CLAIMS

1. A method for performing an enzymatic reaction using electrophoresis, comprising:

(a) providing an electrophoresis system comprising:

an electrophoresis gel matrix having a first end and a second end and a length between the first and second ends;

a first portion proximate to the first end and containing a first enzyme cofactor for an enzyme;

a second portion proximate to the second end and containing a second enzyme cofactor for the enzyme, the second enzyme cofactor having an electrical charge opposite to that of the first enzyme cofactor;

a reaction portion between the first portion and the second portion and containing the enzyme; and

a pair of positive and negative electrodes arranged at the first and second ends, respectively; and

(b) applying an electric field between the pair of electrodes to drive the first enzyme cofactor from the first portion into the reaction portion and drive the second enzyme cofactor from the second portion into the reaction portion to form an activated enzyme complex comprising the enzyme, the first enzyme cofactor, and the second enzyme cofactor.

2. The method of claim 1, wherein upon the first enzyme cofactor is a metallic ion and the second enzyme cofactor is a polynucleotide.
3. The method of claim 1, further comprising applying a substrate for the activated enzyme complex to the reaction portion prior to step (c), and wherein applying the electric field comprises reacting the activated enzyme complex with the substrate in the reaction portion to form a reaction product.
4. The method of claim 1, wherein applying the electric field comprises migrating unreacted first and second enzyme cofactors out of the reaction portion to separate the unreacted first and second enzyme cofactors from the reaction product in the reaction portion.
5. The method of claim 1, wherein the first electrode is a positive electrode and the first enzyme cofactor is positively charged, and the second electrode is a negative electrode and the second enzyme cofactor is negatively charged.
6. The method of claim 3, wherein the substrate is a target double-stranded nucleic acid,

optionally wherein the target double-stranded nucleic acid is double-stranded DNA, double-stranded RNA, or a DNA/RNA hybrid.

7. The method of claim 1, wherein the enzyme is a transposase, optionally wherein the transposase is a Tn5 transposase, and optionally wherein the first enzyme cofactor comprises Mg^{2+}, optionally in the form of $Mg(OAc)_2$ or $MgCl_2$ and optionally the second enzyme cofactor is a polynucleotide transposase adaptor comprising a double-stranded transposon end sequence and a single-stranded tag region.

8. A method of preparing a library of tagged nucleic acid fragments from a target double-stranded nucleic acid, the method comprising:

(a) providing an electrophoresis system comprising:

an electrophoresis gel matrix having a first end and a second end, a width, and a length between the first and second ends;

a first portion proximate to the first end and containing a first transposase cofactor, wherein the first transposase cofactor is a metallic ion;

a reaction portion distant to the first end and containing a transposome complex comprising a transposase and a polynucleotide transposase adaptor comprising a double-stranded transposon end sequence and a single-stranded tag region; and

a pair of positive and negative electrodes arranged at the first and second ends, respectively;

(b) applying a target double-stranded nucleic acid to the reaction portion;

(c) applying a first electric field between the pair of electrodes to drive the first transposase cofactor from the first portion into the reaction portion to form an activated transposome complex comprising the transposase, the polynucleotide transposase adaptor, and the first transposase cofactor; and

(d) incubating the target double-stranded nucleic acid with the activated transposome complex in the reaction portion under conditions sufficient to fragment the target double-stranded nucleic acid and tag the nucleic acid fragments, thereby generating a library of tagged nucleic acid fragments.

9. The method of claim 8, wherein the transposome complex is immobilized on a solid support in the reaction portion, optionally via streptavidin-biotin interaction.

10. The method of claim 9, comprising releasing the transposome complex from the solid

support after generating the tagged nucleic acid fragments.

11. The method of claim 10, further comprising varying the magnitude of the first electric field after step (d) to drive the tagged nucleic acid fragments bound to the transposome complex released from the solid support into the collection portion.

12. A method of preparing a library of tagged nucleic acid fragments from a target double-stranded nucleic acid, the method comprising:

(a) providing an electrophoresis system comprising:

an electrophoresis gel matrix having a first end and a second end, a width, and a length between the first and second ends;

a first portion proximate to the first end and containing a first transposase cofactor for a transposase, wherein the first transposase cofactor is a metallic ion;

a second portion proximate to the second end and containing a second transposase cofactor for the transposase, the second transposase cofactor having an electrical charge opposite to that of the first transposase cofactor, wherein the second transposase cofactor is a polynucleotide transposase adaptor comprising a double-stranded transposon end sequence and a single-stranded tag region;

a reaction portion between the first portion and the second portion and containing the transposase; and

a pair of positive and negative electrodes arranged at the first and second ends, respectively;

(b) applying a target double-stranded nucleic acid to the reaction portion;

(c) applying a first electric field between the pair of electrodes to drive the first transposase cofactor from the first portion into the reaction portion and drive the second transposase cofactor from the second portion into the reaction portion to form an activated transposome complex comprising the transposase, the first transposase cofactor, and the second transposase cofactor; and

(d) incubating the target double-stranded nucleic acid with the activated transposome complex in the reaction portion under conditions sufficient to fragment the target double-stranded nucleic acid and tag the nucleic acid fragments, thereby generating a library of tagged nucleic acid fragments.

13. The method of claim 12, wherein the single-stranded tag region comprises one or more of a

primer sequence, a barcode sequence, a unique molecular identifier (UMI) sequence, an amplification tag, an enrichment tag, or a purification tag.

14. The method of claim 12, wherein the transposase is immobilized on a solid support within the reaction portion, optionally wherein the reaction portion comprises a well and the solid support is a bead particle or the surface of the well.
15. The method of claim 12, wherein the first electric field applied in step (c) is set at a value at which the target double-stranded nucleic acid has substantially no electrophoretic mobility within the electrophoresis matrix.
16. The method of claim 12, wherein the electrophoresis system comprises a collection portion between the first portion and the reaction portion along the length.
17. The method of claim 16, wherein applying the first electric field in step (c) comprises driving the tagged nucleic acid fragments into the collection portion.
18. The method of claim 12, comprising varying a magnitude or a direction of the first electric field across the electrophoresis gel matrix.
19. The method of claim 12, wherein the electrophoresis system comprises additional portions along the width and the length, each containing different reagents for tagmentation, and a second pair of positive and negative electrodes at opposite sides of the width at one of the first end or the second end.
20. The method of claim 19, comprising applying a second electric field between the second pair of electrodes, wherein the direction of second electric field is perpendicular to the direction of first electric field applied in step (c).
21. A method of preparing a library of tagged nucleic acid fragments from a target double-stranded nucleic acid, the method comprising:

(a) providing an electrophoresis system comprising:

an electrophoresis gel matrix having a first end and a second end, a width, and a length between the first and second ends;

a first portion containing a first transposase cofactor for a transposase, wherein the first transposase cofactor is a metallic ion;

a second portion containing a second transposase cofactor for the transposase, the second transposase cofactor having an electrical charge opposite to that of the first transposase cofactor,

wherein the second transposase cofactor is a polynucleotide transposase adaptor comprising a double-stranded transposon end sequence and a single-stranded tag region;

a third portion containing a lysis reagent;

a fourth portion containing the transposase;

a reaction portion between the first portion and the second portion;

a first pair of positive and negative electrodes arranged at the first and second ends, respectively; and

a second pair of positive and negative electrodes arranged at opposite sides of the width at one of the first end or the second end;

(b) applying whole cells containing a target double-stranded nucleic acid to the reaction portion;

(c) applying a first electric field to drive the lysis agent into and/or through the reaction portion to lyse the cells, thereby applying the target double-stranded nucleic acid to the sample portion;

(d) applying a second electric field to drive the first transposase cofactor from the first portion into the reaction portion, drive the second transposase cofactor from the second portion into the reaction portion, and/or drive the transposase from the transposase portion to the reaction portion to form an activated transposome complex comprising the transposase, the first transposase cofactor, and the second transposase cofactor; and

(e) incubating the target double-stranded nucleic acid with the activated transposome complex in the reaction portion under conditions sufficient to fragment the target double-stranded nucleic acid and tag the nucleic acid fragments, thereby generating a library of tagged nucleic acid fragments.

22. The method of claim 21, wherein the first electric field and the second electric field are different, and step (c) is performed prior to step (d); or

wherein the first electric field and the second electric field are the same, and step (c) is performed simultaneously with step (d).

23. An electrophoresis device comprising:

an electrophoresis gel matrix having a first end, a second end, and a length between the first and second ends;

a first portion proximate to the first end and containing a first enzyme cofactor for an enzyme;

a second portion proximate to the second end and containing a second enzyme cofactor for the enzyme, the second enzyme cofactor having an electrical charge opposite to that of the first enzyme cofactor;

a reaction portion between the first portion and the second portion and containing the enzyme; and

a pair of positive and negative electrodes arranged at the first and second ends, respectively.

24. An electrophoresis device comprising:

an electrophoresis gel matrix having a first end and a second end, a width, and a length between the first and second ends;

a first portion proximate to the first end and containing a first transposase cofactor, wherein the first transposase cofactor is a metallic ion;

a reaction portion distant to the first end and containing a transposome complex comprising a transposase and a polynucleotide transposase adaptor comprising a double-stranded transposon end sequence and a single-stranded tag region; and

a pair of positive and negative electrodes arranged at the first and second ends, respectively.

25. An electrophoresis device comprising:

an electrophoresis gel matrix having a first end, a second end, and a length between the first and second ends;

a first portion proximate to the first end and containing a first transposase cofactor for a transposase, wherein the first transposase cofactor is a metallic ion;

a second portion proximate to the second end and containing a second transposase cofactor for the transposase, the second transposase cofactor having an electrical charge opposite to that of the first transposase cofactor, wherein the second transposase cofactor is a polynucleotide transposase adaptor comprising a double-stranded transposon end sequence and a single-stranded tag region;

a reaction portion between the first end and the second end and containing the transposase; and

a pair of positive and negative electrodes arranged at the first and second ends, respectively.

26. An electrophoresis device comprising:

an electrophoresis gel matrix having a first end and a second end, a width, and a length between the first and second ends;

a first portion proximate to the first end and containing a first transposase cofactor for a transposase, wherein the first transposase cofactor is a metallic ion;

a second portion proximate to the second end and containing a second transposase cofactor for the transposase, the second transposase cofactor having an electrical charge opposite to that of the first transposase cofactor, wherein the second transposase cofactor is a polynucleotide transposase adaptor comprising a double-stranded transposon end sequence and a single-stranded tag region;

a third portion containing a lysis reagent;

a fourth portion containing the transposase;

a reaction portion between the first end and the second end; and

a first pair of positive and negative electrodes arranged at the first and second ends, respectively; and

a second pair of positive and negative electrodes arranged at opposite sides of the width at one of the first end or the second end.

27. A system for preparing a library of tagged nucleic acid fragments from a target double-stranded nucleic acid, comprising:

the device of any one of claims 23-26;

a power supply;

a controller configured to control direction and/or magnitude of the first and second electric fields to drive the reagents and/or tagged nucleic acid fragments into and/or through the reaction portion, collection portion, and/or receiver portions.