Challenges for Nanotechnology

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Contributor: Johann Köhler

The term “Nanotechnology” describes a large field of scientific and technical activities dealing with objects and technical components with small dimensions. Typically, bodies that are in–at least–two dimensions smaller than 0.1 µm are regarded as “nanobjects”. By this definition, a lot of advanced materials, as well as the advanced electronic devices, are objects of nanotechnology. In addition, many aspects of molecular biotechnology as well as macromolecular and supermolecular chemistry and nanoparticle techniques are summarized under “nanotechnology”. Despite this size-oriented definition, nanotechnology is dealing with physics and chemistry as well as with the realization of technical functions in the area between very small bodies and single particles and molecules. This includes the shift from classical physics into the quantum world of small molecules and low numbers or single elementary particles. Besides the already established fields of nanotechnology, there is a big expectation about technical progress and solution to essential economic, medical, and ecological problems by means of nanotechnology. Nanotechnology can only meet these expectations if fundamental progress behind the recent state of the art can be achieved. Therefore, very important challenges for nanotechnology are discussed here.

limits of nanotechnology | nanofacility shrinking | modularity | sustainability | hierarchical organiza-tion | entropy export | time scales | life cycles

About half a century ago, nanotechnology was not much more than a vision [1]. However, during the last decades, it has developed quickly, and there are many branches of science and technology which are related to nanotechnology [2]. From the point of application, two fields are particularly far developed: on the one hand, the creation and production of nanomaterials [3] and, on the other hand, the production of electronic chip elements, which play a crucial role in nearly every recent field of advanced technology due to their key role for computer and communication technology, for machine control, sensing, and for many other technical devices.

Highly integrated electronic solid-state devices are built up by billions of single nanostructures, recently. This ultimate degree of integration is based on a very high level of circuit design, micro, and nanolithography, and a lot of special preparation and measurement technologies and sophisticated materials are needed [4]. The enormous power of recent computers is a direct consequence of stepwise downscaling of the minimal structures in microlithography and the continuous improvement of all related technological steps and the equipment for manufacturing over the past five decades. These result in critical structure sizes below about 20 nm in production and below 10 nm in advanced development, which is not very far from the dimension of small molecules [5], and are in the order of magnitude of 1 nm. The basis for this successful development is the general convention of planar technology and a consequent down-scaling of functional structures in the frame of this proved concept.

The opposite development was inspired by the vision of realizing a bottom-up approach instead of a downscaling of microtechniques into the nanometer range. This approach is motivated by the insight into the ability of nature to form very complex functional structures by arranging small molecular units in living cells. The understanding of the chemical structure of complex biomolecules and the causing nature of chemical bonds behind–as it was explained by L. Pauling, F. Crick, J. Watson, and others–gave hope to constructing complex molecular machinery and to build complex functional systems from ultimate small modules artificially [6]. Supermolecular chemistry and strategies of controlled molecular self-assembling [7] are the main approaches for realizing molecular machines [8]. Indeed, these ideas led to a lot of interesting investigations and inventions during the last decades. However, it must be said that the dream of bottom-up nanotechnical manufacturing was not fulfilled, up to now. Thus, very important challenges remain, and some of the important ones will be discussed in the following.

References

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