21. Molecular Electronics and Other Applications

As a conclusion to this book, we have permitted ourselves to describe the outlook in a field which on the one hand is quite fascinating because of the goals it has set itself, but on the other is still uncertain with regard to its eventual limits and potentials.

21.1 What Is it?

For some years now, the imaginations of molecular and solid-state physicists have been fired by a new idea, or a new catchword, referring to a novel application of their research: molecular electronics. What is it? Molecular electronics is the generic term for efforts and speculations which have the goal of complementing present-day conventional electronic devices, particularly microelectronics based on silicon and related semiconductor materials, by electronics which makes use of molecules and molecular functional units, utilizing the specific properties of molecular substances. This goal has been set for the not-too-distant future. The attraction of such ideas is due to the hope of a further significant miniaturisation as compared to silicon-based devices, of being able to use the enormous variety of molecules offered by organic chemistry, and, perhaps, of finding materials which are readily available and easily produced.

In considering the requirements of an electronics based on molecules, one finds that the following functions would be needed:

- Molecules or molecular functional units which can serve as switches: molecular systems which are bistable with regard to light or to electric or magnetic fields;
- Molecules or molecular functional units usable as conductors: for some years, organic metals (i.e. molecular solids with a metallic electrical conductivity) and even organic superconductors have been known;
- Molecules or molecular functional units which perform as logic elements: it must be possible to make such devices by combining switches and conductors;
- Molecules or molecular functional units able to provide information storage, i.e. memory devices which permit the writing and readout of information by means of light or electric or magnetic-field pulses.

What, then, is molecular electronics? The concept can perhaps best be defined thus: molecular electronics includes all of the phenomena and processes in which organic molecular materials play an active role in the processing, transmittal, and storage of information.

If we use this definition, then there is at present hardly such a thing as molecular electronics. Whether it will someday exist, and what it would then be like, we do not yet know; but we can already apply ourselves to tasks in basic research which will prepare the ground
for its possible development, which foresee its applications in the future and keep them in mind. This is an area requiring the combined efforts of solid-state and molecular physicists and chemists; the concept of molecular electronics may thus serve as a stimulus for varied and interdisciplinary research programmes.

### 21.2 Molecular Conductors

Are there organic molecules which are suitable for use as electronic conductors (“molecular wires”) to connect other molecules together in an electrical circuit? One can immediately think of polyenes (Sect. 14.6), or also of the so-called organic metals. The latter are crystalline compounds which are in general composed of two partners, of which the one serves as an electron donor and the other as an electron acceptor. The organic partners are often arranged in stacks, so that they yield a one-dimensional or low-dimensional conductivity when conduction is achieved through overlap of the \( \pi \)-orbitals of neighbouring molecules; cf. Fig. 21.1.

![Fig. 21.1. The crystal structure of the radical-anion salt 2,5 dimethyl- dicyanoquinone-dimine (DCNQI), with copper as its inorganic partner. In the centre of the picture, a chain of Cu ions can be seen; they are, however, not responsible for the metallic conductivity of the material. Around them are four stacks of the organic partner molecules. Conductivity takes place along these stacks. The stacks are joined together via \(-\text{CN}\) groups through the central Cu, so that the one-dimensionality is somewhat reduced. [After P. Erk, S. Hiinig, J.U. v. Schütz, H.P. Werner, and H.C. Wolf, Angew. Chem. 100, 286 (1988)]. The molecular structure diagram at the upper left shows the H atoms as dots only](image-url)