SUMMARY

It is an object of the present disclosure to describe constructs that enable the encapsulation of a virus or viral particle. The solution to that problem, i.e. the use of macromolecular building blocks, such as DNA-based nanostructures, has not yet been taught or suggested by the prior art.

Therefore, in one aspect, the disclosure refers to a macromolecule-based nanostructure, wherein said macromolecule-based nanostructure has a molecular mass of at least 10 MDa and is a DNA-based nanostructure formed by self-assembling DNA-based building blocks, wherein said nanostructure is a shell with an opening for accessing said cavity, wherein each of said self-assembling DNA-based building blocks is formed by a single-stranded DNA template strand and a set of oligonucleotides complementary to said single-stranded DNA template, wherein each of said oligonucleotides is either complementary to one contiguous DNA sequence stretch or to at least two non-contiguous DNA sequence stretches on said single-stranded DNA template, wherein each of said self-assembling DNA-based building blocks is a triangular and/or a rectangular prismoid comprising three or four side trapezoids, respectively; wherein antibody-based binding sites are attached to the interior site of the cavity formed by said macromolecule-based nanostructure; and wherein at least one of the side trapezoids comprise a specific pattern of recesses and/or extrusions formed by missing or additional DNA double helical stretches for specific interaction with a complementary pattern on the side trapezoid of another one of said self-assembling DNA-based building blocks. In another example, there is described a macromolecule-based nanostructure encasing a cavity with a diameter of at least 20 nm for encapsulating a virus or viral particle.

In a particular example, the disclosure describes a macromolecule-based nanostructure, which is a DNA-based nanostructure.

In another aspect, the disclosure refers to a macromolecule-based nanostructure having a molecular mass of at least 10 MDa, encasing a cavity with a diameter of at least 20 nm for encapsulating a virus or viral particle; wherein said macromolecule-based nanostructure is a DNA-based nanostructure formed by self-assembling DNA-based building blocks; wherein each of said self-assembling DNA-based building blocks is a triangular and/or a rectangular prismoid comprising three or four side trapezoids, respectively; and wherein at least one of the side trapezoids comprise a specific pattern of recesses and/or extrusions formed by missing or additional DNA double helical stretches for specific interaction with a complementary pattern on the side trapezoid of another one of said self-assembling DNA-based building blocks. In another aspect, the disclosure refers to a composition comprising a virus or viral particle encapsulated by a macromolecule-based nanostructure according to the present disclosure.

In yet another aspect, the disclosure refers to a method for encapsulating a virus or viral particle, comprising the steps of: providing a macromolecule-based nanostructure according to the present invention, and contacting said macromolecule-based nanostructure with a medium comprising, or suspected to comprise, said virus or viral particle.

The disclosure contemplates all combinations of any one or more of the foregoing aspects and/or embodiments, as well as combinations with any one or more of the embodiments set forth in the detailed description and examples.

Other features, objects, and advantages of the compositions and methods herein will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows the design principles. (A) Triangulation number of icosahedral shells. Each colored triangle represents one of the 20 faces forming an icosahedron.

CLAIMS

1. A macromolecule-based nanostructure,

   wherein said macromolecule-based nanostructure has a molecular mass of at least 10 MDa and is a DNA-based nanostructure formed by self-assembling DNA-based building blocks,

   wherein said nanostructure is a shell with an opening for accessing said cavity,

   wherein each of said self-assembling DNA-based building blocks is formed by a single-stranded DNA template strand and a set of oligonucleotides complementary to said single-stranded DNA template,

   wherein each of said oligonucleotides is either complementary to one contiguous DNA sequence stretch or to at least two non-contiguous DNA sequence stretches on said single-stranded DNA template,

   wherein each of said self-assembling DNA-based building blocks is a triangular and/or a rectangular prismoid comprising three or four side trapezoids, respectively;

   wherein antibody-based binding sites are attached to the interior site of the cavity formed by said macromolecule-based nanostructure; and

   wherein at least one of the side trapezoids comprise a specific pattern of recesses and/or extrusions formed by missing or additional DNA double helical stretches for specific interaction with a complementary pattern on the side trapezoid of another one of said self-assembling DNA-based building blocks.

2. A macromolecule-based nanostructure having a molecular mass of at least 10 MDa, encasing a cavity with a diameter of at least 20 nm for encapsulating a virus or viral particle;

   wherein said macromolecule-based nanostructure is a DNA-based nanostructure formed by self-assembling DNA-based building blocks;

wherein each of said self-assembling DNA-based building blocks is a triangular and/or a rectangular prismoid comprising three or four side trapezoids, respectively; and

wherein at least one of the side trapezoids comprise a specific pattern of recesses and/or extrusions formed by missing or additional DNA double helical stretches for specific interaction with a complementary pattern on the side trapezoid of another one of said self-assembling DNA-based building blocks.

3. The macromolecule-based nanostructure of claim 2, wherein each of said self-assembling DNA-based building blocks is formed by a single-stranded DNA template strand and a set of oligonucleotides complementary to said single-stranded DNA template, wherein each of said oligonucleotides is either complementary to one contiguous DNA sequence stretch or to at least two non-contiguous DNA sequence stretches on said single-stranded DNA template.

4. The macromolecule-based nanostructure of claim 2 or 3, which is a closed three-dimensional geometric shape, in particular a closed three-dimensional geometric shape selected from a sphere, a spherocylinder, and a polyhedron, in particular a tetrahedron, an octahedron or an icosahedron, formed in situ in the presence of said virus or viral particle to be encapsulated, in particular formed in situ from said self-assembling DNA-based building blocks in the presence of said virus or viral particle to be encapsulated.

5. The macromolecule-based nanostructure of claim 2 or 3, which is a shell with an opening for accessing said cavity.

6. The macromolecule-based nanostructure of claim 2 or 3, which is a combination of a first and a second shell with an opening to access a first and a second inner cavity, respectively, wherein said first and said second inner cavity together form said cavity, in particular wherein said first and said second shell are connected by at least one linker.

7. The macromolecule-based nanostructure of any one of claims 2 to 6, which is based on an icosahedral structure.

8. The macromolecule-based nanostructure of claim 7, wherein said macromolecule-based nanostructure is a DNA-based nanostructure formed by self-assembling DNA-based building blocks, wherein each of said self-assembling DNA-based building blocks is a triangular and/or a rectangular prismoid, particularly a triangular prismoid.

9. The macromolecule-based nanostructure of claim 1 or 8,

wherein each said triangular and/or a rectangular prismoid is formed by m triangular, or rectangular, respectively, planes, wherein m is an integer independently selected from 4, 5, 6, 7 and 8, in particular independently selected from 5, 6 and 7, more particularly wherein said integer is 6,

the three, or four, respectively, edges of each of said m planes are formed by n parallel stretches of DNA double helices, wherein n is an integer independently selected from 1, 2, 3, 4, 5 and 6 in particular independently selected from 2, 3, 4 and 5, more particularly independently selected from 3 and 4,

wherein each plane is connected to a plane above and/or a plane beyond said plane (i) by stacking interactions between the DNA double helices forming said planes, and (ii) partially by DNA stretches within said single-stranded DNA template and/or said oligonucleotides forming said DNA-based building block bridging at least two of said planes.

10. The macromolecule-based nanostructure of claim 9, wherein for at least part of said self-assembling DNA-based building blocks the length of at least one edge of each of said m planes is decreasing from the first to the mth plane, so that bevel angles results between planes perpendicular to said first plane and each of the trapezoid planes formed by said m edges.

11. The macromolecule-based nanostructure of claim 9 or 10 comprising at least one set of self-assembling DNA-based building blocks, wherein all three, or four, respectively, side trapezoids comprises a specific pattern of recesses and/or extrusions formed by missing or additional DNA double helical stretches for

specific interaction with a complementary pattern on the side trapezoid of another one of said self-assembling DNA-based building blocks.

12. The macromolecule-based nanostructure of claim 9 or 10, wherein the side trapezoids of the self-assembling DNA-based building blocks forming the rim of said shell, or of said first and second shell, respectively, do not comprises a specific pattern of recesses and/or extrusions formed by missing or additional DNA double helical stretches for specific interaction with a complementary pattern on the side trapezoid of another one of said self-assembling DNA-based building blocks.

13. The macromolecule-based nanostructure of any one of claims 1 to 12, wherein said macromolecule-based nanostructure is a DNA-based nanostructure, which is a shell selected from

(a) a half octahedron, which consists of a set of four copies of a triangular frustum, wherein the base-pair stacking contacts on one of the triangular edges of the triangular frustum are inactivated by either strand shortening or by adding unpaired thymidines;

(b) a half T=1 shell, which consists of two sets of in each case five copies of two different triangular frusta, wherein the five copies of the first set form a closed pentamer, and the five copies of the second set dock onto the edges of said pentamer; and

(c) a “trap” T=1 shell with a missing pentagon vertex, which consists of three sets of in each case five copies of three different triangular frusta, wherein the five copies of the first set form a closed pentamer, the five copies of the second set dock onto the edges of said pentamer the five copies of the second set dock onto the edges of said pentamer, and the five copies of the third set dock into the gaps between the five copies of said second set.

14. The macromolecule-based nanostructure of any one of claims 8 to 13, further comprising

(a) one or more types of DNA brick constructs, each type of such DNA brick constructs being characterized by one or more interaction sites for specific interaction by edge-to-edge stacking contacts with one or more complementary interaction sites present on the plane of a triangular or rectangular frustum on the outer surface of said DNA-based nanostructure, wherein said DNA brick constructs cover the free space between the three, or four, respectively, edges of said plane;

(b) one or more cross-linkages within one of said triangular or rectangular prismoids, and/or between two of said triangular and/or rectangular prismoids; and/or

(c) at least one moiety specifically interacting with said virus or viral particle.

15. A composition comprising a virus or viral particle encapsulated by a macromolecule-based nanostructure according to any one of claims 1 to 14.

16. A method for encapsulating a virus or viral particle, comprising the steps of: providing a macromolecule-based nanostructure according to any one of claims 1 to 14, and contacting said macromolecule-based nanostructure with a medium comprising, or suspected to comprise, said virus or viral particle.