embedded electrode, would require voltages that risk causing the silica layer to breakdown.

Document EP 0592226 A1 describes an optical frequency conversion device obtained by the periodic juxtaposition of parallel strips of inverted polarisation on a face of a ferroelectric substrate having a spontaneous polarisation perpendicular to the plane of extension of the substrate, i.e., perpendicular to this face. Polarisation inversion by strips is obtained by carrying out a proton exchange through a mask.

Document WO 2005/052682 A1 describes the localised inversion of the polarisation of a ferroelectric crystal with spontaneous polarisation perpendicular to one of its faces, by applying an electric field along juxtaposed periodic strips, by means of gel electrodes placed on this face and the face opposite the crystal.

The structures and methods described above, although they allow the polarisation domains of a ferroelectric layer to be effectively controlled on its surface, remain impractical and do not allow the polarisation to be controlled in the thickness of this layer and its integration on a carrier.

SUMMARY

A first aim of the disclosure is to provide a ferroelectric polarisation layer, optionally in a form that is integrated on a substrate, having polarisation domains with orientations that are opposite and perpendicular or oblique with respect to the plane of this layer, with the domains being distributed in the thickness of the ferroelectric layer, with said ferroelectric layer being able to be used with a view to applications based on bulk acoustic waves, for example. A second aim of the disclosure is a manufacturing method for obtaining the aforementioned integrated ferroelectric layer. A third aim of the disclosure is a method for the local and controlled inversion

of the polarisation of any ferroelectric element in the thickness thereof.

In order to achieve these objectives, a first aspect of the disclosure is a structure comprising a ferroelectric layer having a first polarization in a first volume and a second polarization, opposite the first polarization, in a second volume distinct from the first volume, wherein the first polarisation and the second polarisation are oriented perpendicularly or obliquely to the ferroelectric layer, a surface of the first volume forms a face of the ferroelectric layer and the first volume is interposed between this face of the ferroelectric layer and the second volume, the second volume has a higher hydrogen concentration, called polarity inversion concentration, than the first volume, and the polarity inversion concentration ranges between 10^{19} and 10^{22} hydrogen atoms per cubic centimetre.

An advantage of the structure according to the disclosure is the provision of an integrated structure, including a substrate, on which a ferroelectric layer is attached having a perpendicular or oblique polarisation with respect to the planes of extension of the layer and of the substrate, with this polarisation being modulated in the thickness of the ferroelectric layer. Such a structure facilitates, for example, the integration of bulk acoustic functions while keeping costs low.

According to additional non-limiting features of the first aspect of the disclosure, considered individually or according to any technically feasible combination:

- the structure can further comprise a carrier and a metal layer interposed between this carrier and the ferroelectric layer;

- the ferroelectric layer can be formed by a single-crystal;
- the ferroelectric layer can comprise lithium niobate or lithium tantalate;

- the carrier can comprise single-crystal silicon.

A second aspect of the disclosure relates to a method for manufacturing a ferroelectric element, comprising the steps of providing a ferroelectric element having a first polarisation; enriching a given embedded volume of the ferroelectric element with hydrogen ions by ion implantation of the hydrogen ions through a face of the ferroelectric element, with a first volume of the ferroelectric element being interposed between the given embedded volume and the face of the ferroelectric element; and annealing the ferroelectric element after introducing the hydrogen ions, at a temperature ranging between 500°C and 700°C, so as to switch the first polarisation of the ferroelectric element in the given volume to a second polarisation with an opposite orientation to the first polarisation, with the first volume having the first polarisation after the annealing.

The method according to the disclosure is advantageous in that it is simple, flexible and can be easily integrated into a broader manufacturing method based on known and proven manufacturing techniques from the semiconductor industry. In addition, it allows the polarisation of a ferroelectric element to be controlled in the thickness thereof and is applicable to thin layers integrated on a substrate.

According to additional non-limiting features of the second aspect of the disclosure, considered individually or according to any technically feasible combination:

- the first polarisation can be mono-domain, perpendicular or oblique with respect to a face of the ferroelectric element;
- during the selective enrichment of the hydrogen ions, an implantation dose of hydrogen ions can be adapted so as to obtain a hydrogen concentration ranging between 10^{19} and 10^{22} hydrogen atoms per cubic centimetre;

- the hydrogen ion implantation can be implemented at an energy level ranging between 3 keV and 210 keV;
- the ferroelectric element can be a lithium niobate or lithium tantalate layer;
- the method can further comprise assembling a ferroelectric substrate and a carrier, followed by separating or thinning the ferroelectric substrate so as to define the ferroelectric element; and
- the carrier can be a single-crystal silicon substrate, and a metal layer can be interposed between this single-crystal silicon substrate and the ferroelectric substrate.

BRIEF DESCRIPTION OF THE FIGURES

Further features and advantages of the invention will become apparent from the following detailed description of the invention, with reference to the appended figures, in which:

[Figure 1] Figure 1 shows a ferroelectric element with selectively modified polarisation in the thickness thereof and a corresponding manufacturing method according to the present description;

[Figure 2] Figure 2 shows alternative embodiments of the ferroelectric element of figure 1;

[Figure 3] Figure 3 illustrates a first method for integrating a ferroelectric layer on a carrier;

[Figure 4] Figure 4 illustrates a second method for integrating a ferroelectric layer on a carrier;

[Figure 5] Figure 5 is a schematic cross-sectional view of a device according to the present description;

[Figure 6] Figure 6 is a first variation of the device of figure 5; and

[Figure 7] Figure 7 is a second variation of the device of figure 5.

CLAIMS

1. A structure (Struct) comprising a ferroelectric layer ($Ferro_{lay}$) having a first polarization (P1) in a first volume (V1) and a second polarization (P2), opposite the first polarization, in a second volume (V2) distinct from the first volume, wherein the first polarisation and the second polarisation are oriented perpendicularly or obliquely to the ferroelectric layer, a surface of the first volume (V1) forms a face (Sup) of the ferroelectric layer ($Ferro_{lay}$) and the first volume (V1) is interposed between this face of the ferroelectric layer and the second volume (V2),
wherein the second volume (V2) has a higher hydrogen concentration, called polarity inversion concentration, than the first volume (V1), and
wherein the polarity inversion concentration ranges between 10^{19} and 10^{22} hydrogen atoms per cubic centimetre.

2. The structure according to Claim 1, further comprising a carrier (Sprt) and a metal layer (M1) interposed between this carrier and the ferroelectric layer.

3. The structure according to any one of Claims 1 to 2, wherein the ferroelectric layer is formed by a single-crystal.

4. The structure according to any one of Claims 1 to 3, wherein the ferroelectric layer comprises lithium niobate or lithium tantalate.

5. The structure according to Claim 2, wherein the carrier comprises single-crystal silicon.

6. A method for manufacturing a ferroelectric element (10), comprising the steps of:

- providing a ferroelectric element (10, $Ferro_{lay}$) having a first polarisation (P1);
- enriching a given embedded volume (V2) of the ferroelectric element with hydrogen ions (H^+) by ion implantation of the hydrogen ions (H^+) through a face (Sup) of the ferroelectric element, with a first volume (V1) of the ferroelectric element (10) being interposed between the given embedded volume (V2) and the face (Sup) of the ferroelectric element; and
- annealing the ferroelectric element after introducing the hydrogen ions, at a temperature ranging between 500°C and 700°C, so as to switch the first polarisation (P1) of the ferroelectric element in the given volume (V2) to a second polarisation (P2) with an opposite orientation to the first polarisation (P1), with the first volume (V1) having the first polarisation (P1) after the annealing.

7. The method according to Claim 6, wherein the first polarisation (P1) is mono-domain, perpendicular or oblique with respect to a face (Sup) of the ferroelectric element.

8. The method according to Claim 6 or 7, wherein, during the selective enrichment with hydrogen ions, an implantation dose of hydrogen ions (H^+) is adapted so as to obtain a hydrogen concentration ranging between 10^{19} and 10^{22} hydrogen atoms per cubic centimetre in the given volume (V2).

9. The method according to any one of Claims 6 to 8, wherein the ion implantation of hydrogen ions is implemented at an energy level ranging between 3 keV and 210 keV.

10. The method according to any one of Claims 6 to 9, wherein the ferroelectric element (10, $Ferro_{lay}$) is a lithium niobate or lithium tantalate layer.

11. The method according to any one of Claims 6 to 10, further comprising assembling a ferroelectric substrate ($Ferro_{sub}$) and a carrier (Sprt), followed by separating or thinning the ferroelectric substrate so as to define the ferroelectric element ($Ferro_{lay}$).

12. The method according to Claim 11, wherein the carrier (Sprt) is a single-crystal silicon substrate, and a metal layer (M1) is interposed between this single-crystal silicon substrate and the ferroelectric substrate ($Ferro_{sub}$).