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Scanning tunnelling microscopic investigation of fullerene monolayers

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Abstract C_{60} fullerene monolayers have been investigated by scanning tunnelling microscopy/spectroscopy. Single C_{60} molecules have been resolved and a regular surface lattice structure of fullerene – in – surfactant is observed. Tunnel electron spectroscopic measurements results in typical I(V) curves which are interpreted in terms of the two-junction Coulomb blockade effect.

1 Introduction

Scanning tunnelling microscopy (STM) provides new possibilities for spectroscopical investigations of materials and structures.

The quantum electron tunnel transport through a thin gap of several Ångstrøms width between two conducting contacts is the basic phenomenon for STM [1]. Tunnelling current I being strongly dependent on the gap width, the surface profile image may be obtained by the tunnelling current measured while scanning the conductive probe along a surface. Pt-Ro tips as small as several Ångstrøms are now available allowing the spatial resolution in the atomic scale. Besides, the local electronic work function and the electron density of states may be identified using respectively $(dI/dz)_{I=\mathrm{const}}$ and $(dI/dV)_{I=\mathrm{const}}$ for scanning spectroscopy or $I(V)$ and dI/dV for local tunnel spectroscopy (STS), z being the gap width and V - the bias voltage. This results in new modes of an object imaging contrast.

2 Experimental

We used a P4-SPM device produced by "Nanotechnology-MDT" (Russia) in our experiments. Fine mechanics with an electrical feedback control allow the precise tip positioning above the sample while a piezoelectric scanner realises the precise (up to tenth of Ångstrøms) controlled displacement of the tip along the surface. Currents as small as several pA are registered.

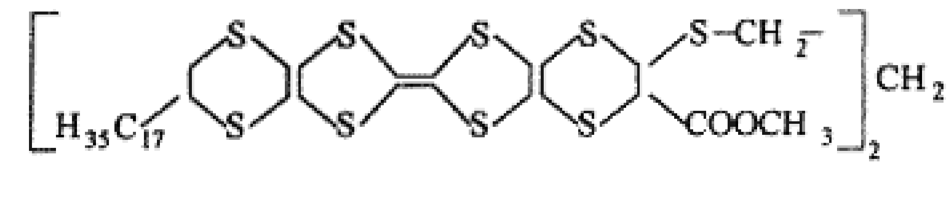
We investigated the C_{60} fullerene structures on highly oriented pyrolytic graphite (HOPG) wafers formed by the Schaefer method (horizontal lift) [2]. Scanning tunnelling microscopic imaging as well as scanning tunnelling spectroscopic investigations were carried out. The minimum scanning step was 0.015 nm, and currents as small as 0.05–0.5 nA were registered under a bias from –2 V to + 2 V.

3 Results and discussion

Figure 1a shows the STM image of fullerene clusters on HOPG wafers. The surface relief as well as the work function relief (dI/dz for I = const.) in a scale of 0.9–1.0 nm is distinguished at the edge of a cluster which may be identified by a single C_{60} molecule.

Figure 1b shows some selected $I(V)$ spectra out of a set obtained from different points of the marked region on Fig. 1a with a line step of 0.05 nm. One can see that along a distance about 0.8–1.0 nm the $I(V)$ spectra change from the HOPG-like form (curve 3) to some specific form of curves 1,2 and than again restore the HOPG-like form. This allows to conclude that the curves 1,2 of Fig. 1b are a kind of typical $I(V)$ electron tunnelling spectrum of the C_{60} molecule probed at its centre, while the set of Fig. 1b corresponds to the development of the $I(V)$ probes from one edge of the molecule to the other.

Figure 2 represents the STM image of a fullerene C_{60} monolayer on an HOPG wafer. A monolayer is formed by the Schaefer method using a mixture of surface active material (surfactant) and the fullerene. The surfactant



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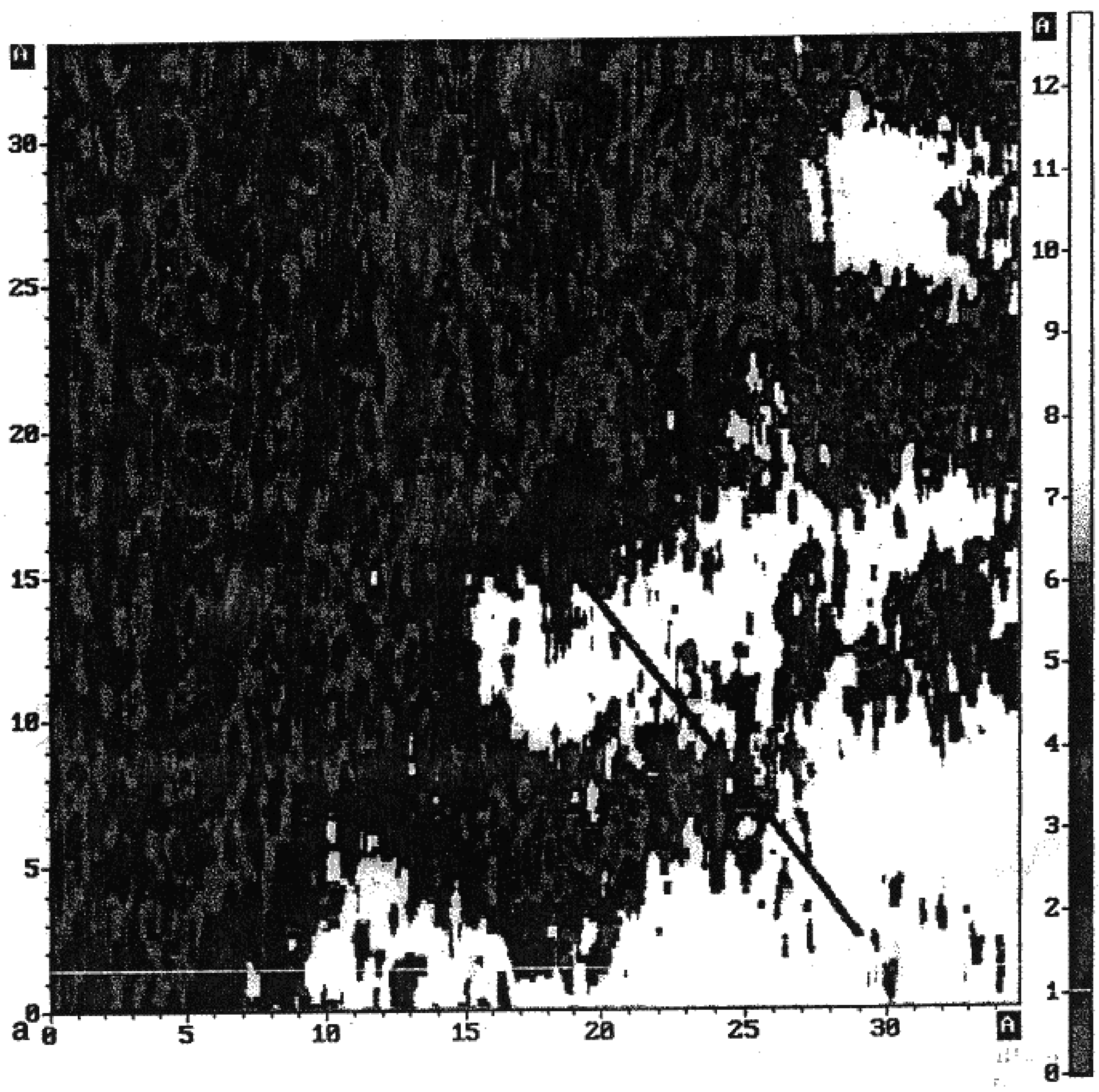

Fig. 1 a STM imaging of fullerene cluster on HOPG wafer. b $I(V)$ spectra from different points of the fullerene monolayer (*1,2*) and from pure HOPG

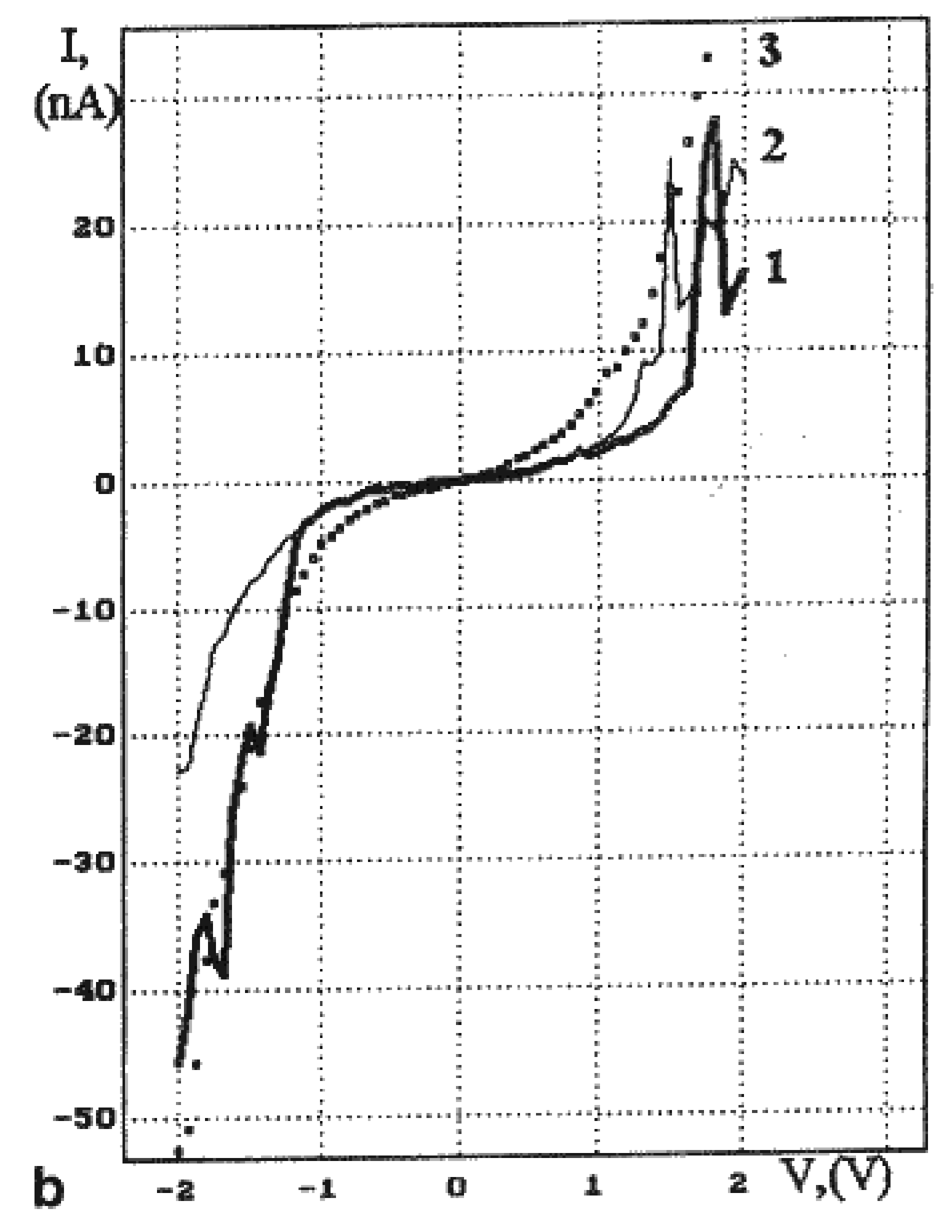

Fig. 2 STM image of a fullerene-in-surfactant monolayer