Electrochemically etched and reorganized porous layer stacks for re-usable silicon growth templates

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Electrochemically etched and thermally reorganized porous layer stacks are one important building block for significant cost and CO_2 footprint reduction of epitaxially grown devices [1, 2]. One main challenge is to realize a smooth and stress-free growth template and a mechanically weak release layer at the same time. The initial electrochemical etching sequence enables complex porous layer stacks by simple changes of current densities. However, the subsequent thermally driven reorganization process is dominated by diffusions of vacancies and Ostwald ripening. Although heating ramps and atmospheres can be adapted the whole layer stack is treated under same conditions which limits the external influence on the final porous structure. An independent optimization of growth template (surface) and release layer (1 – 3 µm into the bulk) is therefore very challenging.

As diffusion of vacancies on inner surfaces is the dominating effect during reorganization of pores, we developed an approach to limit the inter-diffusion between the template region (wafer surface) and the release region (wafer bulk) of the porous layer stacks. This is realized by the introduction of a low porous inter-layer with cavities below 10 nm in diameter and a thickness of only 50-100 nm. This inter-layer should act as a source for vacancies that diffuse towards the layers of higher porosity above and below. Thereby a pore / vacancy depleted zone shall evolve that decouples the reorganization of the release layer and the surface region of the sample.

For the electrochemical etching on 4” Si wafers (p-type, 10 mOhmcm) we used an HF / acetic acid mixture and current densities between 5 and 100 mA/cm^2. Two different layer sequences consisting of a surface layer, a bulk layer and a release layer (total stack thickness of 2 µm) each with or without lowly porous inter-layers were prepared. After electrochemical etching analysis with Secondary Electron Microscopy (SEM) show, that the highly porous structure (release layer) below the inter-layer is not affected by the additional process. The release layer region shows the same thickness (300 – 400 nm) and the same structure (tree shaped). The samples where then reorganized under hydrogen atmosphere for 5 min at 1150°C. SEM cross section analyses proof that the samples with inter-layers lead to cavity sizes in the release area which are significantly larger than the ones without. Second the samples with inter-layer show a clear separation of diffusion between bulk and release area. The inter-layers seem to work as a vacancy source and porosity and/or thickness changes in the release area do not influence any longer the porous structures laying above the inter layer (bulk and surface layer). Aside from that, the surfaces after lift-off show pillar densities below 10 pillars/cm^2 confirming the more advanced reorganization of the release layer. We conclude that the introduction of a 50-100 nm porous inter-layer enables an almost independent development of lift-off and surface development for re-usable epitaxial growth templates.

References

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