Plasma Hydrogenation of a Buried Trap Layer in Silicon: Formation of a Platelet Layer

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ABSTRACT

We observe hydrogen platelets buildup into single crystalline silicon caused by RF plasma processing. The platelets are aligned along a layer of lattice defects formed in silicon before the plasma processing. The buried defect layer is formed by silicon-into-silicon implantation. We analyze the platelet shape and size, and discuss applicability of the plasma hydrogenation to Smart-Cut-like process.

INTRODUCTION

Smart-cut is a process [1] that allows manufacturing silicon-on-insulator high quality (SOI) wafers in big quantities that was not possible before with previous SOI processes as SIMOX. However, the Smart-Cut is still expensive because it requires hydrogen implantation in high dose $5x10^{16}$ cm^{-2} and that dose should be achieved at very low ion beam current (less then 0.1 mA) [2]. Many attempts are known to reduce the dose. Most of the attemps use double-specie implantation, like helium-then-hydrogen. A good review of the attempts can be found in [3], proving that the total dose required can be reduced to $2x10^{16}$ cm^{-2} in best case. More elegant solution how to reduce the total cost for the Smart-cut like process suggested in [4]. Here we are continuing that approach while using plasma for hydrogenation.

EXPERIMENTAL

Crystalline silicon samples, variously doped, <100> orientation, were implanted with silicon at 180 keV, $1x10^{15}$ cm^{-2}. Then the as-implanted samples were processed with RF hydrogen plasma during several hours with 300 W RF power, 1 mTorr hydrogen pressure. The samples were kept at room temperature during first hour, and than the sample temperature were increased to 300^{o}C. The wafer surfaces were analyzed with atomic force microscope and with infrared spectroscopy. Layer transfer experiments were also performed.

RESULTS:

Figs.1, 2 show surface of a wafer processed with the self-implantation+hydrogenation. The surface is covered with features with lateral dimensions about 0.2 micron and vertical dimension about 5 nanometers. Infrared mesurements show high hydrogen peak. Additional layer transfer experiments show successful layer transfer even for much shorter plasma processing time than needed to develop the surface relief Fig.1, 2.

DISCUSSION:

Hydrogen in atomic form is known for its high diffusivity in silicon and its ability to combine with many types of defects in crystalline silicon. It is known since 1987 that plasma hydrogenation of regular single crystalline silicon results in formation of hydrogen platelets [4,5]. Because of lack of defects in silicon bulk and low hydrogen solubility in silicon, the platelets in [4,5] are found in near-surface defect-rich regions only. To control the process of hydrogen platelet distribution in silicon, an additional step of forming of defect-rich layer is needed. To accumulate the hydrogen in the desired part of the wafer we need to pre-form defects that readily interact with hydrogen. Silicon-into-silicon implantation allows forming a dense defect layer at desired depth under the surface.

The RF plasma causes a platelet nucleation and growth along a layer at a depth of about ½Rp of the defect-inducing implant. Room temperature step the plasma process is for nucleation, and 300C step for fast growth, similar as in [4,5]. As compared to surface relief obserfed of surface of heavy hydrogen implanted wafers [2,3], the features Fig.1,2 have about 10X smaller lateral and 100X smaller vertical dimensions.

CONCLUSION

Plasma hydrogenation can be used to develop a process of manufacturing of silicon-on-insulator wafers featuring lower cost and thinner top silicon layer.

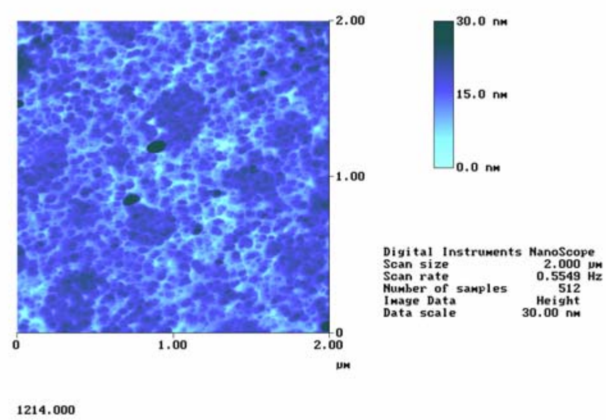

Fig.1. Surface relief developed on self-implanted silicon wafer after plasma hydrogenation, 2 micrometer scale.

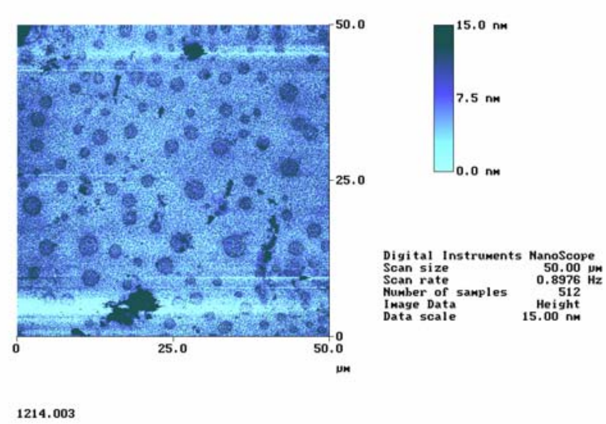

Fig.2. Surface relief developed on self-implanted silicon wafer after plasma hydrogenation, 50 micrometer scale.

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