Tribological propties of Au film plated on the modified surface by shot peening in bounadry lubrication

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ABSTRACT

The present study describes applicability of fine particle peening on substrate treatment of gold (Au) plating. Aluminum alloy (A6063s), recognized as difficult for plating due to the coverage of the dense oxide film was selected as the substrate. Two spherical fine particles (silica glass and fly-ash), and conventional grade abrasives (silicon carbide, black silicon carbide and white alumina) were used for impact media. These impact media were collided to the target surface with developed peening apparatus. The surface after the peening was evaluated with SEM/EDX, stylus profile meter and an atomic force microscope (AFM). In order to estimate the tribological properties including adhesion strength of the Au film in actual operating conditions, face-to-face contact friction experiment was carried out using a ring on disc type testing apparatus in boundary lubricated condition.

Results of the peened surface characterization showed that the surface roughness depended on not only the size but also shape of the media and that migration of the fragment of the impact media occurred at collision to the target surface had significant influenced on the adhesion strength. In the friction experiment, it was confirmed that the lower and stable friction resistance with sufficient adhesion strength of Au film was confirmed on the peened surface containing the media migration. Therefore, it was concluded that the optimization of the peening condition including the impact media was available to increase in the adhesion strength of the Au plating.

KEY WORDS

Fine particle peening, Friction and wear, Migration, Adhesion strength, Aluminum alloy, Au plating, Substrate treatment

INTRODUCTION

Metall plating is one of traditional and conventional technique for surface modification and has aleady been applied various fields, such as elecrical contacts, hard coatings for wear reduction and decolation. In particular, gold (Au) plating is available for not only for decollation and electrical contacts but also solid lubricants operated in extreme low temperature and high vacuum conditions. Accordingly, it is necessary that the adhesion strength is sufficient to the applied load in operating condition. Various chemicals as the substrate treament process were applied to improve the strength and resulted in environmental pollution. Therefore, developments of the substrate treatment without the chemical usage have been expected.

In electro-less plating, it is well recognized that the anchor effect, resulted in the mechanical interlocking related with steep substrate texture is available for the increase in the adhesion strength [1]. Shot peening treatment with fine particle is a candidate process for the texturing without the chemicals usage [2]. Futhermore, the fine particle peening is possible to control not only the texture but also the surface properties obtained by the transfer or migration of the impact media [3]. Consequently, it is expected that the fine particle peening becomes a novel technology for the substrate treament for plating.

The present study describes the applicability of fine particle peening on the substrate treatment of gold (Au) plating applied as the solid lubricants. Aluminum alloy, which was well recognized as difficult for plating due to the dense oxide film formation was selected for the substrate material. The friction and wear properties including adhesion strength was examined in boundary lubricated condition. Optimize condition of peening treatment for plating was discussed.

METHODS

Materials

Five kinds of commercial grade abrasives (white alumina (WA), black silicon carbide(C-SiC) and silicon carbide (GC)) and two kinds of sphere particles (silica glass (GB) and fly-ash (FA)) were used for the impact media. SEM images of the media were shown in Fig. 1. The FA particle, one of the industrial wastes from the power plant using coal as fuel, had a spherical shape including cohesive small particles which was very difficult to isolate. Mean sizes of GB, WA, GC and C-SiC ranged from 8 to 75 μm without cohesion. The impact media was collided to the target surface using the developed peening apparatus whose detail was described elsewhere.

Aluminum alloy (A6063s) was used for the specimen having a disc shape of 50 mm in diameter and 10 mm in thickness. The flat surface of the specimen was polished (less than 0.02 μm in Ra) before the peening treatment. After the treatment, the surface profile and element analysis were evaluated with optical micro scope with topography measurement system, 3-D stylus profile meter, SEM/EDX and AFM were occasionally connected to characterize before the plating. Au film was plated on the treated substrate at 1 μm in thickness. After the plating, the characterization was also carried out.

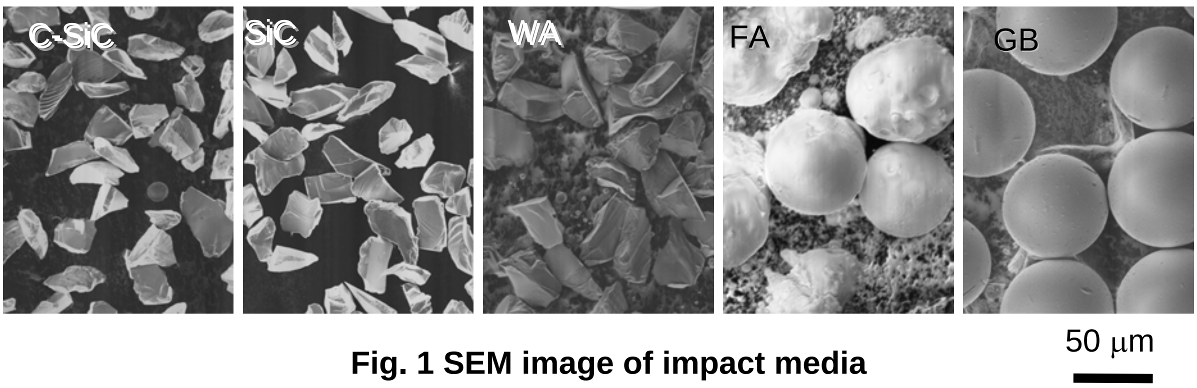

Fig. 1 SEM image of impact media

Friction experiment

In order to evaluate the adhesion strength and tribological properties of the Au film, friction experiments were carried out with a ring on disc type testing apparatus. A schematic of the apparatus was shown in Fig. 2. The specimen was fixed to the drive shaft driven by a DC motor. The mating specimen was aluminum alloy (A6061s) ring with polished surface (less than 0.02 μm in Ra) and mounted to the stationary shaft supported with guide way. The contact load of 43 N was applied by the dead weight and the sliding speed was 0.5 m/s. The friction force was measured continuously during test with dynamo meter consisted from strain gages. The mineral oil of 7 μl (approximately 1 droplet from a micro syringe) was supplied as lubricant just before the test. Since the oil did not supply during the test then replenished with the increase in the sliding distance.

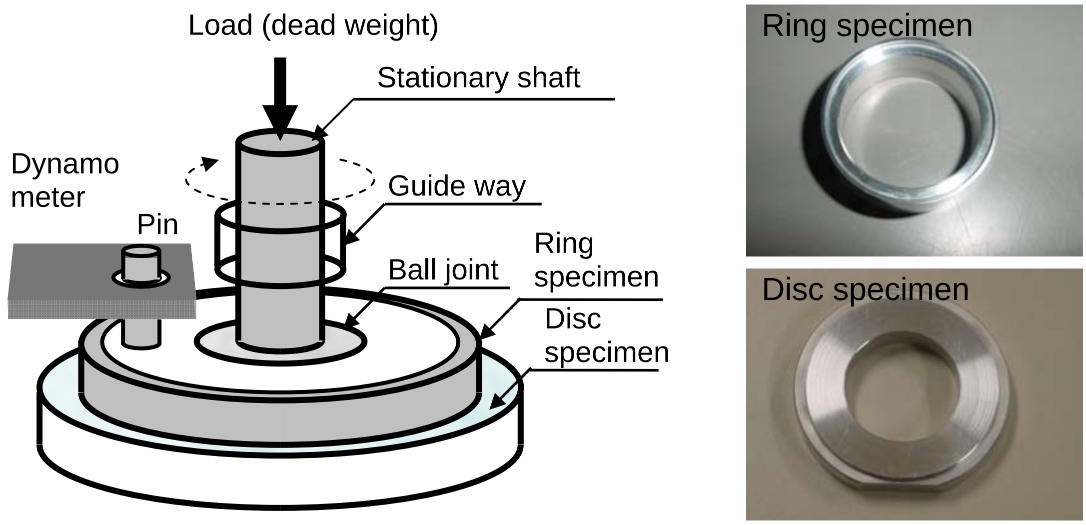

Fig. 2 Schematic of friction testing apparatus and overview of specimens before testing

RESULTS AND DISCUSSION

Peened surface

Relationship between surface roughness before and after plating and media size was shown in Fig. 3. The roughness before and after plating indicated as closed and open marks in the figure corresponded to that of peened and plated surfaces, respectively. It was found that the roughness increased linearly with the increase in the media size and that the slope was different depending on the media material: The results of C-SiC and GC abrasives showed that the roughness after plating and the slope were larger than those obtained in WA abrasive and FA and GB particles.

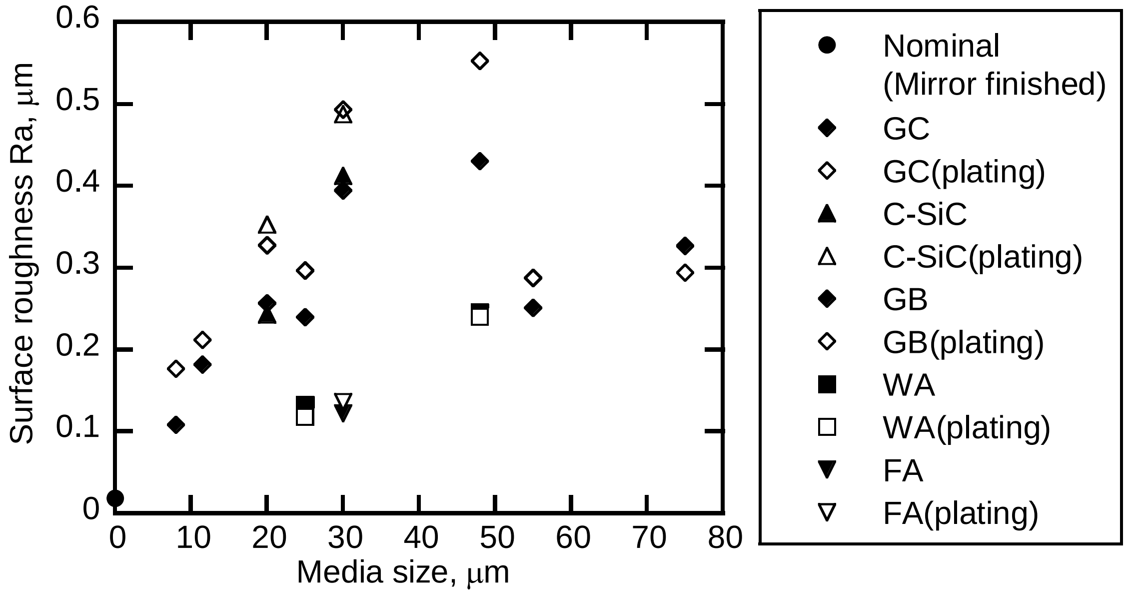

Fig. 3 Relationship between surface roughness and impact media size

SEM image of the peened surface were shown in Fig. 4. The surface profile was different depending on the shape of the impact media: Stiletto asperities and micro dimples were dominant to the surface profile peened with abrasives and particles, respectively. From the EDX analysis, dispersion of the migrated impact media was confirmed except on the GB peened surfaces.

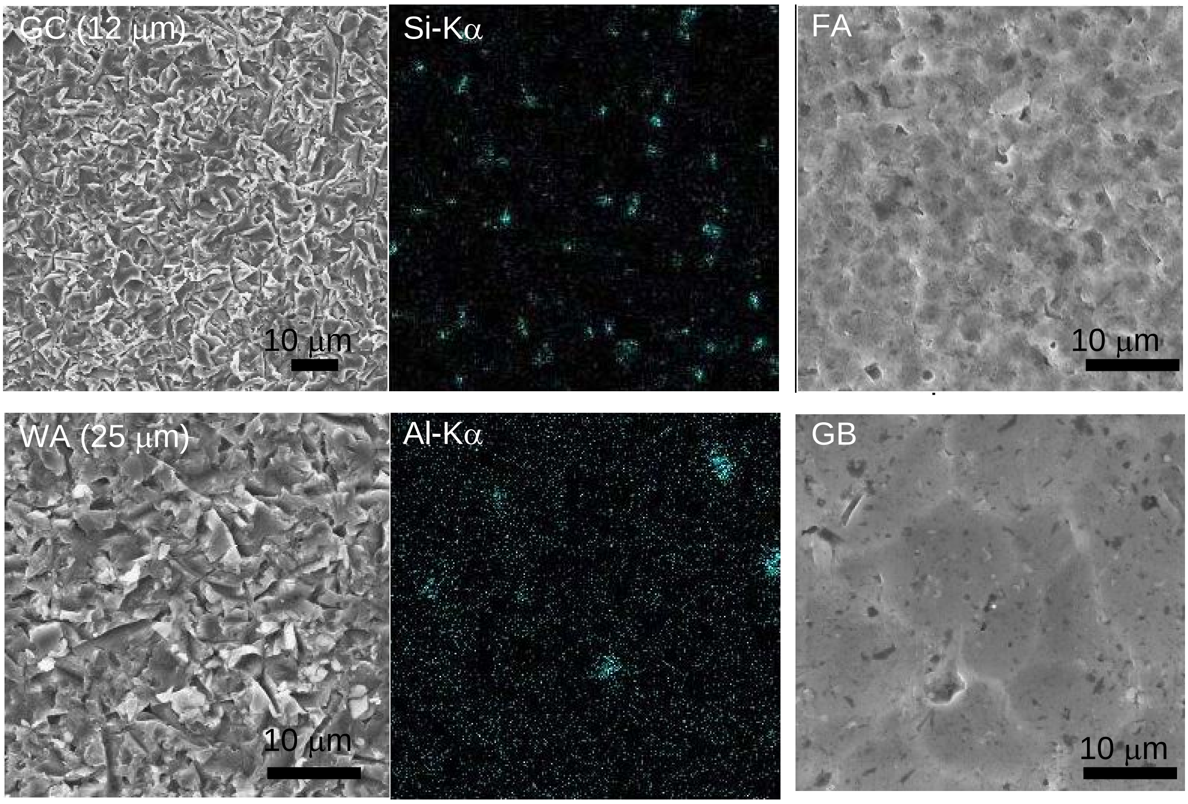

Fig. 4 SEM and EDX mapping images of substrates peened with various impact media

Friction properties

The friction coefficients as a function of sliding distance were shown in Fig. 5 and the optical micro images of the surface after the friction test was shown in Fig. 6. Since the Au film acted as lubricants in the extreme condition where the lubricant oil is impossible to apply, it is possible to detect the adhesion strength from the friction behavior. That is, the friction resistance was depended on the survival of the Au film at the interface; the peeling off of the Au film resulted in the increase in the friction resistance because of the ring and disc consisted from homogeneous materials.

The friction coefficient of Au film plated on the flat (non-peened) substrate increased rapidly at a sliding distance of 100 m and then was kept larger value more than 0.1. It was estimated that the peeling off occurred during the test. Higher value more than 0.1 was maintained in the emery paper polished substrate. Results of peened substrates showed that the lower friction coefficient was maintained. The mean value (approximately 0.1) and the rapid change of friction coefficients were found in results of the GB and WA peened substrates, respectively. In particular, those of FA and C-SiC peened substrates indicate the lowest and stable friction coefficient less than 0.05. Therefore, specific peening treatment was effective for increase in the adhesion strength and the reduction of the friction resistance.

The area fraction of survived Au film corresponded to the order of friction coefficient: Au films were completely removed from non-peened, polished with emery paper and peened with GB substrate and were survived on the C-SiC and FA peened ones. Partial remove was found on the WA-peened one. As shown in Fig. 4, the migration of the media fragment occurred at C-SiC, FA and WA peened substrates. Therefore, it can be concluded that that migration results in the increase in the adhesion strength.

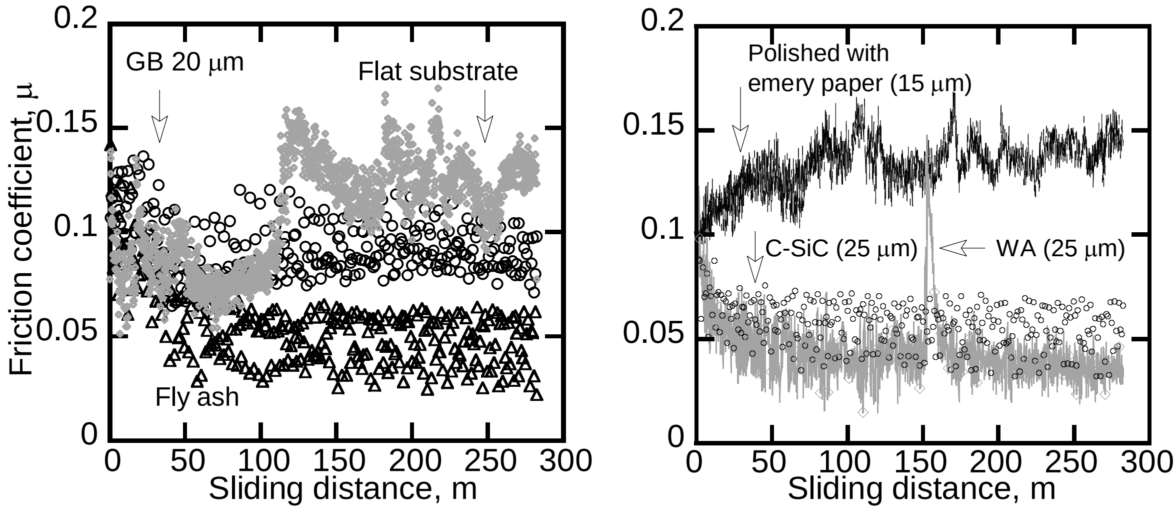

Fig. 5 Friction coefficients as a function of sliding distance

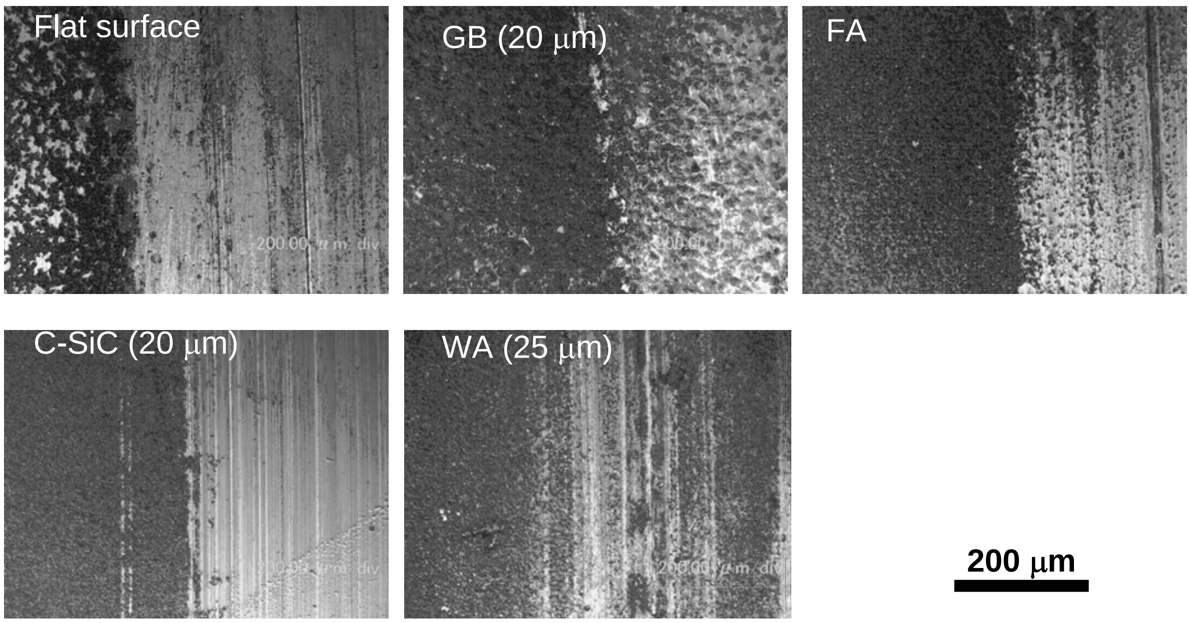

Fig. 6 Optical images of wear scar (Right hand side of the images corresponded to the wear surface. The sliding direction was from top to bottom of the picture.)

Figure 7 showed the relationship between the friction coefficient just before the end of the test and the initial surface roughness of the Au film. The lower friction coefficient of the peened substrate was obtained at smaller roughness; adhesion strength of the substrate peened with FA and C-SiC fine particles was enough to survive. Although the Au film plated on the substrate peened with larger GC abrasives was survived, the surface roughness and the friction coefficient were larger.

It is suggested that explore of migrated particles acted as the abrasive particle. Consequently, peened with smaller abrasives such as silicon carbide or black silicon carbide or fly-ash particle is effective for substrate treatment of Au plating to reduce the friction resistance including the adhesion strength. Considering the abrasive effect of the migrated media on the mating surface and the roughness of the peened surface, fly-ash particle is the candidate material for the treatment because of the sphere shape.

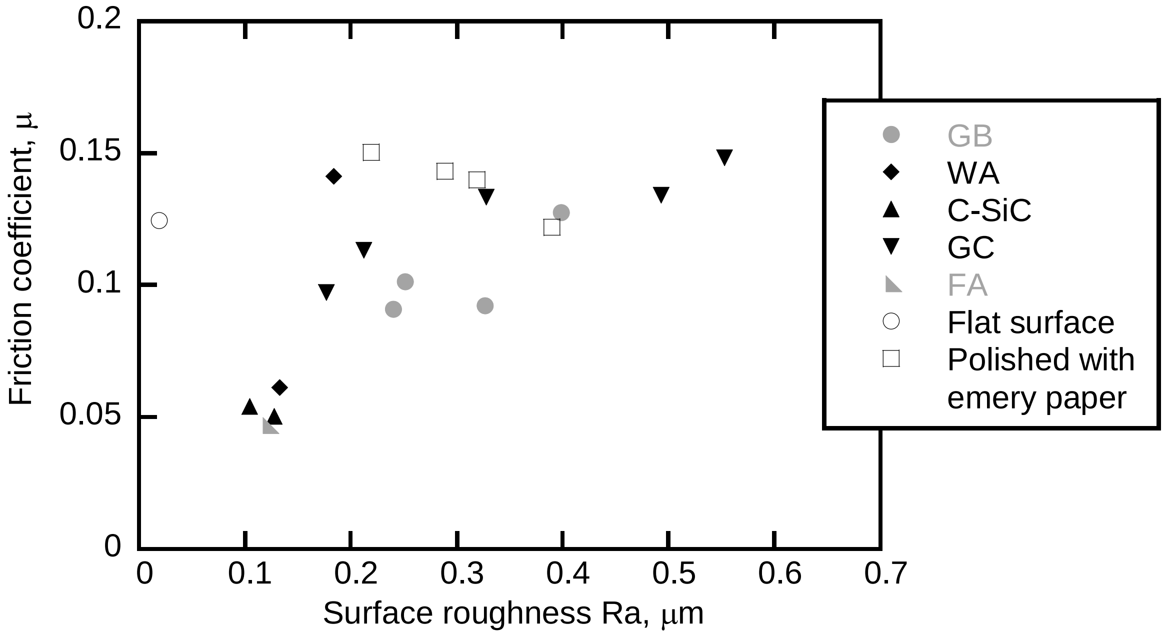

Fig. 7 Relationship between Surface roughness of Au film and friction coefficient

CONCLUSIONS

Applicability of fine particle peening for the substrate treatment of Au plating was evaluated. Friction experiment was connected to estimate the adhesion strength at the interface in actual operating condition. Obtained results were summarized as follows.

1. Migration of the media fragment occurred at silicon carbide, black silicon carbide and whiter alumina abrasives and fly-ash particle was effective to improve the adhesion strength.
2. Lower and stable friction resistance was obtained at the specific condition peened with smaller abrasives or fly ash particles because the migration of the media fragment and lower roughness.
3. Flay-ash particle is the candidate material as the impact media for the substrate treatment of Au plating.

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