WHAT IS CLAIMED IS:

1. A laser processing method of applying a pulsed laser beam to a single crystal substrate to thereby process the single crystal substrate, the laser processing method comprising:

a numerical aperture setting step of setting a numerical aperture (NA) of a focusing lens for focusing the pulsed laser beam so that a value obtained by dividing the numerical aperture (NA) of the focusing lens by a refractive index (N) of the single crystal substrate falls within the range of 0.05 to 0.2;

a positioning step of relatively positioning the focusing lens and the single crystal substrate in a direction along an optical axis of the focusing lens so that a focal point of the pulsed laser beam is set at a desired position in a direction along the thickness of the single crystal substrate; and

a shield tunnel forming step of applying the pulsed laser beam to the single crystal substrate so as to focus the pulsed laser beam at the focal point set in the single crystal substrate by the positioning step, thereby forming a shield tunnel extending between the focal point and a beam incident surface to which the pulsed laser beam is applied,

the shield tunnel being composed of a fine hole and an amorphous region formed around the fine hole for shielding the fine hole.

2. The laser processing method according to claim 1, wherein the positioning step includes

a step of setting the focal point of the pulsed laser beam inside the single crystal substrate at a position near the other surface opposite to the beam incident surface.

3. The laser processing method according to claim 1, wherein the shield tunnel forming step includes

a step of forming a plurality of shield tunnels along a division line set on the single crystal substrate, each shield tunnel being composed of the fine hole and the amorphous region.

4. The laser processing method according to claim 3, wherein the amorphous regions of any adjacent ones of the plural shield tunnels are connected with each other.

5. The laser processing method according to claim 1, wherein the energy of the pulsed laser beam is set so that the length of the shield tunnel is equal to the thickness of the single crystal substrate.

6. The laser processing method according to claim 1, wherein the correlation between the energy of the pulsed

laser beam and the length of the shield tunnel is produced and the energy of the pulsed laser beam corresponding to the length of the shield tunnel desired to be formed is set according to the correlation.

7. The laser processing method according to claim 6, wherein the energy of the pulsed laser beam is 5 μJ/pulse or more and the correlation is expressed as Y = (3.0 to 4.0 μm/μJ)X + 50 μm, where X and Y denote the energy (μJ/pulse) of the pulsed laser beam and the length (μm) of the shield tunnel, respectively.

8. The laser processing method according to claim 1, wherein the wavelength of the pulsed laser beam is set to a value two or more times the wavelength corresponding to a band gap of the single crystal substrate.

9. The laser processing method according to claim 1, wherein the numerical aperture setting step includes

a step of setting the numerical aperture (NA) of the focusing lens to 0.1 to 0.35 in the case that the single crystal substrate is a sapphire (Al_2O_3) substrate, setting the numerical aperture (NA) of the focusing lens to 0.15 to 0.55 in the case that the single crystal substrate is a silicon carbide (SiC) substrate, or setting the numerical aperture (NA) of the focusing lens to 0.1 to 0.5 in the case

that the single crystal substrate is a gallium nitride (GaN) substrate.

CLAIMS

1. A laser processing method of applying a pulsed laser beam to a single crystal substrate to thereby process the single crystal substrate, the laser processing method comprising:

a numerical aperture setting step of setting a numerical aperture (NA) of a focusing lens for focusing the pulsed laser beam so that a value obtained by dividing the numerical aperture (NA) of the focusing lens by a refractive index (N) of the single crystal substrate falls within the range of 0.05 to 0.2;

a positioning step of relatively positioning the focusing lens and the single crystal substrate in a direction along an optical axis of the focusing lens so that a focal point of the pulsed laser beam is set at a desired position in a direction along the thickness of the single crystal substrate; and

a shield tunnel forming step of applying the pulsed laser beam to the single crystal substrate so as to focus the pulsed laser beam at the focal point set in the single crystal substrate by the positioning step, thereby forming a shield tunnel extending between the focal point and a beam incident surface to which the pulsed laser beam is applied, the shield tunnel being composed of a fine hole and an amorphous region formed around the fine hole for shielding the fine hole.

2. The laser processing method according to claim 1, wherein the positioning step includes a step of setting the focal point of the pulsed laser beam inside the single crystal substrate at a position near the other surface opposite to the beam incident surface.

3. The laser processing method according to claim 1, wherein the shield tunnel forming step includes a step of forming a plurality of shield tunnels along a division line set on the single crystal substrate, each shield tunnel being composed of the fine hole and the amorphous region.

4. The laser processing method according to claim 3, wherein the amorphous regions of any adjacent ones of the plural shield tunnels are connected with each other.

5. The laser processing method according to claim 1, wherein the energy of the pulsed laser beam is set so that the length of the shield tunnel is equal to the thickness of the single crystal substrate.

6. The laser processing method according to claim 1, wherein the correlation between the energy of the pulsed laser beam and the length of the shield tunnel is produced and the energy of the pulsed laser beam corresponding to the length of the shield tunnel desired to be formed is set according to the correlation.

7. The laser processing method according to claim 6, wherein the energy of the pulsed laser beam is 5 μJ/pulse or more and the correlation is expressed as Y=(3.0 to 4.0 μm/μJ)X+ 50 μm, where X and Y denote the energy (μJ/pulse) of the pulsed laser beam and the length (μm) of the shield tunnel, respectively.

8. The laser processing method according to claim 1, wherein the wavelength of the pulsed laser

beam is set to a value two or more times the wavelength corresponding to a band gap of the single crystal substrate.

9. The laser processing method according to claim 1, wherein the numerical aperture setting step includes a step of setting the numerical aperture (NA) of the focusing lens to 0.1 to 0.35 in the case that the single crystal substrate is a sapphire (Al_2SO_3) substrate, setting the numerical aperture (NA) of the focusing lens to 0.15 to 0.55 in the case that the single crystal substrate is a silicon carbide (SiC) substrate, or setting the numerical aperture (NA) of the focusing lens to 0.1 to 0.5 in the case that the single crystal substrate is a gallium nitride (GaN) substrate.