

What is Claimed is:

1. A degradable polyester bead comprising a plurality of transposome complexes immobilized to the surface thereof, wherein each transposome complex comprises a transposase bound to a first polynucleotide and a second polynucleotide, wherein the first polynucleotide comprises a 3' portion comprising a transposon end sequence and a tag, and the second polynucleotide comprises a 5' portion that is complementary to and hybridized to the transposon end sequence, and wherein the polyester bead has a melting point of from 50 °C to 65 °C, optionally wherein the polyester bead has a melting point of 60 °C, optionally wherein the polyester bead comprises polycaprolactone.
2. The degradable polyester bead of claim 1, comprising a plurality of magnetic nanoparticles immobilized thereto, optionally wherein the magnetic nanoparticles are beads with a magnetic core, optionally wherein the magnetic core comprises iron, nickel, and/or cobalt.
3. The polyester bead of any one of claims 1 or 2, wherein each transposome complex comprises a polynucleotide binding moiety, the bead comprises a plurality of bead binding moieties covalently bound to the surface thereof, and the transposome complexes are immobilized to the bead surface through binding of the polynucleotide binding moieties to the bead binding moieties.
4. The polyester bead of claim 3, wherein:
 - a. each polynucleotide binding moiety is covalently bound to the first polynucleotide of each transposome complex or covalently bound to the second polynucleotide of each transposome complex;
 - b. the bead binding moiety is streptavidin or avidin and the polynucleotide binding moiety is biotin; and/or
 - c. each bead binding moiety is covalently bound to the polyester bead through a linker, wherein the linker optionally comprises -N=CH-(CH₂)₃-CH=N-, -C(O)NH-(CH₂)₆-N=, or -C(O)NH-(CH₂)₆-N=CH-(CH₂)₃CH=N-.
5. The polyester bead of any one of claims 2-4, wherein each magnetic nanoparticle is covalently bound to the polyester bead through a linker, wherein the linker optionally

comprises $-N=CH-(CH_2)_3-CH=N-$, $-C(O)NH-(CH_2)_6-N=$, or $-C(O)NH-(CH_2)_6-N=CH-(CH_2)_3CH=N-$.

6. The polyester bead of any one of claims 1-5, wherein the polyester bead is immobilized on the surface of a flow cell, optionally wherein the polyester bead is immobilized on the surface of the flow cell through covalent binding of a bead binding moiety to a flow cell binding moiety on the surface of the flow cell.
7. The polyester bead of claim 6, wherein the polynucleotide binding moiety and the flow cell binding moiety are the same type of binding moiety, and the transposome complexes are bound to a first portion of the bead binding moieties on the bead and the flow cell binding moiety is bound to a second portion of the bead binding moieties on the bead.
8. The polyester bead of any one of claims 1-7, comprising a target nucleic acid or one or more fragments thereof, each bound to at least two transposome complexes on the bead, optionally wherein most transposome complexes are immobilized on the surface of the bead.
9. A flow cell comprising a polyester bead immobilized to the surface of the flow cell, wherein the polyester bead comprises a plurality of transposome complexes immobilized to the surface thereof,
wherein each transposome complex comprises a transposase bound to a first polynucleotide and a second polynucleotide,
wherein the first polynucleotide comprises a 3' portion comprising a transposon end sequence and a tag, and the second polynucleotide comprises a 5' portion that is complementary to and hybridized to the transposon end sequence; and
wherein the polyester bead has a melting point of from 50 °C to 65 °C, or 60 °C,
optionally wherein the polyester bead comprises polycaprolactone and/or comprises a plurality of immobilized magnetic nanoparticles immobilized thereto.
10. The flow cell of claim 9, wherein each transposome complex comprises a polynucleotide binding moiety, the bead comprises a plurality of bead binding moieties covalently bound to the surface thereof, and the transposome complexes are immobilized to the bead surface through binding of the polynucleotide binding moieties to the bead binding moieties and optionally wherein:

- a. each polynucleotide binding moiety is covalently bound to the first polynucleotide of each transposome complex or covalently bound to the second polynucleotide of each transposome complex;
 - b. the bead binding moiety is streptavidin or avidin and the polynucleotide binding moiety is biotin; and/or
 - c. each bead binding moiety is covalently bound to the polyester bead through a linker, wherein the linker optionally comprises $-N=CH-(CH_2)_3-CH=N-$, $-C(O)NH-(CH_2)_6-N=$, or $-C(O)NH-(CH_2)_6-N=CH-(CH_2)_3CH=N-$.
11. The flow cell of claim 9 or claim 10, wherein each magnetic nanoparticle is covalently bound to the polyester bead through a linker, wherein the linker optionally comprises $-N=CH-(CH_2)_3-CH=N-$, $-C(O)NH-(CH_2)_6-N=$, or $-C(O)NH-(CH_2)_6-N=CH-(CH_2)_3CH=N-$, and/or wherein the magnetic nanoparticles are used for seeding the polyester bead to a surface of the flow cell.
12. The flow cell of any one of claims 9-11, wherein the polyester bead is immobilized on the surface of the flow cell through covalent binding of a bead binding moiety to a flow cell binding moiety on the surface of the flow cell or wherein the polynucleotide binding moiety and the flow cell binding moiety are the same type of binding moiety, and the transposome complexes are bound to a first portion of the bead binding moieties on the bead and the flow cell binding moiety is bound to a second portion of the bead binding moieties on the bead.
13. The flow cell of any one of claims 9-12, comprising a target nucleic acid or one or more fragments thereof, each bound to at least two transposome complexes on the bead, optionally wherein most transposome complexes are immobilized on the surface of the bead.
14. A method of preparing a nucleic acid library from a target nucleic acid comprising contacting the target nucleic acid with the polyester bead of any one of claims 1-8 or the flow cell of any one claims 9-13 under conditions whereby the target nucleic acid is fragmented by the transposome complexes and the 3' transposon end sequence of the first polynucleotide is transferred to a 5' end of at least one strand of the fragments, thereby producing an immobilized library of fragments wherein at least one strand is 5'-tagged with the tag.

15. The method of claim 14, wherein:
 - a. contacting comprises contacting the target nucleic acid with the polyester bead of any one of claims 1 to 8, and the method comprises immobilizing the bead comprising the immobilized library of fragments to the surface of a flow cell;
 - b. the bead is immobilized to the surface of the flow cell through binding of the bead binding moiety to a flow cell binding moiety on the surface of the flow cell;
 - c. the bead comprises a plurality of immobilized magnetic nanoparticles immobilized thereto, optionally wherein the magnetic nanoparticles are used for seeding the polyester bead to a surface of the flow cell; and/or
 - d. contacting comprises contacting the target nucleic acid with the polyester bead of claim 6.
16. The method of claim 14 or claim 15, further comprising:
 - a. releasing the fragments from the immobilized bead to provide a spent bead and capturing the released fragments on the flow cell surface to produce captured fragments, optionally wherein releasing the fragments from the immobilized bead comprises amplifying the fragments off the bead, and optionally wherein capturing the released fragments comprises hybridizing the released fragments to capture oligonucleotides on the surface of the flow cell;
 - b. amplifying the captured fragments on the flow cell surface to produce immobilized, amplified fragments, optionally wherein amplifying the captured fragments comprises bridge amplification to produce clusters of the fragments;
 - c. detaching the spent bead from the flow cell surface by treating the spent bead with an excess of solution-phase flow cell binding moiety to provide a solution-phase spent bead;
 - d. degrading the solution-phase spent bead with a degrading agent; and/or
 - e. removing the degraded bead from the flow cell.
17. The method of claim 16, wherein the degrading agent is (a) a temperature of from 50 °C to 65 °C, or 60 °C, and/or (b) an aqueous base.

18. The method of claim 17, wherein the aqueous base is NaOH, optionally wherein the NaOH is 1M-5M NaOH, optionally wherein the aqueous base is 1M, 2M, 3M, 4M, or 5M NaOH, optionally wherein the aqueous base is 3M NaOH.
19. The method of any one of claims 14-18, comprising sequencing the immobilized, amplified fragments or the clusters of the fragments.
20. A method of making a polyester bead of any one of claims 1 to 8 comprising immobilizing a plurality of transposome complexes to a polyester bead, wherein each transposome complex comprises a transposase bound to a first polynucleotide and a second polynucleotide, wherein the first polynucleotide comprises a 3' portion comprising a transposon end sequence and a tag, and the second polynucleotide comprises a 5' portion that is complementary to and hybridized to the transposon end sequence, optionally wherein the method further comprises immobilizing a plurality of magnetic nanoparticles to the polyester bead.
21. A composition comprising a bead and at least one nanoparticle, wherein the bead comprises a functional group that is capable of binding to the nanoparticle, optionally wherein the nanoparticle or the bead is magnetic.
22. The composition of claim 21, wherein the nanoparticle:
- is a synthetic dendron, a DNA dendron, or a polymer brush; and/or
 - is a bead with a magnetic core, optionally wherein the magnetic core comprises iron, nickel, and/or cobalt; and/or
 - has a diameter of 50-150 nm, optionally wherein the nanoparticle has a diameter of 100 nm.
23. The composition of any one of claims 1-22, wherein the nanoparticle comprises:
- a single immobilized transposome complex, or
 - more than one immobilized transposome complex, optionally wherein the more than one immobilized transposome complexes are immobilized with similar distances between each transposome complex on the nanoparticle.
24. The composition of claim 23, wherein the immobilized transposome complex or transposome complexes are oriented with the transposase facing away from the nanoparticle.

25. The composition of claim 23 or claim 24, wherein the transposome complex is immobilized to the nanoparticle by:
- binding of a transposon comprising biotin, desthiobiotin, or dual biotin to avidin or streptavidin comprised on the nanoparticle, or
 - a click chemistry reaction between an agent comprised in a transposon and an agent comprised in the nanoparticle, optionally wherein the click chemistry reaction is a reaction between an azide on the nanoparticle and a dibenzylcyclooctyne (DBCO) on the transposon.
26. The composition of claim any one of claims 21-25, wherein the bead is a carrier bead that can bind multiple nanoparticles, optionally wherein the bead has a diameter of 1 μm or larger and/or the bead is a degradable polyester bead of any one of claims 1-8.
27. The composition of any one of claims 21-26, wherein the functional group is a chemical attachment handle and/or a clustering primer, optionally wherein:
- the chemical attachment handle and/or clustering primer directly binds to the nanoparticle;
 - the chemical attachment handle and/or clustering primer indirectly binds to the nanoparticle; or
 - a chemically modified oligonucleotide binds to both the clustering primer comprised in the bead and to the nanoparticle.
28. The composition of any one of claims 21-27, wherein the interaction between the nanoparticle and the bead is a reversible and/or non-covalent interaction, optionally wherein the reversible and/or non-covalent interaction is a protein-ligand interaction or a metal-chelator interaction, further optionally wherein the protein-ligand interaction is a biotin-streptavidin interaction or the metal-chelator interaction is nickel-polyhistidine or cobalt-polyhistidine interaction.
29. The composition of any one of claims 21-28, wherein the bead comprises a clustering primer and the nanoparticle comprises an immobilized oligonucleotide, optionally wherein the immobilized oligonucleotide and the clustering primer bind directly to each other or a linking oligonucleotide is capable of binding to both the immobilized oligonucleotide and the clustering primer.

30. The composition of any one of claims 21-27, wherein the interaction between the nanoparticle and the bead is an irreversible and/or covalent interaction, optionally wherein the covalent interaction is a cleavable linker between the bead and the nanoparticle, further optionally wherein the cleavable linker is a chemically or enzymatically cleavable linker.
31. A method of seeding a flow cell comprising:
- dissociating the bead and the nanoparticle of the composition of any one of claims 21-30, optionally wherein dissociating the bead and the nanoparticle is by cleavage of a cleavable linker or by dissociation of a reversible and/or non-covalent interaction between the nanoparticle and the bead; and
 - immobilizing the nanoparticle on the surface of a flow cell.
32. A flow cell comprising a nanoparticle immobilized to its surface prepared by the method of claim 31 or a flow cell comprising a composition of any one of claims 21-30 immobilized to the surface of the flow cell, optionally wherein the composition is immobilized to the flow cell through binding of the nanoparticle to the surface of the flow cell.
33. The flow cell of claim 32, comprising a target nucleic acid or one or more fragments thereof, each bound to at least two transposome complexes immobilized on nanoparticles.
34. A method of preparing a nucleic acid library from a target nucleic acid in a reaction solution comprising contacting the target nucleic acid with a mixture of compositions each comprising a bead and at least one nanoparticle of any one of claims 23-30 under conditions whereby the target nucleic acid is fragmented by the transposome complexes and the 3' transposon end sequence of the first polynucleotide is transferred to a 5' end of the fragment, thereby producing immobilized double stranded target nucleic acid fragments wherein one strand is 5'-tagged with the tag.
35. The method of claim 34, further comprising:
- adding a sodium dodecyl sulfate (SDS) solution after the producing of fragments, wherein the SDS stops the producing of additional fragments; or

- b. releasing fragments from the transposome complexes after the producing of fragments or after adding the SDS solution, optionally wherein the releasing is performed at a temperature of 80 °C or by amplifying.
36. The method of claim 35, wherein releasing the fragment from the transposome complexes releases the fragments from the nanoparticle, optionally wherein the fragments are in solution after the releasing.
37. The method of claim 36, further comprising removing beads from the reaction solution after the releasing of fragments, optionally wherein:
- a. the beads are magnetic and the removing beads is performed using a magnetic field, or
 - b. the beads are degradable polyester beads and the removing beads is performed using a degrading agent, optionally wherein the degrading agent is (a) a temperature of from 50 °C to 65 °C, or 60 °C, and/or (b) an aqueous base.
38. The method of any one of claims 34-37, wherein:
- a. fragments in solution are amplified, and the amplified fragments are loaded into a flow cell, captured, and sequenced; or
 - b. fragments immobilized to a mixture of compositions comprising beads and nanoparticles are loaded into a flow cell, and fragments are released and/or beads are removed, and fragments are captured on the flow cell, amplified, and sequenced, optionally wherein fragments released from a single composition will be captured in spatial proximity on the flow cell.
39. The method of any one of claims 34-38, wherein a target nucleic acid is fragmented by multiple transposome complexes, optionally wherein all the transposome complexes are identical and the fragments are tagged with the same adapter sequence at the 5' end of both strands of the double-stranded fragments.
40. The method of claim 39, further comprising:
- a. releasing the double-stranded target nucleic acid fragments from the transposome complexes, optionally wherein the fragments are then immobilized to a solid support,
 - b. hybridizing a polynucleotide comprising an adapter sequence and a sequence all or partially complementary to the first 3' end transposon sequence,

- wherein the adapter sequence comprised in the polynucleotide is different from the adapter sequence comprised in the transposome complexes,
- c. optionally extending a second strand of the double-stranded target nucleic acid fragments,
 - d. optionally ligating the polynucleotide or extended polynucleotide with the double-stranded target nucleic acid fragments, and
 - e. producing double-stranded fragments.
41. The method of claim 40, wherein the polynucleotide further comprises a UMI and the double-stranded target nucleic acid fragments comprise the UMI, optionally wherein the UMI is located directly adjacent to the 3' end of the target nucleic acid fragment.
42. The method of claim 40 or claim 41, wherein double stranded fragments produced are tagged with a first-read sequence adapter sequence from the first transposon at the 5' end of one strand and with a second-read sequence adapter sequence from the polynucleotide at the 5' end of the other strand.
43. The method of claim 39, further comprising:
- a. releasing the double-stranded fragments from the transposome complex, optionally wherein the fragments are immobilized to a solid support,
 - b. hybridizing a first polynucleotide comprising an adapter sequence, wherein the adapter in the first transposon is different from the adapter in the first polynucleotide,
 - c. optionally adding a second polynucleotide comprising regions complementary to the first polynucleotide to produce a double-stranded adapter,
 - d. optionally extending a second strand of the double-stranded target nucleic acid fragments,
 - e. optionally ligating the double-stranded adapter with the double-stranded target nucleic acid fragments, and
 - f. producing double stranded fragments.
44. The method of claim 43, wherein the first polynucleotide further comprises a UMI and the double-stranded fragments comprise the UMI, optionally wherein the UMI is located between the target nucleic acid fragment and the adapter sequence from the first polynucleotide.

45. The method of claim 43 or claim 44, wherein double stranded fragments produced are tagged with a first-read sequence adapter sequence from the first transposon at the 5' end of one strand and with a second-read sequence adapter sequence from the first polynucleotide at the 5' end of the other strand.
46. The method of any one of claims 34-45, wherein the average number of nanoparticles immobilized to a bead in the mixture of compositions comprising a bead and at least one nanoparticle determines the size of target nucleic acid fragments, optionally wherein the method does not require size selection of produced fragments before amplifying or sequencing.
47. The method of any one of claims 34-46, wherein steric hindrance between nanoparticles comprised on the same bead reduces generation of fragments of less than 35 base pairs, optionally wherein produced fragments are sequenced using long read sequencing.
48. A method of preparing a mixture of compositions comprising a bead and at least one nanoparticle comprising:
- a. mixing beads and nanoparticles to prepare compositions comprising beads and nanoparticles of any one of claims 21-30, optionally wherein the beads are magnetic and the mixture is performed using a magnetic field;
 - b. separating the beads from the mixture, optionally wherein the beads are magnetic and the separating beads is performed using a magnetic field;
 - c. evaluating the average number of nanoparticles associated with each bead, optionally wherein the evaluating is performed by preparing fragments according to the method of any one of claims 34-47 and determining fragment size; and
 - d. repeating prior steps until a desired average number of nanoparticles is associated with each bead in the mixture of compositions.