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The electrical activity of as-grown and intentionally decorated misfit dislocations in an epitaxial Si/Si(Ge) heterostructure was examined using the electron beam induced current (EBIC) technique in a scanning electron microscope. Misfit dislocations, which were not visible initially, were subsequently activated either by an unknown processing contaminant or a backside metallic impurity. Passivation of these contaminated dislocations was then studied using low energy deuterium ion implantation in a Kaufman ion source. EBIC results show that the recombination activity of the decorated misfit dislocations was dramatically reduced by the deuterium treatment. Although a front side passivation treatment was more effective than a backside treatment, a surface ion bombardment damage problem is still evident.

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EBIC Contrast of Clean, Decorated and Deuterium Passivated Si(Ge) Epitaxial Misfit Dislocations

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INTRODUCTION

Charaterization of structural defects and impurities is a topic of great concern in optimizing semiconductor devices since they usually act as recombination centers, reducing the minority carrier lifetime[1,2], a parameter central to device electrical performance. However, it has been shown that hydrogen can electrically passivate defects such as grain boundaries in EFG or web solar cell materials[3,4], which also usually contain a relatively high concentration of undesirable impurities. In this study, epitaxial Si(Ge) samples containing misfit dislocations were used for extrinsic gettering of metallic impurities (as lifetime killers) and deuterium (for passivation). The impact of both kinds of impurities, i.e. degrading or passivating, on the electrical properties of the sample was examined using the electron beam induced current (EBIC) technique in a scanning electron microscope.

EXPERIMENTAL

The samples used in this study were n-type (100) hetero epitaxial CVD silicon grown at 1120°C containing a 2 μm buried Si(Ge) alloy layer and a 3 to 5 μm capping silicon layer. The lattice misfit dislocation networks were generated at two interfacial planes. Metallic impurities were introduced either during device processing or by intentionally diffusing from a backside deposition of metal during a rapid thermal annealing process (RTA). A 500Å copper film was thermally evaporated on the backside of the sample, followed by 30 seconds RTA at 1000°C. Deuterium treatment was carried out in a Kaufman ion beam source. The samples were subjected to a 1 keV ion beam with beam current density of 1.0 mA/cm^2 from either the front side or backside for 20 mins, as shown in Fig. 1. A 300Å thick Au Schottky diode was subsequently fabricated for the EBIC measurements.

RESULTS

Figure 2a shows the EBIC image of an as-grown sample. Notice that no EBIC contrast was obtained for the misfit dislocations, which are believed to be clean. However, the misfit dislocations were found to be active following wet oxidation in a conventional furnace at 1050°C for 2 hours, see Fig. 2b. The oxide layer was etched off before the Schottky diode fabrication. The dislocations were contaminated with unknown residual processing impurities which form micro-precipitates along the dislocations. Different contrast levels are obtained for dislocations at the upper or lower interfacial planes due to the different distances from the top surface. Figure 2c shows the EBIC image of the same sample after a backside deuterium treatment. We can see that the dislocation contrast at the lower interface is greatly reduced while one dislocation at the upper interface is still very active. This can be explained if the decorated defects at the lower interface trap most of deuterium as it diffuses from the implanted backside.

Cu is a well known fast diffuser in silicon and copper precipitate clusters have been found by TEM at misfit dislocations. An EBIC image of copper decorated misfit dislocations is shown in Fig. 3a illustrating a large increase in electrical activity of dislocation due to impurity decoration. Note also the greatly enhanced contrast at the nodes of intersecting misfit dislocation, which is attributed to a localization of copper silicide precipitate formation. Also in Fig. 3b and c, the EBIC images of the same sample are shown after a deuterium passivation from the backside and front side, respectively. For the backside treated sample, recombination along the lower set of misfit dislocations was reduced following the passivation and only the second phase precipitates remain active at the nodes. For the more heavily deuterated front side treated sample in Fig. 3c, recombination only occurs at the stronger node precipitate recombination centers. Evidence indicating surface damage by the energetic ions[5] and a resulting unstable Schottky diode are encountered for the front side treatment.

SUMMARY

In conclusion, we have show that clean dislocations have no or very low electrical activity until they are contaminated by either an unknown processing residual impurity in a furnace or by deliberate introduction of a metal. Deuterium treatment shows a passivation effect for the impurity-defect complexes.

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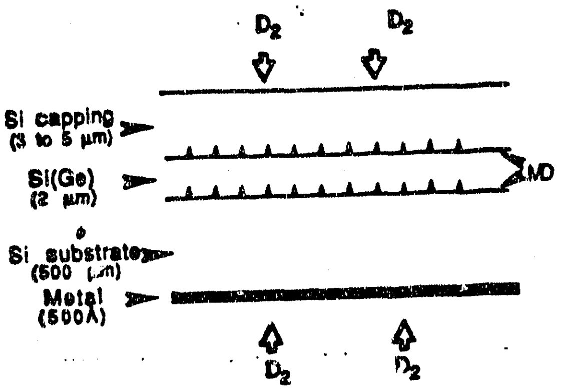

Fig.1 Schematic diagram illustrating the Si capping layer, two misfit dislocation (MD) interfaces, and the backside introduction of impurities and deuterium treatment.

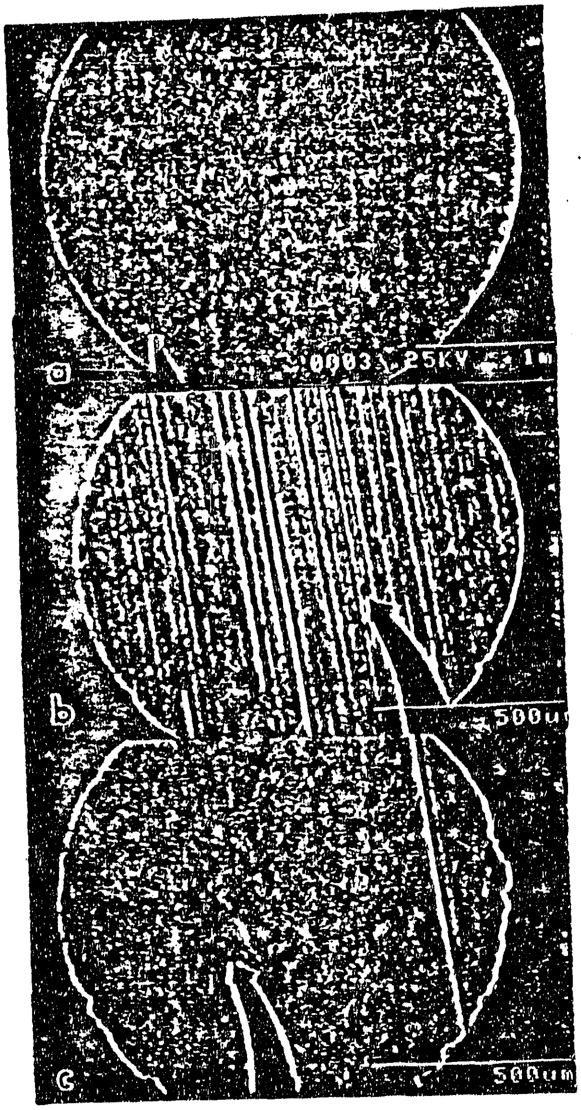

Fig.2 EBIC images of a) as-grown sample, b) oxidation process contaminated dislocations (at 1050°C for 2 hrs.), and c passivated dislocations following a backside deuterium treatment

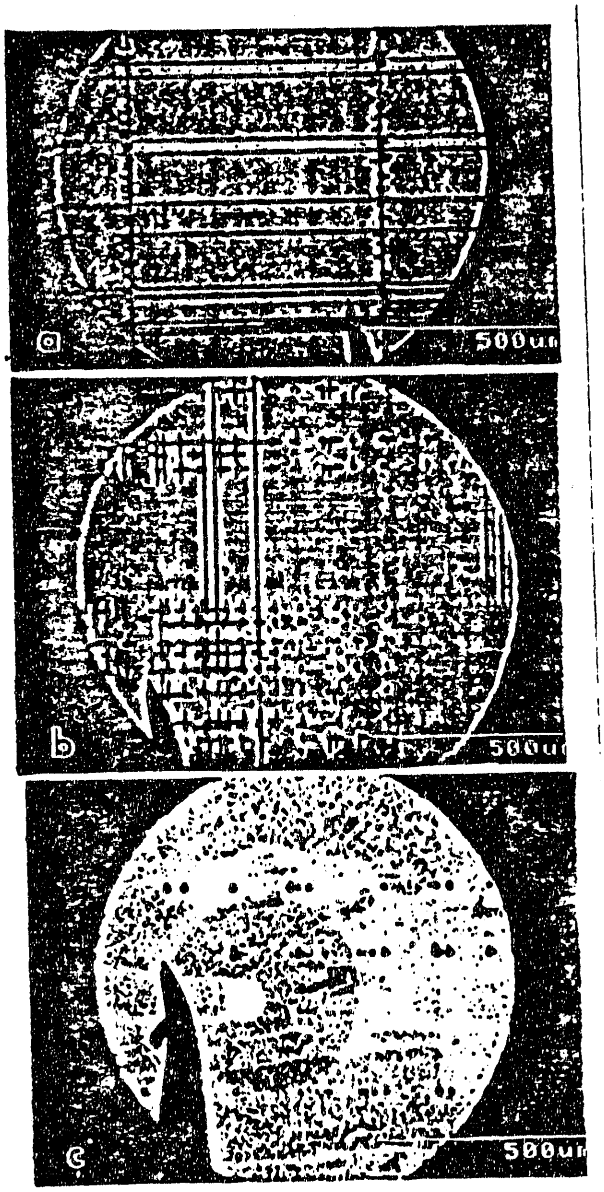

Fig.3 EBIC images of a) Cu-decorated misfit dislocations, b) a backside deuterium treatment of sample in a, and c) a front side deuterium treatment of sample in a.

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