Influence of Ion Beam Position Shift on the Depth Profiling in AES

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The ion beam stability is important for achieving reproducible depth profiles. This report describes how the ion beam position shift occurs after turning on the filament, and how this shift affects the results of depth profiling. It was found that the largest shift was more than 200 nm along the y-direction even when the inclined sample holder was used. It requires more than 5 hours to stabilize the ion beam position in our instrument. Immediately after turning on the filament the sputtering rate of SiO_2 was 10% smaller than the rate measured after stabilization. However, the depth resolutions were almost the same in both cases. It is advisable to check the stability of the ion beam position before measuring the sputtering rate precisely.

1. Introduction

Auger electron spectroscopy (AES) in combination with ion beam sputtering is widely used for depth profiling of thin films, in order to obtain the distribution of elemental composition in depth direction [1~6]. It is a powerful method to analysis the composition in some heteroepitaxial multilayer films, such as GaAs/AlAs heteroepitaxial multilayers in semiconductor devices.

The depth resolution Äz is an important quantity in depth profiling, which is essentially determined by three parameters: atom mixing (w), roughness (σ) and information depth (ë), which is the MRI model [7~9]. Generally, depth profiling with a depth resolution Äz< 5 nm is achieved when low-energy ion (1 keV Ar^+) are used. Ultrahigh depth resolution with Äz< 2 nm is expected with very low ion energy and/or a high incidence angle, and by using low-energy Auger electrons (< 100ev) in AES depth profiling [3]. Hence, with the increase of depth resolution in AES depth profiling, it is possible to measure the film thickness with an accuracy of less than 1 nm when using AES. At the same time, the sputtering rate of film materials can be determined accurately.

In this paper, we describe an AES investigation of the effect of ion beam position shift on the sputtering rate and the depth resolution, in order to supply basic and useful information for operators.

2. Experimental Procedure

The samples used in the study consisted of five SiO_2/Si layer films, which are prepared by NTT-AT Corporation. The nominal thickness of this films was SiO_2 (20.0 nm)/ Si (20.0 nm)/ SiO_2 (20.0 nm)/ Si (20.0 nm)/ SiO_2 (20.0 nm)/ Si substrate. The AES depth profiles of the films were carried out using a scanning Auger electron microprobe PHI 680. A 3 kV 5 nA electron beam was used, and the 1 keV Ar+ ion beam was scanned with a raster control X size 2.0mm, Y size 2.0mm (the across area of 1.7×2.0 mm^2). The ion incidence angle was 35°. Fig.1 shows a schematic arrangement of the ion gun, samples and the electron probe of our system.

The Auger peak-to-peak height (APPH) of Si LVV and O KLL Auger signals was used for recording depth profiles. The sputtering time of the films was calculated when the APPH of SiO_2 layers has decreased to 50% of its maximum value. The depth resolution Äz is defined as the depth difference in the interface region when the APPH falls from 84% to 16% of the maximum APPH [10].

3. Results and Discussion

Figure 2(a) shows the results of the beam position shifts along the beam direction (y-direction) with time after turning on the filament for the two sample holders. The shifts along x-direction were

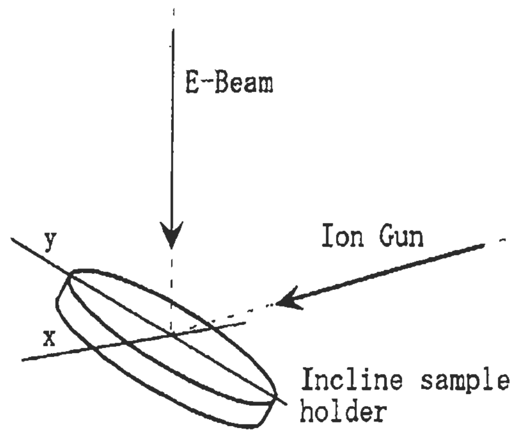


Fig. 1. A schematic arrangement of the ion gun, sample and the electron probe of our system.

almost negligible. When the samples were on the plane holder and on the inclined holder (the angle between the surfaces normal and the ion beam is 55° and 25°, respectively), the maximum sputter position shifts of ion gun were about 1200 nm and 400 nm after a standby time of 10 min, respectively. It takes more than 5 hours to stabilize the ion beam position. After checking the ion gun filament, it is found that such a large shift in the sputter position was caused by the poor filament conductance (due to poor welding joints in the ion gun filament).

Figure 2(b) shows the relationship between the standby time and sputter position when the ion gun operates under a normal condition. The corresponding position shift is smaller than under the abnormal condition. The largest shift was more than 200 nm even when the inclined sample holder was used. However, it still takes 5 to 6 hours to become stable. In order to study the effects of the standby time on the sputter rate, we have selected two experiments for depth profiling. One was to measure the sputter rate at an unstable stage after only 0.5 to 2.5 hours of standby time. While, the other was performed at a stable stage (after 6 hours of standby time). Figure 3 shows the results obtained. It is clear that the standby time affects the sputter rate. The average sputter rate of SiO_2 during the stable and the unstable period was 2.0 nm/min and 1.8 nm/min, respectively. Figure 4 (a, b) and Table 1 show the calculated results of O1 depth profiles according to Hofmann's MRI model [8,10] with the following parameters:

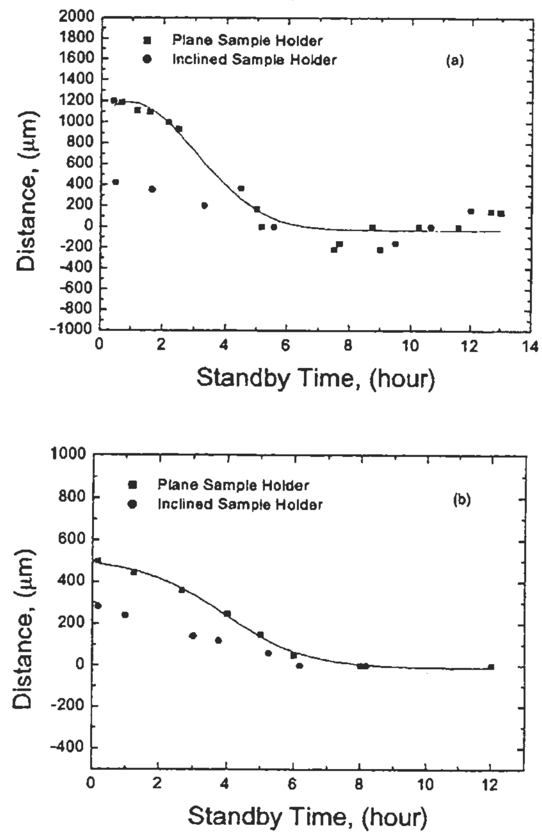


Fig. 2. The sputter position of ion gun as a function of the standby time with the ion gun operating at (a) an abnormal condition, and (b) a normal condition.

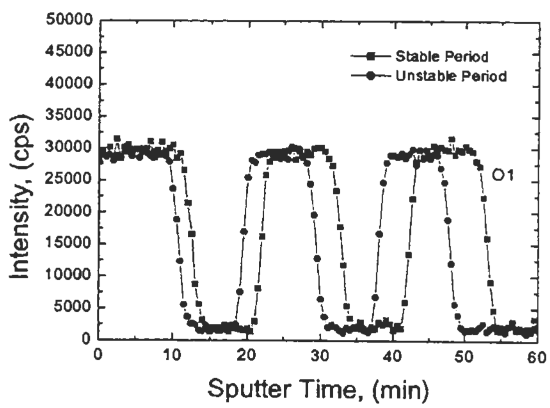


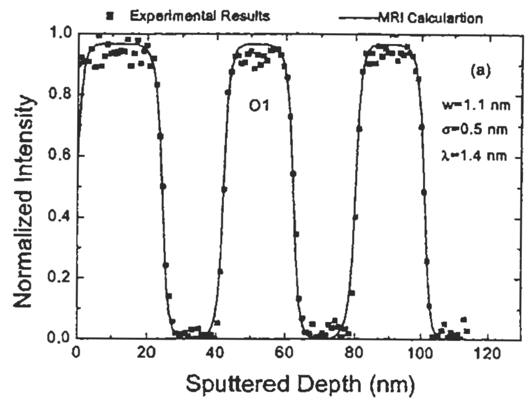
Fig. 3. Depth profile of SiO_2/Si multilayers.

mixing length w=1.1 nm, roughness σ =0.5 nm and information depth ë =1.4 nm. It is obvious that the optimum fitting was obtained by using the above parameters for the two depth profiles at the stable and unstable stages. It is found that the depth resolution, atomic mixing, surface roughness and information depth are almost the same at different standby time period.

The above research shows that the sputter rate is affected by the ion beam position shift, however, the depth resolution is constant. Thus it is necessary to wait five to six hours after setting standby condition in order to obtain precise measurements of the sputter rate.

4. Conclusion

The standby time of ion gun affects the sputtering position and sputtering rate. It is found that it will take five to six hours for the sputter position of the ion gun becoming stable. When the ion gun filament is in a poor conductance condition, the distance shift is larger than under the normal operating condition of the ion gun. The standby time affects the sputter rate. The average sputter rate under unstable conditions is a little smaller than during the stable stage, but the depth resolution remains constant. It is recommended by authors that more than five hours of standby time is necessary in order to obtain precise measurements.



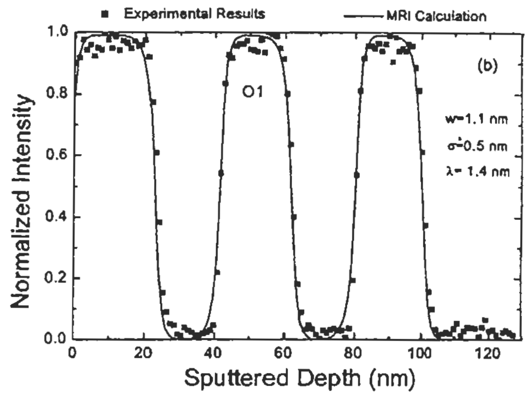


Fig. 4. Sputter depth profile of SiO_2/Si five layers using 1.0 keV Ar^+ and 55° incidence angle, profile simulation (solid lines), (a) unstable stage, (b) stable stage.

Table 1 Simulation results according to the MRI model [10]

Sample	Depth Resolution (nm) 1st	2nd	3rd	4th	5th	Atomic Mixing (nm)	Surface Roughness σ (nm)	Information Depth ë (nm)
Unstable	3.1	2.0	3.1	2.1	3.1	1.1	0.5	1.4
Stable	3.0	2.0	3.2	1.9	3.1	1.1	0.5	1.4

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