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P1-20

Effect of Hydrogen on Helium implant-induced Nanocavities

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1. Introduction

The implantation of helium into crystalline silicon above a certain minimum dose, followed by annealing, leads to the formation of nanocavities within the silicon wafer [1]. These cavities are located at a depth corresponding to that of the vacancy peak created by the implant. Such cavities have attracted research interest over the past few years due to their potential applications [2]. Significant research has been carried out on understanding the mechanism behind the formation of these nanocavities. A detailed review regarding this mechanism is given in ref. [3].

In parallel, there has been extensive work in the past few decades on the effects of hydrogen in silicon, due to the multitude of hydrogen-related phenomena associated with crystalline defects in silicon. While the behaviors of hydrogen in silicon and helium in silicon have both been studied independently, relatively less work has been carried out on simultaneous presence of hydrogen and helium in silicon.

In this work, we attempt to study the effect of atomic hydrogen, introduced via an ECR hydrogen plasma, on the formation and morphology of the helium nanocavities. The processing sequence is varied to elucidate the mechanism by which hydrogen modifies cavity size.

2. Experimental

Pieces of p-type wafers were cleaned by immersion in Buffered Oxide Etch. Some of these wafer pieces were hydrogenated by exposure to an ECR hydrogen plasma at 250 ^{o}C. This causes atomic hydrogen to penetrate in significant concentrations into the silicon. One of the hydrogenated wafer pieces was annealed at 400 ^{o}C, and another was annealed at 650 ^{o}C for 60 seconds. These wafer pieces and other unhydrogenated wafer pieces were implanted with hydrogen at 160 keV. Following implantation, one wafer piece was hydrogenated. Then, each wafer piece was annealed in a nitrogen ambient for 1 hour at 800 ^{o}C. Table 1 summarized the processing sequence for all the wafers. After annealing, the samples were characterized with Transmission Electron Microscopy (TEM) to evaluate cavity size and morphology.

Table 1. Sample processing steps. All He implants are done at 160 keV energy and 5e16/cm^{2} dose.

	Processing steps				
A		He impl.		Anneal 800 ^{o}C	TEM
B		He impl.	Hyd	Anneal 800 ^{o}C	TEM
C	Hydr.	He impl.		Anneal 800 ^{o}C	TEM
D	Hydr. Anneal 400 ^{0}C	He impl.		Anneal 800 ^{o}C	TEM
E	Hydr. Anneal 650 ^{0}C	He impl.		Anneal 800 ^{o}C	TEM

3. Results and discussion

Figure 1 shows the TEM micrographs from sample A, which is the control sample. Figure 2 shows the TEM micrograph from sample B. On comparing the two, it is obvious that average cavity size is greater in sample B, i.e. the sample where hydrogenation was carried out after the helium implant.

Figures 3, 4 and 5 show the TEM micrographs from the samples where hydrogenation was carried out prior to helium implantation. Although a higher cavity density is visibly evident, the cavity size does not seem to have increased.

An earlier work involving the co-implantation of hydrogen and helium [4] demonstrated that doing this has a synergistic effect.

We postulated that when hydrogenation was carried out after implantation, more hydrogen was preferentially absorbed in the damaged region at the dangling bonds. This led to a higher hydrogen gas pressure during the formation of the cavities, thereby producing cavities with greater size. In the samples where the hydrogenation was carried out before the helium implant, the hydrogen did not preferentially accumulate near the damaged region but aided the nucleation of cavities by enabling more vacancy clusters to reach critical size.

We will present further data on samples implanted at 40 keV to show the effect of implant proximity to the surface

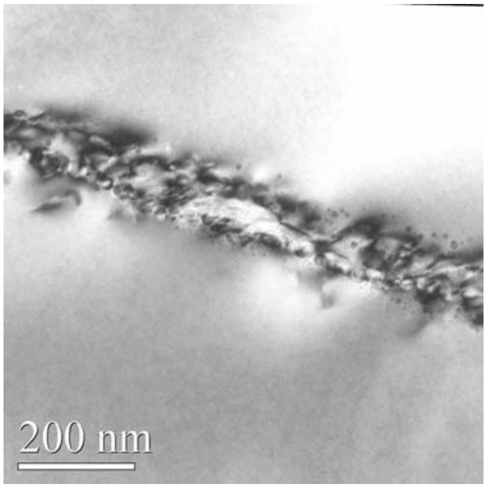

Fig. 1. TEM micrograph of sample A.

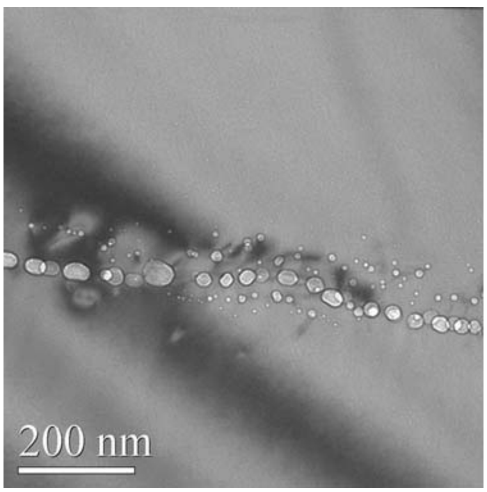

Fig. 2. TEM micrograph of sample B

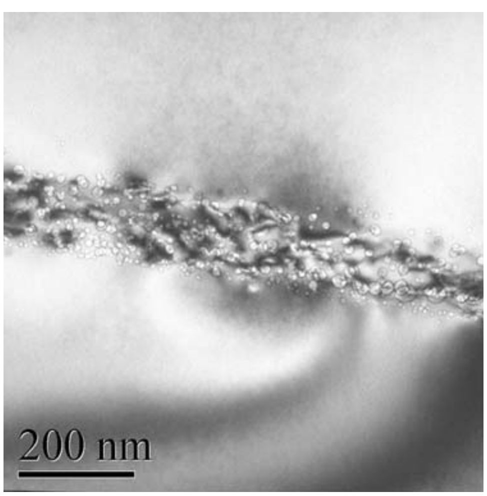

Fig. 3. TEM micrograph of sample C

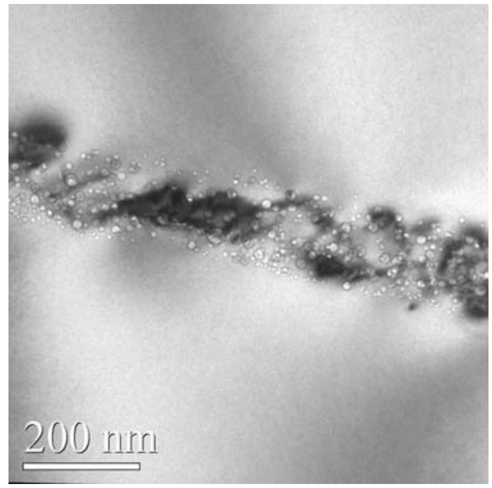

Fig. 4. TEM micrograph of sample D.

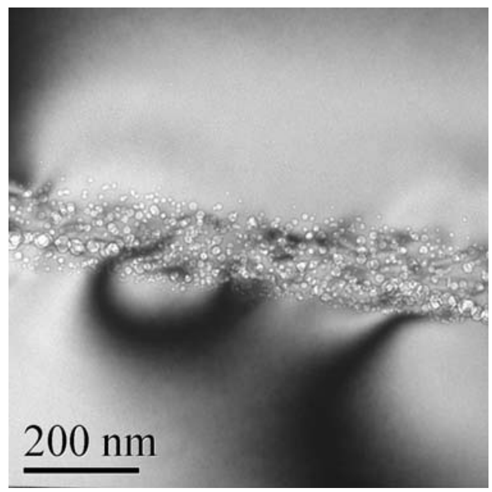

Fig. 5. TEM micrograph of sample E.

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