Two Fundamental Nanotechnology Problems Solved

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The Erwin Schrodinger Prize for Interdisciplinary Research, awarded by the Helmholtz Association of National Research Centres, will go to a research team from the Institute of Nanotechnology of the Forschungszentrum Karlsruhe this year. The jury wishes to honour the team of physicists and chemists in this way for its excellent interdisciplinary achievements in the field of nanotechnology. Professor Walter Kroll, President of the Helmholtz Association, will present the award worth 50,000 euros to the research team at the Helmholtz Annual General Assembly on 7 December 2004 in the Concert Noble in Brussels.

Two pioneer activities have made the Karlsruhe team, Frank Hennrich, Ralph Krupke, Marcel Mayor, and Heiko Weber, famous among fellow specialists worldwide in recent years: they have developed a long sought-after method for the separation of tiny carbon tubes which play an important role in nanotechnology. They have also succeeded in measuring the electric current through individual organic molecules. Working together systematically, the Karlsruhe team has solved two fundamental problems which impact the entire domain of nanotechnology. Their joint work will give rise to a new form of nanoelectronics in the future, in which tiny circuits measuring millionths of a millimetre could be built. This kind of electronics on a very small scale is predicted to play an important part in computer and satellite technology and medical engineering. It would make it possible to build tiny chips and so to decisively improve computing performance on this miniature scale. The carbon tubes of the Karlsruhe researchers could then function as "wires", and the organic molecules serve as a storage medium.

Small is beautiful

The Erwin Schrödinger Prize is awarded annually as a distinction for outstanding scientific or technologically innovative achievements in the interface areas between different fields with the participation of Helmholtz scientists. “The prize-winners this year have succeeded in a unique way in working together across disciplines and in combining the fields of chemistry and physics within an innovative research area,” explains Prof. Karin Mölling, who chaired the jury. “Where components in physics are becoming smaller and smaller and molecules in chemistry are becoming bigger and bigger, physics and chemistry meet,” says the physicist and head of the Institute of Medicinal Virology at the University of Zurich. “Nanotechnology is situated at this interface: here circuits are built on a molecular scale. It can't get any smaller!”

“Macaroni” of carbon atoms

As early as 1991 Japanese researchers discovered that carbon atoms can form tiny tubes whose walls are just one atom thick. Since then, “nanotubes” have become one of the most important research subjects of nanotechnology. Particularly in molecular electronics, they were quickly recognised as the basic building blocks of electronic components. However, up until now there has been one difficulty: production always results in a mixture of two types of nanotubes with differing electric properties. Depending on the arrangement of atoms in the walls, the carbon macaroni either behave like metals or like semiconductors. Only now has the work of the Karlsruhe research team made it possible to separate the semiconducting and metallic tubes from each other in a solution and so to sort them. “In an alternating electrical field with a frequency of 10 million Hertz, the metallic and the semiconducting nano¬tubes drift in opposite directions and can hence be separated. The non-metallic tubes stay in the solution," explains the physicist Dr. Ralph Krupke. Together with the chemist Dr. Frank Hennrich, he was able to solve the problem using a multidisciplinary approach.

Going to the limits

For electric circuits on a nanoscale, further components are needed in addition to tiny wires. Semiconductor engineers in the past 20 years may have succeeded in producing increasingly well-integrated electronic circuits made of silicon, with the dimensions of individual components becoming more and more minute. In the next few years these components are likely to shrink to as little as a few nanometres. Then, however, physical limits will be reached.
The electronic connection of molecules in a circuit apparently offers a way out. For such molecular circuits individual molecules must be contacted electrically. Additionally, molecules are needed whose conduction mechanism is predictable. The Karlsruhe researchers made a breakthrough here: they succeeded in clamping individual molecules between two electrodes and measuring the current through these molecules. "As proof we produced and contacted symmetrical and asymmetrical molecules," explains Dr. Marcel Mayor, who worked with Dr. Heiko Weber in an interdisciplinary partnership of chemistry and physics. In this way, the scientists gained an insight which was of decisive importance to molecular electronics: through an appropriate selection of the molecular structure, the electronic properties of the "components" can actually be determined. Admittedly, the idea of using individual molecules as electronic components was not new. Here, however, electronic transport processes in the molecules have been measured and understood comprehensively for the first time.

Source: Helmholtz-Gemeinschaft