Hydrogen and Helium implantation to achieve layer transfer

C. Lagahe-Blanchard*, N. Sousbie*[+], S.Sartori*,
H. Moriceau*, A. Soubie*, B.Aspar*, P.Nguyen[+],
B.Blondeau[+]
* CEA / LETI – Département Technologies Silicium – 17, avenue des Martyrs 38054 Grenoble Cedex 9 – France
[+] SOITEC – Parc technologique des Fontaines 38190 Bernin – France

The Smart-Cut® process is nowadays an industrial way to elaborate high quality Silicon On Insulator (SOI) material [1]. Moreover, it enables a large number of material combinations : indeed, different material stacking can be obtained by changing the nature of the thin superficial film, or the nature of one of the buried layers or even the nature of the handling substrate [2].
The Smart-Cut® process is based on ion implantation and wafer bonding [3]. The ion implantation step leads to the formation of an in-depth weakened layer located around the mean ion penetration depth. The transfer of a superficial thin film can then be achieved thanks to the splitting in the weakened layer.
In this paper, we will essentially focus on the splitting step involved in the Smart-Cut® process : H and He ability to induce layer transfer will be discussed.

Few papers have already been published on H/He co-implantation to achieve layer transfer [5-7]. Most of the time, authors chose implantation energies in such a way that penetration depth for both ions will be quite similar. Our methodology have been different : He ions were implanted deeper than H ions (figure 1). That system presents a higher interest for at least one reason : the separation of the two specie profiles is more favourable to study the behaviour of each specie during thermal annealing and also to identify the splitting location compared with the two specie peaks.

In a first investigation, we chose implantation energies at 76keV for H and 145keV for He, the implanted Si wafer being covered by a 400nm thermal oxide. We observed the total implanted dose necessary to induce splitting could be decreased thanks to He and H co-implantation, compared to H or He implantation. The figures 2 and 3 show the (He+H) doses conditions enabling thermal splitting, as a function of the [H/(H+He)] dose ratio, for He implanted first and for H implanted first.
In our co-implantation conditions, we also observed that the species implantation order was influent on the final splitting achievement : it seems to be more favourable to first implant helium then hydrogen. This result contradicts previous observations reported by few authors [5,8]. We believe that could be explained by the implantation conditions and especially to the respective positions of the ions profiles (i.e. ion implantation energy) which are different in the experiments described here and the referred papers.

In a second investigation, we performed kinetics studies to identify the effect of H dose variations (keeping He dose constant) and also the effect of He dose variations (keeping H dose constant). In each case, He ions were implanted first. Activation energies were extracted in few co-implantation conditions. When H (or respectively He) dose was increased, keeping He (or respectively H) dose constant, kinetics curves seem to saturate for [H/(H+He)] dose ratio being less than ~0.3 or larger than ~0.5.

All these results will be more detailed in this paper.

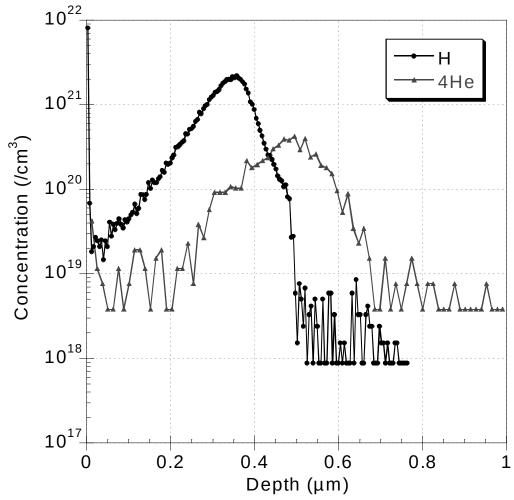

Fig 1 : SIMS profiles for implantation conditions He 145keV-7.5 10^{15}/cm² + H 76keV-3 10^{16}/cm² Superficial 0.4µm thermal oxide was removed before SIMS analysis

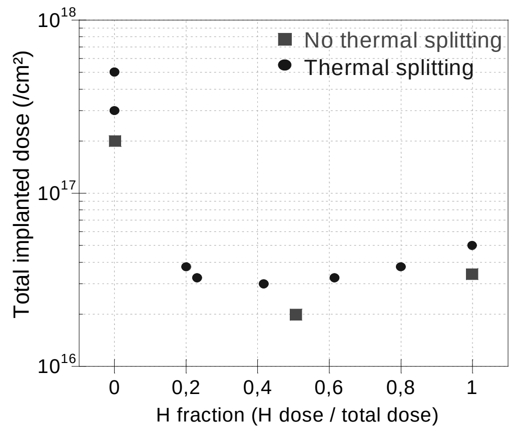

Fig 2 : Total implanted dose (He+H) allowing thermal splitting as a function of H dose fraction ; Implantation conditions: He-145 keV then H-76 keV

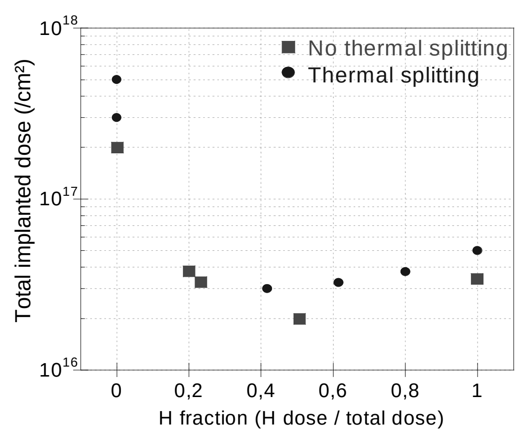

Fig 3 : Total implanted dose (He+H) allowing thermal splitting as a function of H dose fraction ; Implantation conditions : H-76 keV then He-145 keV

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