Light-shielding Al alloy film for image sensor

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Abstract

We have developed new aluminum alloy films for a light-shielding metal layer in image sensors. Unlike conventional tungsten films, which are widely used for light shielding in image sensor but easily peel off due to their high membrane stress of the film, the proposed aluminum alloy films have lesser membrane stress and show good adhesion properties as well as good thermal resistance.

Keywords: Light shielding film, Al alloy

1. Introduction

In order to prevent from entering light into the non-light-receiving part of image sensors, a light-shielding film consisting of a metal thin film is generally formed onto the surface of the sensors. Conventionally, a pure-tungsten film is used as a light-shielding film. It is recognized that the pure-tungsten film is highly thermal stable; however, it easily peels off from substrates due to large membrane stress. On the other hand, it has been reported that light-shielding films formed by pure-aluminum film. The pure-aluminum film has smaller membrane stress than that for pure-tungsten film and, hence has good adhesion to Si substrates. Therefore, the aluminum-based light-shielding film does not easily peel off from the substrates. However, practical application of the light shielding film consisting of aluminum films is difficult. The Formation of hillocks during heat treatments is frequently observed. The hillock causes an increase in the surface roughness. Therefore, the pure-aluminum film does not meet the criteria as material for image sensors.

It is well known that the formation of the hillock is able to suppress by additive element to form aluminum alloys.[1], [2] In this study, an Al-Ta alloy film is proposed as a light-shielding film in image sensors.

2. Properties of Al-Ta alloy film for light-shielding film in image sensors

In Al-Ta alloy films formed by sputtering method, Ta element in aluminum matrix is forcibly dissolved through a solid solution. As a result, an Al-Ta alloy films show elastic deformation in the wide temperature range. This leads to an increase in the critical temperature for hillock formation.[3] Accordingly owing to the thermal property, an Al-Ta alloy film has smooth surface even after heat treatments. We evaluated the property of Al-Ta alloy films such as light shield property, thermal stability, durability of basic environmental test, and adhesion property.

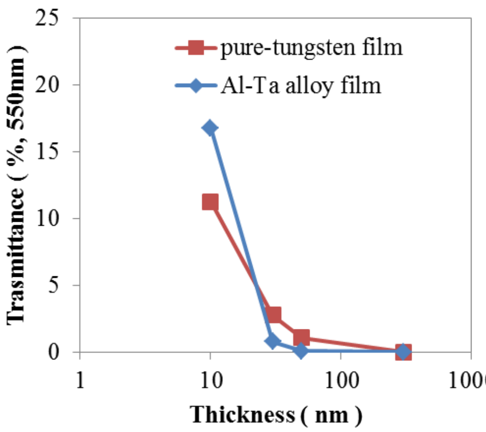

Fig. 1 The dependence of transmittance on film thickness about pure-tungsten and Al-Ta alloy films.

First, we evaluated light shield property. The pure-tungsten film and the Al-Ta alloy film were deposited by DC magnetron sputtering at room temperature on glass substrates. The thicknesses of the samples were 10, 30, 50, and 300 nm. The transmittances of each metal film sample were measured. Here, we compared the transmittance at a wavelength of 550 nm for both pure-tungsten and Al-Ta alloy films. (Fig. 1) The transmittance for both pure-tungsten and Al-Ta alloy films decreased with increasing the film thickness. In the case of thickness of 10 nm or less, the transmittance of the Al-Ta alloy film is larger than that for the pure-tungsten film. It is known that aluminum system alloy film forms aluminum oxide layer of about 5 nm to 10 nm from the surface. In the air atmosphere, 10 nm or less samples were oxidized throughout the films. The surface oxidation caused increase in the transmittance in the thinner aluminum system alloy samples. However, the Al-Ta alloy film sample has better light-shielding property than that for pure-tungsten film in the case of the thickness of 30 nm and more. The reflectance of metal aluminum is higher than that of metal tungsten. In the case of sufficient thickness, in which the film is not influenced by surface oxidation, aluminum system alloy films have better light shielding property than that pure-tungsten film.

Second, we examined thermal resistance of the Al-Ta alloy film. To check the thermal resistance, the change of surface roughness (Ra) was measured by atom force microscope (AFM)

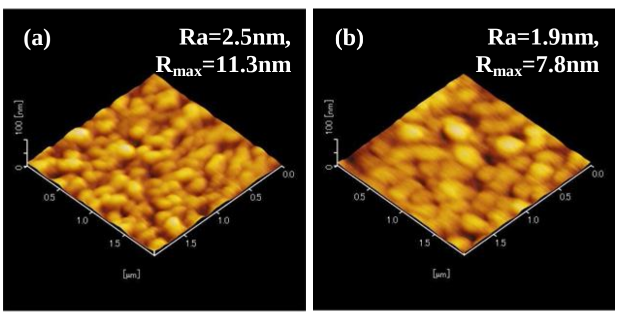

Fig. 2 Surface roughness of Al-Ta film (a) as deposited, (b) after annealing.

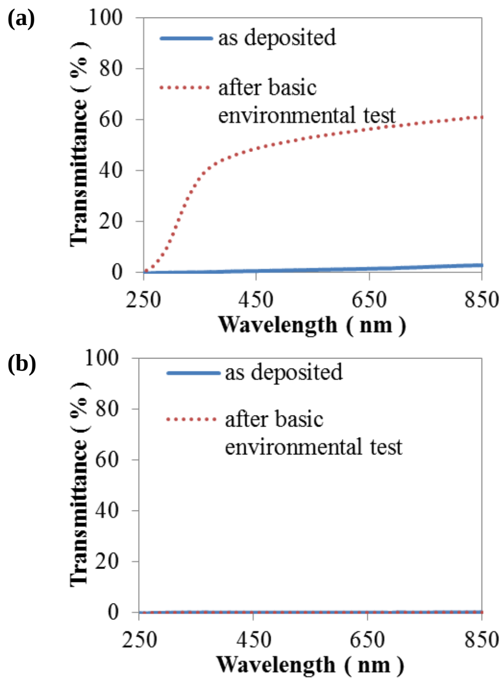

Fig. 3 Transmittance spectrum before and after basic environmental test.
(a) pure-tungsten film, (b) Al-Ta alloy film.

before and after annealing. Annealing condition was 450 °C, 1h treatment under N_2 atmosphere. Figure 2 shows AFM images of the Al-Ta films for (a) as deposited and (b) after annealing. The surface roughness was measured in 2 μm square area. Measured Al-Ta alloy film sample used for evaluation was 50 nm in thickness deposited by DC magnetron sputtering on glass substrates. In the case of pure-aluminum film, surface roughness increased after the annealing originating from hillock formed. On the contrary, the surface roughness of the Al-Ta alloy film was not changed after the annealing about Ra≒2 μm. Thermal resistance of the Al-Ta alloy film is improved by Ta element addition. Because of aluminum alloying, the Al-Ta alloy film has smooth surface after annealing at 450 °C (Fig. 2).

Next, we evaluated basic environmental test. Test conditions were as follows; the temperature was 80 °C, the humidity was 85 %, the test duration was 192 h. The thickness of the measurement samples for both pure-tungsten film and Al-Ta alloy film were 50 nm, which were deposited by DC magnetron sputtering on glass substrates. Figure 3 shows the transmittance before and after basic environmental test. The transmittance of the pure-tungsten film increased after the test about 50 % at 550 nm because the pure-tungsten film was oxidized during the basic environmental test. The transmittance of the Al-Ta alloy film was not changed after temperature and humidity controlled test. The aluminum system film forms a limited oxidation layer

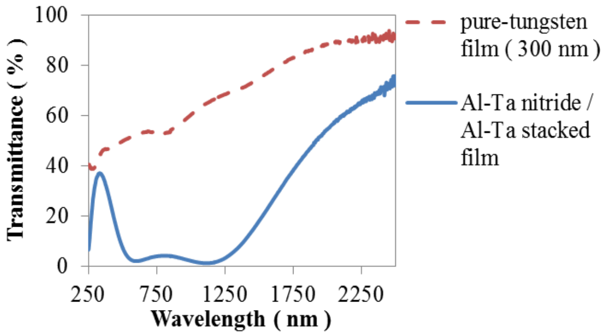

Fig. 4 Reflectance spectrum of Al-Ta nitride / Al-Ta stacked film

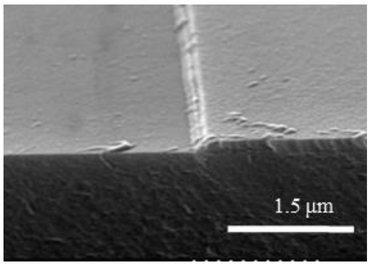

Fig. 5 SEM images of Al-Ta nitride / Al-Ta alloy stacked film after dry etching.

on the surface. Therefore, aluminum system film is stable for O_2 and/or H_2O.

In addition, we compared adhesion on glass substrates for the pure-tungsten film and the Al-Ta alloy film. Each film sample was deposited on a glass substrate by DC magnetron sputtering was about 300 nm in thickness. We evaluated adhesion property after depositing the films on the substrate by visual observation. Pure-tungsten film peeled off from the substrate immediately after deposition. The Al-Ta alloy does not peel off from the substrate.

3. Reflectance of Al-Ta alloy film controlled by nitride layer stacking.

The Al-Ta alloy film has better property for light-shielding film in image sensors than that of pure-tungsten film. However, the aluminum system alloy film has high reflectance. In the practical use as the light-shielding film, high reflectance caused scattering of light. We considered that reflectance controlling by anti-reflection layer which is stacked on the Al-Ta alloy film. The anti-reflection layer used Al-Ta nitride film was formed by the same sputtering target of Al-Ta alloy metal film. The reflectance between 450 nm and 1200nm for the Al-Ta nitride / Al-Ta stacked film can be controlled around 10 % or less as shown in Fig. 4. It was confirmed that the Al-Ta nitride / Al-Ta stacked film can be patterned by dry etching process with chlorine system process gas (Fig. 5)

4. Conclusion

We have evaluated the Al-Ta alloy film for light-shielding film in image sensors. The Al-Ta alloy film has good light-shielding property compared with that of pure-tungsten film. Moreover, durability such as thermal resistance or basic environmental test was improved by alloying. In addition, we can control the reflectance around 10 % or less by stacking the Al-Ta nitride film on the Al-Ta metal film. These Al-Ta system films can be patterned by dry etching process.

References

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