Glycomics & Lipidomics

Extended Abstract

Integration of nanotechnology into glycomics: Construction and application of glycan and lectin biosensors

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Abstract

Integration of nanotechnology into the field of glycomics can address current limitations of fluorescent glycan and lectin microarrays. Moreover, label-free transducing schemes especially when working in an ultrasensitive fashion can be applied in a reliable detection of low abundant disease biomarkers. For example, electrochemical impedance spectroscopy applied in our studies allows detecting analyte molecules down to a single molecule level (i.e., aM level) if immobilization architecture of ligands (lectins or glycans) is controlled at nanoscale. Utilization of such devices in serological glycoprofile of samples from people having some diseases, in analysis of cancer biomarkers, cancer cell lines and viruses will be discussed.

This review comprehensively covers the most recent achievements (from 2013) in the successful integration of nanomaterials in the field of glycomics. The first part of the paper addresses the beneficial properties of nanomaterials for the construction of biosensors, bioanalytical devices, and protocols for the detection of various analytes, including viruses and whole cells, together with their key characteristics. The second part of the review focuses on the application of nanomaterials integrated with glycans for various biomedical applications, that is, vaccines against viral and bacterial infections and cancer cells, as therapeutic agents, for in vivo imaging and nuclear magnetic resonance imaging, and for selective drug delivery. The final part of the review describes various ways in which glycan enrichment can be effectively done using nanomaterials, molecularly imprinted polymers with polymer thickness controlled at the nanoscale, with a subsequent analysis of glycans by mass spectrometry. A short section describing an active glycoprofiling by microengines (microrockets) is covered as well.

The term nanotechnology was first used in 1974 by Professor Nario Taniguchi,1 but the idea and concepts behind nanoscience began more than a decade earlier with a talk by Professor Richard Feynman, "There´s Plenty of Room at the Bottom."2 In this talk, the process by which science could control and manipulate single atoms was described. The real breakthrough in nanoscience came in 1981,3 when the scanning tunneling microscope was developed, enabling the observation of individual atoms, and after the invention of atomic force microscopy (AFM), nanotechnology as a scientific discipline was born. Currently, nanotechnology covers processes for the design, preparation, and application of extremely small things. Materials and structures could be designated as "nano" only if their size (at least one dimension) is within the range of 1 to 100 nm. The discovery of nanomaterials, such as fullerenes5 and graphene, awarded the Nobel Prize to theirs discoverers. Nanomaterials now form a large family of materials, including metal/semiconducting nanoparticles (NPs), quantum dots (QDs), nanowires, fullerenes, graphene and its derivatives, graphene QDs, and carbon nanotubes (CNTs, Fig. Fig.11).7, 8 It is not only the size of nanomaterials that matters, but their remarkable physical and chemical properties are gaining increasing attention from scientists both from fundamental and application points of view, using nanomaterials in biology, chemistry, and applied physics.9 – 14 An interesting feature of nanomaterials is that their dimension is similar to that of biomolecules, such as DNA/RNA, proteins, lipids, and carbohydrates, with numerous applications in biology and biomedicine as well.

For quite a long time, carbohydrates were considered only as reservoirs of energy and as building blocks providing the organisms strength, that is, cellulose and chitin, which are the most abundant polymers on Earth.15 Glycans are complex carbohydrates consisting of saccharide units that link together and are attached to proteins and lipids to form glycoproteins and glycolipids, respectively (Fig. (Fig.22).16 Glycans are bound to proteins during co- and posttranslational modifications via a multistep enzymatic process in the endoplasmic reticulum and Golgi apparatus.17 Glycans can be classified into several categories based on the bond between a glycan and a protein: N-glycans (via –NH2 group to asparagine), O-glycans (via –OH group to serine, threonine, or hydroxylated amino acids), and less-abundant forms of glycans, such as C-glycans (C—C bond via tryptophan) and the quite unusual S-glycans (C—S bond via cysteine). Moreover, glycans can be branched by the formation of biantennary, triantennary, and more complex antennary structures.

Glycomics as a scientific discipline studying the structure and function of glycans is a younger sister of more developed genomics and proteomics. There are several reasons why glycomics is still behind genomics and proteomics: (i) glycans and glycoconjugates are more structurally complex than proteins and DNA/RNA; (ii) it is quite challenging to determine glycan identity/sequences using traditional

instrumental techniques; and (iii) glycan biosynthesis cannot be predicted from a template as in the case of DNA and proteins. In addition, the chemical synthesis of oligosaccharides is very challenging (protection of all functional groups with a variety of protecting groups in order to generate the site-specific deprotection of those which are intended to form a chemical bond) and represents yet another obstacle to obtain valuable intermediate or incomplete structures.

Despite intensive research in genomics and proteomics, there are still many questions that cannot be answered by analyzing genome and proteome alone, and glycomics has to be added into the equation. Currently, it is estimated that 70% of human cytosolic proteins and 80% of membrane proteins are glycosylated, underlining the important involvement of glycans within the human body.

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