CLAIMS

[Claim 1]

A particle imaging apparatus comprising:

a flow path comprising a first flow path section, a second flow path section connected downstream of the first flow path section, and a third flow path section that is branched from the first flow path section, between the first flow path section and the second flow path section, the flow path configured to cause a measurement sample including particles to flow;

a particle detection unit comprising a light source that applies light to a particle that flows in the first flow path section, and a light detector that receives light generated from the particle by application of the light;

a particle sorting unit capable of adjusting a flow direction of the particle flowing in the first flow path section such that the flow direction is selected from among at least a direction toward the second flow path section and a direction toward the third flow path section, based on an intensity of the light received by the light detector; and

a particle imaging unit configured to take an image of a particle that flows in the second flow path section, wherein

the flow path is structured such that a cross-sectional area of the second flow path section is greater than a cross-sectional area of the first flow path section, and

the first flow path section and the second flow path section are disposed so as to be linearly aligned.

[Claim 2]

The particle imaging apparatus of claim 1, wherein

the particle detection unit detects, as an imaging target of the particle imaging unit, at least one cell selected from the group consisting of a circulating tumor cell, a vascular endothelial cell, a vascular endothelial progenitor cell, a mesenchymal stem cell, a hematopoietic stem cell, and an antigen-specific T-cell that are included in the measurement sample.

[Claim 3]

The particle imaging apparatus of claim 1 or 2, wherein

the flow path is structured such that a speed at which a particle flows in the second flow path section is lower than a speed at which the particle flows in the first flow path section.

[Claim 4]

The particle imaging apparatus of any one of claims 1 to 3, wherein

the flow path is structured such that a flow rate in the second flow path section is lower than or equal to 1/3 of a flow rate in the first flow path section.

[Claim 5]

The particle imaging apparatus of any one of claims 1 to 4, wherein

the flow path is structured such that a speed at which a particle flows in the second flow path section is lower than or equal to 1/10 of a speed at which the particle flows in the first flow path section.

[Claim 6]

The particle imaging apparatus of any one of claims 1 to 5, wherein

the flow path is structured such that a central axis of the first flow path section and a central axis of the second flow path section are aligned with each other.

[Claim 7]

The particle imaging apparatus of any one of claims 1 to 6, wherein

the particle sorting unit

guides an imaging target particle so as to flow straight into the second flow path section without applying an external force to the imaging target particle, and

applies an external force to a particle other than imaging target particles, changes a direction in which the particle flows, and guides the particle into the third flow path section.

[Claim 8]

The particle imaging apparatus of any one of claims 1 to 7, wherein

the flow path further comprises a fourth flow path section that branches from the first flow path section, between the first flow path section and the second flow path section, and

the third flow path section and the fourth flow path section are disposed so as to be symmetric about a central axis of the first flow path section.

[Claim 9]

The particle imaging apparatus of any one of claims 1 to 8, wherein

the third flow path section has a cross-sectional area that is gradually increased

from an upstream side of the flow path toward a downstream side thereof.

[Claim 10]

The particle imaging apparatus of any one of claims 1 to 9, wherein

the flow path is structured such that a flow rate in the second flow path section is reduced from a flow rate in the first flow path section due to the third flow path section, and a speed at which a particle flows in the second flow path section is thus made lower than a speed at which the particle flows in the first flow path section.

[Claim 11]

The particle imaging apparatus of any one of claims 1 to 10, wherein

the flow path is structured such that a cross-sectional area of the second flow path section is greater than a cross-sectional area of the first flow path section, and a speed at which a particle flows in the second flow path section is thus made lower than a speed at which the particle flows in the first flow path section.

[Claim 12]

The particle imaging apparatus of any one of claims 1 to 11, wherein

the flow path further comprises: an intermediate flow path section that connects between the first flow path section and the second flow path section; and a branching flow path section that branches from the intermediate flow path section.

[Claim 13]

The particle imaging apparatus of claim 12, wherein

the flow path comprises a plurality of the branching flow path sections, and

the plurality of the branching flow path sections are disposed so as to be symmetric about a central axis of the intermediate flow path section.

[Claim 14]

The particle imaging apparatus of claim 12 or 13, wherein

the intermediate flow path section comprises a flow path section having a cross-sectional area increased toward the downstream side, on a side downstream of a position at which the branching flow path section branches, and

the branching flow path section comprises a flow path section having a cross-sectional area increased toward the downstream side.

[Claim 15]

The particle imaging apparatus of any one of claims 1 to 14, wherein

the flow path comprises an intermediate flow path section that connects between the first flow path section and the second flow path section, and

the intermediate flow path section comprises: a plurality of expanded flow path sections each having a cross-sectional area increased toward the downstream side; and a flow path section having a constant cross-sectional area and disposed between a plurality of the expanded flow path sections.

[Claim 16]

The particle imaging apparatus of any one of claims 12 to 15, wherein

the intermediate flow path section comprises a particle alignment unit that aligns particles in a flow direction.

[Claim 17]

The particle imaging apparatus of any one of claims 12 to 16, wherein

the flow path is structured such that a speed at which a particle flows in the second flow path section is lower than or equal to 1/100 of a speed at which the particle flows in the first flow path section.

[Claim 18]

The particle imaging apparatus of any one of claims 1 to 17, wherein

on a cross-section of the second flow path section at a position where the imaging unit takes an image, a width in a direction perpendicular to an imaging direction and to a flow direction in which a particle flows is greater than a width in the imaging direction.

[Claim 19]

The particle imaging apparatus of any one of claims 1 to 18, further comprising

a particle alignment unit configured to align, in a flow direction, particles that flow in the second flow path section.

[Claim 20]

The particle imaging apparatus of claim 19, wherein

the particle alignment unit applies an acoustic force to particles that flow in the

second flow path section, in the direction perpendicular to the imaging direction and to the flow direction in which the particles flow.

[Claim 21]

The particle imaging apparatus of claim 20, wherein

the particle alignment unit further applies, in the imaging direction, an acoustic force to particles that flow in the second flow path section.

[Claim 22]

The particle imaging apparatus of claim 21, wherein

the particle alignment unit applies an acoustic force to particles that flow in the second flow path section, by using a piezoactuator disposed on a side surface of the second flow path section, and

in the second flow path section, a thickness of a side surface portion in which the piezoactuator is disposed is less than a thickness of other portions.

[Claim 23]

The particle imaging apparatus of any one of claims 19 to 22, wherein

the particle alignment unit applies an input signal of a pulse wave to the piezoactuator to remove bubbles inside the second flow path section, and thereafter applies an input signal of a sine wave to the piezoactuator and aligns the particles.

[Claim 24]

The particle imaging apparatus of any one of claims 19 to 23, wherein

the second flow path section is disposed on a piezoelectric crystal substrate, and

the particle alignment unit causes an electric current to flow through a comb-shaped electrode formed on a surface of the piezoelectric crystal substrate, and thus applies an acoustic force to particles that flow in the second flow path section.

[Claim 25]

The particle imaging apparatus of any one of claims 19 to 24, wherein

the particle alignment unit applies an ultrasonic wave to the measurement sample that flows in the second flow path section to generate a standing wave in the measurement sample, and thus aligns particles in a flow direction in which the measurement sample flows, and

the particle alignment unit changes a precision with which the particles are

concentrated, by adjusting an amplitude of the standing wave.

[Claim 26]

The particle imaging apparatus of any one of claims 1 to 25, wherein

the imaging unit applies light to an imaging region in the second flow path section and receives light from the imaging region, and takes an image of the particle that flows in the imaging region.

[Claim 27]

The particle imaging apparatus of any one of claims 1 to 26, wherein

the particle imaging unit is a TDI camera.

[Claim 28]

The particle imaging apparatus of any one of claims 1 to 27, further comprising

a sample preparation unit configured to mix a blood specimen with a labeled antibody that reacts specifically to a cell other than imaging target cells, to prepare the measurement sample, wherein

a first detector that receives scattered light generated from the particle by application of the light, and a second detector that receives fluorescence generated from the particle by application of the light are provided as the light detector,

the second detector detects a fluorescence signal from the labeled antibody, and

the particle sorting unit adjusts the flow direction of the particle flowing in the first flow path section, based on an intensity of the fluorescence signal.

[Claim 29]

The particle imaging apparatus of any one of claims 1 to 29, further comprising:

an output unit; and

a controller configured to perform analysis of a particle image taken by the imaging unit, and cause the output unit to output the number of the imaging target cells included in the measurement sample, wherein

the controller causes the output unit to output images of the imaging target cells obtained by the analysis.

[Claim 30]

A particle imaging apparatus comprising:

a flow path comprising a first flow path section, and a second flow path section connected downstream of the first flow path section, the flow path configured to cause a measurement sample including particles to flow;

a particle detection unit comprising a light source that applies light to a particle that flows in the first flow path section, and a light detector that receives light generated from the particle by application of the light;

a particle sorting unit disposed between the first flow path section and the second flow path section, the particle sorting unit configured to break a particle other than imaging target particles, based on a result of detection by the particle detection unit; and

a particle imaging unit configured to take an image of a particle that flows in the second flow path section, wherein

the flow path is structured such that a cross-sectional area of the second flow path section is greater than a cross-sectional area of the first flow path section, and

the first flow path section and the second flow path section are disposed so as to be linearly aligned.

[Claim 31]

A particle imaging method comprising:

causing a measurement sample to flow in a flow path which comprises a first flow path section, a second flow path section connected downstream of the first flow path section, and a third flow path section that is branched from the first flow path section, between the first flow path section and the second flow path section, the flow path being structured such that a cross-sectional area of the second flow path section is greater than a cross-sectional area of the first flow path section, and the first flow path section and the second flow path section are linearly aligned;

applying light to a particle in the measurement sample that flows at a first speed, and detecting light generated from the particle;

adjusting a direction in which the particle in the measurement sample flows, based on an intensity of the detected light; and

taking an image of a particle in the measurement sample that flows in the second flow path section at a second speed lower than the first speed.

[Claim 32]

A particle imaging apparatus comprising:

a flow path comprising a first flow path section, a second flow path section connected downstream of the first flow path section, and a third flow path section that is branched from the first flow path section, between the first flow path section and the second flow path section, the flow path configured to cause a measurement sample including particles to flow;

a particle detection unit comprising a light source that applies light to a particle that flows in the first flow path section, and a light detector that receives light generated from the particle by application of the light;

a particle sorting unit capable of adjusting a flow direction of the particle flowing in the first flow path section such that the flow direction is selected from among at least a direction toward the second flow path section and a direction toward the third flow path section, based on an intensity of the light received by the light detector; and

a particle imaging unit configured to take an image of a particle that flows in the second flow path section, wherein

the third flow path section has a cross-sectional area that is gradually increased from an upstream side of the flow path toward a downstream side thereof.

[Claim 33]

A particle imaging apparatus comprising:

a flow path comprising a first flow path section, a second flow path section connected downstream of the first flow path section, and a third flow path section that is branched from the first flow path section, between the first flow path section and the second flow path section, the flow path configured to cause a measurement sample including particles to flow;

a particle detection unit comprising a light source that applies light to a particle that flows in the first flow path section, and a light detector that receives light generated from the particle by application of the light;

a particle sorting unit capable of adjusting a flow direction of the particle flowing in the first flow path section such that the flow direction is selected from among at least a direction toward the second flow path section and a direction toward the third flow path section, based on an intensity of the light received by the light detector; and

a particle imaging unit configured to take an image of a particle that flows in the second flow path section, wherein

the flow path is structured such that a cross-sectional area of the second flow path section is greater than a cross-sectional area of the first flow path section, and a central axis of the first flow path section and a central axis of the second flow path section are aligned with each other.