**Press release**

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***Molecules organize themselves spontaneously into long parallel chains on a prepared surface***

# Using Molecular «Dominos» to make Nanowires

***The trend to miniaturization in the microelectronics field makes it increasingly difficult to manufacture these tiny devices. It would be much easier if all that was necessary was to mix together the substances from which they were made and then let the components put themselves together without any external help! The magic words are "molecular self-assembly", and they make a researcher's pulse rate go up. Empa scientists working in this field were recently able to chalk up a significant success in that they managed to formulate two organic molecules in such a way that they organized themselves spontaneously into long parallel chains (so-called nanowires) on a specially prepared gold surface. Selective self-assembly on surfaces and the fundamental processes which control this phenomenon are, however, not only critical in the area of molecular electronics but also in heterogeneous catalysis – a process used in automotive catalytic converters – and in sensor technologies.***

For some time now researchers have been able to "design" molecules in such a way that they attach themselves to each other in alternating order, and under certain circumstances – for example on surfaces – create chains. This can be thought of as like a game of dominos, without human players, where the rows assemble themselves. Unfortunately the rows are not very long, because all surfaces, even extremely smooth ones, show unevenness at the atomic level. Step edges, although only a few atomic layers high, represent insurmountable hurdles to the self-assembly process, and since they are distributed randomly over the surface, the molecules form themselves into very irregular patterns. This unevenness can only, of course, be "seen" or "felt" using a scanning tunneling microscope. In this instrument an extremely fine, pointed tip is scanned just above the surface being investigated while an electric voltage is applied to it. As the tip approaches the surface a so-called tunnel current flows. If this current is kept constant by regulating the position of the tip, the topography of the surface can be made visible.

Empa researcher Roman Fasel and his colleagues then asked themselves what would happen if all the steps on a surface were arranged parallel to each other like an immense miniature staircase. Theoretically, the molecular chains - which assemble preferentially along step edges - should organize themselves into a long, parallel lattice. To test this hypothesis, doctoral student Marta Cañas-Ventura of the EPF Lausanne together with Empa colleagues suitably prepared the surface of a gold single-crystal. After numerous cycles of argon ion bombardment – a cleaning step which removes minute traces of contamination from the gold surface – and subsequent heating the scientists achieved their goal. The surface of the crystal now

consisted of a flight of stairs of countless parallel steps all of the same height, namely one gold atomic layer or 0.24 nanometers, with each step separated from the next by a constant distance of 5.8 nanometers.

**Designer molecules create self-assembling nanochains**

Now all that was necessary for them to do was to evaporate the constituent components of the nanochains onto the gold surface under ultra-high vacuum. One of the organic building block molecules used had been specially synthesized by colleagues at the Max-Planck-Institute for Polymer Research in Mainz and was shaped so as to match the second component. Thus both ends of each molecule possessed structures which fitted together perfectly with the partner molecule, the joint being held together by hydrogen bonds. After this process was complete Fasel and his team looked at the surface once again under the scanning tunneling microscope.

What the scientists observed confirmed their expectation in every respect. When low concentrations of the two building block molecules were used, a single chain was formed at each step edge. When higher concentrations were used a double chain was deposited. The double chains, with defect-free zones of about 30 nanometers length, in fact showed significantly better ordering than the single chains, “probably because two chains stabilize each other,” according to Fasel. The complete picture showed a kind of lattice over the whole surface of the gold crystal, with countless evenly spaced nanochains running across it. “Our study is a proof-of-principle investigation. We have been able to show that it is fundamentally possible to grow supramolecular chains laid out in parallel over a surface – and that too over relatively large distances,” says the Empa researcher, whose results will shortly be published in the scientific journal «Angewandte Chemie».

The self-assembling supramolecular chains do have one drawback though. They are not suitable as conductors for use in molecular electronics, because on the one hand they are in contact with a metallic substrate – gold – and on the other they show a rather low electrical conductivity. The Empa team is therefore working intensively on methods, and also other classes of molecules, for creating supramolecular chains on insulating substrates which are more suited for conducting electrical current. In addition “switchable” molecules, which might one day take on the role of transistors in electronic circuits made out of self-assembling molecules, are of particular interest. The long term aims of the research is, according to Fasel, to understand and control the process of molecular self-assembly in order to develop applications on the nanometer scale not just in the laboratory, but also for use in industrial production.

Roman Fasel is Coordinator of the RADSAS project (Rational Design and Characterisation of Supramolecular Architectures on Surfaces) which is supported within the 6th EU Framework Program.

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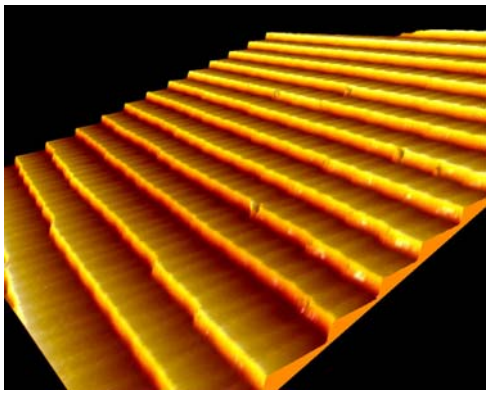
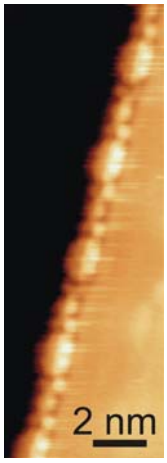
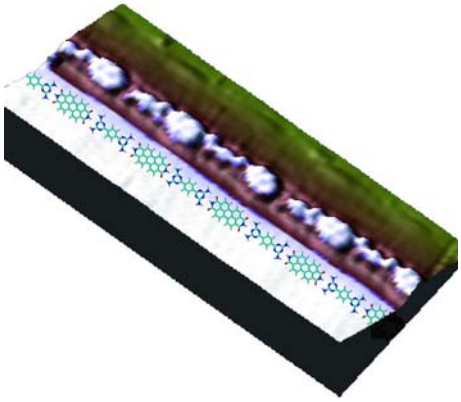
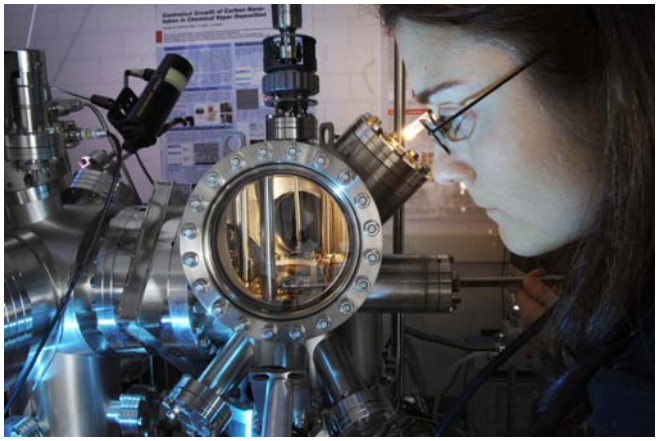


Under the scanning tunneling microscope: regular ordering of steps, 0.24 nanometers high and 5.8 nanometers wide, on a specially prepare gold surface (image area 100 x 100 nanometers).



Scanning tunneling microscope image of a supramolecular chain (left) and a 3-D representation of the molecular chain with a schematic model of the alternating arrangement of building blocks superposed.



The ultra-high vacuum scanning tunneling microscope with which the Empa researchers study surface phenomena, such as the self-assembly of supramolecular structures.

Images are available from remigius.nideroest@empa.ch