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UV-Raman Spectroscopy System for Local and Global Strain Measurement in Si

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Abstract

We developed a new UV-Raman spectroscopy system for local and global strain measurement in Si. By using 364 nm excitation laser and newly developed *in-situ* wavenumber calibration system, energy resolution of 0.1 cm^{-1} and spatial resolution of 0.5 μm were achieved. Strain mapping and relaxation by RTA process in strained-Si substrates were demonstrated.

Introduction

Recently, strain management in Si is a very important technology to realize high performance LSI, because both electron and hole mobility can be modified by introducing strain in a channel region of MOSFET. Two types of techniques are proposed for strain introduction. One is so-call local strain in which strain is introduced only in a desired region during LSI fabrication process. Another is global strain which means using a wafer with strained-Si film as a starting material. Such strained-Si wafer is typically realized settling relaxed SiGe underneath the thin Si film (EPI). There are also some SOI techniques proposed combined with strained-Si, called SGOI (SiGe on insulator) and SSOI (Strained-Si on insulator).

In all cases, the most important factors are absolute value and uniformity of strain in the thin Si layer before and after LSI fabrication process. Raman spectroscopy is one of the most reliable techniques to measure strain without sample destruction. Therefore, we developed new UV-Raman spectroscopy system and demonstrated the strain mapping in 200 mm strained-Si substrates.

UV-Raman spectroscopy system

The UV-Ranan spectroscopy system diveleped in this study is schematically illustrated in Fig. 1. We have already reported the usefulness of UV-Raman for strain evaluation in thin Si layer [1,2]. The penetration depth of the UV laser is appropriate for the evaluation of the thin channel layer less than 10 nm. Moreover, the resonant effect using 364 nm excitation laser is very attractive, because strong Raman signal can be obtained without sample damage. A 300 mm wafer can be sustained with the sample stage and covered by mapping measurement. Mapping for strain (Raman peak shift) and crystal quality (Raman peak width) with the maximum measurement points of 30000 can be obtained automatically. The measurement time for 300 points was approximately 30 minuets. Spatial resolution was 0.5μm with 90x objective lens, which is very close to the theoretical limitation using 364 nm excitation laser.

We also improved the precision of the measurement by *in-situ* calibration of the wavenumber using Rayleigh scattering as a standard. It may be also possible to calibrate the optics using Hg lamp. However, slight difference of light pass and angle between calibration lamp and Raman signal may provide some degradation in repeatability. Rayleigh scattering can be a precise marker. However, it has been difficult to obtain both Reyleigh scattering and Raman signal simultaneously with keeping a high wavenumber resolution due to the limitation of the number of pixel in CCD detector. We therefore, separate the concave mirror (dual focusing mirror) in the spectrometer into two parts. One is for Reyleigh scattering and the other is for Raman signal, and successfully obtained both signal with the same CCD detector simultaneously with keeping high resolution. (Fig. 2). Finally, we obtained energy resolution of 0.1 cm^{-1}. The specification for the Raman system is summarized in Table 1.

Measurement

Figure 3 shows Raman peak shift mapping of SSOI substrate. It can be pointed out that the strain variation was observed even in such small area.

Figure 4 shows Raman spectra obtained from SSOI, SGOI, and EPI before and after RTA at 1050^{o}C for 1, 3, and 5 minutes. Slight peak shift toward larger wavenumber was observed in SSOI after RTA, implying strain relaxation. However, peak shift toward lower wavenumber clearly appeared in EPI. This can be explained by the Ge diffusion occurring rather than strain relaxation.. The characteristics of the peak shift

for SGOI was complicated. This might be some kind of complex what happened on SSOI and EPI.

We believe this newly developed Raman spectroscopy system can be a powerful tool to evaluate both global and local strain.

References

[1] S. Nakashima *et. al.*, Appl. Phys. Lett., **84**, 2533 (2004).

[2] A. Ogura *et. al.*, Extended Abstract of the 4th International Symposium on Advancesd Science and Technology of Silicon Materials.

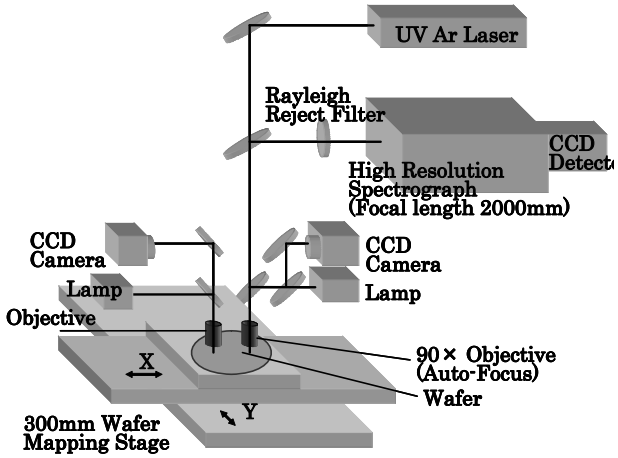

Fig.1 Schematic illustration of UV-Raman apparatus.

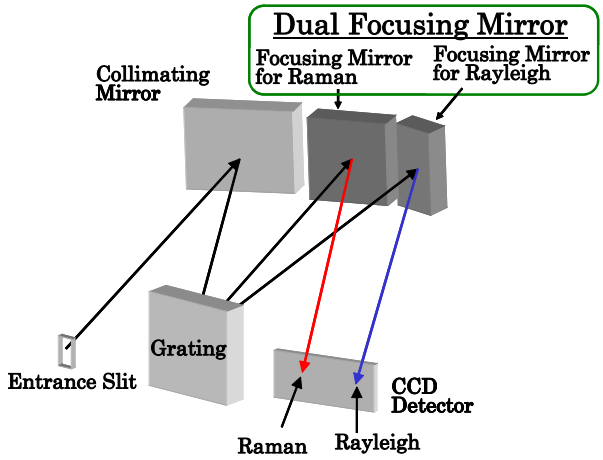

Fig. 2 Novel monocrometer using dual focusing mirror for Raman and Rayleigh sigan

Table 1 Specification of Raman spectroscopy system

Microscope Spatial Resolution	0.5 μm
Mapping stage scan area	300x400mm
Mapping stage minimum scan step	0.1 μm/step
Spectrograph focal length	2000mm
CCD pixel size	13.5 μm
Spectral range	450–550cm^{-1}
Spectral resolution	0.1cm^{-1}/pixel
Max. mapping points	30,000 points
Mapping speed	30minutes (@300mm,300points,CCD shutter time 5secs)

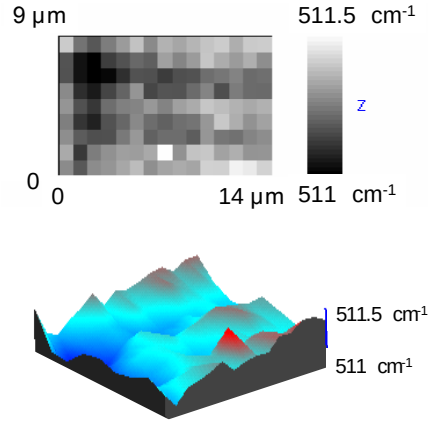

Fig.3 Strain mapping in SSOI substrate.

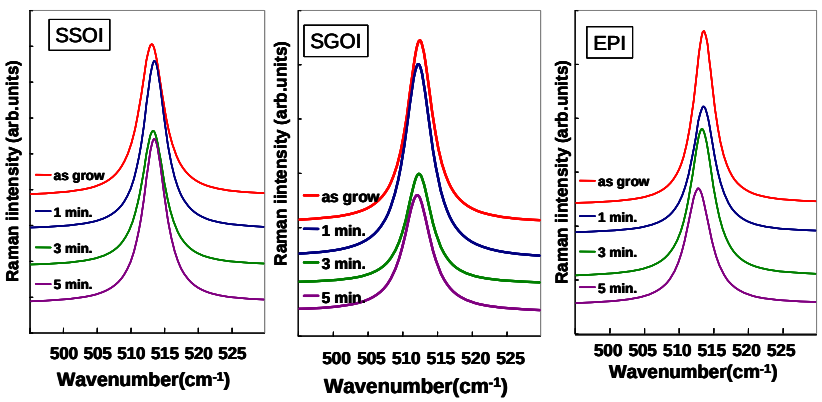

Fig.4 Raman peak shift by RTA at 1050°C for SSOI, SGOI , and EPI substrates.