Porous Silicon Micromachining Patterned by Hydrogen Ion Implantation

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Abstract

Porous silicon patterned by hydrogen ion implantation has been successfully applied as sacrificial layer for to design silicon micromachined device. Advantages of hydrogen ion implantation as mask technique for selective porous silicon formation are discussed. Preliminary results obtained by mean this technique with test microstructures are examined and evaluated by scanning electron microscopy (SEM).

1. Introduction

Microstructures as freestanding membranes, bridges or beams are the essential mechanical components in sensor and actuator devices [NAV 97].

Traditionally there are two types of micromachining: bulk and surface micromachining. The first one involves anisotropic etching with chemical etchants as KOH or TMAH. However, this technique has the disadvantage that devices are generally relatively large, due to the shape of the sidewalls is determined in most cases by the crystallographic planes of the silicon crystal, and therefore consume most of the chip area.

In the case of surface micromachining, layers deposited on the wafer are used as mechanical structures and the sizes of the devices are considerably reduced. However, physic and technologic parameters as mechanical characteristics, deposition rate and subsequent processing of these layers can limit the thickness of microstructures [FRE 97].

Several techniques [SHA 94 – BAR 95] has been developed to take advantages from the two techniques described before while minimizing the disadvantages, but these techniques involves a large number of process steps, which can increase the cost of the devices.

A simple and cheap technique that can be used for this purpose is the use of porous silicon (PS) as sacrificial layer. PS is a sponge like structure generated by electrochemical etching of silicon in hydrofluoric acid (HF) and generally realized by anodic bias into an etching cell [SPL 01].

However it is necessary to obtain these sacrificial layers on selective areas of monocrystalline silicon substrates. As the patterning of PS areas after its formation is incompatible with other microelectronic processes, then several alternatives for patterning PS before its formation are proposed to block anodization current on silicon surface regions where PS is not desired [DAN 00, KRU 96]

In this work, an alternative mask for this proposed is present by hydrogen ion implantation over p-type silicon substrate, combined with rapid thermal annealing (RTA). Such procedure creates a buried high resistivity layer due to damaging of silicon lattice and electrical neutralization of boron donor sites due to hydrogen ion implanted [GAL 01, PER 97].

Among the advantages of this new mask are emphasized its high resistance to HF solutions, and thick PS layers can be obtained, the possibility to form isotropic PS layers and thin Si membranes (smaller than 1µm) with good uniformity after PS etching.

2. Experimental Procedure

Figure 1 shows the micromachining process applying porous silicon patterned by hydrogen ion implantation.

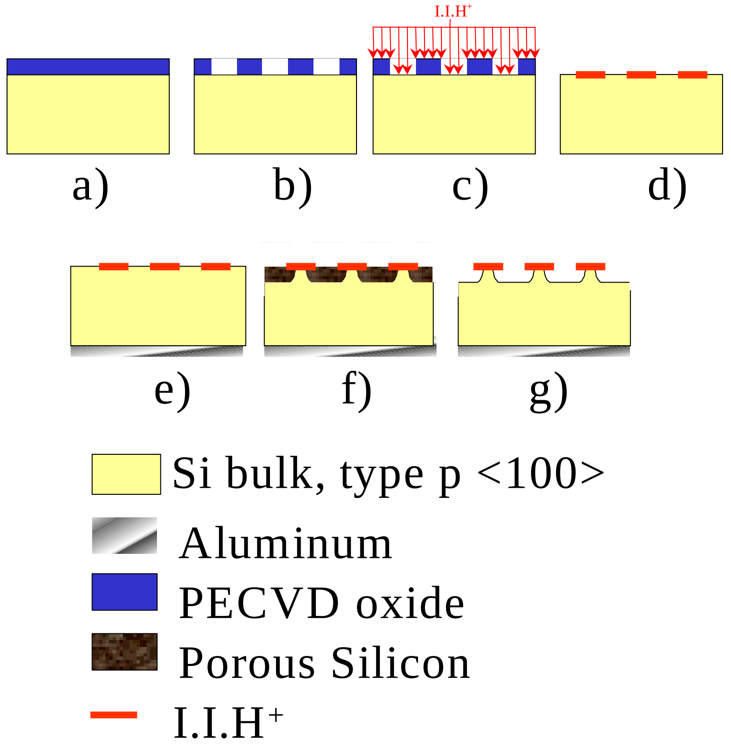

Figure 1 - Micromachining process using porous silicon patterned by hydrogen ion implantation.

The steps shown in figure 1 reply:

(a) Deposition of thickness PECVD (plasma enhanced chemical vapour deposition) oxide as barrier against the I.I.H$^+$;
(b) Definition of regions (by lithography) which are implanted H$^+$;
(c) Hydrogen ion implantation;
(d) PECVD oxide etching;
(e) Al evaporation to form ohmic contact at the backside of silicon bulk and RTA (rapid thermal annealing) to activate the H$^+$ ion on Si as well to form Al/Si alloy;
(f) Selective areas PS formation (anodization process);
(g) PS etching by KOH (1%) for microstructure formation.

3. Results

Applying the hydrogen ion implantation masking, were obtained monocrystalline silicon membranes with thickness less than 1 µm just monitoring process parameters as implantation ion energy or thermal annealing conditions. Figure 2 shows a monocrystalline silicon membrane obtained with hydrogen ion implantation after PS etching with KOH chemical solution.

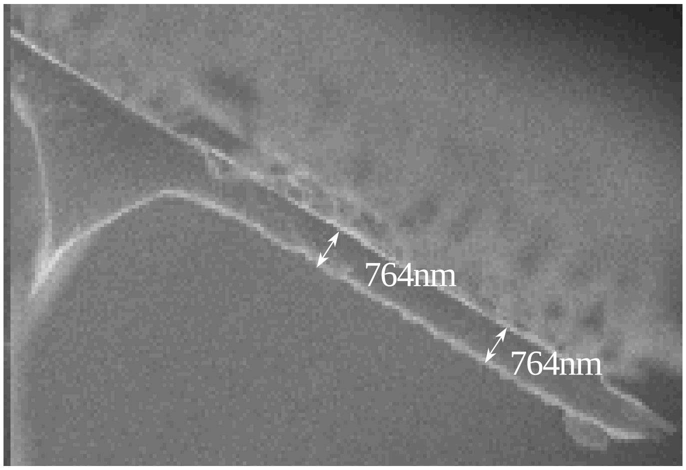

Figure 2 - Cross section (SEM) of one monocrystalline Si membrane (~800 nm) obtained with I.I. H+ mask, after PS etching by KOH solution.

Figure 3 shows a monocrystalline silicon “pedestal” obtained with the same technique described previously.

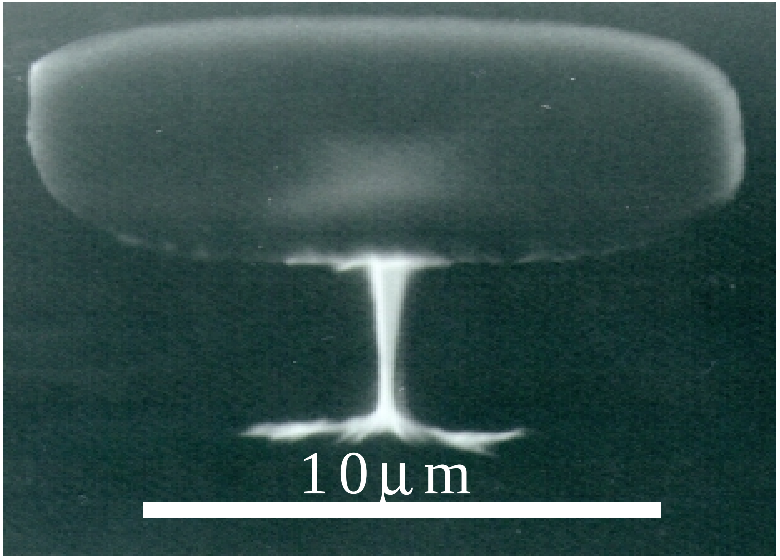

Figure 3 - SEM photographs showing a pedestal of monocrystalline Si after removed PS by KOH. The geometry was defined by I.I.H$^+$ mask.

4. Conclusions

The preliminary results obtained show hydrogen ion implantation masking presents good definition of anodization regions and possibilities to obtain selective, thick and isotropic PS on Si surface. This way, it is a promising procedure to allow new applications for porous silicon integration into microelectronic devices or in the MEMS field.

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