THE ORGANIZATION OF 2,3-IRON-NAPHTHALOCYANINE MOLECULES ON SUBSTRATE AS REVEALED BY SCANNING TUNNELING MICROSCOPY

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ABSTRACT

Surface morphology of thin molecular layer of 2,3-Iron-naphthalocyanine (2,3 FeNPc) was studied by scanning tunneling microscopy (STM) at the ambient conditions. Organic layer with thickness of 40 nm was vapour phase deposited on amorphous carbon substrate. The STM images have revealed the pecularities of surface molecular organization from large range (hundreds of nm) down to atomic scale. Arrays of locally ordered linear stuctures have been distinguished as the main morhological features of the examined surface. At several places the well-ordered STM patterns have been distinguished at the atomic scale. They can be described as stacks of periodicity approximatelly 0.4 nm in a row and 1.5 nm between stacks. These results can be explained by arrangement of 2,3-FeNPh molecules in stacks with a main plane being perpendicular to the substrate surface.

INTRODUCTION

Despite the well-established validity of scanning tunneling microscopy, STM, for advanced surface studies of metalic and semiconductive materials, applications of this new microscopic method to thin organic layers are still in infancy. Monolayers of some organic compounds which are important from the scientific and industrial points of view have conductive or semiconductive properties. Among them are different phthalocyanine derivatives. Due to conductivity in such systems an influence of a variety of experimental conditions, such as layer thickness, nature of substrate and others, on molecular structure and morphology of layer can be easily studied by STM. The STM images of individual copper phthalocyanine molecules adsorbed on metalic and semiconductor surfaces [1-3] and their layers on graphite [4] can be regarded as a basis for future studies. In present communication we describe the STM of molecular layers of other organic system, 2,3-Iron-naphtalocyanine (2,3-FeNPc), on an amorphous carbon surface.

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0379-6779/91/$3.50

RESULTS AND DISCUSSION

The large scale STM images of surface of 2,3-FeNPc molecular layer on carbon surface are presented in Fig. 1a-1d. They have been registrated in different places and show that the examined surface is rather inhomogeneous. Comparatively flat areas are combined with defects of different number and size. The surface morphology becomes more developed in the images of smaller size, Fig.1c-1d. Arrays of ordered linear structures of different size are seen. The largest morphological units are of several nm in width and 10-20 nm in length. In addition one can distinguished a sub-structure consisting of smaller elongated structures which are assembled perpendicular to the main direction of linear element. In some places of the examined areas the atomic scale STM images were registrated, Fig.2a-2d. The STM patterns of atomic scale can be described as locally ordered parallel stacks with well-defined periodicity, 1,5 nm, between neighbouring stacks. The resolution in the atomic scale images is not very high, hovewer, some details of stack arrangement are evident. Each stack consist of two rows of charge density "hills". The repeat distances in row and between rows can be estimated as 0.4 nm and 0.6 nm, correspondingly. By analogy with the STM images of different monocrystals of conductive charge transfer complexes based on tetracyanoquinodimethane [6] we can make the definite conclusion concerning surface structure of 2,3-FeNPc layer. Surface molecules are arranged in stacks with a main plane being perpendicular to the carbon substrate. Such arrangement can be a consequence of strong π-π interactions between neighbouring 2,3-FeNPc molecules with a separation of 0.4 nm. Also the correspondence exists between the geometrical size of 2,3-FeNPc molecule (13 Å) and the repeat distance between stacks. The possibility of this type of molecular packing was discussed earlier [4]. There are a lot of possibilities of an arrangement of 2,3-FeNPc molecules perpendicular to a substrate surface. Thus, a detailed explanation of the STM image requirs a comparison of the image with a electron density distributions in different surface layer geometries. At present we can only assume on the basis of geometrical consideration that double rows present electron density patterns localized near closest edges of neighbouring naphtalene groups. Thus, an arrangement of molecular stacks, in which two naphthalene groups of 2,3-FeNPc interact with lower layer and two others form a surface, seems to be reasonable.

CONCLUSIONS

STM have been proved to be the important method for the morphology studies of conductive molecular layers of 2,3-FeNPc on amorphous carbon substrate. The definite information is obtained about molecular packing which gives motifs for surface morphology features. Questions concerning a dependence of surface molecular structure from layer thickness, way and conditions of deposition will be answered in a nearest future.

EXPERIMENTAL

The surface of mechanically polished amorphous carbon disc (Le Carbone-Lorraine) was used as a substrate for vapour deposition of 2,3-FeNPc. 2,3-FeNPc was prepared in the way described earlier [5]. Vapour deposition have been carried out in the specially constructed vacuum chamber at the following experimental conditions: vacuum - 10^{-6}, temperature of substrate 20^{o}C, a deposition rate - 0.1 nm/sec. The estimated thickness of molecular layer was 40 nm. STM experiments at ambient conditions were conducted with a commercial microscope "Nanoscope II" (Digital Instruments Inc., Santa Barbara, USA). Tunneling conditions were I_{tun}= .12 - .3 nA, V_{bias}= .7 - 1.2 V. For more details see [6].

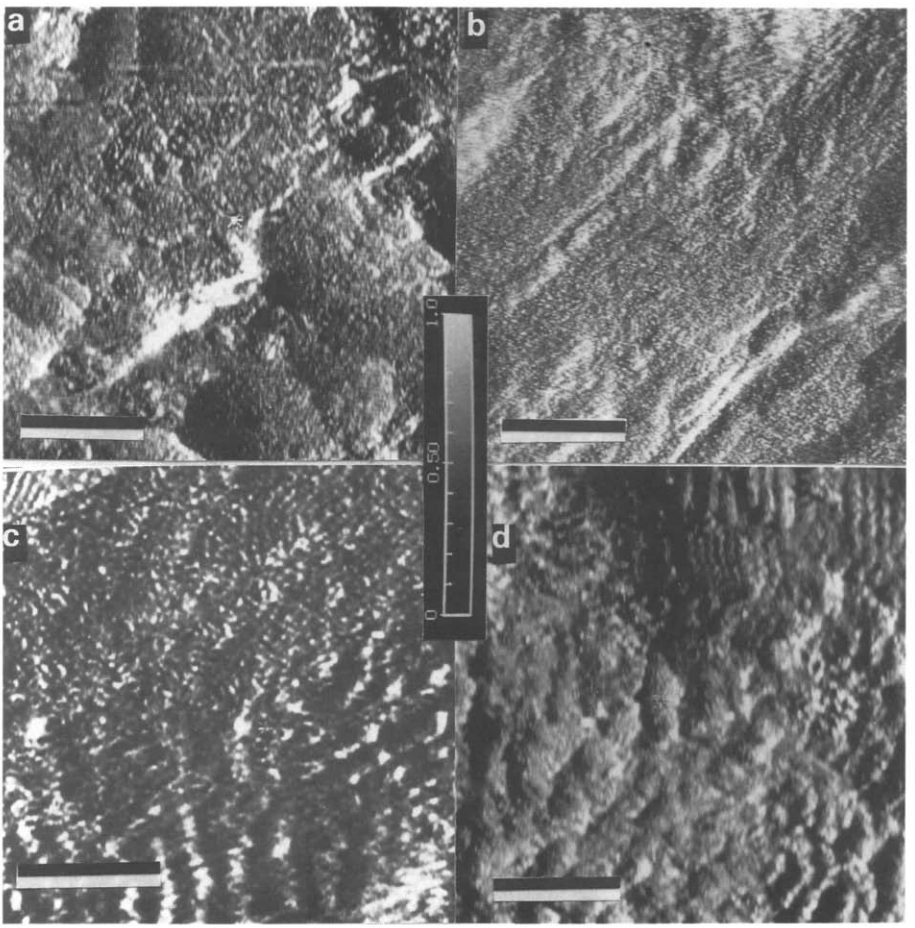

Fig.1a-1d. Large scale STM topview images made at the different places of 2,3-FeNPC layer. Horizontal bars correspond to 100 nm in Fig.1a-1b and to 20 nm in Fig.1c-1d. The vertical grey scale bar shows variations in the direction perpendicular to the examined surface.

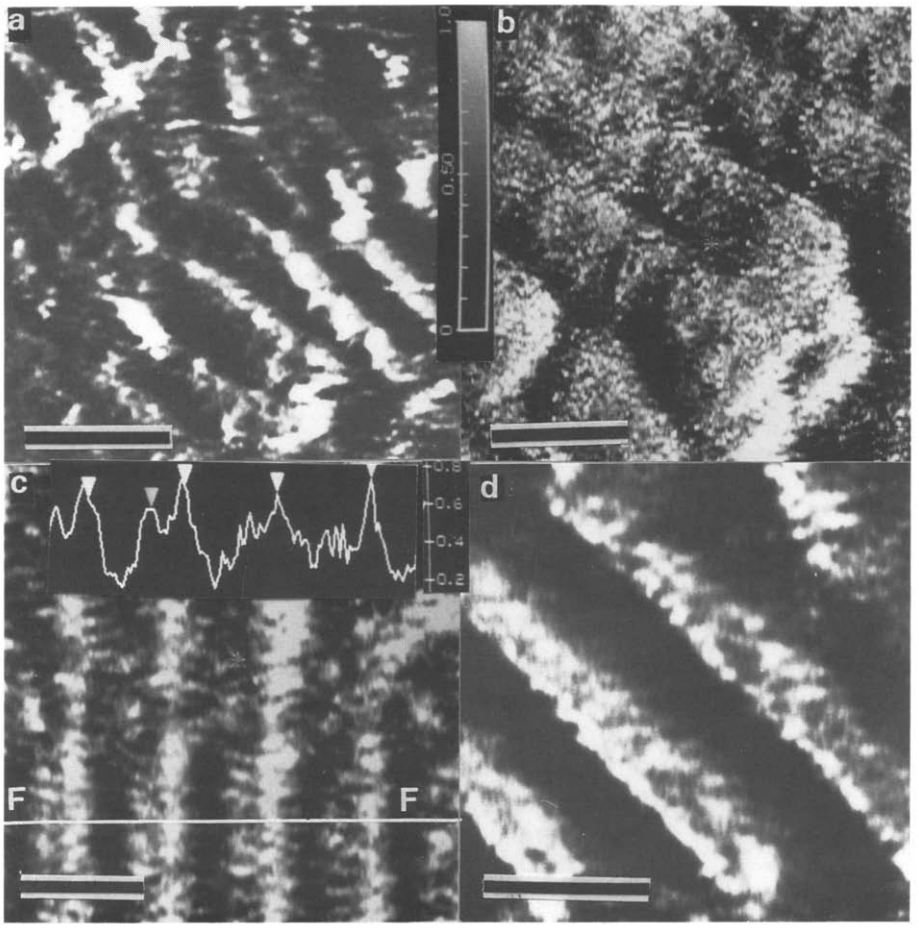

Fig.2a-2d. Atomic scale STM topview images of 2,3-FeNPc layer. The horizontal bars correspond to 4 nm in Fig.2a-2b and to 2 nm in Fig.2c-2d. The vertical grey scale bar (in nm) indicates the variation in the z-direction perpendicular to the examined surface in Fig.2a,2b,2d. The insert in Fig.2 shows the z-contour (in nm) along the F-F line.

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