

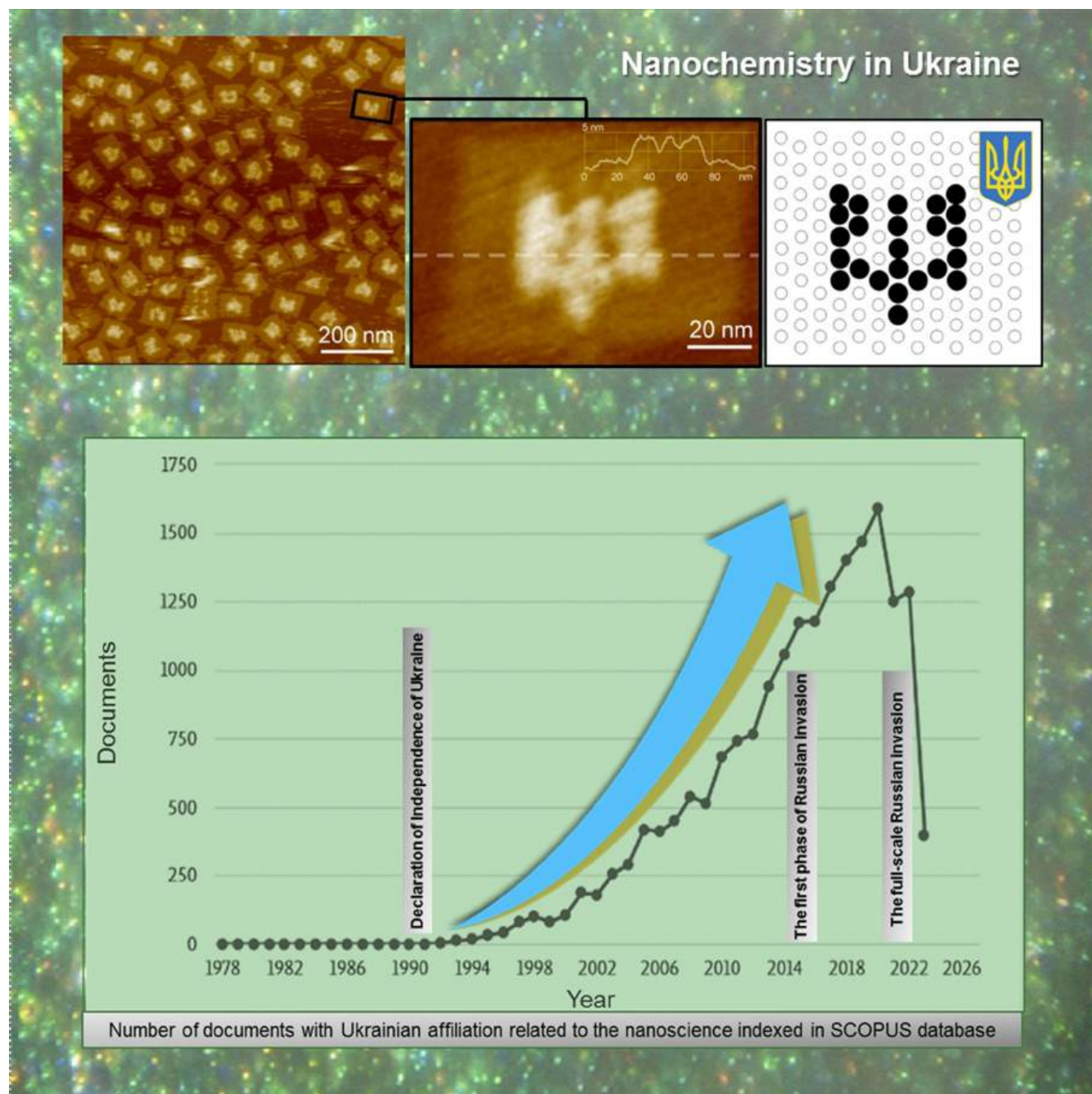
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Chemistry of nanomaterials in Ukraine: per aspera

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This review covers major aspects of nanochemistry in Ukraine. It describes current state of the field, lists main contributors and discuss the trends and limitations of its development. Ukraine's nanotechnology can be traced back to the country's rich scientific heritage, which includes a long tradition of excellence in materials science, chemistry, and physics. Despite limited and

sporadic financial support, nanochemistry has occupied decent place in the country scientific agenda. Related courses in the education institution contributed to the formation of the generation of skilled chemists who build their successful career internationally.

1. Introduction

Chemistry of nanomaterials is a flourishing field of nanotechnology that includes synthesis, modification, functionalization, assembly, and application of nanoparticles of different origins. When the dimension is within the 1–100 nm scale, materials reveal novel phenomena and properties, which can be exploited for brand new applications. Chemical approach is a main source of large-scale production of nanomaterials. Different applications like light harvesting and conversion, biolabeling and contrasting, catalysis and so on require new methods and new materials.^[1] Over the past years, a high level of control over morphology was achieved in the chemical synthesis of nanomaterials by manipulating the growth kinetics of various crystal phases.^[2–4] The interdisciplinary nature of nanomaterials requires nanochemists' understanding of physics, chemistry, biology, computer science, and engineering to achieve progress. In this competitive field those will succeed who possess sound combination of STEM skills.

The purpose of this manuscript is to offer readers a comprehensive understanding of the progress of nanochemistry in Ukraine. This includes an overview of research examples, publishing trends, educational advancements, highlights of prominent conferences, and real-world applications of nanotechnology. Our main emphasis is on identifying and addressing the key obstacles that impede the growth of this field.

2. Historical background

Ukraine has a strong tradition in the natural sciences dating back to the Soviet era, with a particular strength in physics, chemistry, and engineering.^[5] This base provided a strong foundation for the development of nanotechnology.

In the years following Ukraine's independence in 1991, the country faced numerous economic and political challenges. Despite these, the scientific community in Ukraine worked to keep up with global advancements, and nanotechnology emerged as a promising area of research. The government of Ukraine and the National Academy of Sciences began to recognize the potential of nanotechnology and the necessity of investment in this field. The first steps toward the development of nanotechnology in Ukraine were made in the late 1990s and early 2000s, when the first nanotechnology research laboratories and groups began to appear.

The establishment of the State target scientific-technical program of Ukraine "Nanotechnology and Nanomaterials" for the years 2010–2014 was an important milestone, signalling the country's commitment to the development of this field. This initiative sought to foster collaboration between various stakeholders, including government, academia, and the private sector. The purpose of the Program was to create a nano industry by ensuring the development of its industrial-technological infrastructure, using the results of fundamental and applied research, as well as the training of highly qualified scientific and engineering personnel. Unfortunately, budget cuts did not allow us to realize this program. Yet, Ukraine has managed to create research institutions, laboratories, and scientific groups that conduct research and development in nanotechnology. They work on various aspects, including materials science, nanoelectronics, biomedical applications, and energy applications. The ongoing investment in nanotechnology R&D is seen as a crucial part of Ukraine's strategy to build a knowledge-based economy. The program led to a lot of successful developments and unique technologies, especially in the field of nanocomposites. However, compared to countries with average level of development, their introduction into production is rather low. Due to this fact the National Academy of Sciences of Ukraine created and adopted Resolution of the Presidium of NAS of Ukraine from 07.02.2015 of the «Concept of the target-oriented complex program of fundamental research of NAS of Ukraine «Fundamental issues of new nanomaterials creation» for 2015–2019».^[6]

An important milestone in the development of nanotechnology in Ukraine was the EU-funded NANOTWINNING (Increase in opportunities for strategic collaboration in the field of nanotechnology via twinning of Institute of Physics (IOP) with institutions of European Research Area) initiative aimed to promote international collaboration of IOP of the of the National Academy of Science of Ukraine in the field of nanotechnology. The project organised first two international nanotechnology conferences "NANO" in 2013 and 2014, as well as three summer schools to train young scientists. NANOTWIN-

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