STM/STS Studies of SWNTs in Bundles, C_{60} Thin Films and DNA Molecules

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ABSTRACT

In this work we have investigated the nanometer-scale resolved electronic structures of single-walled carbon nanotubes in bundles, C_{60} and Rb-doped-C_{60} thin films, and DNA copolymers by using an STM/STS technique.

Keywords: STM, STS, SWNT, C_{60}, DNA

1 SWNCTs IN BUNDLES

Single-walled carbon nanotubes (SWCNTs) prepared by a contact-arc-discharge followed by a hydrothermal purification are analyzed in the mat-form samples with the use of UHV scanning tunneling microscopy and spectroscopy (STM/STS). The following findings will be reported.

1.1 A strong one-dimensionality in the electronic structure of SWCNTs

Detailed observations of many individual tubes exhibit characteristic stripe lines spaced by 0.14 nm parallel to the tube axes which may correspond to the zigzag lines of armchair-type SWCNTs. This fact means that the π electrons are not homogeneously delocalized on the tube periphery surfaces but rather strongly localized on these lines of carbon chains. Accordingly, the tunneling spectra of this type of tubes at low temperature (25K) may tend to be insulating ones in nature.

1.2 Electronic structures of individual tubes in a bundle[1]

Many STS analysis of individual tubes in one bundle have revealed that almost every tube in the bundle may have similar type of electronic structure and the tubes in different bundle may also have similar type in each other but different type from that in the former bundle. The SWCNTs of the same type in the chirality seem to be assembled in a bundle occasionally when they grew, or somewhat overall common electronic states of the bundle might be dominant on all tubes in one bundle.

1.3 STS measurements on rubidium doped SWCNTs mat

0.2nm- thick Rb metal was evaporated onto the surface of the SWCNTs mat. A characteristic metallic feature around the Fermi level in the DOS spectra appears due to the doping. The metallic character seems to be reduced at low temperatures.

2 STM/STS ANALYSES ON C_{60} THIN FILMS

2.1 Orientation ordering of C_{60} molecules

Low temperature STM study for C_{60} crystalline thin films has revealed the orientation ordering of C_{60} molecules in the crystal at low temperatures in this work. It has been well known that a C_{60} molecule has highly symmetric spherical structure and is rotating with very high speed in a crystal at room temperature. The rotational motion of C_{60} molecules in a crystal causes various phases of intermolecular orientation ordering depending on the temperatures. A first order phase transition of the rotational freedoms from free- to ratchet-rotation occurs at 260 K and below ca.90 K the rotational motion is almost frozen leaving a small amount of static disorder in the orientation. STM studies on the orientation ordering of C_{60} have been carried out for ultra thin layers on silicon or metal single crystal substrates. In these cases the dangling bonds of silicon surface or the charge transfer from metal surface may be effective for hindering the rotation of C_{60} molecules. In our case a few or more molecular layer C_{60} films were deposited on a silicon single

crystal substrate and observed by an STM at low temperatures comparing with the images at room temperature. Clear indication of freezing of molecular rotation and a fairly well orientation ordering were obtained at low temperatures. The correlation of the STM images with the calculated molecular orbital patterns will be discussed.

2.2 Orientation ordering in Rb-doped C_{60} thin films

In the rubidium doped C_{60} films it has been observed that the interaction between Rb ions and C60 molecules may interrupt the rotation of C_{60} molecules and causes a merohedral ordering of the molecular orientation in the crystal even at room temperature. Furthermore, the STM images of some parts of the film exhibited dimerized structure of C_{60} molecules induced by the doping.

2.3 Metallic Nature of Rb-doped C_{60} Films

The other subject of this presentation is an STM/STS study on the metallic nature of alkali metal-C_{60} complex solids. Alkali metal-doped C_{60} solids have been known to be metallic conductors and superconductors at low temperatures when they are properly doped. The main role of alkali metal is believed to be the electron-donation to C_{60} molecules because of its relatively low ionization potential energy. In this work, we have aimed to clarify more detailed functions of the alkali metal to transform the electronic character of the solid from insulator to metal by the doping reaction. We have directly observed the change of the electron density of states due to doping by applying an STS technique in the space- and energy- resolved way. The spatially-resolved STS study has clearly indicated the possible hybridization of the wavefunctions of rubidium ions with those of C_{60} molecules.

3 DOS SPECTRA AND CHARGE MIGRATION IN DNA MOLECULE

The correlation between the electron density-of-states spectra and the charge carrier migration in a DNA copolymer molecule have been studied with applying an STM/STS observation at the base- sites of the molecule. The advantageous character of a GC-pair site compared with an AT-pair for the hole conduction has been revealed[2].

REFERENCES

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