layer. It should be noted that, in such a structure that only comprises electrodes on the sole free face of the crystal, controlling a polarisation that would be perpendicular to the substrate by means of an electric field, in the absence of an 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 effectively allow the polarisation domains of a ferroelectric layer to be controlled, remain impractical and do not allow effective and safe control of a polarisation perpendicular to a face of a ferroelectric crystal, and even less so that of a ferroelectric layer integrated on a carrier.

SUMMARY

A first aim of the disclosure is to provide a ferroelectric layer in a form that is integrated on a substrate, with polarisation having polarisation domains with orientations that are opposite and perpendicular or oblique with respect to the plane of this layer and are able to be used with a view to applications based on non-linear optics or 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 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 zone and a second polarization, opposite the first polarization, in a second zone distinct from the first zone, wherein the first polarisation and the second polarisation are oriented perpendicularly or obliquely to the ferroelectric layer, the second polarisation zone has a higher hydrogen concentration than the first polarisation zone, the structure further comprising a carrier and a dielectric layer interposed between this carrier and the ferroelectric layer.

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 at least two distinct polarisations perpendicular or oblique with respect to the planes of extension of the layer and of the substrate. Such a structure facilitates the integration of non-linear optical or surface 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:

- a hydrogen density in the second zone (V) can range between 10^{19} and 10^{22} atoms/cm^3;
- the first zone and the second zone can define periodic patterns;
- the ferroelectric layer can be formed by a single-crystal;

- the ferroelectric layer can comprise lithium niobate or lithium tantalate;
- the dielectric layer can comprise silicon oxide;
- 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; selectively enriching the ferroelectric element with hydrogen ions through a face of the ferroelectric element; and annealing the ferroelectric element after introducing the hydrogen ions, at a temperature ranging between 400°C and 700°C, so as to switch the polarisation of the ferroelectric layer in a volume defined by the selective introduction of the hydrogen ions.

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 local control of the polarisation of a ferroelectric element for which a single face is accessible and is therefore 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 polarisation can be mono-domain, perpendicular or oblique with respect to a face of the ferroelectric element;
- the selective enrichment of the hydrogen ions can be implemented by ion implantation of the hydrogen ions through a mask defining a region of the ferroelectric element not receiving hydrogen ions;
- the hydrogen ion implantation is at an energy level ranging between 3 keV and 210 keV;

- the selective introduction of the hydrogen ions can be provided by elements intended to form part of a surface acoustic wave device;

CLAIMS

1. A structure (Struct) comprising a ferroelectric layer ($Ferro_{lay}$) having a first polarization (P1) in a first zone and a second polarization (P2), opposite the first polarization, in a second zone (V) distinct from the first zone, wherein the first polarisation and the second polarisation are oriented perpendicularly or obliquely to the ferroelectric layer, the second polarisation zone (V) has a higher hydrogen concentration than the first polarisation zone, the structure further comprising a carrier (Sprt) and a dielectric layer (Diel) interposed between this carrier and the ferroelectric layer.

2. The structure according to Claim 1, wherein a hydrogen density in the second zone (V) ranges between 10^{19} and 10^{22} atoms/cm^3.

3. The structure according to Claim 1 or 2, wherein the first zone and the second zone define periodic patterns.

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

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

6. The structure according to any one of Claims 1 to 5, wherein the dielectric layer comprises silicon oxide.

7. The structure according to any one of Claims 1 to 6, wherein the carrier comprises single-crystal silicon.

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

- providing a ferroelectric element (10, $Ferro_{lay}$) having a first polarisation (P1);

- selectively enriching the ferroelectric element with hydrogen ions (H^+) through a face (Sup) of the ferroelectric element; and

- annealing the ferroelectric element after introducing the hydrogen ions, at a temperature ranging between 400°C and 700°C, so as to switch the polarisation (P1) of the ferroelectric layer in a volume (V) defined by the selective introduction of the hydrogen ions.

9. The method according to Claim 8, wherein the polarisation (P1) is mono-domain, perpendicular or oblique with respect to a face (Sup) of the ferroelectric element.

10. The method according to Claim 8 or 9, wherein selective enrichment of the hydrogen ions is implemented by ion implantation of the hydrogen ions through a mask (M) defining a region of the ferroelectric element not receiving hydrogen ions.

11. The method according to any one of Claims 8 to 10, wherein the ion implantation of hydrogen ions is implemented at an energy level ranging between 3 keV and 210 keV.

12. The method according to any one of Claims 8 to 11, wherein the selective introduction of the hydrogen ions is provided by elements (M/El) intended to form part of a surface acoustic wave device.

13. The method according to any one of Claims 8 to 12, wherein the ferroelectric element (10, $Ferro_{lay}$) is a lithium niobate or lithium tantalate layer.

14. The method according to any one of Claims 8 to 13, 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 ($Ferro_{lay}$).

15. The method according to Claim 14, wherein the carrier (Sprt) is a single-crystal silicon substrate, and a dielectric layer (Diel) comprising silicon oxide is interposed between this single-crystal silicon substrate and the ferroelectric substrate ($Ferro_{sub}$).

16. The method according to any one of Claims 8 to 15, wherein a dose of the selective enrichment of the ferroelectric element with hydrogen ions (H^+) is adapted so as to obtain a hydrogen density ranging between 10^{19} and 10^{22} atoms/cm^3 in said volume (V).