Suppression of Surface Micro-roughness on Si(110)

K. Nii , M. Yamamoto , A. Teramoto, and T. Ohmi

New Industry Creation Hatchery Center, Tohoku University

Aza-Aoba 10, Aramaki , Aobaku , Sendai , 980-8579 , Japan

E-mail: nii@fff.niche.tohoku.ac.jp

Introduction

Micro-roughness of Si surface has direct influence on electrical properties of MOS devices in previous study [1]. Therefore, control of micro-roughness of Si surface is very important.

It has been reported that the current drivability of p-MOSFET on Si(110) surface is much larger than that on Si(100) surface [2].

We have evaluated that ultra pure water used in rinse process of cleaning has an influence on micro-roughness on Si(110) surface.

Experimental

The wafers were used p-type Cz double sides polishing wafer with a resistivity of 8-12 Ωcm. All wafers were chemically cleaned, and treated with the etching with diluted HF and the rising with ultra pure water with a dissolved oxygen concentration of <1 ppb in N_2 ambient. Then these wafers were immersed in ultra pure water for 24 hours after the treatment, we measured surface micro-roughness of the treated Si surface by AFM and amount of dissolved Si atoms released from the treated Si surface by ICP-AES.

Results & Discussions

Fig. 1 shows (a) surface micro-roughness and (b) amount of the dissolved Si atoms released from Si(100), Si(110) and Si(111) surfaces in the ultra pure water in which 8.4 ppm of oxygen was dissolved for 24 hours. Fig. 2 shows AFM images of Si(100), Si(110) and Si(111) surfaces in the ultra pure water in which 8.4 ppm of oxygen was dissolved for 24 hours. The ultra pure water in which 8.4ppm of oxygen was dissolved is same as the ultra pure water in the air.

Si(111) surface is very stable, and the increase of surface micro-roughness and the amount of dissolved Si atoms are very small. Si(100) surface is also stable. However, the surface micro-roughness on Si(110) surface becomes very large, and the amount of dissolved Si atoms released from Si(110) surface is about 3 times larger than that released from Si(100) surface.

Fig. 3 shows (a) surface micro-roughness and (b) amount of the dissolved Si atoms released from Si(100) and Si(110) surfaces in the ultra pure water in which 42, 8.4 and 0 ppm of oxygen were dissolved and in which 1.6 ppm was dissolved hydrogen for 24 hours.

When dissolved oxygen concentration is sufficiency high, the stable SiO_2 film is formed on Si surface and the Si atoms is hard to dissolve into ultra pure water from Si surface, as the result, the micro-roughness does not increase.

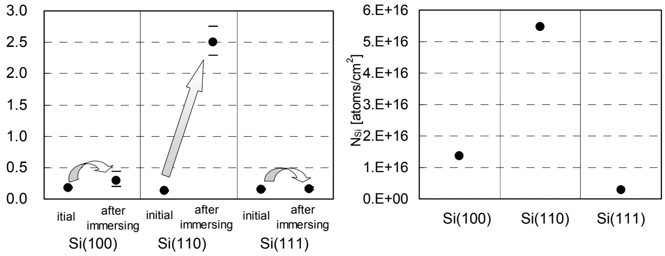
When dissolved oxygen concentration is sufficiency low, the oxidizing of Si(110) surface and the dissolving of Si atoms cannot occur in ultra pure water, as the result, the micro-roughness does not increase.

The oxidizing of Si(110) surface and the dissolving of Si atoms cannot occur less in the ultra pure water in which 1.6 ppm of hydrogen was dissolved, as the result, the increase of micro-roughness is smaller.

Therefore, the surface micro-roughness of Si(110) surface and the amount of dissolved Si atoms released from Si(110) surface in the ultra pure water in which 8.4 ppm oxygen was dissolved have largest value.

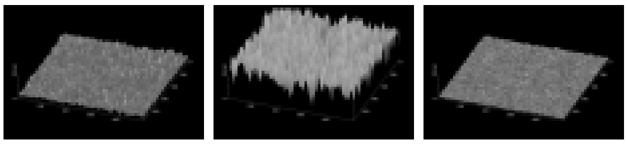
Conclusion

These mean that Si(110) surface is very instable, and when a device on Si(110) surface was formed, cleaning of Si(110) surface must be treated with deaerated ultra pure water or dissolved hydrogen ultra pure water in N_2 ambient.



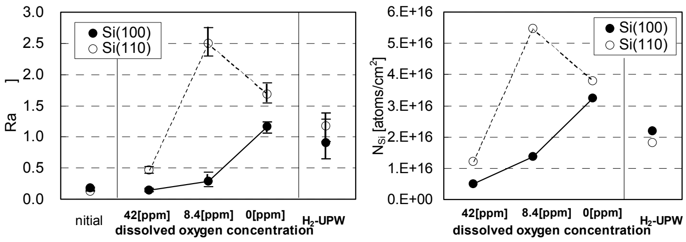
(a)Surface micro-roughness (b)Amount of dissolved Si atoms

Fig.1; (a) Surface micro-roughness [Ra] and (b) amount of dissolved Si atoms [N_{Si}] released from Si(110), Si(110) and Si(111) surfaces by immersing in ultra pure water (dissolved oxygen ; 8.4ppm) for 24 hours.



Si(100) Si(110) Si(111)

Fig.2; AFM images of Si(100), Si(110) and Si(111) surfaces after immersing in ultra pure water (dissolved oxygen ; 8.4ppm) for 24 hours.



(a)Surface micro-roughness (b)Amount of dissolved Si atoms

Fig.3; (a) Surface micro-roughness [Ra] and (b) amount of dissolved Si atoms [N_{Si}] released from Si(100) and Si(110) surfaces by immersing in the ultra pure water in which 42, 8.4 and 0 ppm oxygen were dissolved and in which 1.6 ppm hydrogen was dissolved 24 hours.

References

[1] M. Miyashita, M. Itano, T. Imaoka, and T. Ohmi, “Dependence of Thin Oxide Films Quality on Surface Micro-Roughness,” 1991 Symposium on VLSI Technology, Oiso, pp.45-46, May 1991

[2] T. Sato, Y. Takeishi, H. Hara, and Y. Okamoto, “Mobility Anisotropy of Electrons in Inversion Layers on Oxidized Silicon Surfaces,” Phys. Rev. B, Vol. 4, No.6, pp.1950-1960, September 1971