Single-electron molecular transistors on the base of various types of cluster molecules

E. S. Soldatov†, A. S. Trifonov†, S. P. Gubin‡, V. V. Khanin†, G. B. Khomutov†, S. A. Yakovenko†, A. Yu. Obidenov†, V. V. Shorochov† and D. B. Suyatin†

† Faculty of Physics, Moscow State University, 119899 Moscow, Russia
‡ Institute of General and Inorganic Chemistry, 119899 Moscow, Russia

Abstract. Effect of single-electron tunneling in double-junction tunnel system based on single molecule was investigated. Molecular single-electron transistor was demonstrated. The comparison of measured characteristics with the similar characteristics of molecular single-electron transistors based on a carborane cluster has shown their qualitative resemblance despite essential differences in a chemical structure and strometry of these molecules.

1 Introduction

The traditional microelectronics schemes construction technologies are limited by resolution of the nanolithography equipment, chemical non-uniformity of layers in which the separate elements are formed and non-uniformity of a substrate. Thereby, searching for new alternate ways of electronics engineering development is actual. One of the perspective solutions for nanotechnology is the use properties of separate molecules, as a rule, organic molecules. The capability of creation a molecular electronics engineering and bioelectronics engineering was motivated [1]. As a simple element for construction of electrical elements the authors offer to use a cluster molecule.

The clusters and cluster molecules differ from other organic and inorganic molecules that they consist of a compact heavy nucleus, as a rule, with spherical symmetry, which is surrounded by ligand from light atoms or elementary molecules [1]. The peculiarities of electron structure of cluster molecule condition on the one hand on occurrence of multiple single-electron reversible transitions [1] and, by the other hand, provide sufficient stability of cluster molecule after addition or removing an electron [1]. The electrochemical properties of many of such molecules are reliably determined enough and vary in rather broad borders.

Main advantage of use a cluster molecules as an element of nanoelectronics:

1. The cluster molecules are synthesized chemically, i.e., all molecules are strictly identical both in electronical structure, and in chemical structure.

2. The size of appropriate for realization a tunnel barrier cluster molecule can be essential less, than in elements formed with classical nanolithography.

3. As chemical and the physico-chemical properties of cluster molecules are already well investigated at the present time, there is a capability to dispose cluster molecules on a substrate not only by physical (deposition), but also by chemical methods.

In our previous activities [5, 6] were demonstrated a double junction single-electron system and single-electron transistor, based on a single carborane cluster molecule. However, the problem is still open: what a minimum set of properties of cluster molecule are enough for possibility of using it as simple element of the single-electron scheme.
2 Results and discussion

For the comparative analysis of the SET — transistor characteristics depending on a type of a cluster molecule, similar \[\text{[1]}\] experiment was made, where as a working molecule \(\text{Pt}_5(\text{CO})_6[\text{P(C}_2\text{H}_5)_3]_4\) was used. Though the molecules \(\text{Pt}_5(\text{CO})_6[\text{P(C}_2\text{H}_5)_3]_4\) and the carborane molecule differ entirely by chemical structure, they have a similar structure of energy levels.

For reliability increase of receiving results the samples quantity was increased in comparison with the previous experiments \[\text{[2, 3]}\], the investigation of measurement regimes influence on the \(I-V\) curve and control characteristics (the measure rate, the range of bias voltage, the averaging) was made. The measurements were performed in various characteristic places of a sample (the STM tip above a single cluster on different distances from a gate electrode, above group of clusters and above flat region).

The performed measurements have shown, that

1. The \(\text{Pt}_5(\text{CO})_6[\text{P(C}_2\text{H}_5)_3]_4\) molecules have brightly expressed surface — active substance properties, as it forms own (without stearic acid) LB-monolayer.

2. The LB-deposition (at certain parameters) gives a cluster molecules monolayer, and distance between molecules can smoothly be changed over a wide range, for example to do rather large, to consider a separate molecule isolated. (Fig. 1).

3. The \(I-V\) characteristics above single clusters differ from \(I-V\) curves above flat graphite. (Fig. 2).

4. The control characteristics above single clusters differ from the control characteristics above flat graphite (Fig. 3) by periodicity presence - 2000 ± 200 mV, and this period varies depending on distance between a cluster and a gate electrode.

An observable behavior of \(I-V\) curves and control characteristic indicate that in a double junction tunnel system STM tip—cluster—the substrate a regime of single electron tunneling is realized, and the current through this system can be controlled with changing the voltage on a gate electrode.

3 Conclusions

Thus main result of performed research was the realization of the molecular single-electron transistor on the base of a single \(\text{Pt}_5(\text{CO})_6[\text{P(C}_2\text{H}_5)_3]_4\) molecule cluster. The comparison of measured characteristics with the similar characteristics of molecular single-electron transistors based on a carborane cluster has shown their qualitative resemblance despite...
Fig. 2. The typical $I-V$ curve of double junction system STM tip–cluster–substrate.

Fig. 3. Control characteristics, measured at STM tip above single cluster molecule and above flat graphite area.

essential differences in a chemical structure and stereometry of these molecules.

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