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# Electric Conductivity of Carbon Nanoparticles Stimulated by Electric Field

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Host–guest interactions can be the unique method of spin manipulation in nanoscale. Strong changes in spin localization are generated when potential barriers between nanographitic units of activated carbon fibers are modified by interaction with adsorbed molecules. Stronger modifications occur when dipolar guest molecules are stimulated with external electric field. We report experimental results which show the influence of electric field on the spin localization in activated carbon fibers.

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## 1. Introduction

Properties of nanocarbon materials modified by adsorbed molecules of different types are of the high interest because of many reasons. Among them are spintronic connotations [1, 2], problem of hydrogen storage [3] or construction of highly sensitive molecule detector based on a single graphene sheet [4].

Adsorbed molecules can have a significant influence on the electronic properties of activated carbon fibers (ACF), which are composed of nanographitic particles forming the porous system. Dipolar molecules stronger interact with pore walls — they cause more carriers to be trapped in localized states than it is observed for nondipolar ones [2]. Observations of such localization show that conducting properties of ACF strongly depend on host–guest interactions. These interactions determine the potential barriers between nanographitic particles allowing us to treat the system as a quantum-dots matrix [1, 5].

In this paper we present the results of experiment connected with the controlled process of carrier transport in ACF. The change of the number of charge carriers and simultaneously of the localized spins population, is induced using the host–guest interactions modified by external electric field. $H_2O$ molecules have been chosen as guest molecules, because of their strong interaction with the host material [2].

## 2. Experimental

Activated carbon fibers acquired from Osaka Gas Chemicals Co. Ltd, Japan were kept in a system of four-point contact holder with two additional electrodes for external electric field stimulation — Fig. 1. The external dc field was of the order of 3 kV/cm.

After careful purification, based on heating (150 °C) and pumping (level of $10^{-5}$ Torr), the porous system of ACF were filled with $H_2O$ molecules.

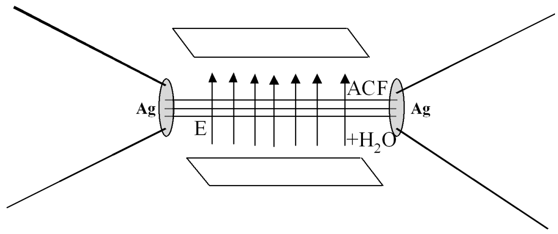


Fig. 1. Schematic configuration of the four-point contact holder with two electrodes for external electric field stimulation.

Electric resistivity measurements were performed by the four-probe method, with data simultaneously acquired with Hewlett–Packard Data Acquisition/Switch Unit 34970 A and RV-Elektronikka OY Picowatt AVS-47 AC Resistance Bridge. The system used the helium cryostat equipped with temperature controller which enabled the stabilization of temperature at the level of ±0.5 K in the range of 4.2–295 K. The sample composed of three activated fibers was kept in the helium gas atmosphere for the duration of the experiment.

## 3. Results and discussion

Systems built of carbon nanoparticles of quasi-graphitic structure exhibit specific electrical transport properties — e.g. spin localization in ACF is described with granular metal model, in which quantum size effects are taken into account [1, 6–8]. These quantum size effects are defined by mechanisms characteristic of quantum dots, such as hopping, tunneling and the Coulomb gap. Adsorption of various molecules (guest) in ACF's (host) porous system strongly influences the transport properties — potential barriers for hopping of charge carriers are modified by guest molecules and, as a result, significant changes in spin localization is observed.

Host–guest interactions determine the possibilities of spin manipulation in nanoscale [2]. Stronger modifications are expected to occur while using external electric field. This field can cause more ordered dipolar configuration which influence the local potential barriers between nanographitic particles of ACF. The expected result of such external electric field stimulation is depicted schematically in Fig. 2 where ordering of dipoles is suggested.

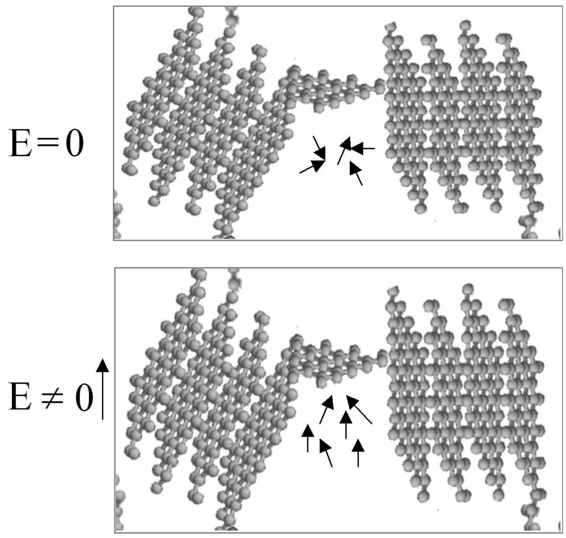


Fig. 2. Ordering of dipoles expected due to external electric field stimulations.

Experiment was performed at wide temperature range, but only a high-temperature region has been selected for presentation. Resistivity at low-temperature region, where Coulomb gap is opened for this system, is highly sensitive to the stabilization of temperature. This problem will be discussed in another paper devoted to the Coulomb-gap mechanism [9].

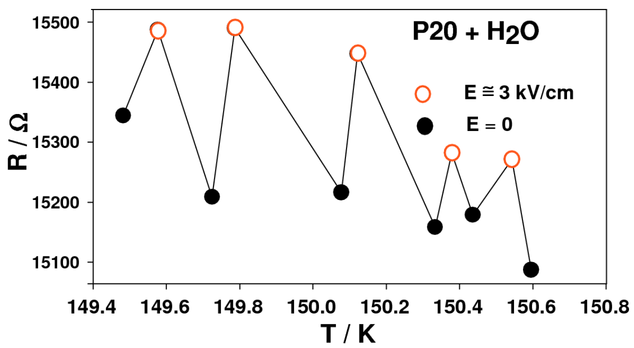


Fig. 3. Results of external electric field stimulation of guest molecules influencing potential barriers between nanographitic particles ($P20 + H_2O$). Open circles show the resistivity of $ACF + H_2O$ with the external field $E$ switched on.

High-temperature region behavior of ACF porous system filled with $H_2O$ molecules stimulated by external electric field is presented in Fig. 3. The result of the subsequent on/off switching of the external electric field is well observed in consecutive steps in resistance as a function of temperature. Changes in resistance stimulated by the dc electric field are not high because we operate in the high-temperature region where ACF is still the good conductor, with weak localization of carriers [1, 2, 5]. It means that because of the screening effects we should interpret the findings as an effect from the surface or as a skin effect. It also shows that in case of low dimensional arrangements of nanographitic systems this effect can play a significant role in controlling the spin population in nanoscale.

## 4. Conlusions

Presented experiment is the first approach to control the electrical transport properties of systems of carbon nanoparticles using adsorbed molecules and external electric field. Featured preliminary results show that there is a possibility to influence the potential barriers for hopping of charge carriers between nanoparticles building the activated carbon fibers. Application of another guest molecules and different fields should give different effects, and will be the subject of the next experiments. We hope that in this way it will be possible to change the electrical transport through the carbon nanoparticles in a controlled way. Such effect would be very important from the point of view of spintronic applications, where carbon nanoparticles are a very promising basis to build single electron devices.

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