HIGHLIGHT

Covalent Attachment of Gold Nanoparticles to DNA Templates

The ability to assemble nanoparticles into arrays, networks, and circuits in a precise and controlled manner is key to the fabrication of a variety of nanodevices. Networks of nanometer–sized metal or semiconductor islands, or quantum dots, may exhibit a variety of quantum phenomena, with applications in optical devices, nanometer-sized sensors, advanced computer architectures, ultra dense memories, and quantum-information science and technology. The challenge is that fabrication with nanoscale precision of nanoparticle arrays in a time and cost effective manner remains a formidable task. Interest in the concept of self-assembled nanostructures led to the idea of using DNA as a scaffold or template for the programmed assembly of nanoscale arrays. DNA can be modified with functional groups at predetermined sites to allow for the attachment of other molecules in a specific manner. We have designed and demonstrated a new approach for binding nanoparticles to DNA. Functionalized nanoparticles are covalently bound to internal, chemically modified bases on double-stranded DNA without the presence of destabilizing "nicks" along the DNA backbone. In addition, we report an approach for thiolating one end of the DNA/nanoparticle product and attaching it to a gold surface. The ability to attach one or both ends of the DNA/gold complex, after generation of the desired pattern, to fixed contacts or electrodes is necessary for nanodevices fabrication.

DNA oligonucleotides were designed with amino-modified bases for attachment to carboxylic acid functionalized gold particles. Two double-stranded DNA sequences were used for binding nanoparticles. Sequence 1 DNA was 22 base pairs long with two binding sites for gold per DNA molecule. The separation between gold binding sites was 3.7 nm. Sequence 2 DNA was 30 base pairs long, had one gold binding site per DNA molecule, and, after ligation, a 10.5 nm separation between binding sites. For AFM imaging, the DNA was ligated to produce longer molecules that would be easier to image. Gold nanoparticles with two different passivating coatings were tested. Particles with an average diameter of 1.5 nm were synthesized with a mercaptosuccinic acid coating, and particles approximately 2.5 nm in size were coated with thioctic acid Each particle has multiple reactive carboxyl groups on its surface. In order to decrease the probability for one particle binding to many amino groups on the DNA, methylamine was used to block some of the carboxyl groups on the gold. Methylamine was chosen for this purpose because of its small size and similarity to the methylene side chain containing the amino group on the DNA. The reaction between the amino group on the DNA and the carboxyl group on the gold particle was facilitated using a standard chemical method for joining carboxyl groups to amino groups. Analysis of the products by gel electrophoresis and atomic force microscopy (AFM) showed the gold particles bound to the DNA. In addition, absorbance spectra of the gold nanoparticles in the presence of DNA provide evidence of binding. This technique addresses a basic need to assemble nanometer-scale objects in a programmable manner and in a parallel fashion, from the bottom up.

Research by K. A. Stevenson, G. Muralidharan, L. Maya, J. C. Wells, J. Barhen, and T.G. Thundat, Center for Engineering Science Advanced Research, ORNL; for details see “Covalent Attachement of Gold Nanoparticles to DNA Templates”, J. Nanosci. Nanotech (submitted, 2002).

AFM images of thioctic acid-coated gold nanoparticles bound to ligated DNA on a mica substrate. (Left) Typical products of the reaction between DNA and gold particles. (Right) Close-up of DNA bound to gold particles.