Atomic-scale Processing of Sputter-deposited Pt-Pd Alloy Film Surface Using AFM Diamond Tips

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Abstract

Fundamental experiments to create the atomic-scale surface on a sputter-deposited Pt-Pd alloy film have been conducted under a constant normal force using the atomic force microscope (AFM) combined with a two-axis capacitive force/displacement transducer. An atomic-scale surface with roughness less than 0.1nm *Ra* (0.5 nm *Rz*) has been achieved under optimal processing conditions.

1 Introduction

Recently, surface modification with a scanning probe microscope has attracted special interest as an ultimate technique for processing surfaces [1]. This study aims to develop a new processing method to create local atomic-scale surfaces with AFM diamond tips. In order to investigate the possibility of the surface processing on an atomic scale, basic surface processing experiments using the AFM combined with a two-axis capacitive force/displacement transducer were carried out on the sputter-deposited Pt-Pd alloy films. The extremely minute tangential processing forces were measured experimentally, and were used to analyze the material removal mechanism in the atomic-scale processing.

2 Experimental procedure

Figure 1 shows the basic experimental model for explaining the mechanics of the processing on the atomic scale. A rectangular surface of length x and width y was processed using the AFM diamond tip as a tool. The rectangular surface was processed under a constant normal processing force f_n, a constant processing speed V_p, and a constant feed f_p. As shown in Figure 2, the diamond tip first moves straight from point ① to point ② at a constant speed and a constant normal force. Next, the

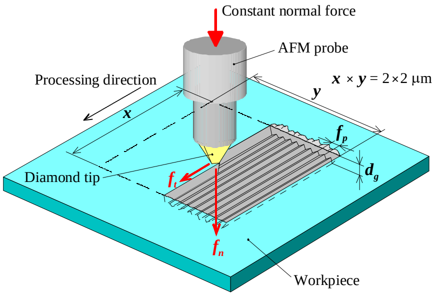


Figure 1: Constant-force surface processing method with AFM diamond tip.

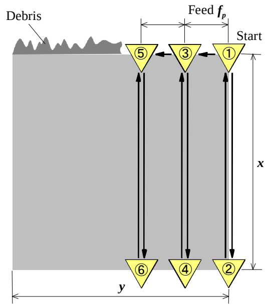


Figure 2: Processing procedure

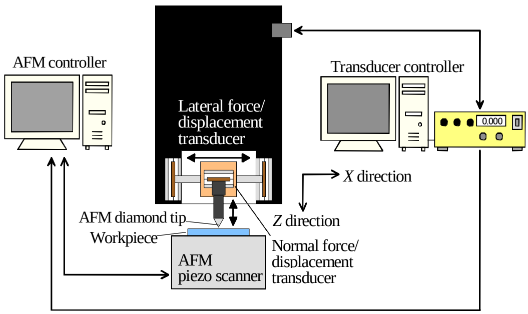


Figure 3 Schematic illustration of constant-force surface processing equipment with AFM

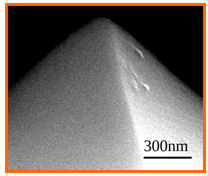


Figure 4: SEM image of diamond tip

tool returns straight from point ② to point ① again at the same constant speed and force. Afterwards, the tool moves from point ① to point ③. And thereafter, the tool repeats the same operation as the previous one.

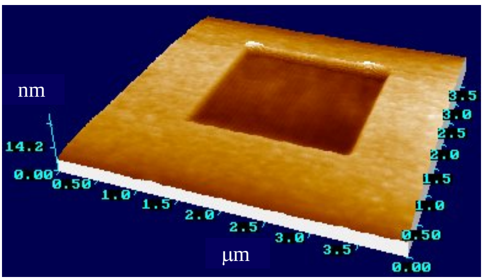
A series of processing experiments on the sputter-deposited Pt-Pd alloy film was performed using an AFM combined with a two-axis capacitive force/displacement transducer, a schematic illustration of which is shown in Figure 3 [2, 3]. The *X*-axis transducer (lateral force transducer) was composed of two additional sensors that were mounted transversely to the *Z*-axis transducer (normal force transducer). The two-axis transducer applied and measured force and displacement in both the *Z* and *X*-directions. A three-sided pyramidal diamond tip (cube corner tip) with a radius of 60~70 nm set in the center of the *Z*-axis force transducer, was used for both processing and imaging. Figure 4 shows a SEM image of the diamond tip used in this study. Experimental conditions for processing the rectangular surfaces are shown in Table 1.

Table1: Processing conditions

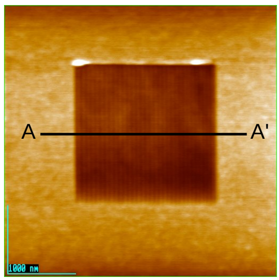
Processing tool		Three-sided pyramidal diamond tip Rake angle: 35°, Tip radius: 60~80nm
Normal force	f_n	20 μN
Processing speed	V_p	1 μm/s
Feed	f_p	15.625~125 nm/stroke
Processing area		2 μm×2 μm
Workpiece		Platinum-palladium alloy film sputter-deposited on Si wafer（Pt : Pd = 8 : 2) Thickness : 360nm Nanohardness : 4.9GPa Elastic modulus : 133.4GPa
Atmosphere		In air

3 Results and discussion

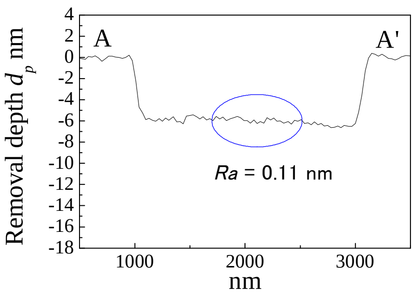
Figures 5 (a) and (b) show a typical 3D AFM image and its top view image of an atomic-scale surface formed at a feed of 62.5μm, respectively. Figure 5 (c) shows the profile at section A-A' in Fig.5 (b). These results show that an atomic-scale surface with a roughness of about 0.11 nm *Ra* was created. This surface was basically



(a) Three-dimensional image



(b) Top view image



(c) Profile at section A-A' in Fig. (b)

Normal force f_n = 20 μN
Processing speed V_p = 1 μm/s
Feed f_p = 62.5μm

Figure 5: AFM image of atomic-scale surface formed at feed of 62.5μm and its sectional profile.

composed of 33 regular straight parallel minute-groves, and was created in a total processing time of 136 seconds. Figure 6 shows the effect of the feed f_p on the surface roughness *Ra* of a processed surface. This result indicates that an atomic-scale roughness less than 0.2 nm can be formed when the feed is less than 80 nm. At the feeds of 30 to 50 nm, the roughness was easily affected by a very small amount of the removed wear debris remaining on the finished surface. However, in processing at a feed of 17 nm, ultimately a smooth surface with roughness of 0.1 nm or less was created.

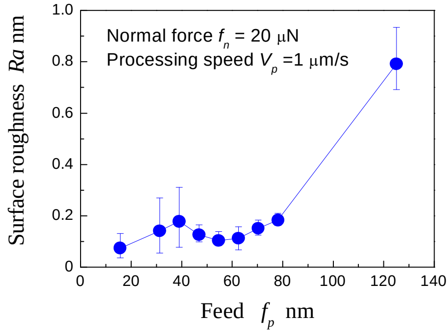


Figure 6: Effect of feed f_p on the roughness of processed surface *Ra*.

5 Conclusions

The main results obtained within the range of experimental conditions in this study are:

(1) An atomic-scale surface with a roughness less than 0.1nm *Ra* (0.5 nm *Rz*) can be produced under optimal processing conditions.

(2) The depth of processed rectangular surface (removal depth d_p) increases with decreasing the feed f_p.

(3) The processing tangential force f_n to create the atom-scale surface is less than 8 μN and this value shows a tendency to increase slightly with decreasing the feed.

References:

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