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Influence of lateral stress on interdiffusion in thin Cr/Au film

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Abstract

The Cr/Au films with lateral compressive stress were fabricated to investigate the influence of the lateral stress on the interdiffusion in thin Cr/Au film. The auger electron spectrometry (AES) measuring results demonstrated that the lateral compressive stress reduced the diffusion coefficient and the saturation concentration in grain boundaries.

1. Introduction

Since the gold adheres poorly to substrates, such as silicon, glass and ceramics, chromium is generally deposited onto the substrate prior to gold deposition as a tenaciously bonding metal. It has been demonstrated that the chromium diffuses heavily into the gold layer when thermally treated [1]. This diffusion will cause several problems, such as the increase of electrical resistivity and the poor adhesion to substrates [2]. The grain boundary diffusion and surface diffusion are verified as the dominant transport mechanisms in the thin Cr/Au film [3]. In some cases, the film is deposited in a trench in MEMS devices [4]. The thermal mismatch between the substrate and the Cr/Au film will cause an additional lateral stress in the film during thermal treatment. However, the influence of this lateral stress on the interdiffusion has not been researched yet.

In this paper, the influence of the lateral stress on the interdiffusion in thin Cr/Au film was first investigated. The films with lateral compressive stress were fabricated and measured by AES, which has been compared with the films without lateral stress. The lateral stress was introduced by depositing the films in the trench of the glass substrate.

2. Experiments and discussions

Fig. 1 has shown the schematic diagram of the idealized interdiffusion model in Cr/Au film with lateral stress. The short-circuit diffusion along surfaces, grain boundaries, and dislocations is the dominant transport path. The lateral compressive stress will reduce the gap between the grains, which will decrease the diffusion coefficient and the saturation concentration in grain boundaries accordingly. It should be noted that the lateral stress also affects the diffusion conditions in grain lattices, but it is ignorable when compared with that of the grain boundary diffusion.

To verify the above conclusions, Cr/Au films with lateral stress were fabricated and measured. The lateral stress was introduced by the thermal mismatch between Cr/Au film and the glass substrate owning to depositing the film in the glass trench. From Fig. 2, it could be seen that the thermal mismatch stress was very high in the trench when annealing at 250 ℃ obtained by ANSYS. All the films in this study were deposited by sputtering. The substrate was B33 glass. The thickness of chromium film was 17 nm, while the thickness of the gold film was 150 nm. Identical Films were deposited both on the glass and in the glass trench, as shown in Fig. 3. Then AES measurement was made on the as-deposited films and repeated after each of the following treatments: at 280 ℃ for 0.5 h, at 350 ℃ for 0.5 h and at 400 ℃ for 0.5 h in nitrogen atmosphere, for the both kinds of films. Fig. 4 and Fig. 5 showed the AES results of the film without lateral stress annealing at 350 ℃ for 0.5 h. From Fig. 5, it could be seen that there were three different regions in the curve of Cr: surface region (A), bulk of the gold layer (B) and the interface between gold and chromium (C). At the interface, there was a slope to the profile. In the bulk region, the concentration (including the chromium in grain boundaries and the chromium diffused from grain boundaries into grain) was almost constant. And a significant amount of chromium accumulated at the surface.

Fig. 6 has shown the chromium concentration versus depth of the film without trench at different annealing conditions. It can be concluded obviously that the diffusion coefficient was enhanced as the temperature increased. The chromium concentration of the bulk region also increased with the temperature increasing, because not only the saturation concentration in grain boundaries increased but also more chromium has diffused from grain boundaries into grain lattice. Almost all of the underlying chromium has diffused into gold layer at 400 ℃ for 0.5 h. The surface concentration was not high as expected when the temperature was high. This was because the nitrogen atmosphere did not provide a perfect sink for chromium. Fig. 7 has shown the chromium concentration versus depth of the films deposited in trench. From the picture, it could be seen that the chromium concentration of the bulk region was much lower than that of Fig. 6 (for example, 7.8% versus 17% with the same annealing conditions: 400 ℃ for 0.5 h). Although the surface maximum concentration of Fig.7 is a little larger than that of Fig. 6, the total surface accumulation of Fig. 7 is still smaller than that of Fig. 6. Therefore, it could be concluded that the lateral compressive stress reduced the saturation concentration in grain boundaries and the diffusion coefficient.

3. Conclusions

To investigate the influence of the lateral stress on the interdiffusion in thin Cr/Au film, different Cr/Au films were fabricated and compared by AES analysis. The experimental results demonstrated that the lateral compressive stress reduced the diffusion coefficient and the saturation concentration in grain boundaries.

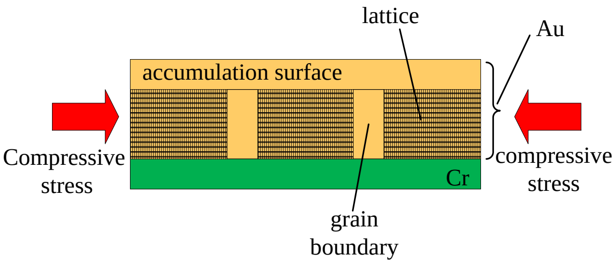

Fig. 1 Schematic diagram of the idealized diffusion model.

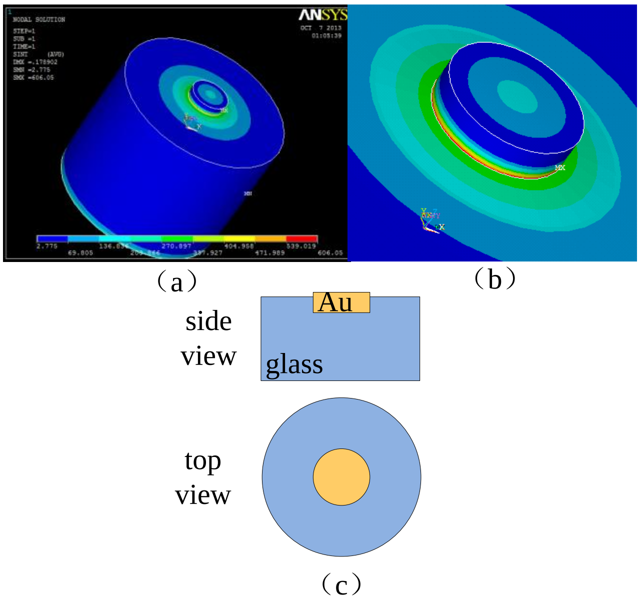

Fig. 2 Simulation results from ANSYS, (a) thermal stress contour plot of the film deposited in trench, (b) magnified photograph of the film, (c) the structure used in simulation.

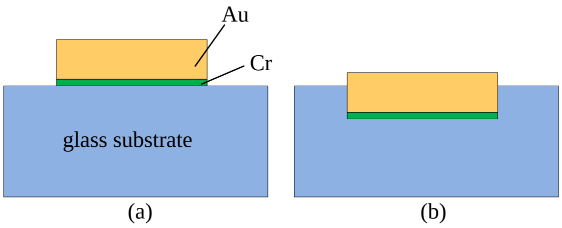

Fig. 3 Structures of the samples.

Acknowledgements

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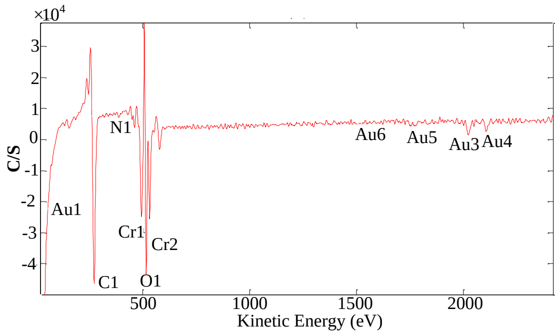

Fig. 4 The AES measuring results of the film annealing at 350 ℃ for 0.5 h.

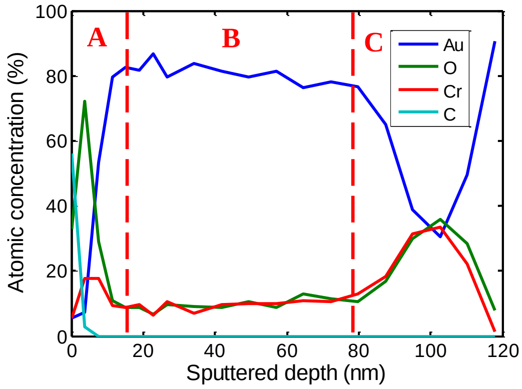

Fig. 5 The AES depth-analysis results of the film annealing at 350 ℃ for 0.5 h.

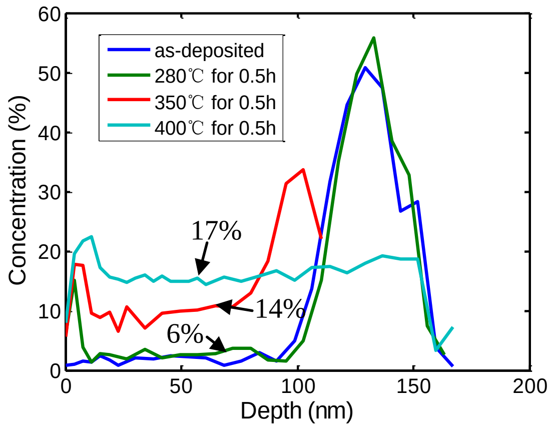

Fig. 6 The chromium concentration versus depth of the film without trench.

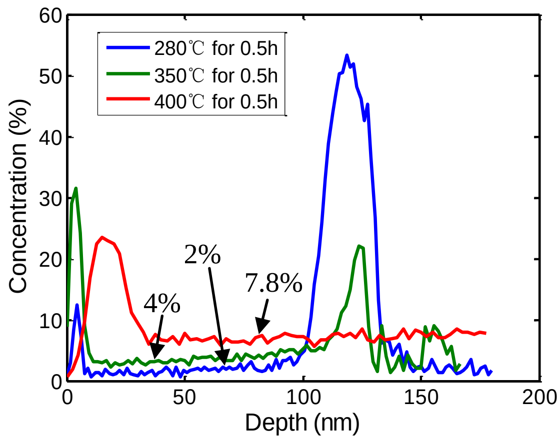

Fig. 7 The chromium concentration versus depth of the film in trench