичних ефектів, таких як вплив рекомбінації в області просторового заряду (ОПЗ) на ключові характеристики високоефективних кремнієвих сонячних елементів, такі як ефективність фотоелектричного перетворення і напруга холостого ходу, що залежить не тільки від часу життя носіїв заряду в ОПЗ, але і від співвідношення перерізу захоплення дірок до електронів, σp/σn. Розглянуто також нетрадиційні СЕ: СЕ з тонкими плівками перовськіту, СЕ з гетеропереходами CdS/CIGS та СЕ на основі гібридів кремнію з вітаміном В12. Крім того, SPQEO також охоплює результати досліджень у галузі квантових приладів, алмазоподібних та оксидних плівок і світлодіодів.

Ключові слова: SPQEO журнал, фізика напівпровідників, квантова електроніка, оптоелектроніка, здоров'я, енергетика, біосенсор.