CONTROLLED FABRICATION OF NANOSTRUCTURES USING SP1 PROTEIN-NANOPARTICLE HYBRIDS

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The development of nanoelectronics is one of the essential goals of the electronic industry and the nanoscience community [1,2]. Biomolecular nanoelectronics has the potential to offer the ultimate solution for the problems of shrinking the size and increasing the complexity of conventional microelectronic circuits. Within the search for ideal candidates to realize self-assembling wires, devices, and circuits, proteins are believed to be valuable building blocks. The realization of nanoelectronics with novel self-assembling hybrid components bears a huge potential. On one hand, it has been demonstrated that natural protein functions can be exploited to develop device functions; on the other hand, proteins may be used to self-assemble functional inorganic objects.

In this work we implement nanoelectronic concepts based on protein-nanoparticle hybrids. SP1, an exceptionally stable protein circumvents the major problem in using proteins for nanotechnology: poor stability and low heat resistance [3-5]. We construct “lego-like" building blocks made of different recombinant SP1 proteins and inorganic nanoparticles. Once optimized, we expect that the designed structures will behave as efficient tunable electrical devices, with electrical response ranging from that of an ohmic wire to various non linear regimes, depending on the bio-inorganic sequence and on the geometrical setup. At the same time arrays of such protein-nanoparticles hybrids may serve as ultra high density memory arrays.

Long nanowires have been synthesized from protein-gold nanoparticle hybrids. Functionalized gold nanoparticles were attached to the central cavity of an extremely stable ring-like protein complex, termed SP1, with a diameter of 11 nanometers and height of 5 nm. The SP1-nanoparticle hybrids serve as building blocks in a “lego-like fashion”. The size,

height, central cavity and binding groups of the building blocks and the distance between them can be tuned by genetic engineering and therefore their electrical properties may be manipulated. TEM, HAADF-STEM, AFM and EFM were used to demonstrate successful binding of gold nano-particles to the SP1 central cavity and the formation of wires with different inter-particle separations. We also demonstrate the formation of large ordered 2D crystalline arrays of SP1 rings induced by a phospholipid interface.

References:

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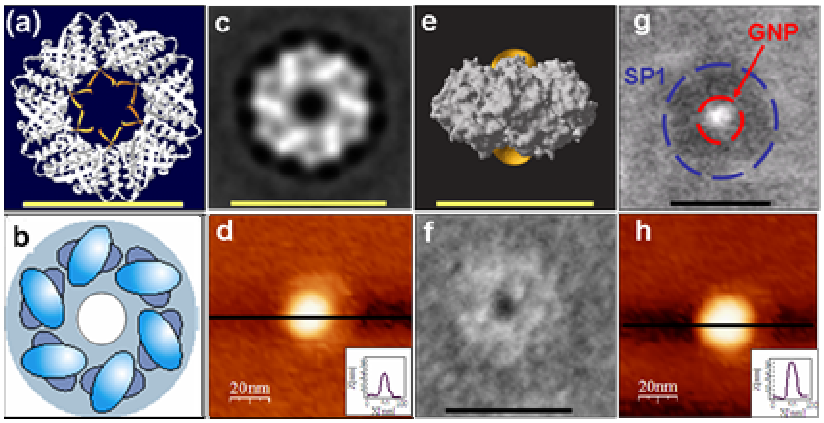
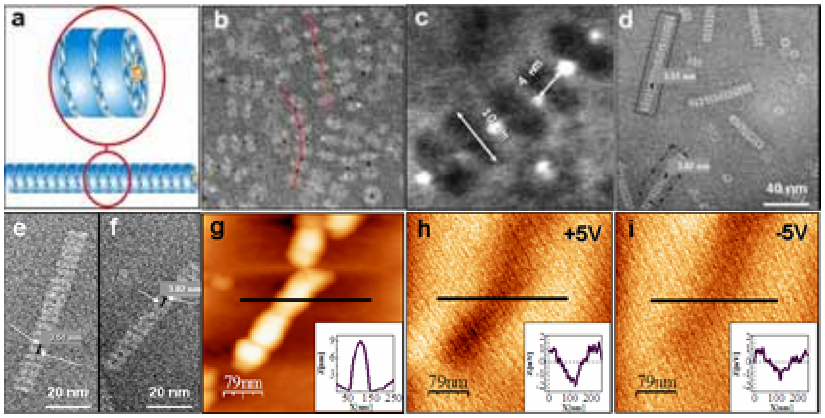
Figures:



(a) X-ray structure of the SP1, showing the N-termini of the monomers in orange. (b) Scheme of the SP1 dodecamer. (c) Top-view TEM. (d) AFM image of a single dodecamer (inset-cross section). (e) Computer simulation of SP1-GNP in a side view. (f) Top view TEM of SP1-GNP. (g) Top view HAADF-STEM of SP1-GNP. (h) Top view AFM image of single SP1-GNP (inset-cross section). Scale bar 11nm.



(a) A scheme representing the organization of nanowires composed of SP1-GNP.(b) TEM image of 6HSP1-GNP nanowires (marked by red lines). (c) HAADF-STEM image of 6HSP1-GNP nanowires with 4 nm GNP separation. (d) TEM image of 6HN-terminal truncated SP1-GNP nanowires with 3.5 and 3.8 nm GNP separation. (e,f) Enlargement of the bold, dashed line boxed nanowire from figure d respectively. (g) 6HSP1-GNP tube formation on mica. (h, i) EFM of 6HSP1-GNP tube formation on mica, a clear polarization effect of the embedded GNP is seen.