Microroughness Analysis of Silicon Wafers Using Ultraviolet Raman Microscopy

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Microroughness is an important parameter for silicon wafers with large diameter. Theoretically, the surface crystalline perfection of silicon wafer is related to the microroughness. The crystalline perfection can be analyzed by Raman microscopy (1-3). In this paper, the microroughness of silicon wafer has been studied for the first time by using UV laser excitation Raman microscopy.

Experimental

Several silicon wafers with different micro-roughness were prepared by using various polishing process. Before Raman analysis, the microroughness of all wafers was measured by using an AFM, by means of the root-mean-square (rms) average roughness in $1\times1\mu m^2$ area. An UV laser (325 nm) was used as the Raman excitation light source.

Results and Discussion

The 520 cm^{-1} peak is the strongest Raman excitation band of silicon. Fig. 1 is plotted by using the data of microroughness and width of 520cm^{-1} band after curve-fit. In the figure, the width trends to increase along with the increasing of microroughness.

In Fig. 1, it can be observed that the difference of mean width of 520 cm^{-1} bands among the samples is obvious despite that there is an undulation range of the width in a sample. The undulation range in sample #1 and #3 is larger than that in sample #2 and #4. Even in sample #1 and #3, most of the width data is only slightly different with the mean width. It is indicated that the wide width variation in the two samples may be caused by the surface non-uniformity.

The microroughness of sample #1 is 0.23 nm larger than that of sample #4, and the variation of width of 520 cm^{-1} band between them is large enough to be distinguished clearly. The difference of microroughness between sample #2, #3, and #4 is less than 0.1 nm. Although the width tends to decrease along with the decreasing of microroughness, it is difficult to confirm the clear relation between them because of the fluctuation of width.

In general, about 2~3 atomic layers are disordered for perfect crystal. The penetration depth of 325 nm laser in silicon is about 4 nm. Only several atomic layers can be penetrated by 325 nm laser. In general, the amount of disordered atoms and the disorder degree would increase as the silicon surface microroughness increases. That is the reason why the width trends to increase along with the increasing of microroughness as shown in the experiment.

The width of 520 cm^{-1} band is responsive for the disordered atoms at the surface, while the microroughness is a parameter of surface morphological characterization. Only when the surface morphology of silicon wafers is similar to each other, the microroughness could be identified by UV Raman spectroscopy. An in situ or precisely located AFM and Raman measurement may be helpful for the study.

Conclusions

Raman results show that the width of 520 cm^{-1} band of silicon tends to decrease along with the decreasing of microroughness. In this study, a resolution of 0.2 nm microroughness (rms) has been achieved by Raman analysis. Although the width trends to decrease as the microroughness decreases, the relationship between the width of 520 cm^{-1} band and the microroughness is under investigation while the microroughness variation is less than 0.1~0.2 nm.

References

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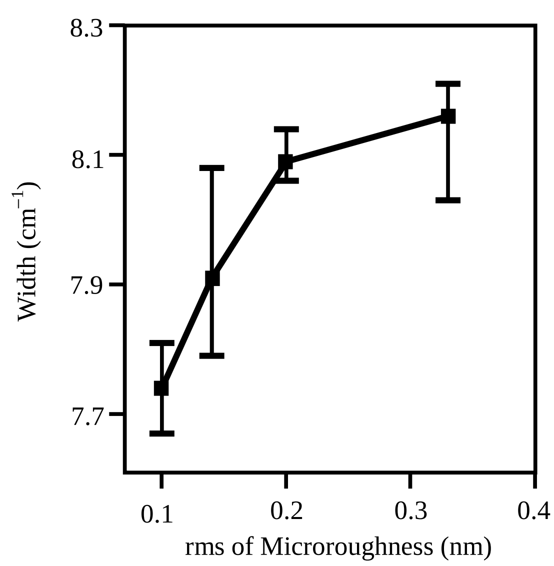

Fig. 1. Relationship between microroughness and width of 520 cm^{-1} band excited by 325 nm laser