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From 2D to 3D peptide assemblies in controlled shape and their applications in pathogen/cancer chip sensors

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Various nano-structures and complex patterns have been fabricated by combining peptide self-assembly, biomineralization, and lithography. One strategy is to use antibody-functionalized peptide nanowires to assemble nanoscale building blocks at uniquely defined positions by molecular recognition. After configuring device geometries with these nanotubes, we turned on the biomineralization function of peptides on the nanotube sidewall to develop various material coatings such as metals and semiconductors for electronics and sensor applications. Another strategy is to write mineralize peptides on substrates by lithography and metal/semiconductor patterns are generated in nanoscale via biomineralization on these peptides.

The ability to control self-assembly of complex three-dimensional (3D) architectures from functional building blocks could allow further development of complex device configurations. While DNA bionanotechnology has recently been used to precisely assemble 3D shapes, the methodology to develop highly ordered macroscopic materials from these nanostructures remains limited and for practical use the production scale, the yield, and the size of the assembled materials need to be amplified. Peptides are another of nature's building blocks with even more specificity, robustness, and versatility for assembly that can be exploited to design new 3D architectures. Here, nanoscale peptides and ligand-functionalized nanoparticle hubs were self-assembled into micron scale 3D cube-shaped crystals, creating a physical framework for the proposed biomimetic assembly strategy. In this approach we took advantage of the naturally robust assembly of collagen triple helix peptides and used them as nanowire building blocks for the 3D crystal generation. Using streptavidin-functionalized Au nanoparticles and the α1 chain of type I wild type collagen specifically modified with a biotin moiety in vivo, we created micro-sized cubes with peptide nanowires as spokes and Au NPs as hubs. This simple, rapid fabrication protocol produces high yields of 3D materials in controlled shapes, dependent on the design of the NP junctions, with extremely high yields, promising ease and flexibility in manufacturing future functional devices. 2D peptide assemblies can be applied to biosensor chips for detecting pathogens and cancer cells. The advantage of this chip sensor as compared to conventional nanoscale chip sensor is that the characteristic capacitance values for pathogens could be used to identify the stains of viruses in addition to the antibody recognition of the nanotube. The sensing with the peptide nanotube sensor chip was fairly robust and the detection limit was on the order of 100 virus or bacteria particles/mL. Cancer cells can also be detected sensitively by probing the difference in membrane mechanics, as cancer cells are more elastic than normal cells and swell under hyposmotic pressure. This sensing platform is reusable by simple washing process, an important practical aspect of this sensor chip.

Professor Hiroshi Matsui is a Professor in Chemistry at CUNY-Hunter College. Professor Matsui completed his B.S. in Chemistry at Japan's Sophia University in 1987, and spent four years at DuPont prior to completing an MS in the Material Science and Engineering Program at Stanford and earning his doctorate in Chemistry from Purdue University in 1996. Dr. Matsui then completed a two-year Postdoctoral Fellowship at Columbia, and was previously on the faculty at Chemistry Department of the University of Central Florida (UCF), before joining Hunter College in 2001.

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