Investigation of Mesh Opening Size in Mesh-Replica Method Toward Standardization of Depth Profiling Technique

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The mesh-replica method has been proposed for determination of actual sputtering rates of various solid-state materials. It is, here, preliminarily investigated for the applicable range of mesh size, varying the commercial mesh kind from 50 to 400. The sputtering procedures were carried out in the scanning Auger apparatus with Ar^+ ion beam of 3 keV at the incidence angle of 23 degrees from the surface normal. The ions sputtered the silicon surfaces down to about 100 nm in depth, where the sputtered depths were measured with the stylus profilometer. For all kinds of meshes investigated here, it is found that they are applicable to the mesh-replica method to estimate the ion-sputtering rates. Though there are small amount of sputter-deposited mesh material on the specimen surfaces for the mesh 150 to 400, it does not seem to affect the sputtering rate of the specimen.

INTRODUCTION

A sputtered depth is a very important quantity measured in surface analysis procedures, especially for depth profiling analysis. A sputtering time is usually converted to the sputtered depth in practical depth profiling analysis, multiplying it by the sputtering rate for the analyzed material. It is, however, not easy to know the actual sputtering rate for various kinds of materials. We have then proposed the "Mesh-Replica Method" to experimentally measure the sputtering rate of homogeneous materials by the very simple way using a metallic mesh[1]. This mesh-replica method has been applied to measure relative sputtering rates of many materials against the silicon dioxide film as the reference material, such as GaAs[2], silicon[3], and aluminum oxide[4].

So far we have conventionally used the metallic mesh with the mesh opening of 200 to 300 mm, which is convenient to measure the sputtered depth by stylus profilometer. Here is a potential in the mesh-replica method to determine the sputtering rate for a small homogeneous area restricted by the mesh openings, even though the specimen surface is macroscopically inhomogeneous. Thus, we preliminarily investigated the applicable range of the mesh-replica method to the mesh opening size. We will report here the electron scattering effect during AES (Auger electron spectroscopy) measurements, the mesh material deposition onto the specimen surface, and crater profiles measured by the stylus profilometer, depending the mesh openings.

EXPERIMENTAL

The specimens used were Si(100) chips and meshes were mounted on the specimen, wrapping with aluminum foils with circular holes, according to the previous reported procedure[1]. The meshes were commercial ones made from copper and prepared mesh kinds were 50, 75, 100, 150, 200, 300, and 400. Each kind respectively corresponds to the nominal specifications of {mesh pitch (mm), mesh opening (mm), bar width (mm), mesh thickness (mm)} as shown in Table 1. Here the thicknesses are not specified values by manufacturers, and were measured values by micrometer. The sputtering procedures were performed with the AES apparatus (PHI-670) and the primary ion was Ar^+ with the accelerated energy of 3 keV hit the specimen surfaces with the incident angle of 23 degrees from the surface normal. The azimuth angle of the ion beam actually corresponded to the diagonal direction from the upper left corner to the lower right corner in the pictures of the following Fig. 1. The ion beam was raster-scanned for 2 x 2 mm^2, which is enough large to sput-

Table 1 Mesh nominal parametric dimensions in this study

No.	kind	pitch (mm)	mesh opening (mm)	bar (mm)	mesh thickness* (mm)
1	50	500	450	50	29
2	75	333	283	50	29
3	100	250	200	50	29
4	150	167	117	50	30
5	200	125	85	40	31
6	300	83	45	38	19
7	400	63	30	33	16

*Thicknesses were measured values, not specified ones.

ter the mesh area. The sputtering time was not specified in this study, because the purpose of this study was an examination of the applicable minimum mesh size in the mesh-replica method, though it was required to reach sufficient time to measure the sputtered depth with the stylus profilometer (DEKTAK 3ST in our laboratory). AES spectra were obtained with a mesh after sputtering in order to investigate the electron scattering effect caused by the mesh. They were also measured without the mesh in order to do the sputter-deposition onto the specimen surface from the mesh. Both measurements were carried out at the central point of the mesh opening. The primary electrons for AES were injected to the surface with the incident angle of surface normal with the primary electrons of 3 kV and 5 nA.

RESULTS AND DISCUSSIONS

The sputtered replica patterns were formed on the silicon surfaces as shown in Fig. 1. The SEM (scanning electron microscope) images were captured after removal of the meshes and aluminum foils. Here are the three examples of replica patterns from seven kinds of mesh type. All of the pictures show that the replica pattern can be certainly formed for the whole area of the meshes, and it is no problem even for the mesh-type 400, though its picture is not shown here. For the mesh of 50 and 150, the grid area is flat, however there are flat regions and dimpled regions in the grid area for the mesh of 300. This inhomogeneous pattern may be formed by the original mesh shape of the mesh 300. Even such a pattern as Fig. 1(c-2), it is applicable to estimate the sputtered depth using a stylus profilometer.

Figure 2 shows crosssectional profiles of replica patterns measured by stylus profilometer. The trapezoid plateaus and valleys correspond to the mesh bars and mes openings, respectively, in each profile. At the right edg of the valley bottom, there are ditch-like shapes, especiall for meshes of 75 and 100. This shape does not exist fc the meshes of 300 and 400. It is thought that scattere ions cause an exceeding sputtering, because the ions wei

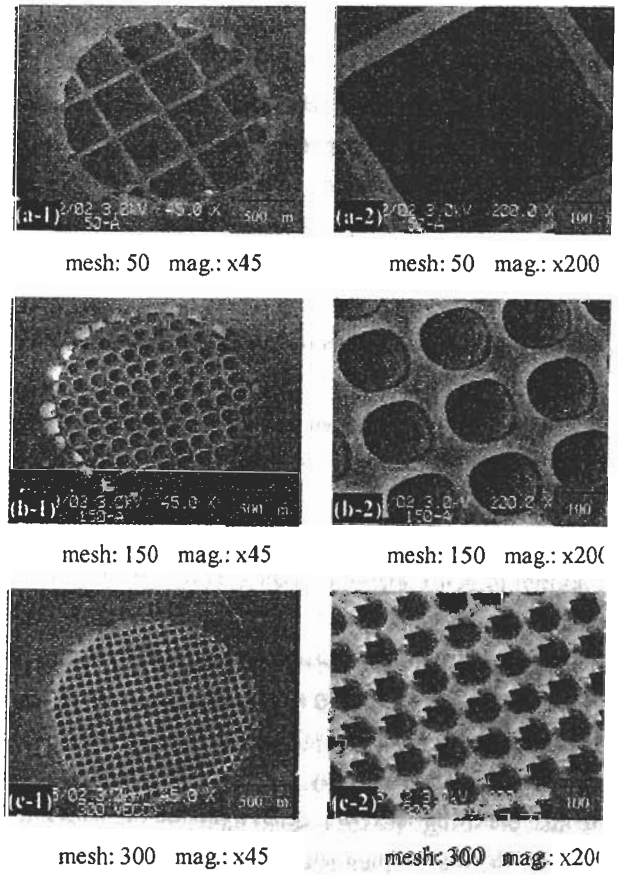
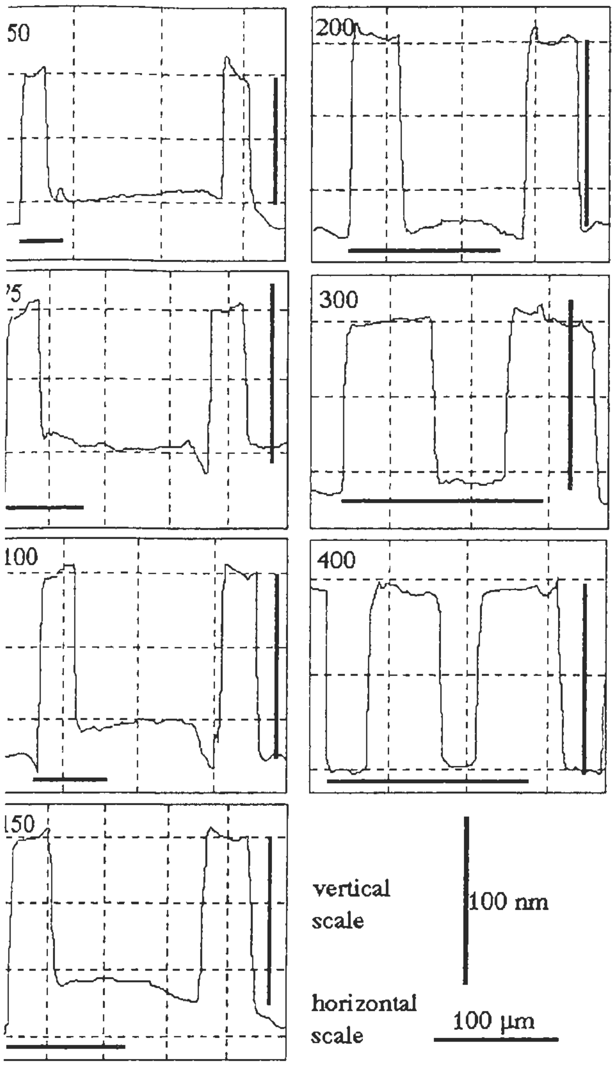


Fig. 1. SEM images of sputtered mesh-replica patterns af removal of meshes and aluminum foils. (a-1) mesh kind: 50, sc bar: 500 mm, (a-2) mesh kind: 50, scale bar: 100 mm, (b-1) me kind: 150, scale bar: 500 mm, (a-2) mesh kind: 150, scale b 100 mm, (c-1) mesh kind: 300, scale bar: 500 mm, (c-2) me kind: 300, scale bar: 100 mm



ig. 2. Crosssectinal profiles of a part of mesh-replica patterns ıeasured by the stylus profilometer. The numerical numbers cor- ›spond to the kind of mesh size. The profiles cover the one pitch om the bar to the neighbor bar for 50 to 300 meshes, and the vo pitches for 400 mesh. The vertical scale and horizontal scale ɔrrespond to the distance of 100 nm and 100 mm, respectively

oming from the upper left to the right corner of the val- ›y bottom in each profile and they were concentrated at ıe bottom corner. It is needed to simulate ion paths in ıis kind of geometry for further detailed analysis.

The AES spectra shown in Fig. 3 were measured af- ›r sputtering procedure in order to clarify the effect of lectron scattering caused by the meshes. It is needed for s to take the notice that the signal dynamic range is small ɔr the mesh 400, comparing the other mesh kinds, and ıe spectrum is normalized at the Si LMM intensity, re- ɹlting in the noisy spectrum. Figure 4 shows the spectra ıeasured after removal of the meshes and aluminum foils ı order to examine sputter deposition onto the specimen ɹrfaces from the meshes. The measured points were the

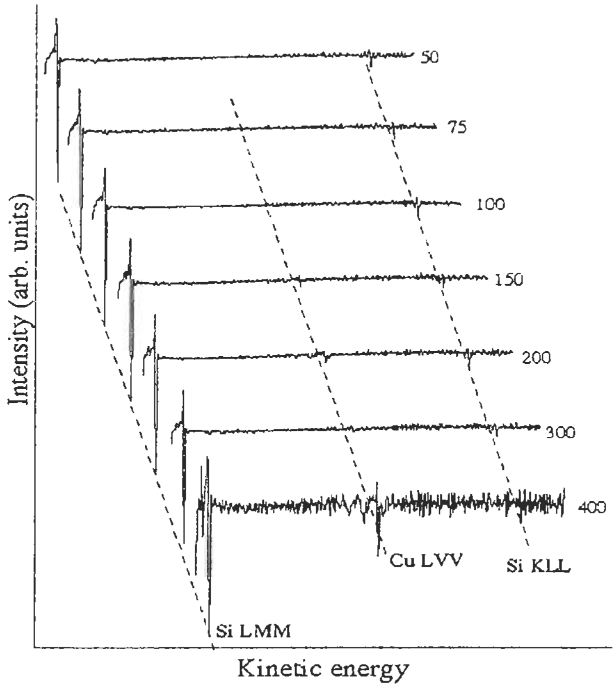


Fig. 3. AES differential spectra from the central points in the mesh openings. They were measured with the meshes, whose kind is denoted at each spectrum, after sputtering procedure.

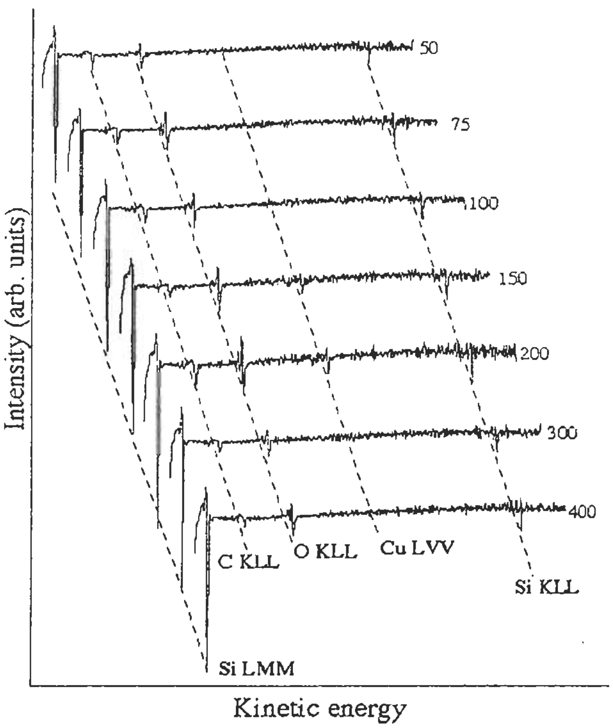


Fig. 4. AES differential spectra from the central points in the mesh openings measure after removal the meshes and aluminum foils. The removing procedure were carried out in air, the specimens were loaded into the vacuum again and the spectra were obtained. Therefore there are contaminated C and O signals for all of spectra.

central positions with the area of several ten-nm-diameter, corresponding to the primary electron beam, in the mesh openings. In Fig. 3, there are no signal corresponding to C (carbon) and O (oxygen) Auger transitions, though there C KLL and O KLL signals in the spectra in Fig. 4, which were atmospherically adsorbed when removing the meshes and foils in air. For the mesh types larger than 150, there are weak signals of Cu LVV at the kinetic energy of around 850 eV in Fig. 3. On the other hand, there are also weak Cu LVV signals for the mesh 150 and 200 in Fig. 4. Their relative intensities (I(Cu LVV)/ I (Si LMM)) seem to be almost same magnitude in the both spectra in Figs. 3 and 4. Then the Cu LVV signals for the mesh 150 and 200 in Fig. 3 might come from the deposited materials on the surfaces. For the mesh 400, the relative intensity of Cu LVV is stronger than those in Fig. 3, and we think this Cu signal is coming from the mesh sidewall. In Fig. 4, there are no Cu signal for the mesh kinds of 300 and 400, which we expected that there were much amount of sputter-deposited mesh material.

Here we do not conclude the electron scattering effects and sputter-depositions of the mesh materials. This is because the amount of Cu signals in Figs. 3 and 4 does not show a systematic change depending the mesh opening size. We need further work for these subjects with two-dimensional investigation in mesh openings. In other words, the electron scattering effects and sputter-depositions have to be studied as a function of the distance from the mesh position and the mesh wall height (= mesh thickness). The authors, however, presently suggest we shall pay attention to the electron scattering effect and sputter-deposition when using metallic meshes. When sputtering the surface in the depth of about 100 nm, Cu signals are so weak and it does not seem to affect the sputtering rate of the matrix material for the mesh kinds of 50 to 400. Thus the mesh-replica method is applicable to estimate sputtering rates with the use of these kinds of mesh sizes, which is the main subject in this study.

CONCLUSIONS

The mesh-replica method has been preliminarily investigated to examine the applicable range of mesh size varying the commercial mesh kind from 50 to 400. The sputtering procedures were carried out in AES apparatus with Ar^+ ion beam of 3 keV at the incidence angle of 23 degrees from the surface normal. The ions sputtered the silicon surfaces down to about 100 nm in depth, where the sputtered depths were measured with the stylus profilometer. For all kinds of meshes investigated here, it is found that they are applicable to the mesh-replica method to estimate the ion-sputtering rates. Though there are small amount of sputter-deposited mesh material on the specimen surfaces for the mesh 150 to 400, it does not seem to affect the sputtering rate of the specimen. The electron scattering effect was also studied with the meshes after sputtering, but it was not clear to be discriminated from the sputter-deposition from the mesh onto the specimen surface.

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Errata

JSA 10, 144 (2003) "Investigation of Mesh Opening Size in Mesh-Replica Method toward Standardization of Depth Profiling Technique" by M. Suzuki et al.

in the second line in the second paragraph
(erratum) 200 to 300 mm
(correct) 200 to 300 μm

in the seventh line in the Experimental clause
(erratum) {mesh pitch (mm), mesh opening (mm), bar width (mm), mesh thickness (mm)}
(correct) {mesh pitch (μm), mesh opening (μm), bar width (μm), mesh thickness (μm)}

in the first line in Table 1
(erratum)

No.	kind	pith (mm)	mesh opening (mm)	bar (mm)	mesh thickness* (mm)

(correct)

No.	kind	pith (μm)	mesh opening (μm)	bar (μm)	mesh thickness* (μm)