CLAIMS

1. An optical modulator comprising:

a substrate; and

a phase modulation portion on the substrate, the phase modulation portion including an optical waveguide comprised of a first clad layer, a semiconductor layer that is laminated on the first clad layer and has a refraction index higher than the first clad layer and a second clad layer that is laminated on the semiconductor layer and has a refraction index lower than the semiconductor layer, a first traveling wave electrode, and a second traveling wave electrode, wherein the semiconductor layer includes:

a rib that is formed in the optical waveguide in an optical axis direction and is a core of the optical waveguide;

a first slab that is formed in the optical axis direction in one side of the rib;

a second slab that is formed in the optical axis direction in the other side of the rib;

a third slab that is formed in the first slab in the optical axis direction at the opposite side to the rib; and

a fourth slab that is formed in the second slab in the optical axis direction at the opposite side to the rib, wherein

the first slab is formed to be thinner than the rib and the third slab, and

the second slab is formed to be thinner than the rib and the fourth slab,

wherein when a thickness of the rib is indicated at t0, a thickness of the first slab is indicated at t1 and a thickness of the third slab is indicated at t3, a relation of the thicknesses meets an unequal expression of t0 > t3 > t1, and when a thickness of the second slab is indicated at t2 and a thickness of the fourth slab is indicated at t4, a relation of the thicknesses meets an unequal expression of t0 > t4 > t2,

wherein

an end of the third slab at the opposite side to the first slab is a high-concentration p-type semiconductor region and an end of the fourth slab at the opposite side to the second slab is a high-concentration n-type semiconductor region, and

the first slab-side of the third slab, the first slab and the first slab-side of the rib are an intermediate-concentration p-type semiconductor region, and the second slab-side of the fourth slab, the second slab and the second slab-side of the rib are an intermediate-concentration n-type semiconductor region,

wherein

a boundary between the high-concentration p-type semiconductor region and the intermediate-concentration p-type semiconductor region exists in the third slab, and

a boundary between the high-concentration n-type semiconductor region and the intermediate-concentration n-type semiconductor region exists in the fourth slab, and

wherein

a doping concentration of the intermediate-concentration is $10^{17\text{-}18}$ cm^{-3}, and

a doping concentration of the high-concentration is higher than the doping concentration of the intermediate-concentration.

2. The optical modulator according to claim 1,

wherein a relation of the thicknesses further meets an unequal expression of t0/2 > t1 and an unequal expression of t0/2 > t2.

3. The optical modulator according to claim 2,

wherein

the first traveling wave electrode is formed in the optical axis direction on an upper surface of an end in the third slab at the opposite side to the rib, and

the second traveling wave electrode is formed in the optical axis direction on an upper surface of an end in the fourth slab at the opposite side to the rib.

4. The optical modulator according to claim 1, wherein

a junction portion between the intermediate-concentration p-type semiconductor region and the intermediate-concentration n-type semiconductor region has a p-n junction structure.

5. The optical modulator according to claim 1,

wherein a junction portion between the intermediate-concentration p-type semiconductor region and the intermediate-concentration n-type semiconductor region has a p-i-n junction structure in which an i-type semiconductor region not doped is further interposed between the intermediate-concentration p-type semiconductor region and the intermediate-concentration n-type semiconductor region.

6. The optical modulator according to claim 2,

wherein when a width of the first slab is indicated at w1 and a width of the second slab is indicated at w2, a relation of the w1 meets an unequal expression of 60 nm < w1 < 600 nm, and a relation of the w2 meets an unequal expression of 60 nm < w2 < 600 nm.

7. The optical modulator according to claim 1,

wherein in a connecting portion between the phase modulation portion and a rib waveguide formed in the optical modulator, a width in a region of each of the first slab and the second slab of the phase modulation portion is gradually narrower toward the phase modulator.

8. The optical modulator according to claim 1,

the doping concentration of the high-concentration p-type semiconductor region is on the order of 10^{20} cm^{-3},

the doping concentration of the high-concentration n-type semiconductor region is on the order of 10^{20} cm^{-3},

the doping concentration of the intermediate-concentration p-type semiconductor region is on the order of 10^{17} cm^{-3}, and

the doping concentration of the intermediate-concentration n-type semiconductor region is on the order of 10^{17} cm^{-3}.