Method for producing a layer structure

The invention relates to a method for producing a layer structure comprising a smoothed interlayer and an overlying layer applied on the interlayer. Layer structures of this type are produced for example as substrates for electronic, optoelectronic and microelectromechanical applications. The layers are for example deposited on a carrier by means of CVD methods or connected to the carrier by means of bonding methods. Representatives of such substrates are for example semiconductor wafers with a plurality of deposited or bonded layers, in particular SOI substrates (silicon on insulator), substrates with a layer of Si_xGe_{1-x} (silicon-germanium) and a layer of strained silicon (strained silicon on bulk) and sSOI substrates (strained silicon on insulator).

The application of the overlying layer to the interlayer constitutes a critical step because it generally necessarily requires the microroughness of the interlayer to be as low as possible. Various methods have been proposed, therefore, in order to meet this requirement. Thus, in accordance with US2005/0104067 an SGOI substrate (SiGe on insulator) is subjected to chemical mechanical polishing prior to the deposition of a layer of strained silicon, in order to achieve the necessary smoothing. In accordance with US2003/0060020, polishing is effected using a magnetorheological fluid (MRF) in order to reduce the microroughness further. What is disadvantageous about these methods is the outlay which they require. US 6,995,077 describes a method which serves especially for smoothing semiconductor wafers composed of monocrystalline silicon prior to the deposition of an epitaxial layer and comprises a treatment of the semiconductor wafer with a mixture of hydrogen and hydrogen chloride.

The object was to present a method of the type mentioned which involves a lower outlay than known methods and is not just suitable for smoothing surfaces composed of monocrystalline silicon prior to epitaxy.

The invention relates to a method for producing a layer structure comprising a smoothed interlayer and an overlying layer applied on the interlayer, wherein the interlayer is treated with a gaseous etchant containing hydrogen fluoride, a material removal being obtained and the interlayer being smoothed.

The method can be applied in particular to layer structures in which an interlayer is to be smoothed which comprises a material contained in a group including monocrystalline silicon, polycrystalline silicon; silicon oxide, silicon-germanium, germanium, silicon carbide, III/V compound semiconductors and II/VI compound semiconductors. It is suitable in particular for smoothing monocrystalline semiconductor wafers composed of silicon on which an epitaxial layer is to be deposited, or for smoothing thin layers composed of monocrystalline silicon which are separated from a donor wafer after an ion implantation and are transferred to a substrate wafer in order to form an SOI wafer, or for smoothing a "cross-hatch" on sSOI substrates prior to the deposition of a layer of strained silicon, for example, or for smoothing interlayers or entire semiconductor wafers composed of polycrystalline silicon, composed of silicon carbide or composed of silicon dioxide prior to bonding. Polycrystalline silicon is etched isotropically, that is to say smoothed independently of the orientation of the crystallites. The roughness of interlayers composed of silicon dioxide which arise as a result of thermal oxidization of silicon is generally lower than that of interlayers composed of silicon dioxide produced by the decomposition of TEOS (tetraethyl orthosilicate). Therefore, the application of the method for smoothing

such interlayers produced on a silicate basis is particularly advantageous.

The interlayer is treated with a gaseous etchant containing hydrogen fluoride in order to obtain the smoothing effect. Interlayers composed of silicon are oxidized beforehand or at the same time in order that the hydrogen fluoride can dissolve and remove the oxide layer with the formation of water. The oxidizing agent, if it is required, is passed to the interlayer before or together with the gaseous etchant. Ozone is particularly preferred as oxidizing agent.

The smoothing treatment of the interlayer preferably takes place in a moist environment, that is to say in the presence of supplied water. By way of example, water is sprayed onto the interlayer before the gaseous etchant is supplied. The oxidizing agent or the gaseous etchant or both can be enriched with water, for example by these substances being passed through water before they reach the interlayer. Instead of pure water, ozone-containing water may also be sprayed onto the interlayer.

The etchant supplied in gaseous form may also contain, besides hydrogen fluoride, one or more further substances, for example nitrogen having the function of carrier gas, water vapor or ozone. It is also possible to add additives, such as isopropanol, which intensify the wetting of the surface of the interlayer. A reactor that is suitable for the smoothing treatment of the interlayer is described in US2004/0020513 A1, for example.

The smoothing treatment of the interlayer is preferably performed at a temperature of 20 to 70°C. A temperature range of 30 to 70°C is particularly preferred because at temperatures below that the smoothing takes place too slowly and at temperatures above that no smoothing

effect arises, rather the roughness of the processed side increases. A temperature in the region of 40°C is optimal.

The smoothing treatment of the interlayer is preferably repeated a number of times, for example 1 to 5 times, particularly preferably 1 to 2 times. It is also expedient to rinse the interlayer with water after each repetition of the smoothing treatment.

As a result of the application of the method, the roughness of the interlayer decreases preferably to less than 5 Å RMS, measured by AFM on a measurement area of 40 x 40 μm^2, particularly preferably to less than 2 Å RMS. The material removal obtained by means of the smoothing treatment of the interlayer amounts to preferably no more than 0.5 µm, particularly preferably 0.1 to 0.2 µm.

After the smoothing treatment, a further layer is applied to the interlayer. This is done for example by deposition, in particular CVD deposition, or bonding.

Example:

A 4 µm thick SiGe layer is deposited epitaxially on a 300 mm silicon substrate, the concentration of germanium being increased from 0 to 20% over the thickness of the layer. The roughness of the layer exhibits an RMS value of 100 Å in the case of AFM measurement with a zone of 40 x 40 μm^2. The epitaxially coated substrate is subsequently smoothed by treatment by means of the method described. For this purpose, it is sprayed with water at 40°C in an etching chamber and subsequently etched by means of HF gas and ozone. After treatment twice with this cycle, the substrate is sprayed with water again and spun dry. In this case, 0.2 µm is removed overall from the SiGe layer. The AFM

measurement with a zone of 40 x 40 μm^2 shows an improvement in the RMS roughness to 3 Å.

Patent Claims:

1. A method for producing a layer structure comprising a smoothed interlayer and an overlying layer applied on the interlayer, wherein the interlayer is treated with a gaseous etchant containing hydrogen fluoride, a material removal being obtained and the interlayer being smoothed.

2. The method as claimed in claim 1, wherein the interlayer is treated at a temperature of 20 to 70°C.

3. The method as claimed in claim 1 or claim 2, wherein the material removal amounts to no more than 0.5 µm.

4. The method as claimed in one of claims 1 to 3, wherein the gaseous etchant contains an oxidizing agent.

5. The method as claimed in one of claims 1 to 4, wherein the gaseous etchant contains isopropanol.

6. The method as claimed in one of claims 1 to 5, wherein the gaseous etchant contains water.

7. The method as claimed in one of claims 1 to 6, wherein the interlayer comprises a material contained in a group including monocrystalline silicon, polycrystalline silicon, silicon oxide, silicon-germanium, germanium, silicon carbide, III-V compound semiconductors and II/VI compound semiconductors.

8. The method as claimed in one of claims 1 to 7, wherein the interlayer is smoothed to a roughness of less than 5 Å RMS.

9. The method as claimed in one of claims 1 to 8, wherein the overlying layer is bonded onto the interlayer.

10. The method as claimed in one of claims 1 to 8, wherein the overlying layer is deposited onto the interlayer.