Process for correcting the thickness of a piezoelectric layer

Technical field

The present invention relates to a process for correcting the thickness of a piezoelectric layer, and to a piezoelectric-on-insulator substrate the thickness of which has been corrected using said process. The invention is especially applicable to the fabrication of radio-frequency devices, such as resonators or filters.

Prior art

It is known practice to fabricate a radio-frequency (RF) device, such as a resonator or filter, on a substrate comprising, in succession, from its base to its surface, a carrier substrate, generally made of a semiconductor such as silicon, one or more intermediate layers, and a piezoelectric layer.

The piezoelectric layer is typically obtained by transferring a thick substrate of a piezoelectric material (for example obtained by slicing an ingot) to a carrier substrate, for example using the Smart Cut™ process. The carrier substrate is typically a silicon substrate that optionally comprises one or more layers of one or more other materials.

Transfer of the piezoelectric layer entails bonding the thick piezoelectric substrate to the carrier substrate, followed by thinning the thick piezoelectric substrate so as to leave only a thin piezoelectric layer on the carrier substrate, of the thickness desired for the fabrication of the RF device.

To obtain good adhesion of the piezoelectric substrate to the carrier substrate, a layer of oxide (for example a silicon oxide SiO_2) is generally deposited on each of the two substrates, and said substrates are bonded by way of said oxide layers.

The properties of the piezoelectric layer, such as the electromechanical coupling coefficient, the propagation velocity of acoustic waves and the frequency temperature coefficient depend on the thickness of the piezoelectric layer.

It is known to locally adjust the thickness of the piezoelectric layer by milling with a beam of ions, argon ions for example, that is scanned over the surface of the piezoelectric layer, in order to increase the uniformity of this thickness. This adjustment process is called trimming.

However, since the piezoelectric layer is very thin, irregularities in the thickness of the one or more layers located under the piezoelectric layer may result in substantial variations in these properties.

Summary of the invention

Embodiments of the invention seek to provide a process allowing a uniform distribution of at least one among the following parameters of the piezoelectric layer to be obtained:

electromechanical coupling coefficient, propagation velocity of acoustic waves, and frequency temperature coefficient.

An aspect of the invention provides a process for correcting the thickness of a piezoelectric layer arranged on a piezoelectric-on-insulator substrate, comprising the following steps:

- measuring the thickness of at least one intermediate layer located between the piezoelectric layer and a carrier substrate,
- measuring the thickness of the piezoelectric layer,
- based on said measurements of the thickness of the at least one intermediate layer and of the piezoelectric layer and on a numerical model of at least one property of the piezoelectric layer as a function of a plurality of pairs of thicknesses of the piezoelectric layer and of said at least one intermediate layer, computing a thickness correction for the piezoelectric layer with a view to obtaining a target value for each property,
- applying the thickness correction to the piezoelectric layer using a milling process in a topographically discriminating manner.

Advantageously, said property of the piezoelectric layer is chosen from an electromechanical coupling coefficient, a wave propagation velocity and/or a frequency temperature coefficient.

The one or more properties of the piezoelectric layer may be chosen depending on the application for which the substrate is intended. A single property may be chosen so as to obtain a very uniform distribution of this property over the whole of the substrate, or a compromise between two or three parameters may be chosen such that each parameter is as uniform as possible without generating substantial non-uniformities in the other respective parameters.

Preferably, the thickness of the at least one intermediate layer and of the piezoelectric layer is measured locally at a plurality of measurement points, the process further comprising a step of linear interpolation of the thickness of each layer between at least two measurement points. The grid of measurement points may be chosen depending on the measurement technique and on the desired precision.

Advantageously, the milling process is an ion-beam etching process. The process may comprise a step of scanning the ion beam along two axes of a main plane of the piezoelectric layer, in which step the duration of irradiation by said ion beam in each position is adjusted depending on the thickness of the piezoelectric layer to be obtained.

Advantageously, the intermediate layer comprises a dielectric layer, a stack of a plurality of dielectric layers, a metal layer and/or a layer for trapping electrical charge.

Preferably, the thickness of the piezoelectric layer and/or of the intermediate layer is measured by ellipsometry and/or reflectometry. Use of these techniques allows a plurality of thicknesses of superposed layers to be measured simultaneously.

Another aspect of the invention provides a process for fabricating a piezoelectric-on-insulator substrate, comprising the following steps:

- providing a carrier substrate,
- providing a piezoelectric donor substrate,
- bonding the donor substrate to the carrier substrate, an intermediate layer being arranged at the interface between the donor substrate and the carrier substrate,
- thinning the donor substrate so as to transfer a piezoelectric layer from said donor substrate to the carrier substrate,
- correcting the thickness of said piezoelectric layer using a process such as described above.

Preferably, thinning the donor substrate comprises, before bonding, forming a weakened region so as to delineate a piezoelectric layer to be transferred, and, after bonding, detaching the donor substrate along said weakened region.

In certain embodiments, the thickness of the at least one intermediate layer is measured after the piezoelectric layer has been transferred to the carrier substrate.

In other embodiments, the thickness of the at least one intermediate layer is measured before the donor substrate has been bonded to the carrier substrate. This method also allows the thickness of opaque layers to be measured

Advantageously, the at least one intermediate layer comprises: a metal layer, a dielectric layer, a stack of a plurality of dielectric layers, and/or a layer for trapping electrical charge.

Another aspect of the invention provides a piezoelectric-on-insulator substrate comprising, in succession, a piezoelectric layer, an intermediate layer and a carrier substrate, in which the local thickness of said piezoelectric layer is adjusted depending on the local thickness of the intermediate layer by milling the piezoelectric layer in a topographically discriminating manner based on a numerical model of at least one property of the piezoelectric layer as a function of a plurality of pairs of thicknesses of the piezoelectric layer and of said at least one intermediate layer, according to a process as described above.

Brief description of the figures

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

Figure 1 illustrates a piezoelectric-on-insulator (POI) substrate comprising a base substrate, an intermediate layer and a piezoelectric layer.

Figures 2A to 2E illustrate steps of a process for fabricating a POI substrate comprising an adjustment of the thickness of the piezoelectric layer according to the invention.

Figure 3 illustrates a grid of points of measurement of the thickness of the intermediate layer.

Figure 4 is a map of a POI substrate, showing the thickness of an $LiTaO_3$ layer.