ultrasonic wave in the cleaning tank. The document indicates that this allows an object, or a substrate, disposed in the cleaning tank to be cleaned substantially uniformly.

Problems to be Solved by the Invention

However, the apparatus disclosed in JP2009-231668 is required to have a mechanical structure in the cleaning tank to swing the ultrasonic refraction member, and as a result the apparatus is complex and expensive. Furthermore, while the apparatus disclosed in JP2001-057354 allows a substrate to have a surface having a relatively large area exposed to an ultrasonic wave, the apparatus cannot adjust ultrasonic exposure in conformity to a cleaning condition, and it is thus difficult to completely entirely expose the surface to the ultrasonic wave.

The present invention has been made to solve the above described issue and it contemplates a cleaning apparatus, equipment and method that can have a relatively simple configuration to clean an object without an area which is not directly exposed to an ultrasonic wave.

Means for Solving the Problems

The present invention provides a cleaning apparatus comprising a cleaning tank, a coupling tank, an ultrasonic wave generation unit, and a modification unit. The cleaning tank has an inclined bottom surface and holds a cleaning liquid for cleaning an object to be cleaned. The coupling tank holds an intermediate medium and is disposed such that the cleaning tank has the inclined bottom surface~~a portion~~ in contact with the intermediate medium. The ultrasonic wave generation unit is provided at the coupling tank and ultrasonically vibrates the cleaning liquid via the intermediate medium. The modification unit modifies a difference in sonic velocity between the cleaning liquid and the intermediate medium.

Varying a difference in sonic velocity between the cleaning liquid and the intermediate medium can modify a condition applied to refract an ultrasonic wave at a boundary of the cleaning tank and the coupling tank. This allows the ultrasonic wave to travel through the cleaning tank in a modified direction and can thus reduce an area of the object (e.g., a substrate) held in the cleaning liquid that is shadowed by a holding member or the like holding the object (i.e., an area that is not directly exposed to the ultrasonic wave).

The present invention provides cleaning equipment equipped with a plurality of cleaning units cleaning an object to be cleaned with a cleaning liquid, and at least one of the plurality of cleaning units is the cleaning apparatus as described above. At least one cleaning unit that has the configuration of the present cleaning apparatus can have a condition (applied to refract an ultrasonic wave at an interface of the cleaning tank and the intermediate medium) set to be different than another cleaning unit. The object cleaned through the cleaning units sequentially can be cleaned without a surface having a large area which is shadowed and thus not directly exposed to an ultrasonic wave.

The present invention provides a cleaning method comprising the steps of: disposing in a cleaning liquid held in a cleaning tank having an inclined bottom surface an object to be cleaned; and ultrasonically vibrating the cleaning liquid via an intermediate medium in contact with the inclined bottom surface of the cleaning tank to clean the object, and the step of ultrasonically vibrating includes the steps of: ultrasonically vibrating the cleaning liquid with the cleaning liquid and the intermediate medium allowing sonic velocities, respectively, having a first difference; and ultrasonically vibrating the cleaning liquid with the cleaning liquid and the intermediate medium allowing sonic velocities, respectively, having a second

difference different from the first difference. The first and different, second differences can vary for each cleaning step a condition applied to refract an ultrasonic wave at a boundary of the cleaning tank and the intermediate medium. As a result, the object to be cleaned (e.g., a substrate) held in the cleaning liquid does not have a large area shadowed by a holding member or the like (i.e., a large area that is not directly exposed to an ultrasonic wave).

The present invention provides a cleaning method comprising the steps of: disposing in a first cleaning liquid held in a first cleaning tank having an inclined bottom surface an object to be cleaned; ultrasonically vibrating the first cleaning liquid via a first intermediate medium in contact with the inclined bottom surface of the first cleaning tank to clean the object; disposing the object in a second cleaning liquid held in a second cleaning tank having an inclined bottom surface; and ultrasonically vibrating the second cleaning liquid via a second intermediate medium in contact with the inclined bottom surface of the second cleaning tank to clean the object. The first cleaning liquid and the first intermediate medium allow sonic velocities, respectively, having a first difference and the second cleaning liquid and the second intermediate medium allow sonic velocities, respectively, having a second difference, and the first and second differences are different from each other.

A single coupling tank holds an intermediate medium without having the intermediate medium's condition modified as occasion would require. Rather, first and second intermediate media's respective conditions can be fixed, and the object can thus be cleaned continuously. This allows cleaning to be done in a more efficient and hence less costly method.

Effects of the Invention

Claims

1. A cleaning apparatus comprising:
- a cleaning tank holding a cleaning liquid for cleaning an object to be cleaned,
- a coupling tank holding an intermediate medium and disposed such that said cleaning tank has a portion in contact with said intermediate medium;
- an ultrasonic wave generation unit provided at said coupling tank and ultrasonically vibrating said cleaning liquid via said intermediate medium; and
- a modification unit modifying a difference in sonic velocity between said cleaning liquid and said intermediate medium.

2. The cleaning apparatus according to claim 1, wherein said modification unit includes a temperature adjustment unit varying said intermediate medium in temperature.

3. The cleaning apparatus according to claim 2, wherein said temperature adjustment unit has a heating member heating said intermediate medium.

4. The cleaning apparatus according to claim 2, wherein said intermediate medium is degassed water and said temperature adjustment unit has a flow rate adjustment unit adjusting an amount of said degassed water supplied to said coupling tank.

5. The cleaning apparatus according to claim 1, wherein said modification unit includes a composition adjustment unit modifying said intermediate medium in composition.

6. Cleaning equipment equipped with a plurality of cleaning units cleaning an object to be cleaned with a cleaning liquid, at least one of said plurality of cleaning units being the cleaning apparatus of any of claims 1 – 5

7. A cleaning method comprising the steps of:
- disposing in a cleaning liquid held in a cleaning tank an object to be cleaned; and
- ultrasonically vibrating said cleaning liquid via an intermediate medium in contact with said cleaning tank to clean said object, the step of ultrasonically vibrating including the steps of:
  - ultrasonically vibrating said cleaning liquid with said cleaning liquid and said intermediate medium allowing sonic velocities, respectively, having a first difference; and
  - ultrasonically vibrating said cleaning liquid with said cleaning liquid and said intermediate medium allowing sonic velocities, respectively, having a second difference different from said first difference.

8. The cleaning method according to claim 7, wherein in the step of ultrasonically vibrating, said intermediate medium is modified in temperature to change said first difference to said second difference in sonic velocity between said cleaning liquid and said intermediate medium.

9. The cleaning method according to claim 8, wherein in the step of ultrasonically vibrating, a heating member is used to modify said intermediate medium in temperature to change said first difference to said second difference in sonic velocity between said cleaning liquid and said intermediate medium.

10. The cleaning method according to claim 8, wherein said intermediate medium is degassed water and wherein, in the step of ultrasonically vibrating, a retention time of said degassed water in contact with said cleaning tank is varied to modify said degassed water in temperature to change said first difference to said second difference in sonic velocity between said cleaning liquid and said intermediate medium.

11. The cleaning method according to claim 7, wherein in the step of ultrasonically vibrating, said intermediate medium is modified in composition to change said first difference to said second difference in sonic velocity between said cleaning liquid and said intermediate medium.

12. The cleaning method according to claim 11, wherein the step of ultrasonically vibrating further includes one or more steps of ultrasonically vibrating said cleaning liquid with said cleaning liquid and said intermediate medium allowing sonic velocities, respectively, having a difference different from said first and second differences.

13. A cleaning method comprising the steps of:
- disposing in a first cleaning liquid held in a first cleaning tank an object to be cleaned;
- ultrasonically vibrating said first cleaning liquid via a first intermediate medium in contact with said first cleaning tank to clean said object;
- disposing said object in a second cleaning liquid held in a second cleaning tank; and
- ultrasonically vibrating said second cleaning liquid via a second intermediate medium in contact with said second cleaning tank to clean said object, said first cleaning liquid and said first intermediate medium allowing sonic velocities, respectively, having a first difference, said second cleaning liquid and said second intermediate medium allowing sonic velocities, respectively, having a second difference, said first and second differences being different from each other.

14. The cleaning method according to claim 13, wherein at least one of said first intermediate medium and said second intermediate medium is adjusted in temperature to set said first difference and said second difference differently.

15. The cleaning method according to claim 14, wherein at least one of said first intermediate medium and said second intermediate medium is adjusted in temperature by a heating member.

16. The cleaning method according to claim 14, wherein said first intermediate medium is degassed water and wherein a retention time of said first intermediate medium in contact with said first cleaning tank is modified to set a temperature of said first intermediate medium to be different from that of said second intermediate medium.

17. The cleaning method according to claim 13, wherein said first intermediate medium and said second intermediate medium have mutually different compositions so that a first difference in sonic velocity between said first cleaning liquid and said first intermediate medium and a second difference in sonic velocity between said second cleaning liquid and said second intermediate medium are different from each other.

Claims

1. A cleaning apparatus comprising:
- a cleaning tank having an inclined bottom surface and holding a cleaning liquid for cleaning an object to be cleaned,
- a coupling tank holding an intermediate medium and disposed such that said cleaning tank has said inclined bottom surface in contact with said intermediate medium;
- an ultrasonic wave generation unit provided at said coupling tank and ultrasonically vibrating said cleaning liquid via said intermediate medium; and
- a modification unit modifying a difference in sonic velocity between said cleaning liquid and said intermediate medium.

2. The cleaning apparatus according to claim 1, wherein said modification unit includes a temperature adjustment unit varying said intermediate medium in temperature.

3. The cleaning apparatus according to claim 2, wherein said temperature adjustment unit has a heating member heating said intermediate medium.

4. The cleaning apparatus according to claim 2, wherein said intermediate medium is degassed water and said temperature adjustment unit has a flow rate adjustment unit adjusting an amount of said degassed water supplied to said coupling tank.

5. The cleaning apparatus according to claim 1, wherein said modification unit includes a composition adjustment unit modifying said intermediate medium in composition.

6. Cleaning equipment equipped with a plurality of cleaning units cleaning an object to be cleaned with a cleaning liquid,

at least one of said plurality of cleaning units being the cleaning apparatus of any of claims 1 - 5.

7. A cleaning method comprising the steps of:
- disposing in a cleaning liquid held in a cleaning tank having an inclined bottom surface an object to be cleaned; and
- ultrasonically vibrating said cleaning liquid via an intermediate medium in contact with said inclined bottom surface of said cleaning tank to clean said object, the step of ultrasonically vibrating including the steps of:
  - ultrasonically vibrating said cleaning liquid with said cleaning liquid and said intermediate medium allowing sonic velocities, respectively, having a first difference; and
  - ultrasonically vibrating said cleaning liquid with said cleaning liquid and said intermediate medium allowing sonic velocities, respectively, having a second difference different from said first difference.

8. The cleaning method according to claim 7, wherein in the step of ultrasonically vibrating, said intermediate medium is modified in temperature to change said first difference to said second difference in sonic velocity between said cleaning liquid and said intermediate medium.

9. The cleaning method according to claim 8, wherein in the step of ultrasonically vibrating, a heating member is used to modify said intermediate medium in temperature to change said first difference to said second difference in sonic velocity between said cleaning liquid and said intermediate medium.

10. The cleaning method according to claim 8, wherein: said intermediate medium is degassed water; and in the step of ultrasonically vibrating, a retention time of said degassed

water in contact with said cleaning tank is varied to modify said degassed water in temperature to change said first difference to said second difference in sonic velocity between said cleaning liquid and said intermediate medium.

11. The cleaning method according to claim 7, wherein in the step of ultrasonically vibrating, said intermediate medium is modified in composition to change said first difference to said second difference in sonic velocity between said cleaning liquid and said intermediate medium.

12. The cleaning method according to claim 11, wherein the step of ultrasonically vibrating further includes one or more steps of ultrasonically vibrating said cleaning liquid with said cleaning liquid and said intermediate medium allowing sonic velocities, respectively, having a difference different from said first and second differences.

13. A cleaning method comprising the steps of:
- disposing in a first cleaning liquid held in a first cleaning tank having an inclined bottom surface an object to be cleaned;
- ultrasonically vibrating said first cleaning liquid via a first intermediate medium in contact with said inclined bottom surface of said first cleaning tank to clean said object;
- disposing said object in a second cleaning liquid held in a second cleaning tank having an inclined bottom surface; and
- ultrasonically vibrating said second cleaning liquid via a second intermediate medium in contact with said inclined bottom surface of said second cleaning tank to clean said object, said first cleaning liquid and said first intermediate medium allowing sonic velocities, respectively, having a first difference, said second cleaning liquid and said second intermediate medium allowing sonic velocities, respectively,

having a second difference, said first and second differences being different from each other.

14. The cleaning method according to claim 13, wherein at least one of said first intermediate medium and said second intermediate medium is adjusted in temperature to set said first difference and said second difference differently.

15. The cleaning method according to claim 14, wherein at least one of said first intermediate medium and said second intermediate medium is adjusted in temperature by a heating member.

16. The cleaning method according to claim 14, wherein: said first intermediate medium is degassed water; and a retention time of said first intermediate medium in contact with said first cleaning tank is modified to set a temperature of said first intermediate medium to be different from that of said second intermediate medium.

17. The cleaning method according to claim 13, wherein said first intermediate medium and said second intermediate medium have mutually different compositions so that a first difference in sonic velocity between said first cleaning liquid and said first intermediate medium and a second difference in sonic velocity between said second cleaning liquid and said second intermediate medium are different from each other.