Transforming a Ion-Cut Silicon Layer from Damage-dense to Defect-free Status *via* Microwave-anneal and Recrystallization

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Hydrogen implantation based layer transfer technique, *i.e.* Ion-Cut [1], or Smart-Cu [2], is developed for two decades to directly peel off a silicon layer from a prime wafer for many emerging applications.

However, a cavity-filled dense damage layer with wider than 100 nm usually generates on the surface of an as-split layer due to the high dose ion implantation. When the body of the desired silicon layer is incorporated in the 100-nm range from the implant concentration peak, the produced cavities in the layer will evolve into stable defect clusters after thermal splitting during Ion-Cut process.

Therefore to achieve a defect-free layer, the as-split thickness needs to include an allowance space adjoining to the cavity-filled dense damage layer for additional thickness thinning through polishing or etching to remove the defects [3].

In the study, we demonstrate an ion-shower implant technique cutting a large-area nanoscale thick layer, pasting it to another substrate and then transforming it to a defect-free crystalline layer by using high temperature recrystallization. We present the potentiality for fabricating a nano-scale monocrystalline silicon membrane at with an approximate square-metre- sized area by using the ion shower (IS) implantation technique [4].

The issue of using plasma based ion shower implantation is co-implant contamination [5]. Hence, the major challenge for recrystallization is the formation of impurity clusters forming in the as-split membrane during the extremely high-dose hydrogen ion implantation (> 5×10^{16} ions/cm^3) without screening ions.

For the purpose of large-area hydrogen-ion implantation, we adopted a ribbon-beam IS implantation system without the components that cause a restriction of the implant area, such as mass selectors, acceleration columns and beam-scanning systems.

We incorporated a material structure, which is schematically illustrated in Figure 1, to fabricate the nanoscale monocrystalline Si layer using hydrogen ion shower implantation. To fabricate 100-nm silicon layer using 60 KeV H_2^+ ion shower implantation, a 150-nm silicon layer was deposited over a 100-nm thermal-oxide-coated 12-inch silicon wafer (herein referred to as a device wafer) prior to H_2^+ ion shower implantation. After hydrogen ion shower implantation and wafer bonding, we irradiated the bonded pairs with 2.45 GHz microwaves at a power of 900 W for 60 minutes until layer splitting occurred.

The deposited silicon layer acts as a sacrificial layer to achieve the desired thickness of the as-split membrane (the implant depth minus the thickness of the sacrificial layer) on the once incident [6] and also as a filtration layer for the selection of the passing ion species subject to atomic mass. Similar to how the deposition silicon layer traps H_3^+ (i.e., the co-implanted hydrogen species from the plasma source), the layer can also block any co-implanted ions with more than two atomic weights.

The absence of co-implanted contamination is a key condition to eliminate the growth of a hetrohomogeneous crystalline structure during recrystallization [7]. The growth rates of recrystallisation are exponentially enhanced by the compressive hydrostatic stresses attributed to impurities present in the layer. The EDS (Energy Dispersive Spectrometer) signal results indicate that the silicon layer was completely free from co-implanted contamination, which was filtered out by the deposited silicon layer; only silicon is present. After recrystallization, a perfect sub-100nm crystal silicon layer is achieved as shown in Figure 2.

Figure

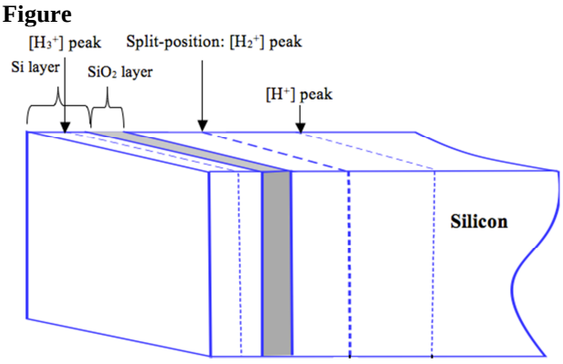

Figure 1: The structure of the processing materials for hydrogen IS implantation.

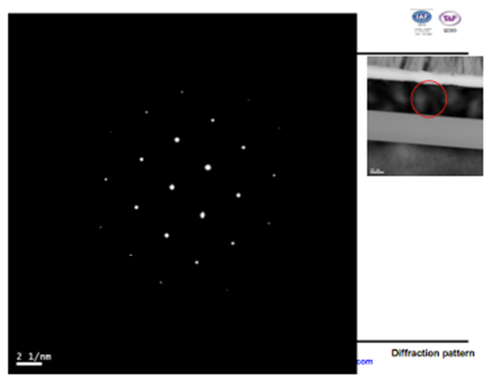

Figure 2: A high-resolution TEM image that illustrates the perfect crystalline nature of the matrix of the transferred Si membrane after recrystallisation at 1050°C.

Reference

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