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Chemical State Identification Using Ion Scattering. Low energy Cs^+ scattering from H_2O/Si(111) surface

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1. Introduction

The study of the interaction of H_2O with a silicon semiconductor surface is very important because of its fundamental and applicational needs. Many researchers investigated the H_2O/Si surface system, reaching three different conclusions: 1) partially dissociative state of H and OH[1], 2) molecularly adsorbed state of H_2O[2], and 3) mixture state of partial dissociation and molecuar H_2O adsorption on the silicon surface at room temperature[3].

In order to study the water state further, we carried out the low energy (less than 100 eV) ion beam scattering experiment from Si(111) surface covered with water of 1000 L. The low energy ion beam has characteristics such that its penetration depth is very shallow and the substrate damage is minimal, and so it provides a novel and suitable means for probing the surface non-distructively.

2. Experiment

Our experiment was performed using the low energy ion beam apparatus equipped with a 2 m long-ion beam line, QMS, and UHV chamber[4]. The Cs^+ ion was made from CsCl powder heated in the Colutron ion source and the Cs^+ ion beam buffered with Ar gas was focused by an Eienzel lens. The ion beam was mass purified by Wien filter and 12° deflected to reject the unwanted gas species before it reached the silicon surface placed in an UHV chamber. Our UHV chamber was maintained at 2×10^{-9} Torr. The incident angle of ion beams was fixed at 45° from the surface normal and the scattered ions were detected at 90° from the incidence beam using a quadrupole mass spectrometer. The sample surface was cleaned by a cycle of 2 keV Ar^+ sputtering and 1000 °C annealing using electron bombardment. The water molecules were introduced into the chamber through a leak valve, giving a 1000 L exposure on the silicon surface.

3. Results and Discussion

The ion yields were measured as a function of incident energy of Cs^+ ion beam, and the results are shown in Fig. 1 for the scattered Cs^+ and the complex secondary ions. The intensities of $CsOH^+$ and $CsOH_2^+$ ions increase with increasing incident energy and are maintained flat for high collision energies. The threshold energies, which are the minimum collisional energies for ejecting the complex ions from the surface, were obtained from a linear fit to the curve to be 5 and 7 eV for $CsOH^+$ and $CsOH_2^+$, respectively.

It is known that the complex ions are produced due to recombination of the scattered, low kinetic energy Cs^+ ions and the neutral species emitting from a surface[5]. The recombinative formation of the complex ions reflects that the neutral H, OH and H_2O species are ejected from the surface, they are believed to exist on the Si(111) surface at room temperature, and escape from a surface instantaneously.

4. Conclusion

We identified that the water molecules have mixture states of partially dissociative and molecular adsorption on the Si(111) surface at room temperature. This study demonstrates that Cs^+ ion scattering can probe surface chemical states in a non-distructive way.

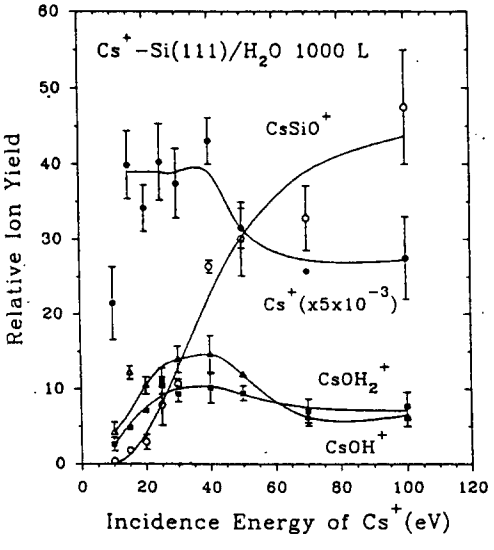

Fig. 1. The ion emission yields of Cs^+, $CsOH^+$, and $CsOH_2^+$ as a function of Cs^+ beam energy.

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