Extended Abstracts of the 2008 International Conference on Solid State Devices and Materials, Tsukuba, 2008, pp. 376-377

P-2-1

Stress Depth Profiling of Silicon from Nickel / Silicon Interface before and after Silicide Formation using Polychromator-based Multi-wavelength Raman Spectroscopy

Woo Sik Yoo, Takeshi Ueda and Kitaek Kang

WaferMasters, Inc., 246 E. Gish Road, San Jose, CA 95112, U.S.A.
Phone: +1-408-451-0850 Fax: +1-408-451-9729 E-mail: woosik.yoo@wafermasters.com

1. Introduction

Resistivity measurement often used as a simple method for monitoring electrical and crystallographic phase characteristics following silicide formation. Inter-diffusion of metallic and silicon atoms takes place at the reaction interfaces during silicide formation. It is easy to visualize that changes in atomic density and lattice parameters during silicide formation induce stress and strain in the Si lattice.

In this paper, we have non-destructively characterized the lattice stress/strain depth profiles below the NiSi/Si interface using a special polychromator-based multi-wavelength Raman spectroscopy system (MRS-300) designed by WaferMasters.

2. Experiment

NiSi/Si Sample Preparation

Thin (15nm) Ni films were sputtered on p^- Si wafers followed by deposition of a thin (~20nm) TiN capping layer. Changes in sheet resistance after annealing were measured using a four point probe before and after wet etching of the TiN capping and un-reacted Ni layers (Fig.1). Annealing was done in a WaferMasters SRTF-300LP system for 10 min.

Sheet resistance and uniformity of as-prepared wafers were ~10.5ohm/sq. At 200^{o}C, the sheet resistance increased to ~14.2ohm/sq. due to the onset of formation of the high resistivity Ni_2Si phase. Between 200^{o}C and 250^{o}C, the sheet resistance increased to ~19.0ohm/sq. as the phase transition from the low resistivity metallic Ni phase to the Ni_2Si phase progressed. The sheet resistance sharply decreases down to ~4.9ohm/sq. at 350^{o}C as the phase transition from the Ni_2Si phase to the NiSi phase takes place. Sheet resistance started to increase again above 600^{o}C. Once NiSi ohmic contact is formed with the Si wafer, the sheet resistance is no longer a good indicator of integrity of the NiSi. Above the ohmic contact formation temperatures, other non-electrical characterization techniques must be combined for obtaining useful material information.

Multi-wavelength Raman Spectroscopy (MRS-300)

Microscopic Raman scattering is a powerful, non-destructive technique for characterizing crystallinity and degree of stress/strain of the crystal. For this purpose intensity, shift, and full width at half maximum (FWHM) of Raman signals are measured. [1, 2]

We have designed the MRS-300 system as an in-line stress/strain monitoring system. The system has three thermoelectrically cooled charge coupled device (CCD) cameras that can measure Raman peaks from three different excitation wavelengths without any disruption (ie, without scanning the monochromator or switching the excitation laser) (Fig. 2). The measurement capability of the system is summarized in Fig. 3. Three major spectral lines (457.9, 488.0 and 514.5nm) from a multi-wavelength Ar^+ ion laser are used as the excitation source. By selecting the wavelength of the excitation laser, the crystal quality, stress and strain in the depth direction can be characterized.

3. Raman Results and Discussions

Figure 4 shows the Raman spectra observed from 457.9nm excitation of TiN/Ni/Si wafers annealed between 200~700^{o}C followed by wet etching under. Intensity and width of Raman peaks change dramatically with annealing temperature. Figure 5 shows the intensity, shift and FWHM of Raman peaks from TiN/Ni/Si wafers annealed in the temperature range of 200^{o}C to 750^{o}C under excitation at all three wavelengths.

Up to 350^{o}C, Raman signal intensity decreases as annealing temperature increase regardless of excitation wavelength. This can be explained as an effect of the NiSi thickness increasing with increasing annealing temperature. Between 350~550^{o}C, signal intensity is weak. The Si is under compressive stress. Widening of FWHM suggests that crystal quality (lattice spacing) of the Si is becoming less homogeneous as NiSi formation temperatures increase. Above 550^{o}C, intensity becomes stronger and the Si crystal experiences tensile stress. FWHM becomes wider. Raman signals from the shorter wavelength excitation showed the largest change in both shift and FWHM, suggesting lattice stress/strain is concentrated near the NiSi/Si interface. NiSi agglomeration was observed in wafers annealed above 550^{o}C, giving rise to the sudden increase in Raman intensity and sheet resistance seen in Figs. 1 and 4. These NiSi islands left areas of exposed silicon indicated by the data. [3]

4. Summary

Depth profiling of process induced stress and lattice strain in TiN/Ni/Si wafers after NiSi formation and anneal in the temperature range of 200~750^{o}C were successfully characterized using the MRS-300 system.

Acknowledgement

The authors would like to thank Prof. H. Harima and Prof. M. Yoshimoto of Kyoto Institute of Technology for useful technical discussions.

References

[1] H. Harima, Proc. 14th IEEE Int. Conf. on Advanced Thermal Processing of Semiconductors, RTP 2006, (2006) 117.
[2] M. Yoshimoto, H. Nishigaki, H. Harima, T. Isshiki, K. Kang and W.S. Yoo, J. Electrochem. Soc., **153** (2006) G697.
[3] T. Murakami, B. Froment, M. Ouaknine and W. S. Yoo, Electrochem. Soc. Proc., **PV 2002-13** (2003) 347.

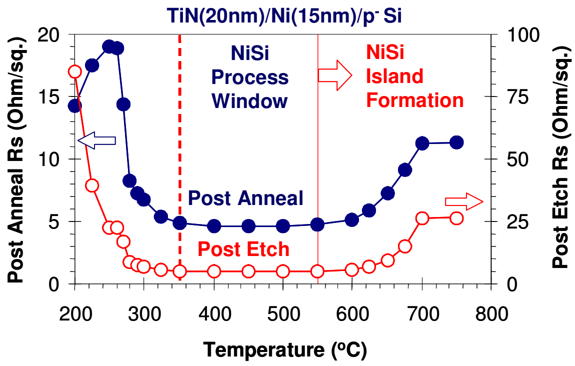
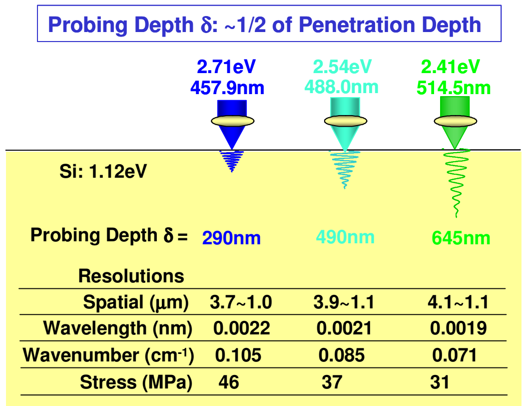


Fig. 1. Sheet resistance after silicide formation and etching.



Resolutions			
Spatial (μm)	3.7~1.0	3.9~1.1	4.1~1.1
Wavelength (nm)	0.0022	0.0021	0.0019
Wavenumber (cm⁻¹)	0.105	0.085	0.071
Stress (MPa)	46	37	31

Fig. 3. Summary of measurement capability of MRS-300 with various excitation wavelengths of multi-wavelength Ar^{+} laser.

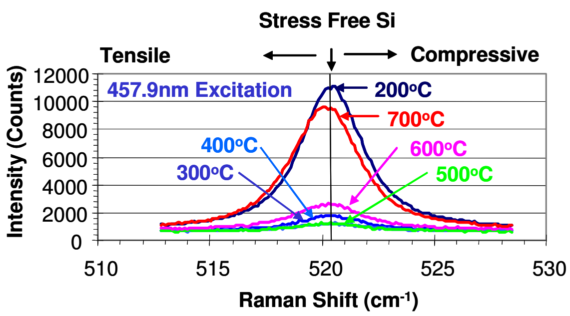


Fig. 4. Raman spectra from NiSi/Si formed at different temperatures (457.9nm excitation).

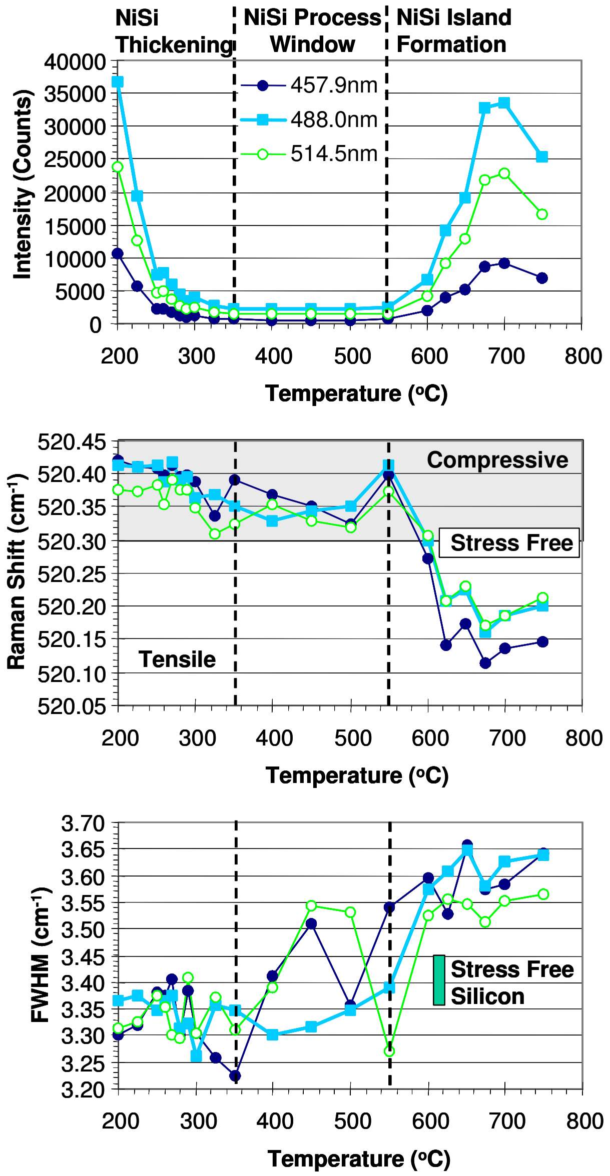


Fig. 5. Intensity, shift and FWHM of Raman peaks from NiSi layers formed under various annealing temperatures.

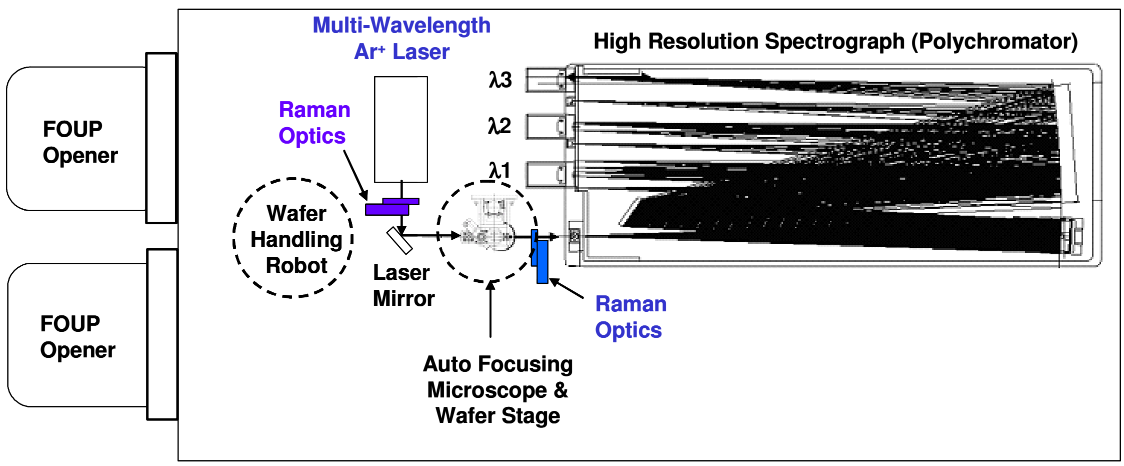


Fig. 2. Schematic illustration of multi-wavelength Raman spectroscopy (MRS-300) system.