Mechanical Delamination for the Materials Integration

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Wafer bonding and various layer transfer techniques such as the ion-cutting of Si are becoming important processess in the microelectronics and microsystems industry. The exfoliation of the H-implanted and bonded silicon can be induced by thermal or mechanical means. Mechanical splitting of the implanted and bonded wafer pair can be performed under 300°C, whereas the thermal exfoliation process typically requires annealing at > 300°C [1,2,3]. Wafer bonding research has typically focused to achieve the strongest possible bonds at low temperatures using plasma exposure or other surface activation methods [4]. However, temporary bonded wafer pairs with the intermediate bond strength of 500-1500 mJ/m^2 would be desirable in some applications. This type of bonding would permit the mechanical delamination and transfer of processed thin layers to another substrate. The mechanical delamination of the bonded wafer pair could be performed near room temperature without generating excessive stresses due to the difference in thermal expansion coefficient. In principle, the delamination of the processed and temporary bonded layers would pave the way to the fabrication of integrated materials and 3D-devices. The objective of this work was to study the mechanical exfoliation process in hydrogen implanted Si and to survey the possibility of transferring thin layers of Si onto another substrate using the controlled wafer bonding and the mechanical delamination methods.

Chochralski grown 100 mm <100> oriented p-type silicon wafers with a resistivity of 1-35 ohmcm were used to investigate the mechanical exfoliation process in hydrogen implanted Si. The donor Si wafers were implanted with H_2 at 50-100 keV using various implantation doses. After implantation the donor wafers were bonded to the handle Si wafers. The annealing of the implanted and bonded wafer pair was carried out at 100-500°C. The energy required for the delamination of the implanted layer was measured by the crack opening method.

Figure 1 shows the surface energy of the bonded interface and the H-implanted layer. The wafers were exposed to plasma prior to the bonding. It appears that as the bonded wafer pair is subjected to mechanical splitting forces the delamination occurs through the weakest interface. The key to the mechanical layer transfer is good control of the bond strength. The bond strength can be limited to 1500 mJ/m^2 at temperatures under 1050°C by using suitable bonding procedures, whereas a surface energy of about 2500 mJ/m^2 can be achieved at around 200°C with well-adjusted processes. We will present results on the controlled wafer bonding and subsequent de-bonding procedure for various materials and bonding processes.

In conclusion, we have studied the mechanical transfer process of ion implanted Si and the mechanical delamination technique. We suggest that controlled wafer bonding in combination with the delamination techniques could enable the fabrication of multilayer substrates and 3D-structures.

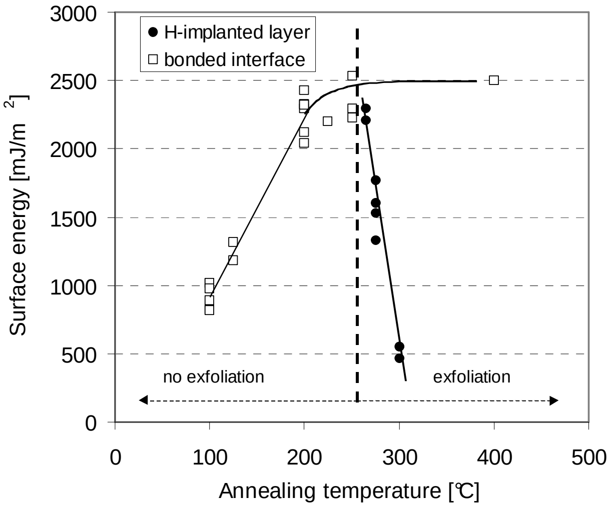

Figure 1. The evolution of the strength of the H-implanted layer and the bonded interface. The donor Si wafers were implanted with H_2 at 100 keV with a dose of 4.5 x 10^{16} H_2/cm^2 prior to the plasma assisted bonding. The annealing time was 2 hours.

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