According to the present invention, an apparatus for forming a single-crystalline thin film of a prescribed material on a substrate having a single-crystalline structure comprises irradiation means for irradiating the substrate with gas beams of low energy levels causing no sputtering of the prescribed material from directions which are perpendicular to a plurality of densest crystal planes having different directions in the single-crystalline thin film to be formed, and attitude control means for controlling the attitude of the substrate for setting prescribed relations between directions of crystal axes of the substrate and directions of incidence of the beams.

The apparatus according to the tenth aspect of the present invention comprises attitude control means, whereby it is possible to set prescribed relations between the crystal axes of the single-crystalline substrate and the directions of incidence of the gas beams by employing this apparatus. Thus, it is possible to epitaxially form a new single-crystalline thin film on a single-crystalline substrate at a temperature below the crystallization temperature.

According to the present invention, an apparatus for forming a single-crystalline thin film of a prescribed material on a substrate comprises film forming means for forming an amorphous or polycrystalline thin film of the prescribed material on the substrate by supplying a reaction gas, irradiation means for irradiating the substrate with gas beams of low energy levels causing no sputtering of the prescribed material from directions which are perpendicular to a plurality of densest crystal planes having different directions in the single-crystalline thin film to be formed, and substrate rotating means for rotating the substrate.

The apparatus according to the present invention comprises substrate rotating means, whereby it is possible to facilitate formation of an amorphous or polycrystalline thin film by intermittently applying the beams while regularly supplying the reaction gas and rotating the substrate during application pauses. Thus, it is possible to form an amorphous or polycrystalline thin film having high homogeneity, whereby high homogeneity is also attained in a single-crystalline thin film which is obtained by converting the same.

According to the present invention, an apparatus for forming a single-crystalline thin film of a prescribed material on a substrate comprises film forming means for forming an amorphous or polycrystalline thin film of the prescribed material on the substrate by supplying a reaction gas, and irradiation means for irradiating the substrate with gas beams of low energy levels causing no sputtering of the prescribed material from directions which are perpendicular to a plurality of densest crystal planes having different directions in the single-crystalline thin film to be formed. The film forming means has supply system rotating means for rotating an end portion of a supply path for supplying the substrate with the reaction gas with respect to the substrate.

The apparatus according to the present invention comprises supply system rotating means, whereby it is possible to obtain a single-crystalline thin film having high homogeneity while regularly supplying the reaction gas and applying the beams with no intermittent application of the beams. Namely, it is possible to efficiently form a single-crystalline thin film having high homogeneity.

According to the present invention, an apparatus for forming a single-crystalline thin film of a prescribed material on a substrate comprises a plurality of irradiation means for irradiating the substrate with a plurality of gas beams of low energy levels causing no sputtering of the prescribed material from directions which are perpendicular to a plurality of densest crystal planes having different directions in the single-crystalline thin film to be formed respectively, and control means for independently controlling operating conditions in the plurality of irradiation means respectively.

In the apparatus according to the present invention, control means independently controls operating conditions in irradiation means such as output beam densities, for example, whereby states of a plurality of beams which are applied to the substrate are optimumly controlled. Thus, it is possible to efficiently form a high-quality single-crystalline thin film.

The irradiation means preferably comprises an electron cyclotron resonance type ion source, and the gas beams are supplied by the ion source.

According to the present invention, an apparatus for forming a single-crystalline thin film of a prescribed material on a substrate comprises irradiation means for irradiating the substrate with beams of a gas supplied by an ion source at low energy levels causing no sputtering of the prescribed material from directions which are perpendicular to a plurality of densest crystal planes having different directions in the single-crystalline thin film to be formed, and bias means for applying a bias voltage across the ion source and the substrate in a direction for accelerating ions.

In the apparatus according to the present invention, bias means applies a bias voltage across the ion source and the substrate, whereby the gas beams are improved in directivity. Thus, it is possible to form a high-quality single-crystalline thin film having high homogeneity of the crystal orientation.

According to the present invention, an apparatus for forming a single-crystalline thin film of a prescribed material on a substrate comprises irradiation means for irradiating the substrate with beams of a gas supplied by an ion source at low energy levels causing no sputtering of the prescribed material from directions which are perpendicular to a plurality of densest crystal planes having different directions in the single-crystalline thin film to be formed, with a grid which is provided in the vicinity of an ion outlet of the ion source, and grid voltage applying means for applying a voltage to the grid for controlling conditions for extracting ions from the ion source.

In the apparatus according to the present invention, grid voltage applying means optimumly controls conditions for extracting ions from the ion source, whereby it is possible to efficiently form a high-quality single-crystalline thin film.

In the apparatus according to the present invention, the beam source is preferably an electron cyclotron resonance type ion source.

In the apparatus according to the present invention, the gas beams are supplied by an electron cyclotron resonance type ion source, whereby the ion beams are excellent in directivity while it is possible to obtain strong neutral beams having excellent directivity at positions beyond a prescribed distance from the ion source without employing means for neutralizing ions.

According to the present invention, a beam irradiator for irradiating a target surface of a sample with a gas beam comprises a container for storing the sample, and a beam source for irradiating the target surface of the sample which is set in a prescribed position of the container with the gas beam, and at least a surface of a portion irradiated with the beam is made of a material having threshold energy which is higher than energy of the beam in sputtering by irradiation with the beam among an inner wall of the container and a member which is stored in the container.

At least the surface of the portion irradiated with the beam is made of a material having threshold energy which is higher than energy of the beam in sputtering by the irradiation with the beam among the inner wall of the container and the member stored in the container, whereby no sputtering is caused even if the beam reaches the member. Therefore, consumption of the member by sputtering is suppressed, while contamination of the target sample with the material element forming the member is prevented.

According to the present invention, a beam irradiator for irradiating a target surface of a sample with a gas beam comprises a container for storing the sample, and a beam source for irradiating the target surface of the sample which is set in a prescribed position of the container with the gas beam, and at least a surface of a portion irradiated with the beam is made of a material having threshold energy with respect to sputtering which is higher than that in the target surface of the sample among an inner wall of the container and a member which is stored in the container.

At least the surface of the portion irradiated with the beam is made of a material having threshold energy with respect to sputtering which is higher than that in the target surface of the sample among the inner wall of the container and the member stored in the container, whereby no sputtering is caused in this member when the target surface of the sample is irradiated with the beam causing no sputtering. Therefore, consumption of the member by sputtering is suppressed under such usage, while contamination of the target sample with the material element forming the member is prevented.

According to the present invention, a beam irradiator for irradiating a target surface of a sample with a gas beam comprises a container for storing the sample, and a beam source for irradiating the target surface of the sample which is set in a prescribed position of the container with the gas beam, and at least a surface of a portion irradiated with the beam is made of a material containing an element which is larger in atomic weight than that forming the gas among an inner wall of the container and a member which is stored in the container.

At least the surface of the portion irradiated with the beam is made of a material containing an element which is larger in atomic weight than that forming the beam gas among the inner wall of the container and the member stored in the container, whereby permeation of a different element in the member is suppressed. Therefore, deterioration of the member caused by invasion of the different element is suppressed.

According to the present invention, a beam irradiator for irradiating a target surface of a sample with a gas beam comprises a container for storing the sample, and a beam source for irradiating the target surface of the sample which is set in a prescribed position of the container with the gas beam, and at least a surface of a portion irradiated with the beam is made of the same material as that forming the target surface of the sample among an inner wall of the container and a member which is stored in the container.

At least the surface of the portion irradiated with the beam is made of the same material as that forming the target surface of the sample among the inner wall of the container and the member stored in the container, whereby the target sample is not contaminated with the material element forming the member even if sputtering is caused in this member.

The member stored in the container preferably includes reflecting means which is interposed in a path of the beam for separating the beam into a plurality of components and irradiating the target surface of the sample with the plurality of components from directions which are different from each other.

The reflecting means is stored in the container and at least the surface of the portion irradiated with the beam is made of a material causing no sputtering, the same material as that of the target surface of the sample, or a material containing an element which is larger in atomic weight than that forming the beam gas, whereby contamination of the sample by sputtering of the reflecting means is prevented or deterioration of the reflecting means is suppressed.

The present invention is also directed to a beam irradiating method. According to the present invention, a beam irradiating method of irradiating a target surface of a sample with a gas beam comprises a step of setting the sample in a prescribed position of a container, and a step of irradiating the target surface of the sample which is set in the container with the gas beam, and the target surface is irradiated with the beam at energy which is lower than threshold energy of sputtering in a surface of a portion which is irradiated with the beam among an inner wall of the container and a member stored in the container.

The target surface is irradiated with the beam at energy which is lower than threshold energy of sputtering on the surface of the portion irradiated with the beam among the inner wall of the container and the member stored in the container, whereby no sputtering is caused even if the beam reaches the member. Therefore, consumption of the member by sputtering is suppressed, while contamination of the target sample with the material element forming the member is prevented.

The present invention is also directed to a method of forming single-crystalline thin film. According to the present invention, a method of forming a single-crystalline thin film of a prescribed material on a substrate comprises a step of depositing the prescribed material on the substrate under a low temperature causing no crystallization of the prescribed material and irradiating the prescribed material as deposited with a gas beam of low energy causing no sputtering of the prescribed material from one direction, thereby forming an axially oriented polycrystalline thin film of the material, and a step of irradiating the axially oriented polycrystalline thin film with gas beams of low energy causing no sputtering of the prescribed material under a high temperature below a crystallization temperature of the prescribed material from directions which are perpendicular to a plurality of densest crystal planes of different directions in the single-crystalline thin film, thereby converting the axially oriented polycrystalline thin film to a single-crystalline thin film.

The axially oriented polycrystalline thin film is previously formed on the substrate and thereafter irradiated with the beams from a plurality of directions so that the thin film is converted to a single-crystalline thin film. Therefore, even if the substrate is not uniformly irradiated with the beams from the plurality of directions due to a screen formed on the substrate, for example, at least either a single-crystalline thin film or an axially oriented polycrystalline thin film is formed on any portion on the substrate, whereby no remarkable deterioration of characteristics is caused.

According to the present invention, a method of forming a single-crystalline thin film of a prescribed material on a substrate comprises a step of depositing the prescribed material on the substrate thereby forming a thin film of the material, a step of irradiating the thin film with a gas beam of low energy causing no sputtering of the prescribed material under a high temperature below a crystallization temperature of the prescribed material from one direction after the step, thereby converting the thin film to an axially oriented polycrystalline thin film, and a step of irradiating the axially oriented polycrystalline thin film with gas beams of low energy causing no sputtering of the prescribed material under a high temperature below the crystallization temperature of the prescribed material from directions which are perpendicular to a plurality of densest crystal planes of different directions in the single-crystalline thin film, thereby converting the axially oriented polycrystalline thin film to a single-crystalline thin film.

The axially oriented polycrystalline thin film is previously formed on the substrate and thereafter irradiated with the beams from a plurality of directions, so that the thin film is converted to a single-crystalline thin film. Therefore, even if the substrate is not uniformly irradiated with the beams from the plurality of directions due to a screen formed on the substrate, for example, at least either a single-crystalline thin film or an axially oriented polycrystalline thin film is formed on any portion on the substrate, whereby no remarkable deterioration of characteristics is caused.

The direction of the gas beam in formation of the axially oriented polycrystalline thin film is preferably identical to one of the plurality of directions of the gas beams in the conversion of the axially oriented polycrystalline thin film to the single-crystalline thin film.

The direction of application of the gas beam in formation of the axially oriented polycrystalline thin film is identical to one of the plurality of directions of gas beams for converting the axially oriented polycrystalline thin film to a single-crystalline thin film, whereby conversion to the single-crystalline thin film is smoothly carried out.

The gas is preferably an inert gas.

The beam of an inert gas is so applied that no particularly remarkable influence is exerted on the electrophysical properties of the thin film even if the gas remains in the single-crystalline thin film as formed, while it is possible to easily remove the as-invaded gas from the thin film.

The atomic weight of an element forming the inert gas is preferably lower than the maximum atomic weight among those of elements forming the prescribed material.

The atomic weight of the element forming the inert gas is lower than the maximum atomic weight of elements forming the prescribed material which is grown as the thin film, whereby most part of atoms or ions of the applied inert gas are rearwardly scattered on the surface of the thin film or in the vicinity thereof, to hardly remain in the thin film.

The prescribed material preferably contains an element forming a gas material which is a gas under a normal temperature, and the gas beam is preferably a beam of the gas material.

The gas as applied contains an element forming the material grown as a thin film. Even if atoms or ions of the element remain in the thin film after irradiation, therefore, these will not exert a bad influence on the single-crystalline thin film as impurities.

The gas beam is preferably formed by an electron cyclotron resonance ion source.

The beam generation source is an electron cyclotron resonance ion generation source. Therefore, the ion beam has high directivity, while a strong neutral beam can be obtained at a distance exceeding a prescribed length from the ion generation source without employing means for neutralizing ions. Further, it is possible to employ an electrically insulating substrate without employing means for neutralizing the ions.

According to the present invention, a beam irradiator for irradiating a target surface of a sample with a gas beam comprises a single beam source for supplying the beam, and reflecting means for reflecting the beam which is supplied by the beam source, thereby enabling irradiation of the target surface with the gas in a plurality of prescribed directions of incidence, and the reflecting means comprises a reflector having a plurality of reflecting surfaces for reflecting the beam in a plurality of directions, and a screen which is interposed in a path of the beam between the beam source and the reflecting surfaces for selectively passing the beam thereby preventing multiple reflection by the plurality of reflecting surfaces.

Multiple reflection of the beam by the plurality of reflecting surfaces is prevented by the screen, whereby no beam is applied from a direction other than a prescribed direction of incidence.

The screen preferably further selectively passes the beam to uniformly irradiate the target surface with the beam.

The target surface is uniformly irradiated with the beam by action of the screen. Therefore, a high quality single-crystalline thin film is formed when the apparatus is applied to formation of a single-crystalline thin film, for example.

The present invention is also directed to a beam reflecting device. According to the present invention, a beam reflecting device for reflecting a gas beam which is supplied from a single beam source thereby enabling irradiation of a target surface of a sample with the gas in a plurality of prescribed directions of incidence comprises a reflector having a plurality of reflecting surfaces for reflecting the beam in a plurality of directions, and a screen which is interposed in a path of the beam between the beam source and the reflecting surfaces for selectively passing the beam thereby preventing multiple reflection by the plurality of reflecting surfaces.

Multiple reflection of the beam by the plurality of reflecting surfaces is prevented by the screen, whereby no beam is applied from a direction other than a prescribed direction of incidence.

The screen preferably further selectively passes the beam to uniformly irradiate the target surface with the beam.

The target surface is uniformly irradiated with the beam by action of the screen. Therefore, a high-quality single-crystalline thin film is formed when the apparatus is applied to formation of a single-crystalline thin film, for example.

According to the present invention, a beam irradiator for irradiating a target surface of a sample with a gas beam comprises a single beam source for supplying the beam, and reflecting means for reflecting the beam which is supplied by the beam source, thereby enabling irradiation of the target surface with the gas in a plurality of prescribed directions of incidence, and the reflecting means comprises a first reflector which is arranged in a path of the beam supplied from the beam source for reflecting the beam in a plurality of directions thereby generating a plurality of divergent beams having beam sections which are two-dimensionally enlarged with progress of the beams, and a second reflector having a concave reflecting surface for further reflecting the plurality of divergent beams to be incident upon the target surface substantially as parallel beams from a plurality of directions.

The gas beams applied to the target surface of the sample are obtained by the single beam source and the reflecting means provided in the path, whereby it is possible to irradiate the target surface with gas beams from a plurality of different prescribed directions with no requirement for a plurality of beam sources. Further, the beam is reflected by the first reflector to be two-dimensionally diverged in a plurality of directions and then converted to substantially parallel beams by the second reflector, whereby the beam can be uniformly applied to the target surface which is wider than the section of the beam supplied from the beam source. Therefore, it is possible to widely and efficiently form a single-crystalline thin film of a prescribed material on a wide substrate provided with a thin film of the prescribed material on its surface or a wide substrate having a thin film of the prescribed material being grown on its surface without scanning the substrate, by irradiating the substrate with a gas beam by this apparatus.

The reflecting means preferably further comprises rectifying means which is provided in a path of the beams between the first reflector and the substrate for regularizing directions of the beams.

The rectifying means is arranged in the path of the beam between the first reflector and the sample, whereby the beam can be regulated along a prescribed direction. Therefore, no strict accuracy is required for the shapes and arrangement of the respective reflectors, whereby the apparatus can be easily structured.

The reflecting means preferably further comprises beam distribution adjusting means which is interposed in a path of the beam between the beam source and the first reflector for adjusting distribution of the beam on a section which is perpendicular to the path, thereby adjusting the amounts of respective beam components reflected by the first reflector in the plurality of directions.

The beam distribution adjusting means adjusts the amounts of a plurality of beam components reflected by the first reflector, whereby the amounts of a plurality of beam components which are incident upon the target surface from a plurality of directions can be adjusted. Therefore, the amounts of the respective beam components incident upon the substrate can be optimumly set to be identical to each other, for example, whereby it is possible to efficiently form a high-quality single-crystalline thin film.

According to the present invention, a beam reflecting device for reflecting a gas beam which is supplied from a single beam source thereby enabling irradiation of a target surface of a sample with the gas in a plurality of prescribed directions of incidence comprises a first reflector for reflecting the beam in a plurality of directions thereby generating a plurality of divergent beams having beam sections which are two-dimensionally enlarged with progress of the beams, and a second reflector having a concave reflecting surface for further reflecting the plurality of divergent beams to be incident upon the target surface substantially as parallel beams from a plurality of directions.

The gas beam which is supplied from the single beam source is reflected by the first reflector to be two-dimensionally diverged in a plurality of directions and then converted to substantially parallel beams by the second reflector, whereby it is possible to irradiate the target surface which is wider than the section of the beam supplied from the beam source from a plurality of directions with no requirement for a plurality of beam sources. Therefore, it is possible to widely and efficiently form a single-crystalline thin film of a prescribed material on a wide substrate provided with a thin film of the prescribed material on its surface or a wide substrate having a thin film of the prescribed material being grown on its surface without scanning the substrate, by irradiating the substrate with a gas beam by this apparatus.

According to the present invention, a beam irradiator for irradiating a target surface of a sample with gas beams comprises a plurality of beam sources for supplying the gas beams, and a plurality of reflecting means for reflecting the beams which are supplied by the plurality of beam sources thereby enabling irradiation of a common region of the target surface with the gas in a plurality of prescribed directions of incidence, and each reflecting means comprises a first reflector which is arranged in a path of each beam supplied from each beam source for reflecting the beam thereby generating a beam having a beam section which is two-dimensionally enlarged with progress of the beam, and a second reflector having a concave reflecting surface for further reflecting the divergent beam to be incident upon a linear or strip-shaped common region of the target surface substantially as a parallel beam, while the beam irradiator further comprises moving means for scanning the sample in a direction intersecting with the linear or strip-shaped common region.

The beams are reflected by the first reflector to be substantially one-dimensionally diverged and thereafter converted to substantially parallel beams by the second reflector, whereby it is possible to irradiate a linear or strip-shaped region which is wider than the beams supplied from the beam sources with parallel beams from prescribed directions of incidence. Further, the sample is scanned in a direction intersecting with the linear or strip-shaped region, whereby the beams can be uniformly applied to a wide target surface. In addition, a plurality of beam sources and a plurality of reflecting means are so provided that a wide target surface can be uniformly irradiated with beams from a plurality of directions of incidence.

DOCKET ALARM

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming inter-face) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.