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# A method to determine the pressure and densities of gas stored in blisters: application to H and He sequential ion implantation in silicon

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## Abstract :

H and He sequential ion implantation of silicon followed by annealing leads to the formation of gas pressurized cavities. When close enough to the surface, they elastically deform this surface and generate blisters. Gaining knowledge of the characteristics and thermal behavior of these blisters is mandatory for the optimization of the Smart Cut ™ process. In this paper, we develop the idea and demonstrate that the pressure and the concentrations of the gases inside a blister can be inferred from its actual dimensions and depth location by using simulations based on Finite Element Method (FEM) modelling. We apply this method to initiate a study on the influence of the respective fluences of H and He ions used in a sequential implantation on blistering efficiency.

## Introduction

Hydrogen and Helium sequential implantation in Si followed by wafer bonding and annealing allows for slicing and the transfer of Si layers from a donor substrate to a host material. The Smart Cut™ technology, based on this principle [1], is used to fabricate Silicon-On-Insulator (SOI) substrates, the starting material of many electronic and photovoltaic modern devices [2, 3]. After implantation and during annealing, silicon vacancies and hydrogen atoms precipitate in the form of platelets of nanometer dimensions that progressively grow by Ostwald ripening [4, 5]. When their density is large enough, the platelets further evolves during annealing and finally form highly pressurized micro-cracks [5]. When these micro-cracks are located close enough to the wafer surface, stress relaxation occurs through the formation of blisters elastically deforming the surface [6]. Alternatively, when a stiffener is bonded onto the implanted layer, such relaxations cannot occur and the in-plane stress exerted by these micro-cracks finally leads to the fracture and delamination of the whole layer, the working principle of the Smart Cut ™ process. This is why the optimization of the various parameters which define a particular sequential implantation (order, energies, fluences), in order to minimize the total fluence needed to fracture the implanted layer when bonded to a stiffener, is often undertaken by studying the characteristics of the blisters formed at the free surface of this layer.

One important characteristic of these blisters is the concentration and composition of the gas they contain. Indeed, the efficiency of the process is directly linked to the proportion of the implanted dose which is ultimately stored within them. Unfortunately, up to now, a method to measure these characteristics was lacking. In this paper, we develop the idea that the pressure and the concentrations of the gases inside a blister can be inferred from its actual dimensions and depth at which it is formed with the help of simulations based on Finite Element Method (FEM) modelling. We apply this method to initiate a study and understand the influence of the respective fluences of H and He ions used in a sequential implantation onto the blistering efficiency.

## Samples

(001) Si wafers covered by a 25 nm-thick thermally grown $SiO_2$ layer (wet oxidation at 800°C) were sequentially implanted at room temperature with He at 8 keV (Rp from SIMS not shown at about 100 nm below the surface) then with H at 3 keV (Rp from SIMS not shown at about 60 nm below the surface), so that the He ions were implanted before and deeper than H ions. The H fluence ($\Phi_H$) was fixed at 0.6x $10^{16}$ $cm^{-2}$ while the He fluence ($\Phi_{He}$) was 0.4x $10^{16}$, 0.6x $10^{16}$, 0.9x $10^{16}$ or 1.2x $10^{16}$ $cm^{-2}$, depending on the samples. These samples were then annealed at 550 ° C for 30 min under nitrogen in a conventional furnace.