
WHAT IS CLAIMED IS:

1. A vaccine composition, comprising a polypeptide immunogen that is displayed on the surface of a self-assembling nanoparticle, wherein a locking domain is embedded inside the self-assembling nanoparticle and is linked to a subunit of the self-assembling nanoparticle, and wherein the locking domain ~~is a protein subunit that can naturally form a dimer with another locking domain attached to a nearby nanoparticle subunit in solution through non-covalent interactions at~~ comprises the interface amino acid sequence selected from SEQ ID NOs:1-9, or a conservatively modified variant thereof.

~~2. The vaccine composition of claim 1, wherein the locking domain is a protein domain that forms a homodimer with another identical protein domain.~~

~~3. The vaccine composition of claim 2, wherein subunit of the locking domain comprises the amino acid sequence as shown in any one of SEQ ID NOs:1-9, a conservatively modified variant or a substantially identical sequence thereof.~~

~~4.2.~~ The vaccine composition of claim 1, wherein the locking domain is covalently linked to a subunit of the self-assembling nanoparticle.

~~5.3.~~ The vaccine composition of claim ~~4.2~~, wherein N-terminus of the locking domain is fused to C-terminus of the self-assembling nanoparticle subunit via a linker sequence.

~~6.4.~~ The vaccine composition of claim 1, further comprising a pan-reactive T-cell epitope.

~~7.5.~~ The vaccine composition of claim ~~6.4~~, wherein N-terminus of the pan-reactive T-cell epitope is fused to the C-terminus of the locking domain.

~~8.6.~~ The vaccine composition of claim 1, further comprising a neck region inserted between the immunogen and the self-assembling nanoparticle subunit, wherein the neck region comprises a 3-helix protein domain that elevates the immunogen further away from the surface of the self-assembling nanoparticle.

9.7. The vaccine composition of claim 1, further comprising a protein domain inserted between the immunogen and the self-assembling nanoparticle subunit, wherein the protein domain stabilizes the immunogen polypeptide.

10.8. The vaccine composition of claim 1, wherein the self-assembling nanoparticle is a ball-shaped nanoparticle with rotational symmetry.

11.9. The vaccine composition of claim ~~11,8~~, wherein the rotational symmetry has 3-fold axis and/or 5-fold axis.

12.10. The vaccine composition of claim ~~11,9~~, wherein the nanoparticle is of an icosahedral structure.

13.11. The vaccine composition of claim 1, wherein the polypeptide immunogen is a viral immunogen.

14.12. The vaccine composition of claim ~~13,11~~, wherein the polypeptide immunogen is a viral immunogen from a virus utilizing class-I fusion mechanism.

15.13. The vaccine composition of claim ~~14,12~~, wherein the virus is selected from the group consisting of HIV-1 virus, Ebola virus, Marburg virus, Arenaviruses, *respiratory syncytial viruses* (RSV), and coronaviruses.

16.14. The vaccine composition of claim ~~13,11~~, wherein the polypeptide immunogen is a viral immunogen from a virus utilizing class-II fusion mechanism.

17.15. The vaccine composition of claim ~~16,14~~, wherein the virus utilizing class-II fusion mechanism is HCV or Zika virus.

18.16. The vaccine composition of claim ~~13,11~~, wherein the polypeptide immunogen is a non-viral immunogen.

19.17. The vaccine composition of claim ~~18,16~~, wherein the polypeptide immunogen is an antigen from *Plasmodium falciparum*, an antigen from *Mycobacterium tuberculosis* (TB), or human protein proprotein convertase subtilisin/kexin type 9 (PCSK9).

20.18. The vaccine composition of claim 1, wherein the polypeptide immunogen is an HIV-1 Env-~~derived~~ trimer protein.

21.19. The vaccine composition of claim ~~20,18~~, wherein N-terminus of the locking domain is fused to C-terminus of the nanoparticle subunit via a linker sequence that comprises one or more tandem copies of GGGGS (SEQ ID NO:17).

22.20. The vaccine composition of claim ~~20,18~~, further comprising a pan-reactive T-cell epitope.

23.21. The vaccine composition of claim ~~22,20~~, wherein N-terminus of the pan-reactive T-cell epitope is fused to the C-terminus of the locking domain.

24.22. The vaccine composition of claim 20, wherein the pan-reactive T-cell epitope comprises the sequence AKFVAAWTLKAAA (SEQ ID NO:18).

25.23. The vaccine composition of claim ~~20,18~~, wherein C-terminus of subunit of the HIV-1 trimer protein is covalently linked to N-terminus of subunit of the self-assembling nanoparticle.

26.24. The vaccine composition of claim ~~20,18~~, wherein the HIV-1 trimer protein subunit is fused to the self-assembling nanoparticle subunit via a linker sequence.

27.25. The vaccine composition of claim 24, wherein the linker sequence comprises the sequence (GaSb)_n, wherein a is an integer of 1 to 5, b is an integer of 1 to 2, and n is an integer of 1 to 5.

28.26. The vaccine composition of claim ~~20,18~~, wherein the self-assembling nanoparticle comprises a trimeric sequence.

29.27. - The vaccine composition of claim ~~20,18~~, wherein the subunit of the self-assembling nanoparticle comprises the polypeptide as shown in selected from SEQ ID NO:21-~~(E2p)~~,₂ SEQ ID NO:22-~~(I3-01)~~,₂ SEQ ID NO:25 ~~(I3-01-variant)~~-or SEQ ID NO:26 ~~(ferritin)~~,₂ or a conservatively modified variant ~~or a substantially identical sequence~~ thereof.

30.28. The vaccine composition of claim **20.18**, wherein the HIV-1 Env-~~derived~~ trimer protein is ~~derived from a~~ gp140 trimer.

31.29. - The vaccine composition of claim **20.18**, wherein the HIV-1 Env-~~derived~~ trimer protein is an uncleaved prefusion-optimized (UFO) gp140 trimer.

32.30. - The vaccine composition of claim **31.29**, wherein the UFO gp140 trimer is a chimeric trimer comprising a modified gp41_{ECTO} domain from HIV-1 strain BG505.

33.31. The vaccine composition of claim **31.29**, wherein subunit of the UFO gp140 trimer comprises the sequence ~~shown in~~ SEQ ID NO:23, or a conservatively modified variant ~~or a substantially identical sequence~~ thereof.

34.32. The vaccine composition of claim **31.29**, having a subunit sequence that comprises from the N-terminus to the C-terminus: HIV-1 ~~Env-derived~~ uncleaved prefusion-optimized (UFO) gp140 trimer subunit ~~as shown in~~ comprising SEQ ID NO:23, self-assembling nanoparticle subunit ~~as shown in~~ comprising SEQ ID NO:21 (E2p), the locking domain ~~as shown in~~ comprising SEQ ID NO:1 (LD4), and T-cell epitope AKFVAAWTLKAAA (SEQ ID NO:18).

35.33. The vaccine composition of claim **34.32**, further comprising a first linker sequence (GGGS)₂ (SEQ ID NO:24) between the HIV-1 uncleaved prefusion-optimized (UFO) gp140 trimer subunit and the self-assembling nanoparticle subunit, and/or a second linker sequence GGGGS (SEQ ID NO:17) between the self-assembling nanoparticle subunit and the locking domain.

36.34. The vaccine composition of claim **31.29**, having a subunit sequence that comprises from the N-terminus to the C-terminus: HIV-1 ~~Env-derived UFO~~ uncleaved prefusion-optimized (UFO) gp140 trimer ~~as shown in~~ comprising SEQ ID NO:23, self-assembling nanoparticle subunit ~~as shown in~~ comprising SEQ ID NO:22 or 25 (I3-01), the locking domain ~~as shown in~~ comprising SEQ ID NO:2 (LD7), and T-cell epitope AKFVAAWTLKAAA (SEQ ID NO:18).

37.35. The vaccine composition of claim **36.34**, further comprising a first linker sequence (GGGS)₂ (SEQ ID NO:24) between the HIV-1 uncleaved prefusion-optimized (UFO)

gp140 trimer subunit and the self-assembling nanoparticle subunit, and/or a second linker sequence GGGGS (SEQ ID NO:17) between the self-assembling nanoparticle subunit and the locking domain.

38.36. A pharmaceutical composition, comprising the vaccine composition of claim 1, and a pharmaceutically acceptable carrier.

~~39. A polynucleotide, encoding a fusion protein comprising an immunogen polypeptide at the N-terminus, a self-assembling nanoparticle subunit, and subunit of a locking domain; wherein the locking domain is a protein subunit that can naturally form a dimer with another locking domain attached to a nearby nanoparticle subunit in solution through non-covalent interactions at the interface.~~

~~A method of treating or preventing HIV-1 infection in a subject, comprising administering to the subject a pharmaceutical composition comprising a therapeutically effective amount of the HIV-1 vaccine composition of claim 20, thereby treating or preventing HIV-1 infection in the subject.~~