# Applications of Detonation Nanodiamonds in the Design of Sensor Composites and Biosensors

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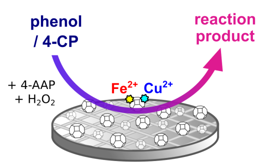
## Introduction

Nanomaterials are bringing significant advantages in the design of new analytical sensors or improvements of the existing devices. Nanomaterial application in environmental monitoring and biomedical analyzing are demonstrating great potential in enhancing sensitivity, stability and in general performance of (bio)sensor devices. **Detonation nanodiamonds (DNDs)** possessing the chemically inert diamond core, mechanical strength, large specific surface area with the abundance of different chemically active groups and traces of metals [1] are an attractive nanomaterial applicable as structural, catalytic, and enzyme carrier element for the development of new (bio)sensing systems.

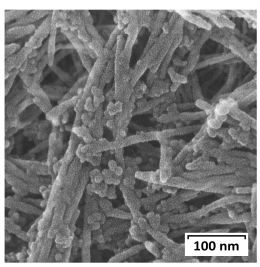
The report summarizes the results of many years of studies carried out at the Institute of Biophysics SB RAS (Krasnoyarsk) with modified DNDs possessing high colloidal stability in dispersion media [2,3] and aimed at studying their properties and applicability in the design of new (bio)sensing systems.

## DND-based nanocomposite

DNDs can serve simultaneously as a structural element and as a catalyst with enzyme-like activity in the design of nanocomposites for analytical purposes. A novel composite material based on alumina nanofibers and DNDs was fabricated for non-enzymatic detecting phenol in aqueous medium [4].



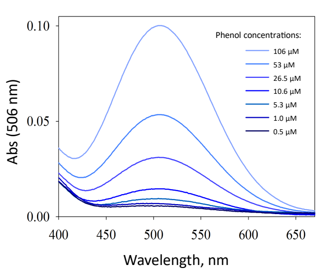

**Scheme of the action of the sensor composite.**



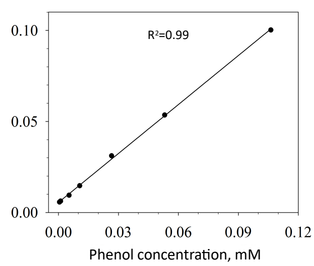

**SEM image of the composite structure.**


**Visual dynamics of colored reaction product formation.**

DNDs in the composite catalyze the co-oxidation reaction of phenol with 4-aminoantipyrine (4-AAP) in the presence of hydrogen peroxide to form a colored product. The catalytic effect of DNDs is realized due to the presence of copper and iron impurities on their surface [5]. The proposed composite ensures an easy-to-perform colorimetric analysis for qualitative and quantitative determination of phenol in aqueous samples with linear response over a wide range of concentrations (0.5 – 106 µM).



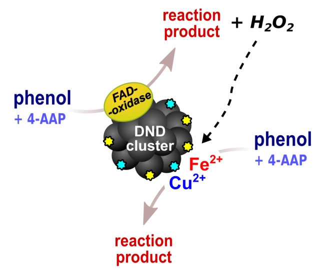

**Absorbance spectra of colored reaction product in the presence of different concentrations of phenol.**



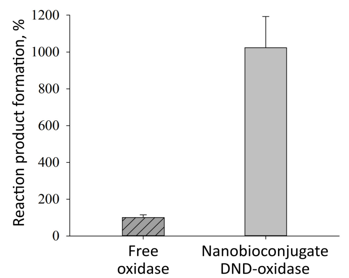

**The response curve of the composite towards different concentrations of phenol (0.5 – 106 µM).**

## DNDs as enzyme carrier and enhancer of catalytic effect

A nanobioconjugate for detection of phenol in aqueous medium based on the reaction of its co-oxidation with 4-AAP without using exogenous $H_2O_2$ was proposed [6]. The nanobioconjugate was obtained by adsorption of FAD-containing enzyme from *Neonothopanus nambi* fungus onto DNDs. The enzyme is an oxidase with a mixed function: in the presence of phenol in an aqueous medium it first generates hydrogen peroxide, which is then used in the reaction of phenol co-oxidation with 4-AAP.




**Suggested scheme of functioning of the nanobioconjugate.**

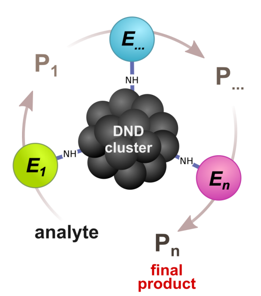



**The product formation in the co-oxidation reaction of phenol with 4-AAP without adding exogenous $H_2O_2$.**

As a result, the rate of formation of a reaction product in the presence of the DND–oxidase conjugate increases by an order of magnitude, compared with the reaction with a free enzyme. More effective product formation by the DND–oxidase complex occurs in two ways: *enzymatic* (with the participation immobilized oxidase) and *non-enzymatic* (with the participation of iron and copper ions on the DND surface).

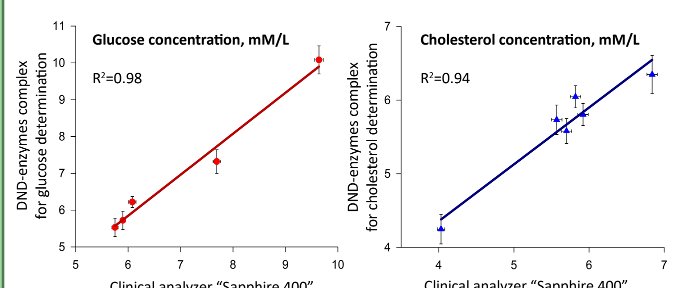
## DND-based bioconjugates for determination of physiologically important blood substances

One (urease), two (glucose oxidase and peroxidase) and three (cholesterol esterase, cholesterol oxidase and peroxidase) enzymes have been covalently immobilized onto the surface of DNDs to construct nanobioconjugates for biochemical detection of urea, glucose, and total cholesterol, respectively [7]. The experiments revealed that the obtained nanobioconjugates demonstrated a linear output of the reaction product over a wide concentration range of all analytes and exhibit activity after long-term storage in DI water at a temperature of 4 °C.




**A schematic representation of the functioning of the designed DND-based bioconjugates.**

Practical applicability of the designed testing systems was successfully demonstrated during determine glucose and cholesterol concentrations in human blood serum in comparative experiments with clinical biochemical analyzer as a reference tool.




**Correlation dependence of two measurement methods for glucose and cholesterol quantitation in human blood serum: *via* use of biochemical analyzer "Sapphire 400" (Niigata Mechatronics, Japan) and designed DND-enzymes systems.**

## References

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