Structure of the Composites Based on Bacterial Cellulose and Multi Walled Carbon Nanotubes

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Introduction

Bacterial cellulose (BC), consisting of a 3-D network of oriented cellulose 2-8 nm diameter fibrils, which combine into nanofibers, can be a promising substance to produce electrically conductive composite materials with biodegradable properties [1,2]. Biocompatible composite films containing carbon nanotubes (CNTs) due to their electrical conductivity can serve as sensors for communication between living tissues in the body and biomedical instruments or neuroelectronic prostheses [3].

The aim of our work was to create a composite material based on BC, synthesized by bacteria of the genus *Gluconacetobacter sp*., and multi walled CNTs, and studying the effect of the method of its preparation on the composite structure.

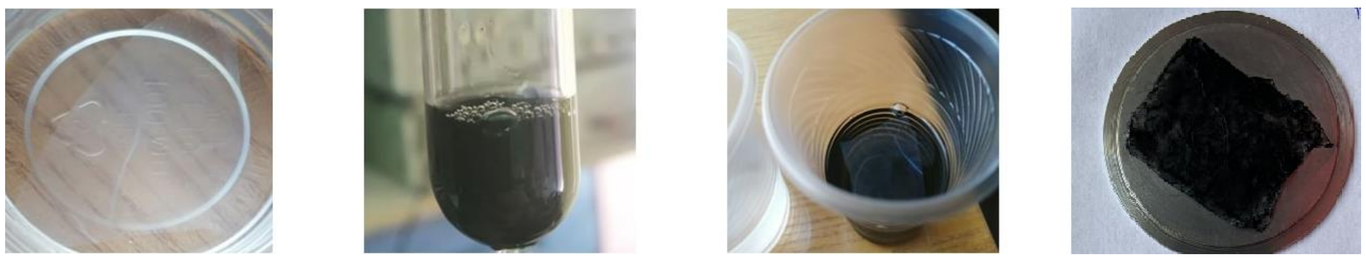
Samples

Bacterial cellulose was synthesized by bacteria of the genus *Gluconacetobacter sp.* from the museum of cultures of microorganisms of D. K. Zabolotny Institute of Microbiology and Virology of National Academy of Sciences of Ukraine.

Multi-walled carbon nanotubes were obtained by CVD synthesis using three-component iron-containing catalysts [4]. The outer diameter of CNTs was 10–20 nm, the purity was approximately 99%. The size of CNT agglomerates was 20–500 µm. To eliminate agglomerates, CNTs were dispersed in a 1% aqueous solution of SDS using an ultrasonic generator.

The samples of composite materials were formed with wet gel films and dried films of BC and CNTs with different degrees of dispersion.

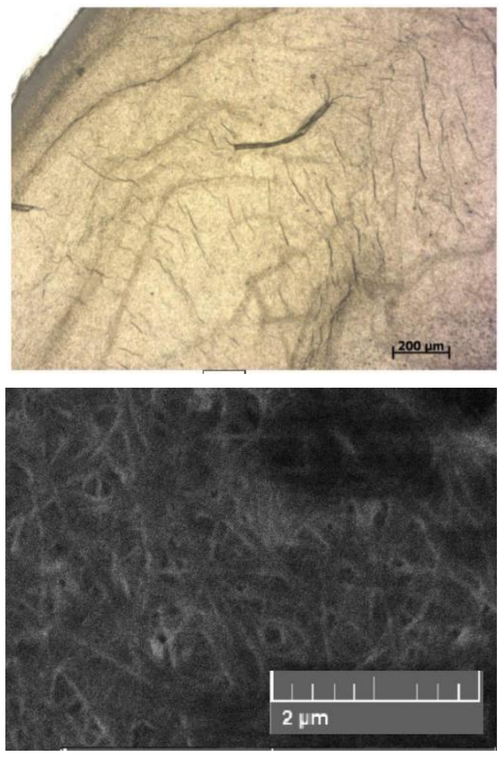
Stages of preparation of BC samples from CNTs based on BC gel



BC wet gel | suspension of nanotubes after dispersion | BC gel with CNTs in suspension | dried film

Results of optical and scanning electron microscopy

Dried film of pure BC



On the surface of dried cellulose, the presence of pores ranging in size from several units to several hundreds of nanometers were observed. Maximum size of pores is 200 nm. Most of the pores have sizes up to 50 nm. Pores were observed on the surface of the dried cellulose.

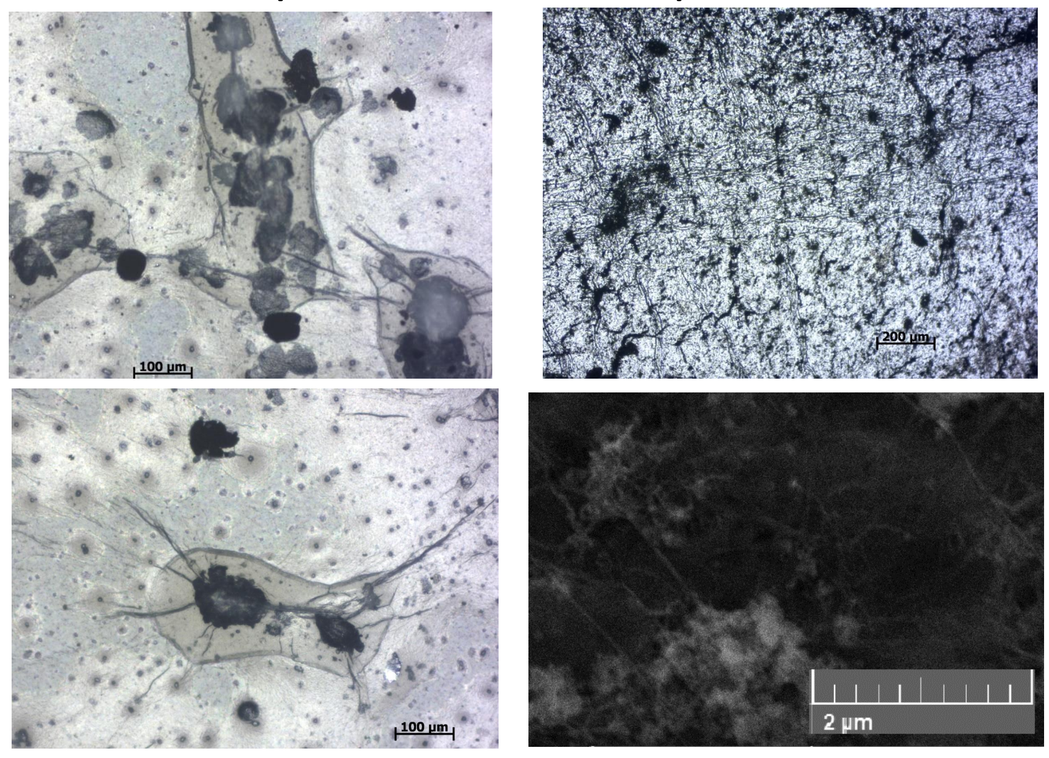
In composites BC network acts as a matrix, containing dispersed CNTs and aggregated CNTs.

In composites with non-dispersed CNTs adsorbed CNT aggregates actively interact with the network surface of BC, namely, a kind of "cocoons" are formed. Probably, the surface of CNT aggregates has high adhesive characteristic as nanostructured material.

Composites formed with wet BC gel and dispersed CNTs contained a continuous branched network of carbon components showing an ability for current conduction that contrasted with composites synthesized by other methods.

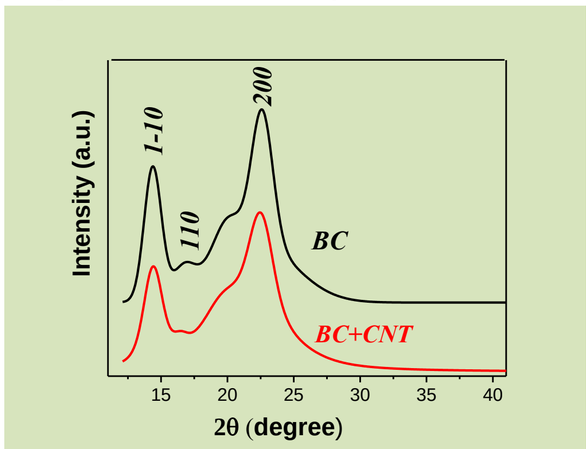
Dried BC film with CNTs based on BC gel

with undispersed CNTs **with dispersed CNTs**



X-ray diffraction analysis

Diffractograms of BC and BC samples with dispersed nanotubes were obtained on an automated X-ray machine DRON-4M. Radiation (Cu Kα with a wavelength of 0.15418 nm) was used. Information about the size of the crystallites was obtained by analyzing the width of the X-ray diffraction lines using Scherrer's formula. The degree of crystallinity of BC in the composite was estimated by the method of decomposition into peaks.



D_{hkl} crystallite sizes and degree of crystallinity C of cellulose and cellulose with dispersed CNTs

	cellulose	cellulose with dispersed CNTs
$D_{1\bar{1}0}$, нм	5,2	4,8
D_{200}, нм	4,3	3,6
C, %	53	49

X-ray diffraction analysis showed that the structure of pure BC and cellulose, which was a matrix of BC composite with CNTs have some differences. Namely, for the composite made with wet cellulose gel and dispersed CNTs, a decrease in the size of the crystallites in the cellulose and a decrease of the degree of its crystallinity were observed.

Conclusions

The peculiarities of the surface morphology of bacterial cellulose were studied and evaluated pore sizes on the surface of the gel film in order to obtain information about particle sizes that can effectively penetrate deep into the cellulose film. Such dimensions are up to 200 nm. So, to form a composite on the basis of BC, it is effective to use CNTs or their bundles, the diameter of which is lower than this value. Although CNT agglomerates are much larger dimensions also interact with the network of bacterial cellulose forming so called "cocoons", but their penetration deep into the film is insignificant. In our opinion, the decrease in the size of the crystallites and the increase in the content of the amorphous component in BC samples with dispersed CNTs can be related both with the embedding of nanotubes in the BC structure and with the influence of ultrasound treatment on cellulose during the formation of the composite.

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[3] Pandit, A., Kumar, R. A Review on Production, Characterization and Application of Bacterial Cellulose and Its Biocomposites. *J Polym Environ* 29, 2738–2755 (2021).

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