QUANTITATIVE APPLICATION OF LATERAL FORCE MICROSCOPY FOR CARBON NANOTUBES INVESTIGATION

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Introduction

One of the most suitable methods for research carbon nanotubes is atomic force microscopy (AFM) [1-3]. AFM allows to receive not only a relief of the studied sample, but also distribution of mechanical characteristics, electric, magnetic and other properties on its surface. At studying carbon nanotubes and structures on their basis definition of strength characteristics of such formations is of interest. To solve this problem it is possible to use a method of lateral forces (MLF). In spite of good visualization of MLF, its lack is absence of reliable techniques of quantitative interpretation of results. The new way of calibration developed by us has allowed to pass from qualitative estimations to quantitative investigations [4]. The given calibration technique is much more exact, than others known till now [5], and does not assume simplification.

At studying carbon nanotubes quantitative MLF opens a simple way for investigation of strength characteristics of the given structures, namely durability of nanotubes on break, force of their interaction with each other and other parameters. This report concerns description of the lateral force calibration method and demonstration of possibilities of the quantitative MLF for carbon nanotubes investigation.

The description of experiment

The equipment and a method of research. Research was made on a atomic-force microscope NTegra (NT-MDT, Russia).

In MLF the sample is scanned in a contact mode in a direction perpendicular to axis of cantilever. Lateral force twists a beam. Twisting angle is registered by optical system (Fig. 1). The laser beam, being reflected from the top surface of cantilever, comes on a four-section photodetector which generates signals DFL and LF, depending from displacement of a light spot in two mutually perpendicular directions. Thus to a vertical bend of a beam of cantilever corresponds signal DFL, and to the twisting caused by lateral forces corresponds signal LF.

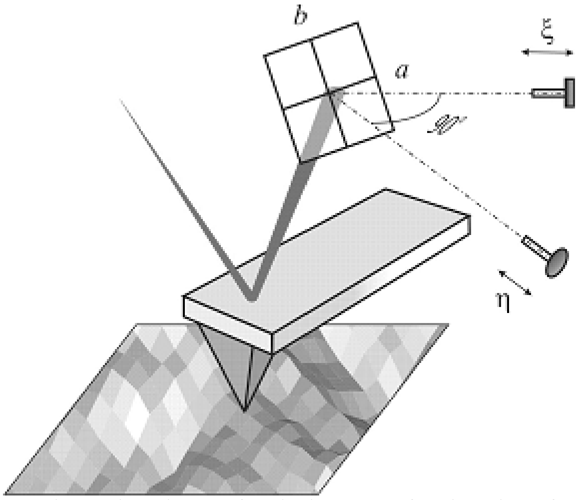
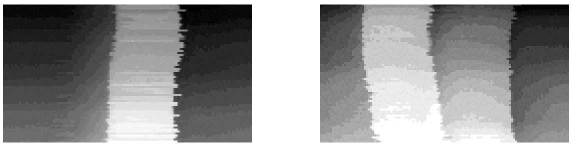


Fig.1. The scheme of optical system of registration of a microscope

The sample. Single-wall opened carbon nanotubes have been provided by Dr. V.E. Muradyan (Institute of Problems of Chemical Physics of the Russian Academy of Science). Nanotubes have been synthesized by the arc discharge[6]. Their initial length made 5-10 microns, diameter made 1.5 nanometers. Then they have been milled in a solution of nitric and sulfuric acids during 8 hours. After washing of carbon nanotubes powder was dispersed in ethyl alcohol. A final spirit solution contains 1/10 part of nanotubes. The drop of a solution has been placed on a surface of highly oriented pyrolitical graphite (HOPG). After evaporation on a surface of the sample single nanotubes and groups in the form of bunches were besieged. Namely bunches of nanotubes also became object of research in the given work.

According to our measurements, on the average diameter of single nanotubes is 1.5 nanometers, height of bunches is up to 100 nanometers (below the bunch with height of 20 nanometers is considered).

Experiment. The sample was scanned in a direction at a right angle to a bunch of nanotubes. The relief of a bunch received in a contact mode is presented in Figure 2a. The purpose of experiment was studying influence of external lateral action on a bunch of nanotubes stuck together. AFM allows to control magnitude of such action by change of vertical force of cantilever's pressing onto a surface of sample. During experiment this force gradually raised. As a result the bunch of nanotubes was deformed and — it has broken up to two independent bunches (Fig. 2b). Simultaneously with a relief signal LAT showing size of lateral force which leads to splitting of a bunch nanotubes was registered.



(a) (b)

Fig. 2. A relief of a bunch нанотрубок: initial (a) and split (b)

The given technique allows not only to find the lateral force leading splitting of a bunch, but also to trace deformation of group of nanotubes "in real time".

Quantitative interpretation of results

Traditional MLF does not allow to find absolute value of size of the lateral action which have caused splitting of a bunch since the factor of proportionality between signal LAT measured in terms of a current, and lateral force is unknown. Specially developed method of calibration has allowed to solve the given problem [4].

The required factor of proportionality depends not only on a design of a microscope, but also on used cantilever and adjustment of the optical system. At the first stage from parameters of cantilever (namely, constants of rigidity and the geometrical dimensions) and also information about a design of a microscope there is a dependence between force and moving of a light spot on a photodetector. At the second stage by means of special procedure it is possible to measure proportionality of output signals and displacement of a spot. For that purpose the adjusting screws serving for moving of the photodetector have been used. So unusual way based on additional calibrational measurements allows to not consider the complex form and intensity of a light spot in cross-section that is a greater advantage compare to other methods [5]. The offered method of calibration allows to find lateral force with accuracy of 8-10 %.

Summary

Methods of AFM, by means of a new method of calibration lateral forces, allow to quantitavely investigate various mechanical characteristics of nanotubes.

In more detail developed method of calibration, a technique and results of experiments will be given in the report.

References

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