STRUCTURE EFFECTS OF SILICON AND CARBON BY CLUSTER MASS SPECTRA

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ABSTRACT

Microclusters from different structures of silicon and carbon are studied by SIMS under UHV conditions in the mass range below $M = 200$. The sputtered mass spectra of ions Si_n^+, C_n^+ and C_n were obtained from the 10 keV O_2^+ primary beam bombardment. Comparisons of each spectrum in each group have shown the strong structure effects on the cluster patterns. A brief discussion on the results has been given.

Key words: Structure effects Cluster mass spectra Silicon Carbon

I. INTRODUCTION

The investigation of structure effects on the cluster yields was reported before by A.L.Southern[1], G.D.Magnuson[2] et al.. Experiments and theories have shown that the emission intensities of secondary ions are closely related to the surface structure of the bombarded sample. For a single crystal it also has something to do with the orientation of the crystaline plane. However the surface structure analysis is handicapped by the fact that chemical process dominates the sputtering yields in the presence of oxygen so that it obscures the structure effects[3]. Up to now SIMS is normally used as the measurements of contents and profiles of trace elements. The present work is undertaken to obtain the mass spectra of various structures of silicon and carbon by SIMS. Comparisons of mass spectra show that each spectrum is different from others which means that the pronounced structure effects exist. In other words, the mass spectra of secondary ions are strongly dependent on the surface structure of the analyzed sample, and so may provide us with some helpful information about the surface structure in some extent. Furthermore, the structure effects might give theorists certain useful evidence concerning the mechanism of forming clusters.

II. SAMPLE PREPARATION

Two groups of samples were used in our experiment. Group 1 (carbon) includes four targets: monocrystalline diamond, polycrystalline diamond, polycrystalline graphite and amorphous graphite. They have irregular shapes with fairly rough surfaces. Group 2 (silicon) contains two thick targets and three thin targets. The thick targets

are single crystal silicons with (1,1,1) and (1,0,0) orientations, respectively, and the thin silicon targets are formed on Al_2O_3 substrates by CVD epitaxial growth in different temperatures, they were prepared as follows:

Si (1,0,0)	~540 nm	1050°C
polycrystalline Si	~350 nm	850°C
amorphous Si	~290 nm	160°C

The structures of these samples were confirmed by the X-ray diffraction experiment.

III. EXPERIMENT

The experimental arrangement is shown in Fig.1.

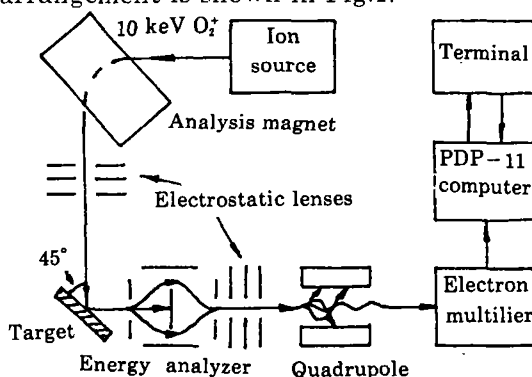

Fig.1 Diagram for experimental arrangement

The spectrometer developed by RIBER Co. (France) has a mass resolution of about 0.5 u and five samples can be mounted in the introducing chamber. All measurements were performed using a primary beam of 10 keV O_2^+ ions[4]. the incident beam with a diameter of about 15 μ m has a current stability of better than 1% and scanning area of about 3×3 mm^2, and the projectile with an incident angle of 45° is perpendicular to the ejected direction of ion clusters. The beam spot can be observed through the system of the secondary electron imaging. Near the target surface the residual gas pressure was as low as 133.332× 10^{-9} Pa. All samples were cleaned by an ion pre-bombardment of about 10^{-8} As/cm^2. The spectrometer at the Laboratory for Surface Physics of Academia Sinica (LSPAS), Beijing, P.R.China is connected to a PDP-11 computer system. The spectrum collection process was carried out through a terminal.

In the experiment the acquisition time was taken to be 500 ms per channel, i.e. for enery step of atomic mass number (u) the recorded time was 500 ms. From 1 to 100 u the primary beam was controlled to be about 50 nA for Si_n^+ spectra, 200 nA for C_n^+ spectra and 1000 nA for C_n^- spectra, and from 100 to 200 u the current was increased to about 2.6 μ A. Although the mass spectra for all targets were normalized in a certain integrated charge, the comparisons between different samples are difficult because

there was not a biased electrode to restrain secondary electron emissions. Besides, the geometry of emitted clusters was different from one another. The typical radiation time for each thin target was not longer than 4 minutes, and the estimated erosion thickness of the sample surface was thinner than 200 nm. Therefore the substitute elements (aluminum and oxygen) do not affect the mass spectra significantly.

IV. RESULTS AND DISCUSSION

Fig.2 shows the mass spectra of sputtered $^{28}Si_n^-$ ions from various structures of silicon samples. As can be seen that except the single crystal silicon with (1,1,1) orientation all samples are not observed to emit larger than two-atom ion-clusters because of the background, and that secondary ions of general composition Si_n^- are with decreasing intensity for higher masses. Compared with previous report[3] the intensity ratio of Si_2^+/Si^+ for silicon with (1,1,1) orientation in Fig.2 agrees quite well with that in the case of the oxygen exposure with 2.25 keV argon bombardment.

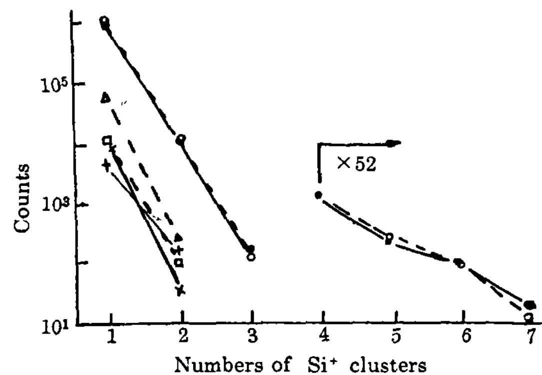

Fig.2 Mass spectra of sputtered $^{28}Si_n^-$ ions with 10 keV O_2^+ ion bombardment

Thick sample: ● (111)Si ○ (111)Si with 1.5° rotation × (100)Si

Thin sample: △ (100)Si ⌜ Si (monocrystal) + Si (polycrystal)

For comparisons the thin and thick monocrystalline silicon samples with the same structure (1,1,1) orientation were chosen. It is found from Fig.2 that the intensity ratios of Si_n^-/Si^- are nearly equal for the two samples, which is what we expect. Another comparison between the mass spectra of the same sample with 1.5° difference of incident angle shows clearly that two mass spectra are essentially identical within the statistical errors. If we further contract the Si_n^- relative yields of all samples with different structures, it is obvious to see that each sample bombarded in the same experimental conditions has a characteristic of the sputtered mass patterns, which accounts for the strong structure effects.

Fig.3 and Fig.4 give the $^{12}C_n^+$ and $^{12}C_n^-$ mass spectra, respectively.

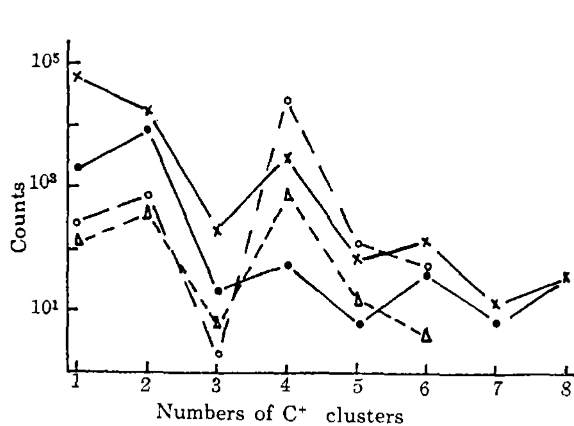

Fig.3 Mass spectra of $^{12}C_n^+$ ions by 10 keV O_2^+ ion bombardment

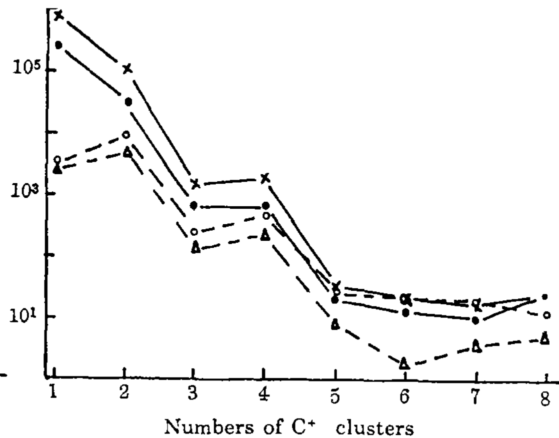

Fig.4 Mass spectra of $^{12}C_n^-$ ions by 10 keV O_2^+ ion bombardment

● Monocrystalline diamond ○ Polycrystalline diamond

× Polycrystalline graphite △ Amorphous graphite

The distinct odd－even property of carbon in Fig.3 is somewhat consistent with the report[6] by P.Joyes et al. in which the C_n^- mass spectrum was obtained by the 6.5 keV Ar^+ bombardment. However, the odd－even property of positive carbon ion clusters in Fig.4 appears completely opposite, compared with that in Ref. [6] or in the spark source situation[7]. The main reason may be the chemical sputtering in our experiment. Anyway, the mass spectra of either C_n^+ or C_n^- ions, like those of Si_n^+ strongly rely on the structures of bombarded samples. This significant structure effects on the sputtered ion mass spectra may result in the possible application to the measurement of surface structure by SIMS, or at least to the comparison between samples with identical constituents to determine whether they have the same surface structure or not. The fact of structure effects may also be helpful for theorists to create a complete model of forming clusters.

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