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Substrate Temperature Effect in the Interaction of Hydrogen Plasma with a Silicon Surface

水素プラズマ-シリコン基板表面相互作用の温度依存性

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We investigated hydrogen insertion process into silicon crystal from silicon surface, with infrared absorption spectroscopy in multiple internal reflection geometry (MIR-IRAS). Infrared spectra suggested that kinds of generated silicon hydride components were changed with the substrate temperature. The formation of amorphous SiH components was increased with the substrate temperature; on the other hand, the formation of amorphous SiH_2 components was decreased on the contrary to the substrate temperature.

1. Introduction

Silicon (Si) is an important semiconductor material used for electronic devices such as LSI, solar cells and so on. Reaction of silicon with plasma is one of the important processes in Si device processing. Hydrogen plasma is one of the important plasmas, because the hydrogen radicals and ions generated in hydrogen plasma play an important role in either etching or deposition processes. Then, to control preciously either process, it is important to investigate an interaction of hydrogen plasma with Si surface. A lot of works have been so far reported, but the interaction has not been cleared. One of the problems is to know the interaction process. The comprehension of the process tells us how to control the process. However, the process is hard to be investigated, because the surface is subjective to oxidation. At least “in-situ” measurement has to be required. Then, we use infrared spectroscopy in multiple internal reflection geometry (MIR-IRAS) to investigate it. The interaction depends on various factors, such as substrate bias, substrate temperature, and so on. In this study, we focus on the substrate temperature effect on the interaction between Si crystal and hydrogen plasma. We have investigated the interaction of Si(100) and Si(110) surfaces with hydrogen plasma. In this paper we present about the interaction on Si(110) surface.

2. Experiments

The chamber used in this study was equipped with RF plasma source, high vacuum pump system, and IRAS monitoring system. The pressure was evacuated to 1×10^{-6} Torr. RF plasma was generated by applying 13.56 MHz RF power to a coil wrapped around a glass tube. Hydrogen plasma was generated using 30W RF power at a hydrogen pressure of 50 mTorr. The substrate temperature is controlled by heater. The Si prisms were used as a substrate. The prisms were made of n-type Si (110) wafers with the resistivity of approximately 10Ωcm. The prisms had a dimension of 0.5 × 10 × 40 mm, with mirror-polished 45° bevels on each of the short

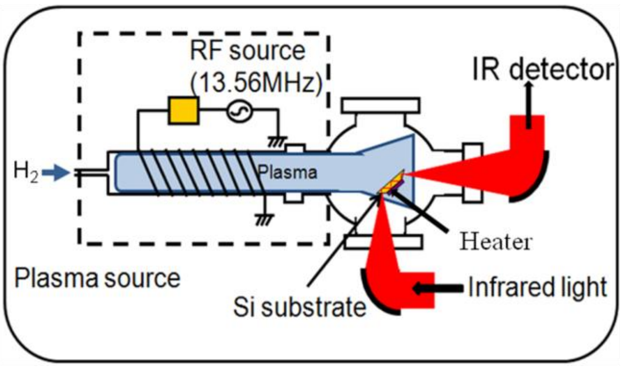

Fig.1 Experimental set up

edges. As the reference spectrum, the surface of silicon covered with a chemical oxide layer was used. The chemical oxide layer was produced in a boiled H_2O_2/H_2SO_4 solution.

3. Results and Discussions

Figure 3 shows the infrared absorption spectrum of Si(110) exposed to hydrogen plasma with substrate temperature from 70 to 200 °C. The peak at approximately 2070 cm^{-1} and the peak at approximately 2090cm^{-1} can be assigned to SiH-SiH chains of Si(110) surface. The peak at approximately 2140 cm^{-1} can be assigend to the SiH_2 on the step of Si(110) surface. The surfaces should become atomically random with the hydrogen plasma exposure, since the observed peaks in this region were broad. The amorphous SiH_2 had a peak at approximately 2100cm^{-1}. These components were overlapped with the surface silicon hydride components. The peak became sharp with the substrate temperatures. It means that the amorphous SiH_2 compoinets was suppressed with the substrate temperatures. The peak at 2000 cm^{-1} was also observed. The peak can be assigned to SiH component observed in amorphous phase. The peak was increased with the substrate temperature. The amount of the SiH components in amorphous phase were increased with the substrate temperature. These results indicated that the formation of amorphous SiH_2 components was supressed with the substrate temperature, and that the formation of amorphous SiH components was increased with the substrate temperature.

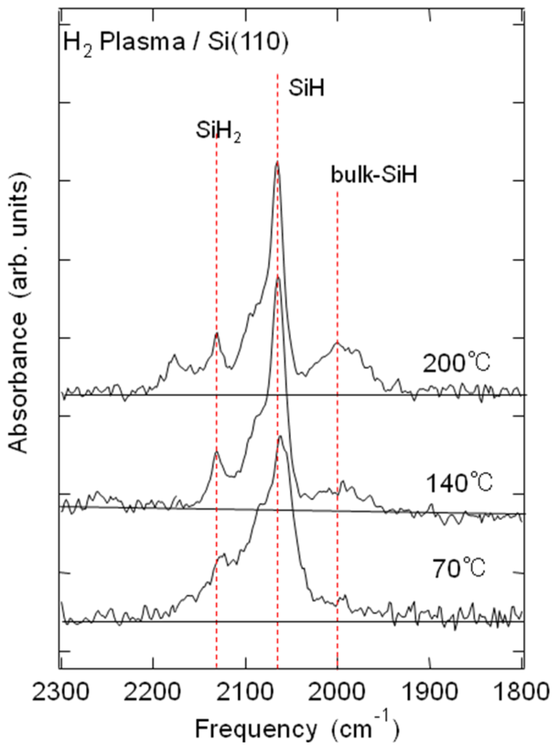

Fig.3 Infrared spectra (from 70 to 200 °C)

4. Conclusion

We investigated the interaction of hydrogen plasma with Si(110) surface, and its substrate temperature effect, by using infrared spectroscopy in multiple internal reflection geometry (MIR-IRAS). Infrared spectra suggested that kinds of generated silicon hydride comoponents were chaneged with the substrate temperature. The formation of amorphous SiH components was increased with the substrate temperature; on the other hand, the formation of amorphous SiH_2 components was decreased on the contrary to the substrate temperature.

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