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Editorial: The DNA molecule as an object of nanotechnology and the creation of helical-structured metamaterials and metasurfaces

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Editorial on the Research Topic
The DNA molecule as an object of nanotechnology and the creation of helical-structured metamaterials and metasurfaces

The spring of 2023 marks the 70th anniversary of the discovery of the DNA structure by eminent scientists, later Nobel laureates James Watson and Francis Crick (Watson and Crick, 1953). The years that followed confirmed the importance of a great scientific discovery, which gave a real impetus to endless research on the DNA molecule, its structure, properties and possible applications. It is no exaggeration to say that the DNA molecule is the source and basis of numerous technologies in various fields of human activity.

This Research Topic compiles a variety of contributions (very few have been published recently) highlighting new types of analysis and methods for more effective work with DNA data, simulated and real, obtained via different methods. These approaches let us shed light on the mechanisms of DNA organization, focusing on the relationship between DNA structure, function and dynamics, as well as consider *The DNA molecule as an object of nanotechnology and the creation of helical-structured metamaterials and metasurfaces*. The Research Topic is between biophysics, nanotechnology, chemical and biomedical engineering, and the articles presented by scientists from various fields make it possible to convey to the reader a variety of research methods related to this Research Topic, as well as to put this into a broader context.

The first article on this Research Topic (Hu et al.) presents a mini-review summarizing the latest advances in the development of endogenous stimulus-sensitive DNA nanostructures featuring precise self-assembly, targeted delivery and controlled release of drugs for cancer theranostics. This mini review briefly discusses the diverse dynamic DNA nanostructures aiming at bioimaging and biomedicine, including DNA self-assembling materials, DNA origami structures, DNA hydrogels, etc., elaborate the working principles of DNA nanostructures activated by biomarkers (e.g., miRNA, mRNA, and proteins) in tumor cells and microenvironments of tumor tissue (e.g., pH, ATP, and redox gradient). Applications of the endogenous stimuli-responsive DNA nanostructures in biological imaging probes for detecting cancer hallmarks as well as intelligent carriers for drug release *in vivo* are discussed. In conclusion, the current challenges of DNA nanotechnology and the further development of this promising research direction are highlighted.

The second article on this Research Topic (Huo et al.) reviews the state-of-the-art technology in developing essential components in DNA sequencers and analyzes the feasibility to achieve miniaturized DNA sequencers for personal use. Future perspectives on the opportunities and associated challenges for compact DNA sequencers are also identified.

The emergence of next-generation sequencing technology, featuring short read lengths at high measurement throughput and low cost, has been shown to revolutionize the field of life sciences, medicine, and even computer science. The subsequent development of third-generation sequencing technologies, represented by nanopore and zero-mode waveguide techniques, provides even higher speed and longer read lengths with promising applications in portable and rapid genomic tests in field conditions. In addition, future development of disease diagnosis, treatment, and tracking techniques may also require frequent DNA testing. As a result, DNA sequencers with miniaturized size and highly integrated components for personal and portable use to tackle increasing needs for disease prevention, personal medicine, and biohazard protection may become future trends. Just like many other biological and medical analytical systems that were originally bulky in sizes, collaborative work from various subjects in engineering and science eventually leads to the miniaturization of these systems. DNA sequencers that involve nanoprobes, detectors, microfluidics, microelectronics, and circuits as well as complex functional materials and structures are extremely complicated but may be miniaturized with technical advancement.

The following article (Semchenko et al.) shows the possibility of using a conducting double DNA-like helix as the basis of an electromagnetic wave polarizer, which converts an incident linearly polarized wave into a reflected wave with circular polarization. A high-frequency resonance is studied, at which the wavelength of the incident radiation is approximately equal to the length of a helical turn. The simulation of a double DNA-like helix has been carried out. The electric currents arising in the helical strands under waves with circular polarization at high-frequency resonance have been analyzed. Fundamentally different behavior of the double DNA-like helix concerning waves with right-hand or left-hand circular polarization has been established, which can be called the effect of polarization selectivity. This effect is manifested in the fact that a double DNA-like helix at high-frequency resonance can create a reflected wave having only one sign of circular polarization. The electric vector of the reflected wave produces a turn in space with the opposite winding direction compared to the double helix. These studies also highlight the electromagnetic forces of interaction between helical strands. The equilibrium of the double DNA-like helix has been studied, including as an element of metamaterials and as an object with a high potential for use in nanotechnology.

The next mini review (Semchenko and Khakhomov) considers the DNA molecule as an object of nature-like technologies, with the focus on the special electromagnetic properties of DNA-like helices. This is the difference from the traditional approach to the DNA molecule as the repository of genetic information. DNA-like helices are regarded as artificial micro-resonators, or "meta-atoms," exhibiting both dielectric and magnetic properties, that are equally pronounced. The article presents methods for creating spatial structures directly from DNA molecules, as well as from DNA-like helices. It is shown that the design of metamaterials and metasurfaces should be carried out considering the special electromagnetic properties of DNA-like helices. This will make it possible to obtain the required properties of metamaterials and metasurfaces and achieve advantages over other types of artificial structures.

We hope that the reader will consider this Research Topic as a useful reference to the state of affairs in the evolving field of DNA nanotechnology based on various methods and approaches.

Author contributions

IS prepared the material for the introduction, SK prepared the material for the first and second article of this Research Topic for discussion, JW prepared the material for the third and fourth article of this Research Topic. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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