PHYSICAL CHEMISTRY OF NANOSTRUCTURED SYSTEMS

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LECTURE No. 3
CARBON BASED MATERIALS

Introduction

- Carbon is a well-known chemical element. It is present in many areas of our life. It has a variety of allotropic forms.
- Fullerenes are the third most stable form of carbon, after diamond and graphite.
- Among the fullerenes are **carbon nanotubes, graphene and porous carbon materials**.

OBJECTIVES

- To describe carbon nanotubes, graphene and nanoporous materials.
- To explain properties of carbon based materials (CBM) and the most important applications.
- To elucidate some methods for producing nanoporous materials.

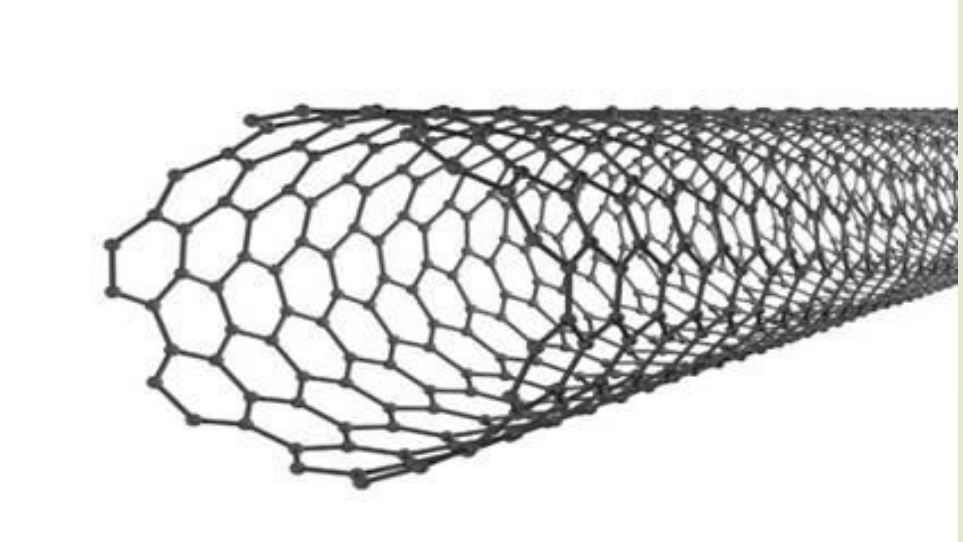
OUTLINE

- Carbon nanotubes. Characteristics, types and applications.
- Graphene. Structure and properties.
- Porous carbon materials. Characteristics, sources and methods for their production. Applications.

Carbon nanotubes

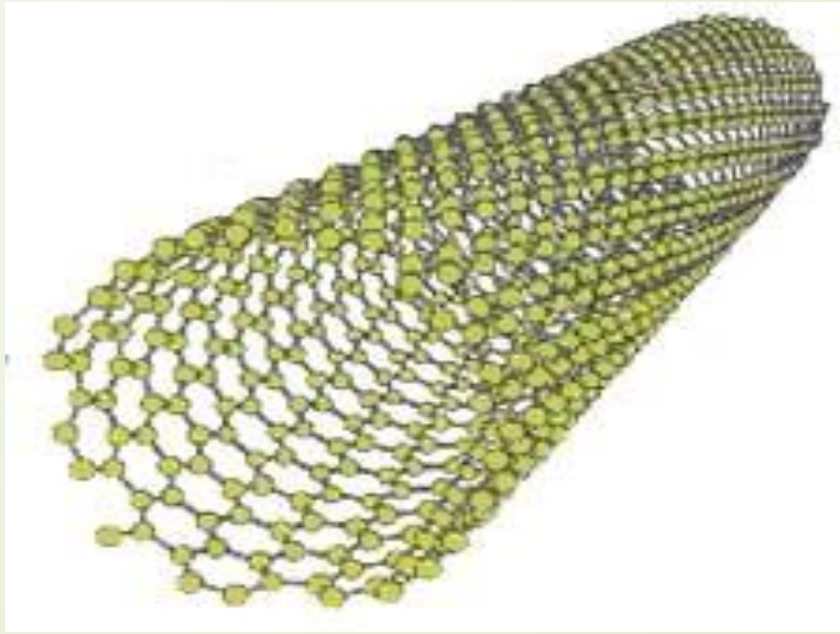
- Tubular structures whose diameter is of the order of nanometer (nm)
- Length of several tens of microns.
- Carbon atoms are located at the vertices of regular hexagons.

Carbon nanotubes



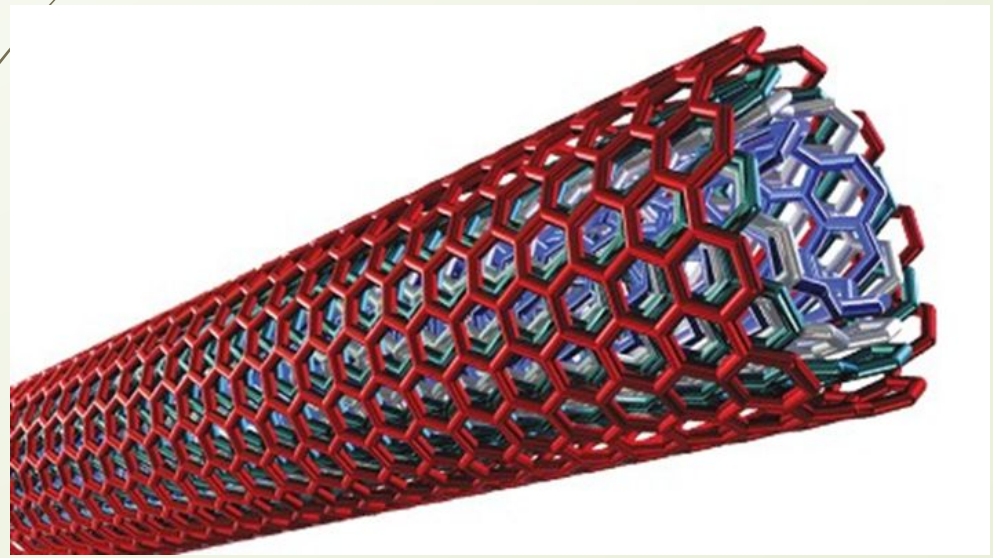
Carbon nanotubes. Types

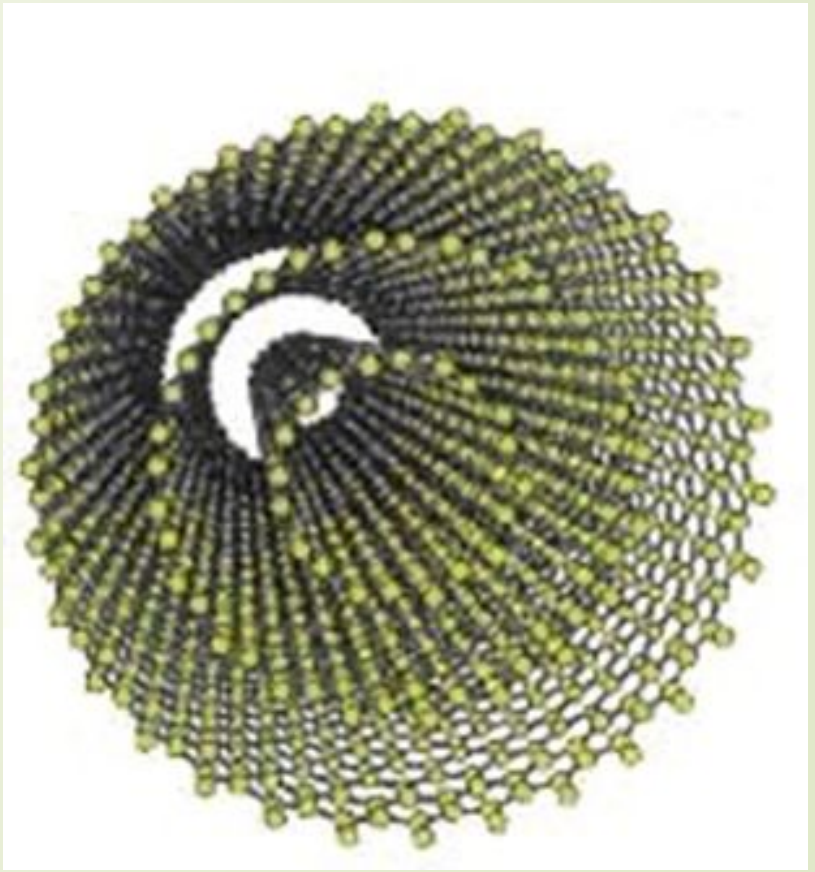
- Single walled nanotubes, SWNT (diameter of about 1 nm and length many thousands nm)



Carbon nanotubes. Types

- Multi-walled Nanotubes. MWNT (tens of nanometers in diameter)





Carbon nanotubes. Characteristics

- 100 thousand times thinner than a human hair, but it is a very durable material.
- 50 to 100 times stronger than steel. Six times less density.
- Twice resistance to deformation than conventional carbon fibers

Carbon nanotubes. Characteristics

- They can be conductors and semiconductors of electricity. They can pass electricity, practically without heat generation at high values.

  A classical conductor at such values would instantly evaporate

- Good thermal conductors

  Transmit about 20 times more heat than metals like copper

- Intercalation (introduction): Gd@C60@SWNT

Applications

- Semiconductor heterostructures, i.e. structures such as "metal / semiconductor"
- Television and computer screens
- Needle for a scanning microscope

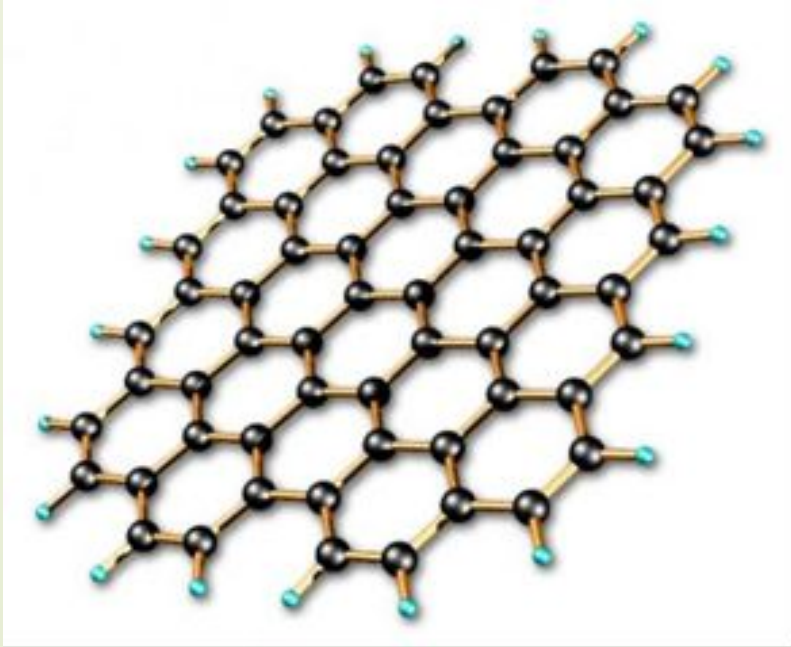
Graphene

Graphene was opened in 2004 by A. Geim and K. Novoselov. For the discovery of graphene Geim and Novoselov in 2010 received the **Nobel Prize in Physics**.

It was unexpected, because nobody thought that a sheet of carbon of atomic thickness could not be stable.

Graphene. Structure

Graphene is a two-dimensional allotropic form of carbon, which are combined in the hexagonal crystal lattice. The atoms form a layer with a thickness of one atom.

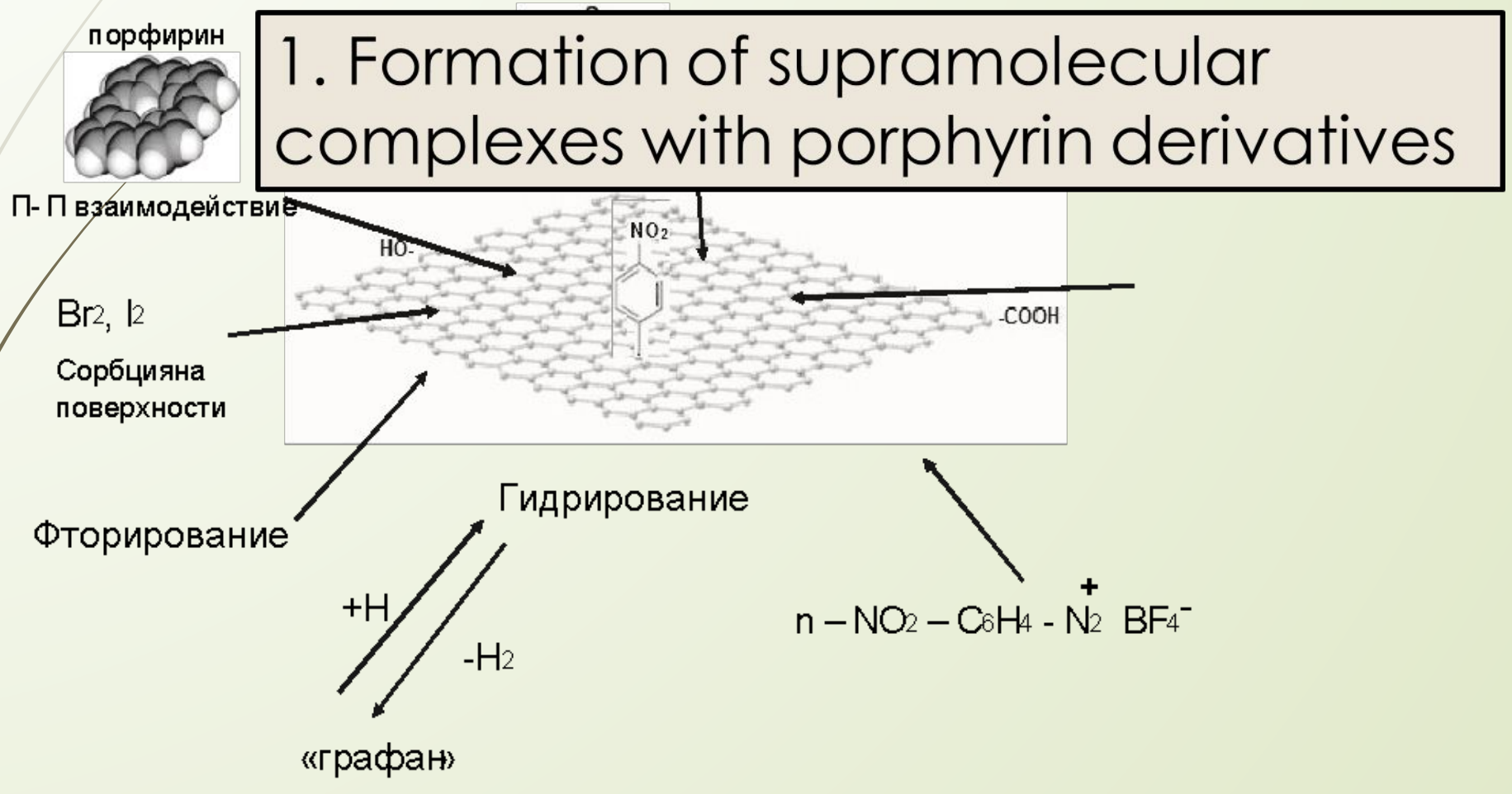


Properties of Graphene

- High strength. Its sheet with area of one square meter and a thickness of one atom can hold an object weighing 4 kilograms.
- High conductivity of electricity and heat, which makes it ideal for use in various electronic devices.
- Highly reactive material.

Properties of Graphene

Interaction with nucleophile and electrophilic compounds.



Properties of Graphene

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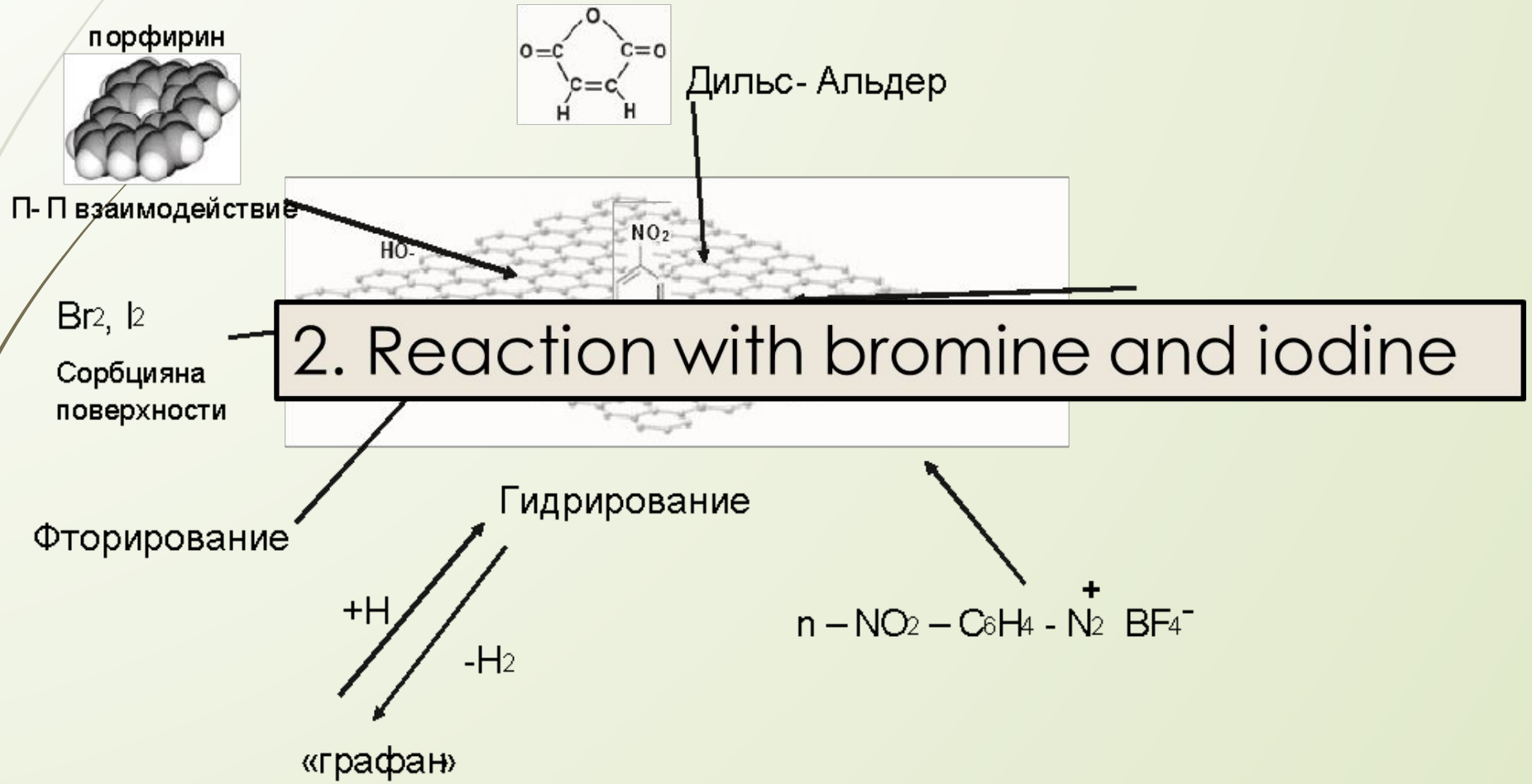

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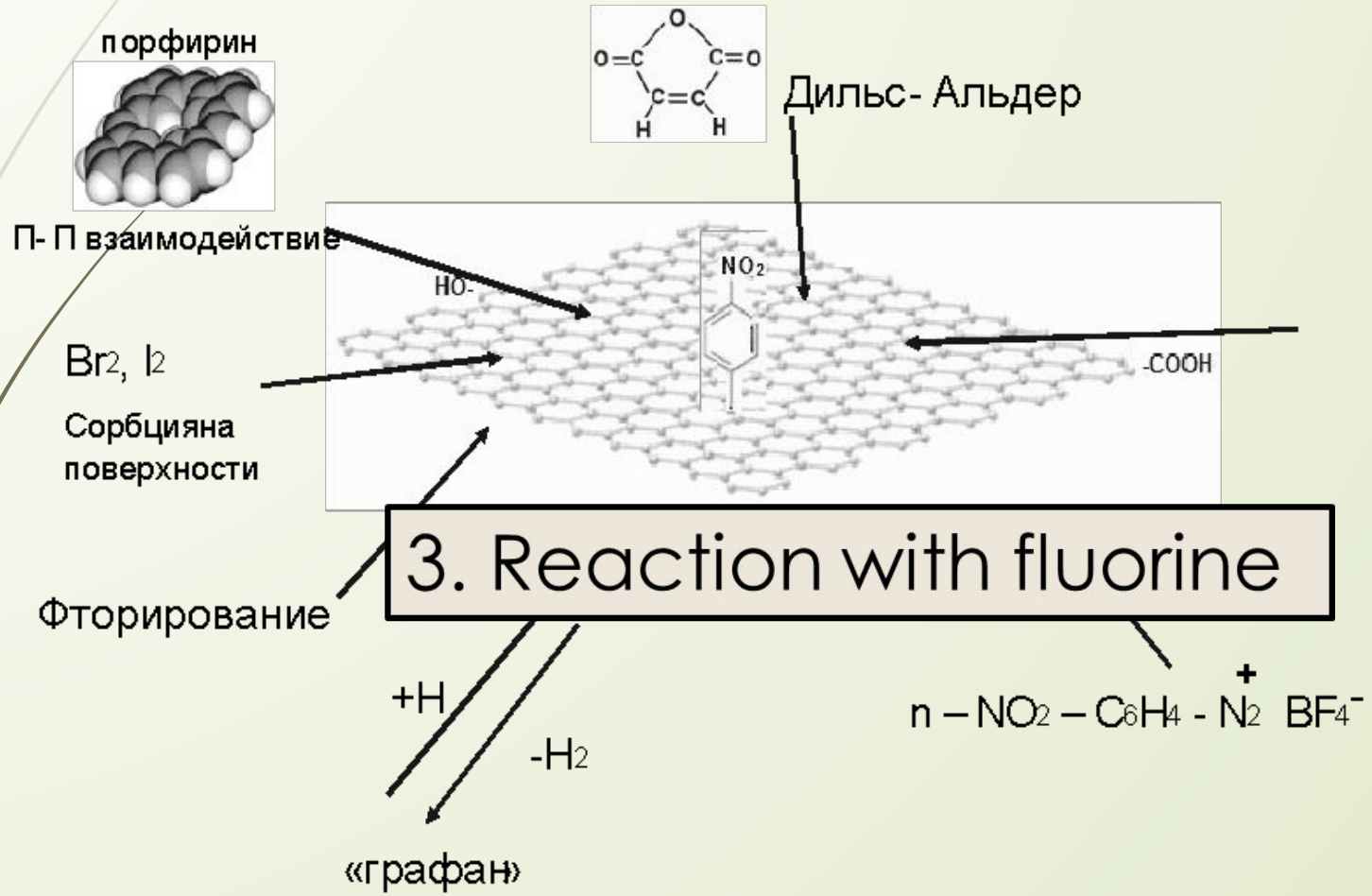

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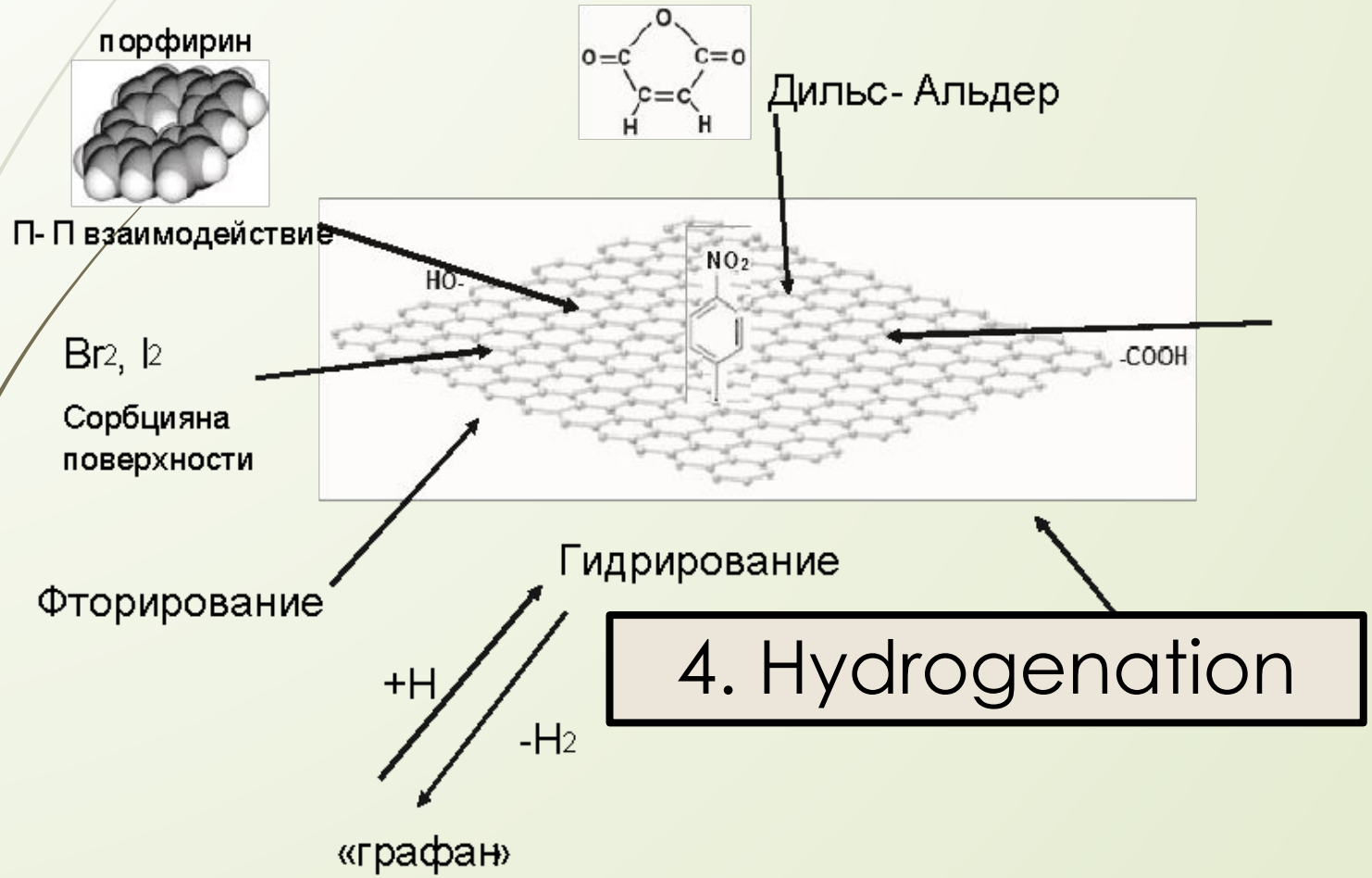

Porous carbon materials. Features

- High specific adsorption and catalytic activity.
- Stability in non-oxidative media.
- Possibility of varying the specific surface in the range 0.1-10^3 m^2/g and pore size from one angstrom to hundreds of microns.
- Wide range of forms of the final product, which includes powders, granules, block products, film, fibrous materials, etc.

Porous carbon materials. Sources for production.

- wood,
- stone and brown coals,
- agricultural waste,
- polymeric materials,
- liquid and gaseous hydrocarbons,
- carbon-containing industrial and household waste.

Porous carbon materials. Production.

- Physical activation

- preparation of raw materials (separation, crushing, drying)

- pyrolysis (heat treatment at temperature 550 -1000 °C without access of oxidizer)

- activation (heat treatment at in the presence of an oxidizer, CO_2 or steam at 700 -1000 ^0C

Porous carbon materials. Production.

- Thermochemical activation

- introduction of chemical additives into the starting material.

- carbonization in an inert atmosphere or in a gaseous oxidizer.

Transformation is carried out using as catalyst: ($ZnCl_2$, Al_2O_3, H_3PO_4, carbonates or oxides of alkali metals, etc.)

Porous carbon materials. Considerations for their use.

- Specific surface area,
- Pore volume and size,
- Pore size distribution.

Porous carbon materials. Chemical modifications.

- ✔ Anthracites: insufficient and inefficient (temperature, reagent ratio, reaction medium).
- ✔ Brown coals: relatively cheap. Porous carbon materials with a well-developed microporous structure.
- ✔ Wood waste: the most promising way. (high volume of pores).

Porous carbon materials. Applications

- Catalysts
- Adsorbents for chromatography
- Gas storage systems
- Environmental protection

Поскольку пористые углеродные материалы получают из любого вида углеродсодержащего сырья, включая отходы, и сами применяются в целях охраны окружающей среды, можно уверенно прогнозировать, что пористые углеродные материалы внесут важный вклад в решение назревших проблем устойчивого развития человечества в XXI веке.

Control questions

1. Describe, briefly, the structure of carbon nanotubes. Mention existing types.
2. Explain some characteristics of carbon nanotubes.
3. Mention three applications of carbon nanotubes.
4. Mention some properties of graphene.
5. Explain the importance of porous carbon materials.
6. Give some examples of sources that can be used for production of nanoporous materials.
7. Explain one method for production of nanoporous materials.

THANK YOU FOR YOUR ATTENTION!