CLAIMS

1. A magnetic mixing apparatus comprising:

a driving magnet system configured to rotate about a driving magnet rotational axis, the driving magnet system comprising one or more driving magnets;

a drive motor, wherein the driving magnet system is operably coupled to the drive motor, and the drive motor is capable of driving rotation of the driving magnet system about the driving magnet rotational axis;

a driven magnet system configured to rotate about a driven magnet rotational axis, the driven magnet system comprising one or more driven magnets;

a gap separating the driving magnet system and the driven magnet system,

wherein the arrangement of the driven and driving magnet systems effectuates a magnetic coupling between each driving magnet and a corresponding driven magnet whereby rotation of the driving magnet system about the driving magnet rotational axis induces rotation of the driven magnet system about the driven magnet rotational axis;

a stationary mixing assembly disposed within the gap, wherein the mixing assembly comprises a mixing chamber having a mixing chamber volume and comprising a bounding surface surrounding the mixing chamber volume with a sample transfer channel and a sample exit channel in fluid communication with the mixing chamber volume within the mixing chamber; and

a stir bar contained within the mixing chamber volume, the stir bar comprising a stir bar volume and a ferromagnetic material,

wherein disposition of the stir bar between the driving magnet system and the driven magnet system induces a magnetic dipole across the stir bar, wherein the magnetic dipole of the stir bar creates a low-reluctance magnetic circuit and effectuates a magnetic coupling between the stir bar, at least one of the one or more driving magnets, and at least one of the one or more driven magnets, whereby rotation of the driving magnet system about the driving magnet rotational axis and rotation of the driven magnet system about

the driven magnet rotational axis induces rotation of the stir bar about a stir bar rotational axis.

2. The magnetic mixing apparatus of claim 1, wherein at least one of the one or more driving magnets has a magnetic axis aligned to a magnetic axis of one of the one or more driven magnets, such that the magnets are attracted to one another.

3. The magnetic mixing apparatus of claim 1, wherein the one or more driving magnets are mounted in a driving magnet holder configured to rotate about the driving magnet rotational axis.

4. The magnetic mixing apparatus of claim 3, wherein a driving magnet spindle is operably coupled to the driving magnet holder and the drive motor, the driving magnet spindle substantially collinear with the driving magnet rotational axis, and wherein the drive motor is capable of driving rotation of the driving magnet holder about the driving magnet rotational axis.

5. The magnetic mixing apparatus of claim 1, wherein the driving magnet system comprises a single driving magnet, and wherein a largest dimension of the single driving magnet is perpendicular to the driving magnet axis of rotation.

6. The magnetic mixing apparatus of claim 1, wherein the driving magnet system comprises two driving magnets separated by a distance that transects the driving magnet rotational axis.

7. The magnetic mixing apparatus of claim 1, wherein a residual flux density of the driving magnet system is between 5000 and 40000 Gauss and a residual flux density of the driven magnet system is between 5000 and 40000 Gauss.

8. The magnetic mixing apparatus of claim 1, wherein the one or more driven magnets are mounted in a driven magnet holder configured to rotate about the driven magnet rotational axis.

9. The magnetic mixing apparatus of claim 8, wherein a driven magnet spindle is operably coupled to the driven magnet holder, the driven magnet spindle substantially collinear with the driven magnet rotational axis.

10. The magnetic mixing apparatus of claim 1, wherein the driven magnet system comprises a single driven magnet, and wherein a largest dimension of the single driven magnet is perpendicular to the driven magnet axis of rotation.

11. The magnetic mixing apparatus of claim 1, wherein the driven magnet system comprises two driven magnets separated by a distance that transects the driven magnet rotational axis.

12. The magnetic mixing apparatus of claim 1, wherein a relative magnetic permeability of the stir bar is between 500 - 1,000,000.

13. The magnetic mixing apparatus of claim 1, wherein the one or more driving and driven magnets are neodymium magnets.

14. The magnetic mixing apparatus of claim 1, wherein the ferromagnetic material of the stir bar is ferritic stainless steel.

15. The magnetic mixing apparatus of claim 1, wherein the mixing assembly is disposed within the gap such that the driving magnet rotational axis, the driven magnet rotational axis, and the stir bar rotational axis are substantially collinear and such that the stir bar makes little contact with the bounding surface of the mixing chamber.

16. The magnetic mixing apparatus of claim 1, wherein the gap separating the driving magnet system and the driven magnet system is 10-30 mm.

17. The magnetic mixing apparatus of claim 1, further comprising beads contained within the mixing chamber volume.

18. The magnetic mixing apparatus of claim 1, wherein the mixing assembly is disposable.

19. The magnetic mixing apparatus of claim 1, wherein the mixing chamber volume and the stir bar volume are proportioned such that the stir bar makes little contact with the bounding surface of the mixing chamber.

20. The magnetic mixing apparatus of claim 1, wherein the mixing chamber volume comprises 0.1 mL-100 mL.

21. The magnetic mixing apparatus of claim 1, wherein the stir bar volume comprises 50 uL-10 mL.

22. The magnetic mixing apparatus of claim 1, wherein a largest dimension of the mixing chamber volume comprises 1 mm-200 mm.

23. The magnetic mixing apparatus of claim 22, wherein a largest dimension of the stir bar volume is 0.5 mm-180 mm.

24. The magnetic mixing apparatus of claim 1, wherein the driving magnet system is mechanically coupled to the drive motor.

25. The magnetic mixing apparatus of claim 1, further comprising one or more field focusers coupled to at least one of the one or more driving magnets and the one or more driven magnets, the field focusers positioned to focus magnetic fields generated by the driving magnet system and the driven magnet system towards a narrow radial segment along a largest dimension of the driving and driven magnetic systems.

26. The magnetic mixing apparatus of claim 1, further comprising an acoustic mechanism for detecting magnetic decoupling of the stir bar from one or more of the driving magnet system and the driven magnet system, wherein the acoustic mechanism is configured to detect a change in one or more of an amplitude and a frequency of vibrations produced by the stir bar during rotation of the driving magnet system, the change indicating the magnetic decoupling of the stir bar.

27. The magnetic mixing apparatus of claim 26, wherein the change comprises a sudden decrease in one or more of the amplitude and the frequency of the vibrations produced by the stir bar.

28. The magnetic mixing apparatus of claim 26, wherein the acoustic mechanism comprises a microphone.

29. A method of lysing a cell, comprising introducing a sample comprising a cell into the mixing chamber of claim 1, and energizing the drive motor, whereby energizing the drive motor rotates the stir bar to mix the sample within the mixing chamber and thereby promotes cell lysis.

30. A method of lysing a cell, comprising introducing a sample comprising a cell into the mixing chamber of claim 17, and energizing the drive motor, whereby energizing the drive motor rotates the stir bar to mix the sample within the mixing chamber and thereby promotes cell lysis by mixing the beads with the sample.