ULTRA-HIGH-SPEED ROTOR

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the filing benefit of co-pending U.S. Provisional Applications having Serial No. 63/112,018 filed on November 10, 2020 and Serial No. 63/256,014 filed on October 15, 2021, the disclosures of which are each incorporated by reference herein in their entireties.

TECHNICAL FIELD

[0002] The present invention relates generally to centrifuge rotors and, more particularly, to a rotor for ultracentrifugation.

BACKGROUND

[0003] Exosomes are cell-derived vesicles that can carry nucleic acids, lipids, or proteins from one cell to another. Exosomes play an important role in communication between cells, and are necessary for the proper functioning of the human body. In addition to their role in the regular physiology of humans, exosomes are also connected with certain diseases. There has been growing interest in exosome research due to their role as intercellular messengers and their potential in both the diagnosis and treatment of disease. For example, because exosomes have different secretory components under physiological and pathological conditions, they have been studied as a therapeutic target, a drug or gene delivery vector, and a cancer marker.

[0004] Exosomes are a type of extracellular vesicle secreted from most cell types, and typically have diameters of between 30 nm and 140 nm. Exosomes are normally secreted along with other types of extracellular vesicles, such as apoptotic bodies having diameters of 50–500 nm, and ectosomes having diameters of 30–100 nm. Exosomes may be separated from these other types of extracellular vesicles using centrifugation. However, because these additional extracellular vesicles often have similar physical properties as exosomes (e.g., similar sizes and densities), isolating exosomes from other cellular secretions commonly found in biological suspensions can require extremely high g-forces.

[0005] The amount of g-force that can be generated by a centrifuge depends at least in part on the physical properties of the rotor. Minor imperfections such as

uneven distributions in mass or minor structural defects that would not be an issue in conventional centrifuges can cause vibrations or failures at the rotational speeds desired to efficiently separate exosomes.

[0006] Thus, there is a need for improved rotors that can be used in ultracentrifugation applications for separating exosomes and other materials having similar physical properties.

SUMMARY

[0007] ~~The~~Embodiments of the present invention overcome~~s~~ the foregoing and other shortcomings and drawbacks of centrifuge rotors heretofore known for use in ultra-high-speed centrifugation. While aspects the present invention will be discussed in connection with certain embodiments, it will be understood that the aspects of the present invention ~~is~~are not limited to the specific embodiments described herein.

[0008] ~~In an embodiment~~According to an aspect of the present invention, a rotor for use in a centrifuge is provided. The rotor includes a rotor body having an axis of rotation, an upper surface, a lower surface opposite the upper surface, and an elongated bore extending along the axis of rotation between the upper surface and the lower surface. The upper surface of the rotor body includes a plurality cavities extending from the upper surface and into the rotor body, each of the plurality of cavities being configured to receive a sample container. The lower surface of the rotor body includes a lower bore opening in communication with the elongated bore and having a first cross-sectional shape transverse to the axis of rotation. The rotor further includes a drive hub mounted within the elongated bore and having a drive portion with a second cross-sectional shape transverse to the axis of rotation that is complementary to the first cross-sectional shape such that the drive portion of the drive hub applies torque to the rotor body via engagement of the drive portion with the lower bore opening of the rotor body.

[0009] In an ~~aspect~~embodiment of the present invention, each of the first cross-sectional shape and the second cross-sectional shape may be rectangular.

[0010] In another ~~aspect~~embodiment of the present invention, the rotor body may include an upper bore opening in communication with the elongated bore, and the elongated bore may be cylindrical in cross-section transverse to the axis of rotation between the lower bore opening and the upper bore opening.

[0011] In ~~another~~embodiment aspect of the present invention, the rotor may further include a lid having a central wall portion, a conical wall portion extending upwardly and outwardly from the central wall portion, and an annular wall portion extending radially outward from the conical wall portion remote from the central wall portion such that the annular wall portion is radially and axially offset from the central wall portion.

[0012] In another ~~aspect~~embodiment of the present invention, the conical wall portion of the lid may be configured to engage each sample container placed into a respective cavity when the lid is operatively coupled to the rotor.

[0013] In another ~~aspect~~embodiment of the present invention, the upper surface of the rotor body may define an upper recess, and the central and conical wall portions of the lid may be received in the upper recess.

[0014] In another ~~aspect~~embodiment of the present invention, the lid may include a lid-lifting handle that projects axially upward from the central wall portion of the lid.

[0015] In another ~~aspect~~embodiment of the present invention, the lid-lifting handle may include a cylindrical wall and a handle flange that projects radially outward from a free end of the cylindrical wall remote from the central wall portion of the lid.

[0016] In another ~~aspect~~embodiment of the present invention, the drive hub may include a cylindrical shaft that projects upwardly through the elongated bore from the drive portion of the drive hub.

[0017] In another ~~aspect~~embodiment of the present invention, an upper portion of the cylindrical shaft may include a threaded outer surface.

[0018] In another ~~aspect~~embodiment of the present invention, the rotor may further include a lid screw having a lower bore with a threaded inner surface and a lid screw flange that extends radially outward from a lower end of the lid screw. The threaded outer surface of the drive hub may be configured to threadedly engage the threaded inner surface of the lower bore of the lid screw, and the lid screw flange may have a lower surface configured to urge the lid into contact with the rotor body in response to threaded engagement of the lid screw and the drive hub.

[0019] In another ~~aspect~~embodiment of the present invention, the cylindrical wall of the lid-lifting handle may be configured to receive the lid screw flange and position the lid screw concentrically with the lid-lifting handle.

[0020] In another ~~aspect~~embodiment of the present invention, the lower surface of the lid screw flange may include an annular groove, and the rotor may further

include an elastic member positioned within the annular groove that is compressed against an upper surface of the central wall portion of the lid in response to threaded engagement of the lid screw with the drive hub.

[0021] In another ~~aspect~~embodiment of the present invention, the lower bore opening may include one or more sidewalls, the drive portion of the drive hub may have one or more faces each engaging a respective sidewall of the lower bore opening, and the application of torque to the rotor body may be by the one or more faces engaging the respective sidewalls.

[0022] ~~In another embodiment of the present invention, another~~Disclosed herein is a rotor for use in a centrifuge~~ is provided~~. The rotor includes a rotor body having an axis of rotation and an upper surface with a first annular groove, and a balance ring positioned in the first annular groove. The balance ring includes an upper surface and a plurality of apertures formed in the upper surface. Each aperture in the upper surface of the balance ring is configured to selectively receive a weight.

[0023] In ~~another aspect of the present invention~~the above disclosure, the rotor body may include a lower surface opposite its upper surface and an elongated bore extending along the axis of rotation between the upper and lower surfaces of the rotor body, and the rotor may further include a drive hub mounted within the elongated bore and having a cylindrical shaft that projects upwardly through the elongated bore. The cylindrical shaft may include an upper portion having a threaded outer surface. The rotor may further include a lid screw having a lower bore with a threaded inner surface configured to threadedly engage the threaded outer surface of the drive hub and a lid screw flange that extends radially outward from a lower end of the lid screw, a lid including a wall portion extending radially outward and including a lower surface having a second annular groove, and an elastic member positioned within the second annular groove that is compressed against the upper surface of the balance ring in response to threaded engagement of the lid screw with the drive hub.

[0024] In ~~another aspect of the present invention~~the above disclosure, the threaded outer surface may include threads having a major diameter and a minor diameter, and the cylindrical shaft may include a protruding end having the minor diameter and that extends a distance beyond the threads of the threaded outer surface.

[0025] In ~~another aspect of the present invention~~the above disclosure, the first annular groove may include a shoulder, and the balance ring may include a balance ring flange that projects radially inward to engage the shoulder.

[0026] In ~~another aspect of the present invention~~the above disclosure, the rotor body may include a circumferential sidewall, and the rotor may further include a reinforcement that extends around the circumferential sidewall.

[0027] In ~~another aspect of the present invention~~the above disclosure, the reinforcement may extend around and above the circumferential sidewall of the rotor body to define a channel with the first annular groove, and the balance ring may be positioned in the channel.

[0028] In ~~another aspect of the present invention~~the above disclosure, the circumferential sidewall may include a circumferential recess, and the reinforcement may conform to the circumferential recess.

[0029] In ~~another aspect of the present invention~~the above disclosure, the balance ring may be operatively coupled to the first annular groove by an adhesive, a shrink-fit, or both the adhesive and the shrink-fit.

[0030] In ~~another aspect of the present invention~~the above disclosure, each aperture may be spaced the same angular distance from each angularly adjacent aperture.

[0031] In ~~another aspect of the present invention~~the above disclosure, the plurality of apertures may be arranged into a plurality of aperture groups each including two or more apertures seperated by a first angular distance, and each aperture group may be seperated from each adjacent aperture group by a second angular distance different from the first angular distance.

[0032] In ~~another aspect of the present invention~~the above disclosure, the balance ring may further include a plurality of markers on its upper surface, and each marker may be positioned between two aperture groups.

[0033] In ~~another aspect of the present invention~~the above disclosure, the rotor body may further include a plurality cavities extending from its upper surface into the rotor body, each of the plurality of cavities may be configured to receive a sample container, and each marker may be radially aligned with a respective cavity.

[0034] In ~~another aspect of the present invention~~the above disclosure, the rotor may further include at least one weight received by at least one of the apertures.

[0035] In ~~another aspect of the present invention~~the above disclosure, the at least one weight may be a screw including a threaded outer surface, and each of the apertures may include a threaded inner surface configured to threadedly engage the screw.

[0036] In ~~another aspect of the present invention~~the above disclosure, the screw may have a head and a first length, the at least one aperture may have a second length longer than the first length, and the head of the screw may be below the upper surface of the balance ring.

[0037] In ~~another aspect of the present invention~~the above disclosure, each aperture of the plurality of apertures may be the same radial distance from the axis of rotation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the present invention and, together with the general description of the present invention given above, and the detailed description given below, serve to explain the present invention.

[0039] FIG. 1 is a perspective view of a rotor in accordance with an exemplary embodiment of the present invention.

[0040] FIG. 2 is an exploded perspective view of the rotor of FIG. 1 showing a rotor body, a balance ring, a drive hub, and a lid of the rotor.

[0041] FIG. 2A is a perspective view showing additional details of the lid of FIG. 2.

[0042] FIG. 2B is a top perspective view showing additional details of the rotor body of FIG. 2.

[0043] FIG. 2C is a bottom perspective view showing additional details of the rotor body and drive hub of FIG. 2.

[0044] FIG. 3 is a cross-sectional view of the rotor of FIG. 1.

[0045] FIG. 3A is an exploded cross-sectional view of a portion of the rotor of FIG. 3 showing additional details of the lid, balance ring, and rotor body.

[0046] FIGS. 4 and 5 are top views of the rotor of FIG. 1 with the lid removed.

[0047] FIG. 6 is a top view of the rotor of FIG. 1 with the lid removed showing a balance ring in accordance with an alternative embodiment of the present invention.

[0048] FIG. 6A is a cross-sectional view of the balance ring of FIG. 6.

[0080] While various aspects in accordance with the principles of the present invention have been illustrated by the description of various embodiments, and while the embodiments have been described in considerable detail, they are not intended to restrict or in any way limit the scope of the present invention to such detail. The various features shown and described herein may be used alone or in any combination. Additional advantages and modifications will readily appear to those skilled in the art. The present invention in its broader aspects is therefore not limited to the specific details, representative apparatus and methods and illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the scope of the general inventive concept.

~~What is claimed is:~~

CLAIMS

1. A rotor for use in a centrifuge, comprising:

a rotor body including an axis of rotation, an upper surface, a lower surface opposite the upper surface, and an elongated bore extending along the axis of rotation between the upper surface and the lower surface, the upper surface of the rotor body including a plurality cavities extending from the upper surface and into the rotor body, each of the plurality of cavities being configured to receive a sample container, and the lower surface of the rotor body including a lower bore opening in communication with the elongated bore and having a first cross-sectional shape transverse to the axis of rotation; and

a drive hub mounted within the elongated bore and including a drive portion having a second cross-sectional shape transverse to the axis of rotation that is complementary to the first cross-sectional shape such that the drive portion of the drive hub applies torque to the rotor body via engagement of the drive portion with the lower bore opening of the rotor body.

2. The rotor of claim 1, wherein the first cross-sectional shape and the second cross-sectional shape are each rectangular.

3. The rotor of claim 1 or 2, wherein:

the rotor body includes an upper bore opening in communication with the elongated bore, and the elongated bore is cylindrical in cross-section transverse to the axis of rotation between the lower bore opening and the upper bore opening.

4. The rotor of any of claims 1 to 3, further comprising:

a lid including a central wall portion, a conical wall portion extending upwardly and outwardly from the central wall portion, and an annular wall portion extending radially outward from the conical wall portion remote from the central wall portion such that the annular wall portion is radially and axially offset from the central wall portion.

5. The rotor of claim 4, wherein the conical wall portion of the lid is configured to engage each sample container placed into a respective cavity when the lid is operatively coupled to the rotor.

6. The rotor of claim 4 or 5, wherein the upper surface of the rotor body defines an upper recess, and the central wall portion and the conical wall portion of the lid are received in the upper recess.

7. The rotor of any of claims 4 to 6, wherein the lid includes a lid-lifting handle that projects axially upward from the central wall portion of the lid.

8. The rotor of claim 7, wherein the lid-lifting handle includes a cylindrical wall having a handle flange projecting radially outward from a free end of the cylindrical wall remote from the central wall portion of the lid.

9. The rotor of claim 8, wherein the drive hub includes a cylindrical shaft that projects upwardly through the elongated bore from the drive portion of the drive hub.

10. The rotor of claim 9, wherein an upper portion of the cylindrical shaft includes a threaded outer surface having threads with a major diameter and a minor diameter, and the cylindrical shaft includes a protruding end having the minor diameter and that extends a distance beyond the threads of the threaded outer surface.

11. The rotor of claim 10, further comprising:

a lid screw including a lower bore having a threaded inner surface, and a lid screw flange that extends radially outward from a lower end of the lid screw,

wherein the threaded outer surface of the drive hub is configured to threadedly engage the threaded inner surface of the lower bore of the lid screw, and

the lid screw flange has a lower surface configured to urge the lid into contact with the rotor body in response to threaded engagement of the lid screw and the drive hub.

12. The rotor of claim 11, wherein the cylindrical wall of the lid-lifting handle is configured to receive the lid screw flange and position the lid screw concentrically with the lid-lifting handle.

13. The rotor of claim 11 or 12, wherein the lower surface of the lid screw flange includes an annular groove, and further comprising an elastic member positioned within the annular groove that is compressed against an upper surface of the central wall portion of the lid in response to threaded engagement of the lid screw with the drive hub.

14. The rotor of any of claims 1 to 13, wherein the lower bore opening includes one or more sidewalls, the drive portion of the drive hub has one or more faces each engaging a respective sidewall of the lower bore opening, and the application of torque to the rotor body is by the one or more faces engaging the respective sidewalls.

~~15. A rotor for use in a centrifuge, comprising:~~

~~a rotor body including an axis of rotation and an upper surface having a first annular groove; and~~

~~a balance ring positioned in the first annular groove, the balance ring including an upper surface and a plurality of apertures formed in the upper surface of the balance ring, each aperture configured to selectively receive a weight.~~

~~16. The rotor of claim 15, wherein the rotor body includes a lower surface opposite the upper surface of the rotor body and an elongated bore extending along the axis of rotation between the upper and lower surfaces of the rotor body, and further comprising:~~

~~a drive hub mounted within the elongated bore and including a cylindrical shaft that projects upwardly through the elongated bore, the cylindrical shaft including an upper portion having a threaded outer surface;~~

~~a lid screw including a lower bore having a threaded inner surface configured to threadedly engage the threaded outer surface of the drive hub, and a lid screw flange that extends radially outward from a lower end of the lid screw;~~

a lid including a wall portion extending radially outward, the wall portion including a lower surface having a second annular groove; and

an elastic member positioned within the second annular groove that is compressed against the upper surface of the balance ring in response to threaded engagement of the lid screw with the drive hub.

17. The rotor of claim 16, wherein the threaded outer surface includes threads having a major diameter and a minor diameter, and the cylindrical shaft includes a protruding end having the minor diameter and that extends a distance beyond the threads of the threaded outer surface.

18. The rotor of any of claims 15 to 17, wherein the first annular groove includes a shoulder, and the balance ring includes a balance ring flange that projects radially inward to engage the shoulder.

19. The rotor of any of claims 15 to 18, wherein the rotor body includes a circumferential sidewall, and further comprising:

a reinforcement that extends around the circumferential sidewall.

20. The rotor of claim 19, wherein the reinforcement extends around and above the circumferential sidewall of the rotor body to define a channel with the first annular groove, and the balance ring is positioned in the channel.

21. The rotor of claim 19 or 20, wherein the circumferential sidewall includes a circumferential recess, and the reinforcement conforms to the circumferential recess.

22. The rotor of any of claims 15 to 21, wherein the balance ring is operatively coupled to the first annular groove by an adhesive, a shrink-fit, or both the adhesive and the shrink-fit.

23. The rotor of any of claims 15 to 22, wherein each aperture is spaced the same angular distance from each angularly adjacent aperture.

~~24. The rotor of any of claims 15 to 22, wherein the plurality of apertures is arranged into a plurality of aperture groups each including two or more apertures seperated by a first angular distance, and each aperture group is seperated from each adjacent aperture group by a second angular distance different from the first angular distance.~~

~~25. The rotor of claim 24, wherein the balance ring further includes a plurality of markers on the upper surface of the balance ring, and each marker is positioned between two aperture groups.~~

~~26. The rotor of claim 25, wherein the rotor body further includes a plurality cavities extending from the upper surface of the rotor body into the rotor body, each of the plurality of cavities is configured to receive a sample container, and each marker is radially aligned with a respective cavity.~~

~~27. The rotor of any of claims 15 to 26, further comprising:~~

~~at least one weight received by at least one of the apertures.~~

~~28. The rotor of claim 27, wherein the at least one weight is a screw including a threaded outer surface, and each of the apertures includes a threaded inner surface configured to threadedly engage the screw.~~

~~29. The rotor of claim 28, wherein the screw has a head and a first length, the at least one aperture has a second length longer than the first length, and the head of the screw is below the upper surface of the balance ring.~~

~~30. The rotor of any of claims 15 to 29, wherein each aperture of the plurality of apertures is the same radial distance from the axis of rotation.~~