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ЗЕЛЕНІ НАНОТЕХНОЛОГІЇ: ЄВРОПЕЙСКИЙ ТА УКРАЇНСЬКИЙ ДОСВІД

GREEN NANOTECHNOLOGIES: EUROPEAN AND UKRAINIAN EXPERIENCE

The International Environmental School
"EUROPEAN GREEN DIMENSIONS: CHALLENGES FOR UKRAINE“
June, 6−8, 2024, Mykolaiv, Ukraine

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Ключові слова	Key words
Зелена хімія	Green chemistry
Альтернативні технології	Alternative technologies
Зелені технології	Green technologies
Альтернативні джерела сировини	Alternative feedstocks
Наноматеріали	Nanomaterials

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Fundamentals of Green chemistry

Green chemistry is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances. Green chemistry applies across the life cycle of a chemical product, including its design, manufacture, use, and ultimate disposal.

Green chemistry:

- prevents pollution at the molecular level.
- is a philosophy that applies to all areas of chemistry, not a single discipline of chemistry;
- applies innovative scientific solutions to real-world environmental problems;
- results in the reduction of pollution sources because it prevents the generation of pollution;
- reduces the negative impacts of chemical products and processes on human health and the environment;
- lessens and sometimes eliminates hazards from existing products and processes;
- designs chemical products and processes to reduce their intrinsic hazards.

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Fundamentals of Green chemistry

The 12 Green Chemistry Principles:

1. **Wastes prevention.** Waste prevention is better and easier than waste treatment is the first and most important principle.
2. **Atom economy.** Maximal incorporation of starting materials into the final product is a fundamental principle to design and development of synthetic methods.
3. **Safer synthesis.** The designing of chemical methods with utilization and generation of substances with low or no toxicity to people and the environment is major priority.
4. **Safer chemicals.** Chemical products and side products should be designed to achieve a desired function with minimal toxicity.
5. **Safer solvents and auxiliaries.** Auxiliary substances such as solvents and separation agents should be minimized or eliminated whenever possible and made innocuous when used.
6. **Energy efficiency.** The development of methods conducted at ambient temperature and pressure whenever it is possible is invited.
7. **Renewable feedstocks.** Starting materials from renewable origins should be used whenever economically and technically practicable.
8. **Derivatives minimization.** The utilization of protection/deprotection, blocking groups, and temporary modification of physical/chemical processes should be excluded or at least minimized with purposes of waste reduction.
9. **Catalysts.** Catalytic reagents that are engineered for high selectivity and efficiency for less waste production are needed.
10. **Design for degradation.** The design chemical products which break down into innocuous degradation materials at the end of their function and not dangerous for the environment is important.
11. **Real-time analysis.** It is important to develop and adopt real-time analytical methods that provide continuous process monitoring and control of the formation of hazardous compounds.
12. **Accident prevention for safer chemical production.** The potential for chemical accidents such as releases, explosions, and fires should be minimized by choosing inherently safer substances.

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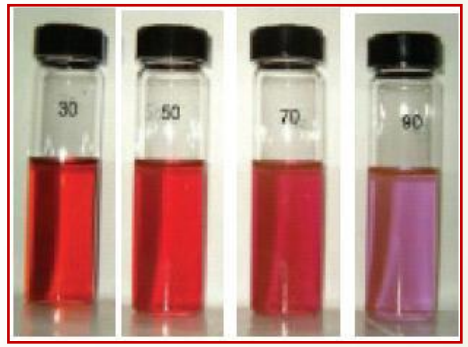
Nanomaterials

Nanomaterials are substances that are, or have been, reduced in size to the range from 1 nm to ~100 nm (i.e. 1 to ~100 nanometers, or 1 to ~100 x 10^{-9} meters).

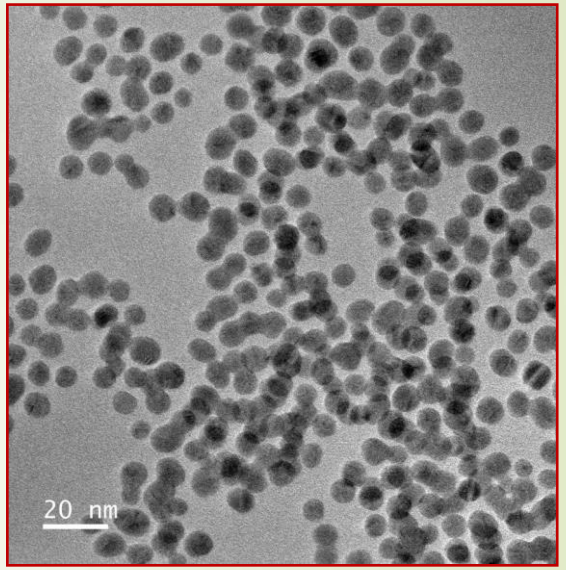
Nanotechnology is the science and applications of nanomaterials, and is growing at an ever increasing pace. At this particle size the properties of materials can be altered dramatically.

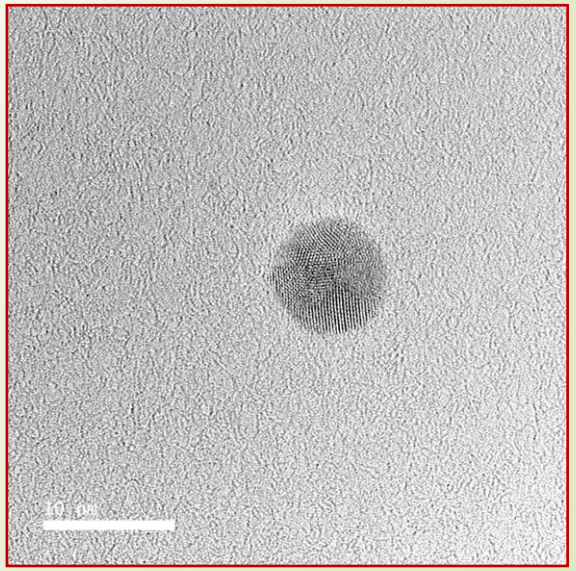


Properties such as

- *solubility*,
- *reactivity*,
- *spectroscopy*,
- *electrical and magnetic*,
- *transport through cell membranes* etc.

are generally different from those of the same materials with large particle size. The applications of materials of nano size have escalated in the last fifteen or so years and are currently gaining momentum. The technology has broad applications in performance materials, health, consumer products, water, information technology and energy.





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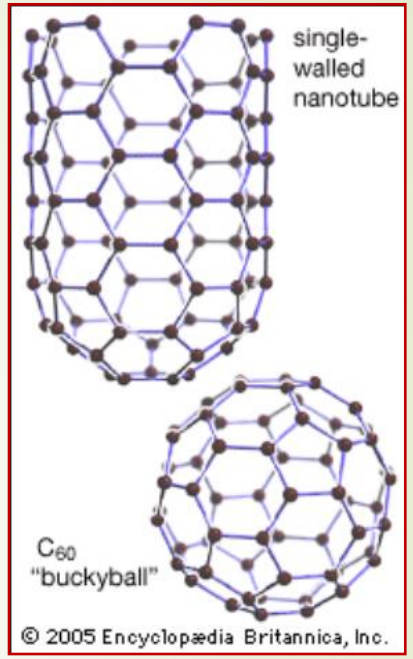
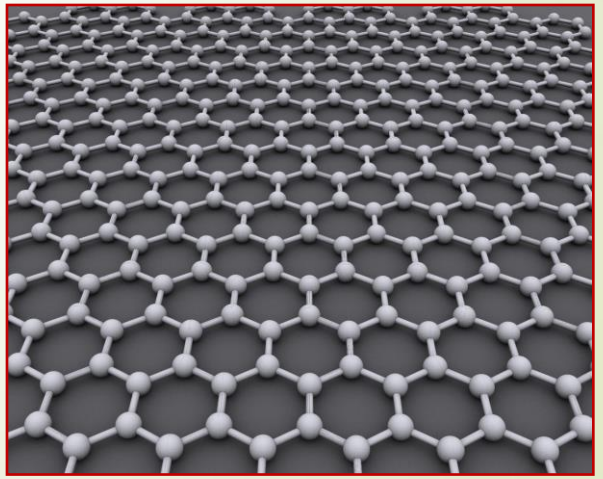
Nanomaterials

The discovery of **fullerenes** (**1996 Nobel Prize for Chemistry** to H.W. Kroto, R.E. Smalley and R.F. Curl) and of **graphene** (**2010 Nobel Prize for Physics** to A. Geim and K Novoselov) are very important factors in the development of nanotechnology.

A **fullerene** is an allotrope of carbon whose molecules consist of carbon atoms connected by single and double bonds so as to form a closed or partially closed mesh, with fused rings of five to seven atoms.

Graphene is a material that is extracted from graphite and is made up of pure carbon, one of the most important elements in nature and which we find in daily objects like the lead of a pencil. Graphene stands out for being tough, flexible, light, and with a high resistance.





Kroto, Harold W. and Walton, David R.M.. "fullerene". Encyclopedia Britannica, 18 May. 2024, https://www.britannica.com/science/fullerene. Accessed 6 June 2024.

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Nanomaterials

Quantum dots are tiny particles or nanocrystals of a semiconducting material with diameters in the range of 2-10 nanometers (10-50 atoms). They were first discovered in 1980.

Bawendi, Louis E. Brus and Aleksey Yekimov are awarded the **Nobel Prize in Chemistry 2023** for the discovery and development of quantum dots.

Potential applications of quantum dots include single-electron transistors, solar cells, LEDs, lasers, single-photon sources, second-harmonic generation, quantum computing, cell biology research, microscopy, and medical imaging.

Maxwell T., Nogueira Campos M.G., Smith S. *et al.* Quantum dots (2019) Nanoparticles for Biomedical Applications: Fundamental Concepts, Biological Interactions and Clinical Applications, pp. 243 – 265
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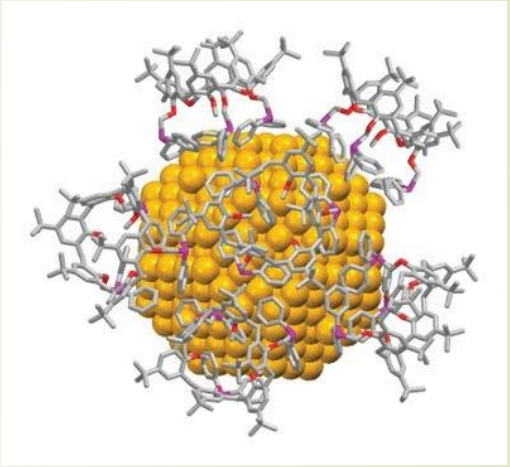
Nanomaterials

Metal nanoparticles are nanomaterials that are made up of only one element. Individual atoms or groups of numerous atoms can exist. Au, Ag, Pt, Cu, Pd, Re, Zn, Ru, Co, Cd, Al, Ni, and Fe are some of the most commonly produced nanoparticles.



Metallic nanoparticles show **unique** characteristics such as strong plasma absorption, enhanced Rayleigh scattering, surface-enhanced Raman scattering, determination of chemical information on metallic nanoscale substrate, and biological system imaging.

http://nanoall.blogspot.com/2012/01/synthesis-of-metallic-nanoparticles.html

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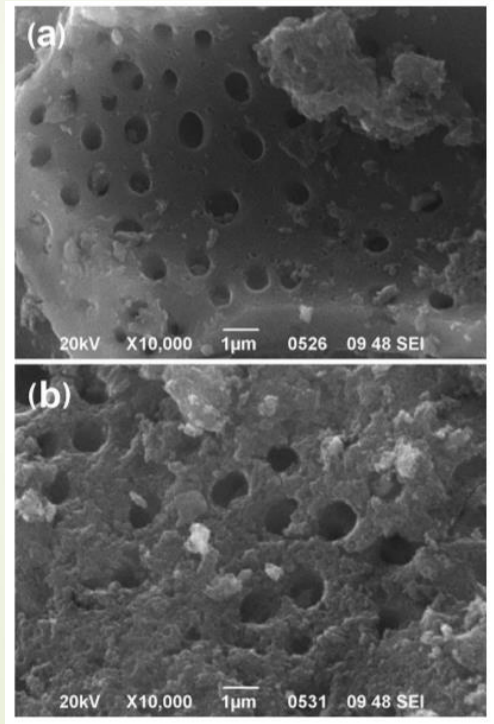
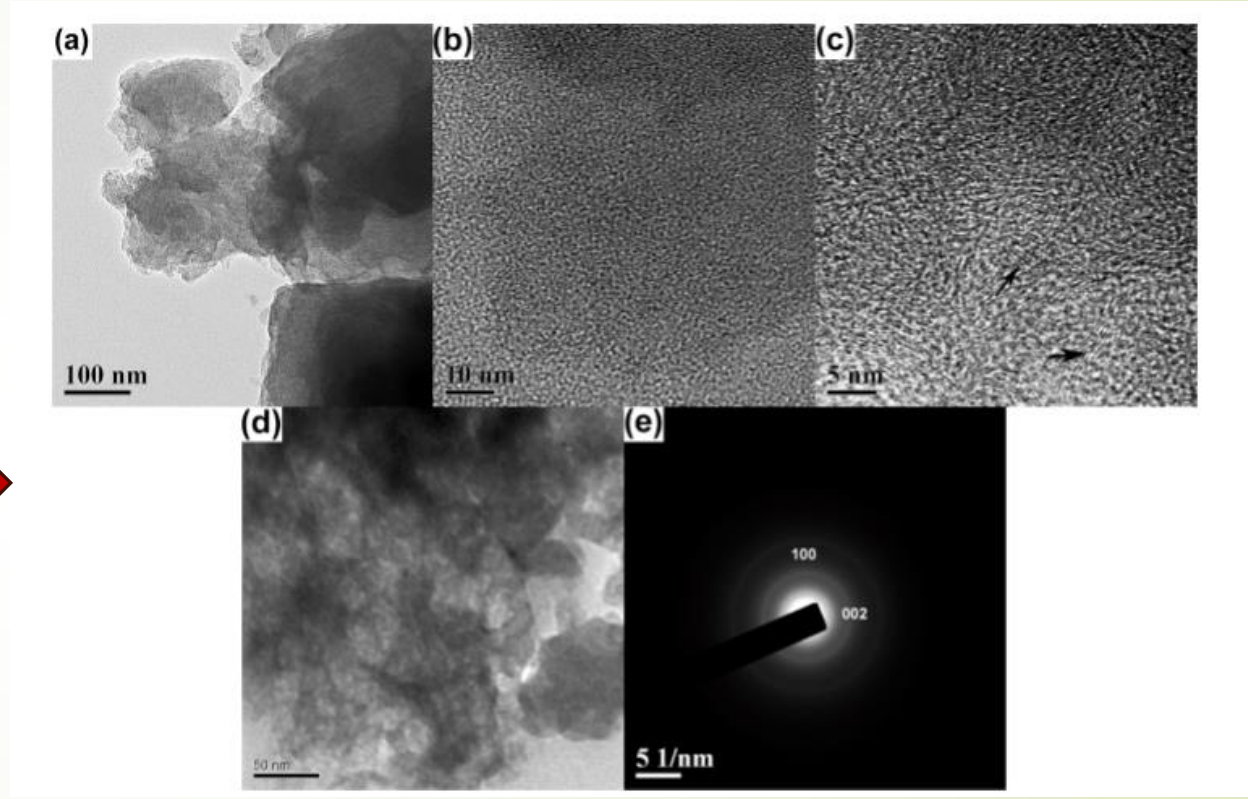
Green synthesis and green applications





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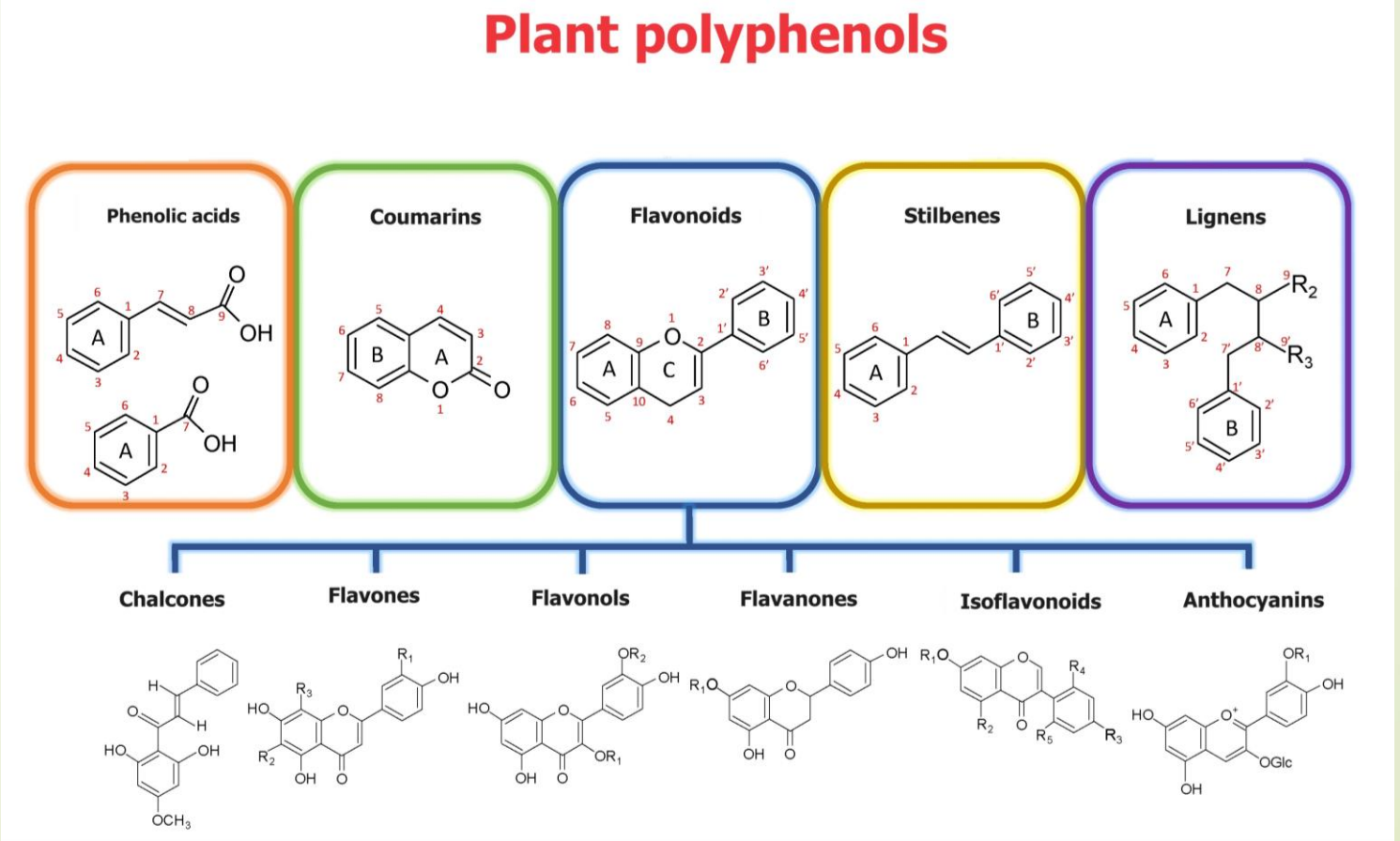
Green synthesis

BIOREDUCTION

- ***Using cell-free extracts***: plants, microorganisms, macrofungi, macroalgae
- ***Using whole organisms***: plants, mushrooms, seaweeds, microbial cells



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Green synthesis

Blackcurrant (*Ribes nigrum*)

Peppermint (*Menta piperita* L.)

Elderberry (*Sambucus nigra*)

Canada goldenrod (*Solidago canadensis*)

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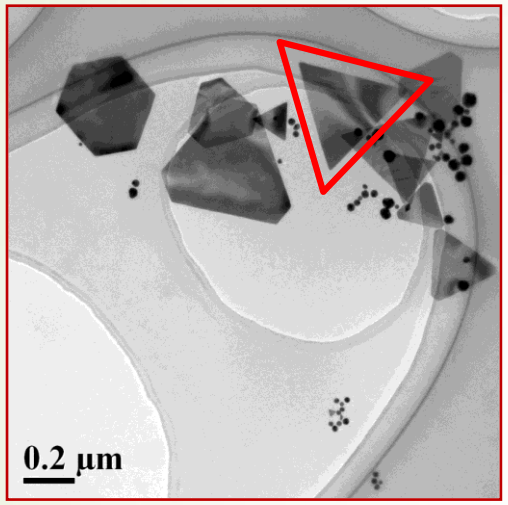
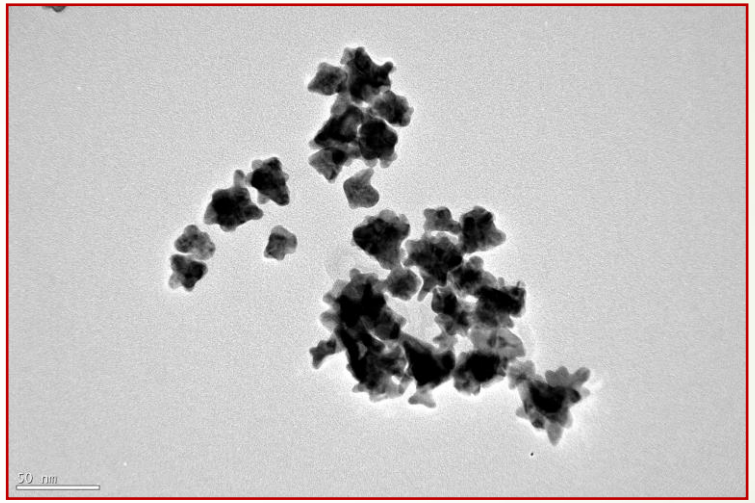
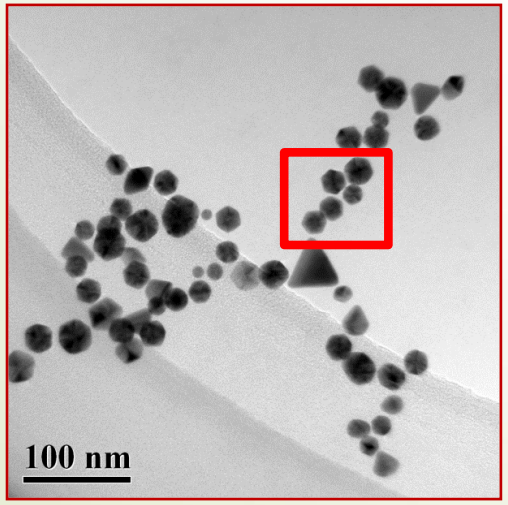
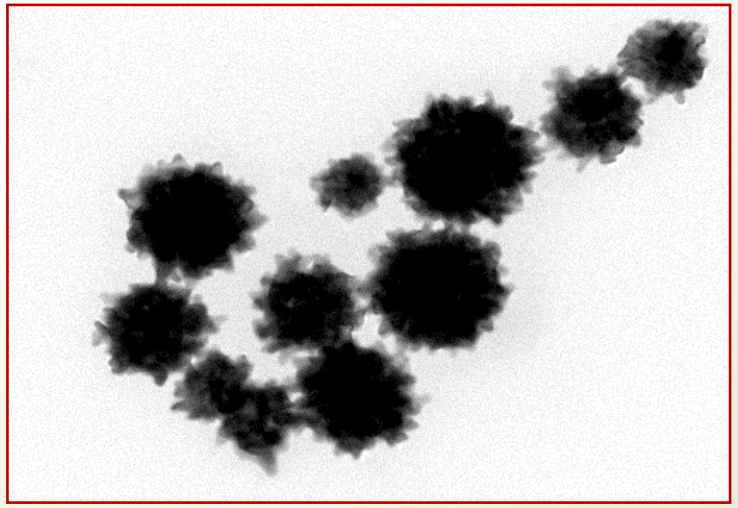
Green synthesis









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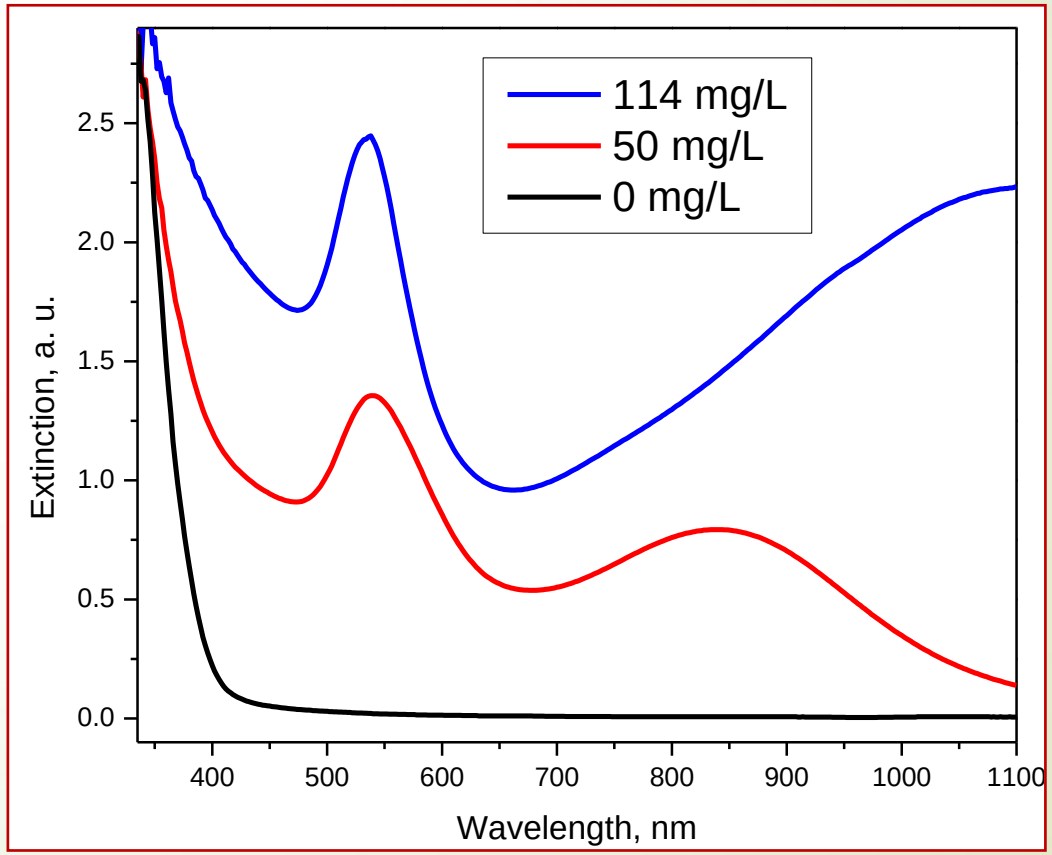
Application in nanomedicine

- **Photothermia**
- **Target drug delivery system with controlled drug release**

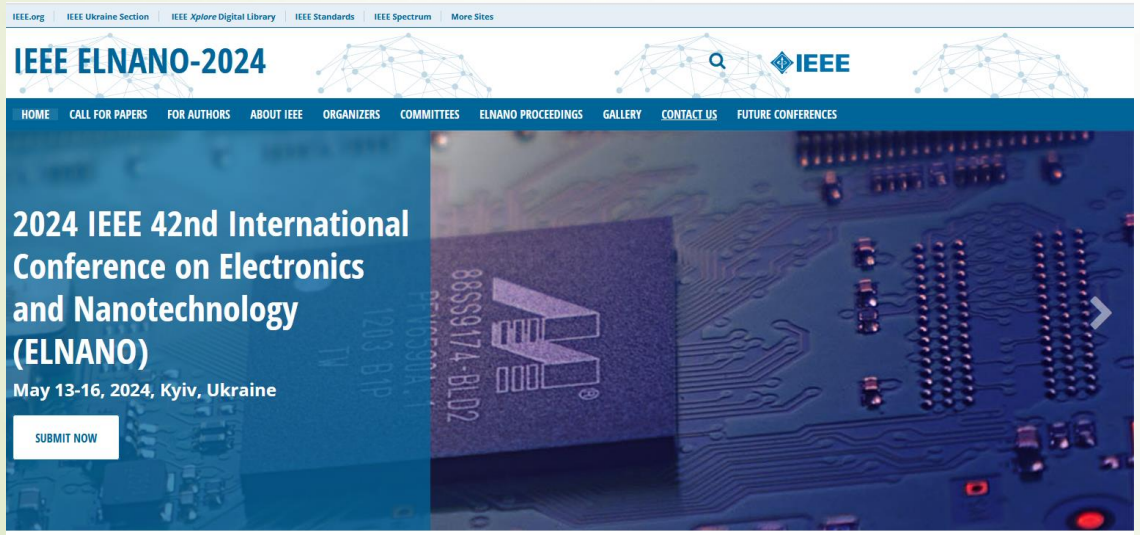
- biocompatibility
- surface modification
- chemical stability
- photothermal heating

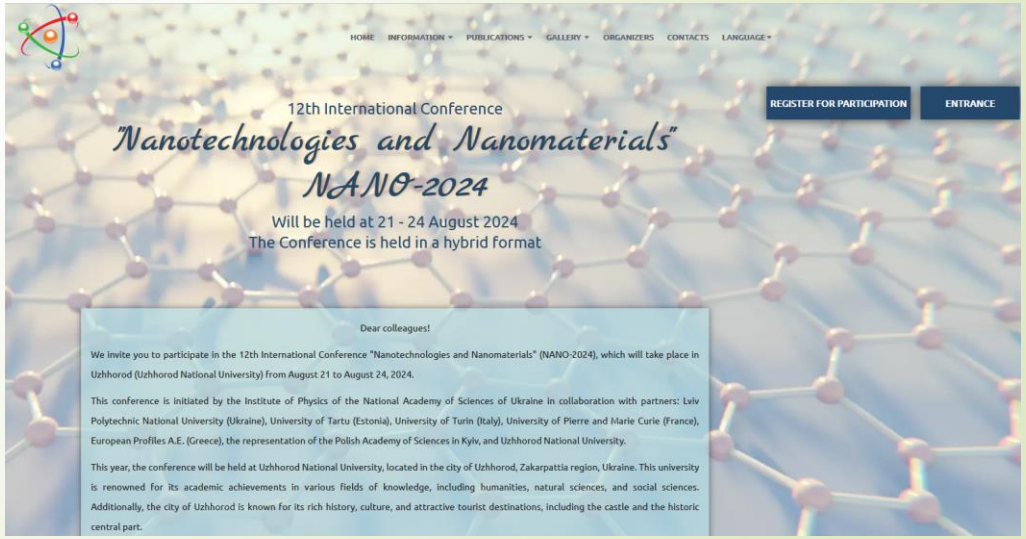


Nanoscience in Ukraine

42nd International Conference on Electronics and Nanotechnology (ELNANO), which will be held in frames of IEEE Kyiv Polytechnic Week at Igor Sikorsky Kyiv Polytechnic Institute on May 13 – 16, 2024 in Kyiv, Ukraine.

12th International Conference "Nanotechnologies and Nanomaterials" (NANO-2024) will take place in Uzhhorod (Uzhhorod National University) from August 21 to August 24, 2024.





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