The Future of Bio-technology

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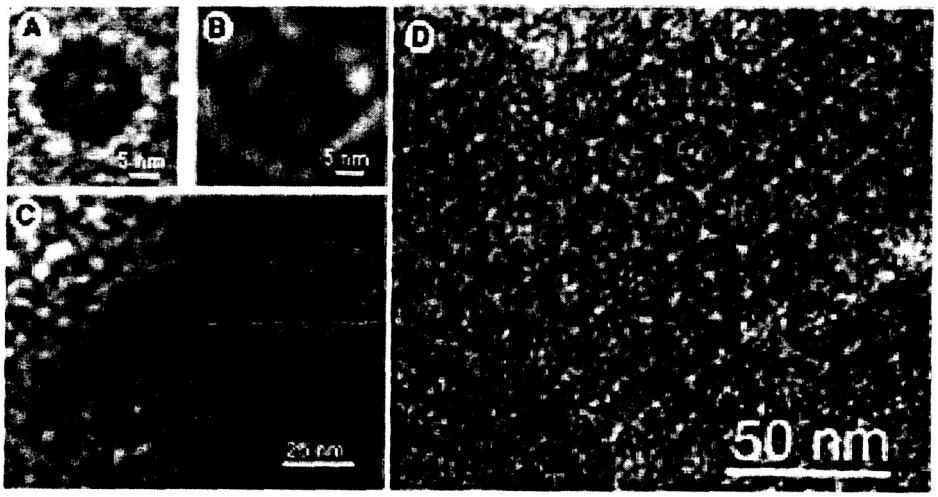
Abstract

Hosts of technologies, most notably in electronics, have been on the path of miniaturization for decades and in 2005 they have crossed the threshold of the nano-scale. Crossing the nano-scale threshold is a milestone in miniaturization, setting impressive new standards for component-packing densities. It also brings technology to a scale at which quantum effects and fault tolerance play significant roles and approaches the feasible physical limit form many conventional "top-down" manufacturing methods. I will suggest that the most formidable manufacturing problems in nanotechnology will be overcome and major breakthroughs will occur in a host of technologies, when nanotechnology converges with bio-technology; i.e. I will argue that the future of bio-technology is in nanotechnology.

In 2005, methods in molecular biology, microscopy, bioinformatics, biochemistry, and genetic engineering have focused considerable attention on the nano-scale. On this scale, biology is a kind of recursive chemistry in which molecular recognition, self-assembly, self-organization and self-referencing context-control lead to the emergence of the complexity of structures and processes that are fundamental to all life forms. While we are still far from understanding this complexity, we are on the threshold of being able to use at least some of these biological properties for technology.

I will discuss the use of biomolecules, such as DNA, RNA, and proteins as "tools" for the bio-technologist of the future. More specifically, I will present in some detail an example of how we are using a genetically engineered 60-kDa protein (HSP60) from an organism living in near boiling sulfuric acid to build nano-scale templates for arranging metallic nano-particles.* These "extremophile" HSP60s self-assemble into robust double-ring structures called "chaperonins," which further assemble into filaments and arrays with nanometer accuracy (see Fig below). I will discuss our efforts to use chaperonins to organize quantum dots, electronic and magnetic nano-particles for electronic and photonic applications.



HSP60s form double-rings called "chaperonins" that we use as "nano-lego" blocks for building structures. The individual HSP60 proteins form the subunits that self-assemble into chaperonin rings seen end-on (A) or seen as layers when viewed from the side (B). Under appropriate conditions chaperonins self-assemble into chains (C) or two-dimensional arrays (D).

*McMillan, R.A. et al. 2002. Ordered nanoparticles arrays formed on engineered chaperonin protein templates *Nature Materials* 1: 247-252.