Extended Abstracts of the 2018 International Conference on Solid State Devices and Materials, Tokyo, 2018, pp139-140

Low-Resistive, Highly-Reflowable Aluminum Contact Plug with Co Wetting Film

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Abstract

In this work, we report low resistive Al contact plug with Co wetting film. Excellent step coverage of CVD-Co wetting film enhances the reflowability of Al. As a result, small (35nmϕ) contact hole is successfully filled with Al. Even after reflow-anneal, the resistivity of Al with CVD-Co wetting films is lower than that of CVD-W film. These results indicate that Al contact plug with CVD-Co wetting film can lower the contact plug resistance compared with that of conventional CVD-W based plug.

1. Introduction

In recent years, low resistive contact plug has gained considerable attention in the advanced LSIs, because it is predicted that high resistance of conventional CVD-W based contact limits the device performance. To address this issue, Co has been reported as an alternate material to W[1]. For further reduction of contact resistance, we focus on Al based contact, which is more attractive in terms of lower resistivity than that of W or Co (Fig.1). Al based contact plug filled by reflow method has been used in legacy process node (>0.4μm). However, because of the poor reflowability of Al films, Al plug had been alternated to CVD-W based plug in the history of Si-based semiconductor devices. Recently, Al reflow method is reused for replacement metal gate (RMG) process in 20nm-node gate pattern [2]. For the RMG process, filling performance of Al reflow method is enhanced by insertion of CVD-Co wetting films prior to Al deposition.

In this work, we adopt Al reflow method with Co wetting film to small size (ϕ=35nm) contact plug and evaluate filling performance. Also, Co diffusion into Al films and resistivity of Al after reflow-anneal are studied.

2. Experimental

To assess the filling performance of Al reflow process with CVD-Co wetting film, contact hole of 35nmϕ structure were prepared. Schematics of the process flow are shown in Figure 2. Sputter etch preclean was applied on the NiPtSi formed on the bottom of hole. Then PVD-Ti and MOCVD-TiN stacked barrier films were deposited. A CVD-Co wetting film was deposited on the MOCVD-TiN barrier films followed by deposition of a PVD-Al film. Finally annealing was carried out in the Al-PVD chamber to reflow Al into the contact hole. Filling performance was confirmed by X-TEM images and compared with a sample with PVD-Ti wetting film.

Resistivity of Al and diffusion of Co into Al films were evaluated by blanket films. Resistivity was measured by 4-point probe method. XPS analysis was used to confirm diffusion of Co into Al films.

3. Results and Discussion

Figure 3 shows X-TEM images of (a) contact hole using Al reflow method with PVD-Ti wetting film and (b) that with CVD-Co wetting film. While contact hole was not filled with Al in case of Ti wetting film, Co wetting film shows good Al filling. Because the side coverage of PVD-Ti is poor, thicker film is required to obtain enough thickness on the sidewall of hole pattern. As a result, overhang shape at the top of hole is enhanced and Al is hard to flow into the hole. On the contrary, superior step coverage of CVD-Co enables us to thin down the deposited film and no overhang shape is formed on the top of hole, which enhances the filling performance of Al reflow.

Figure 4 shows the EDX images of trench pattern filled with Al on a Co wetting film. It is clear that Co diffuses in the Al film in trench pattern. Figure 5 shows the relation between anneal time and Co content in Al blanket films. The Co content tends to increase with the annealing time. To confirm the influence of Co diffusion, resistivity of Al blanket films deposited on Co/TiN bilayer were compared with that of W/TiN on blanket wafers (Fig.6). The resistivity of Al after 120sec-anneal, although slightly increased from as-deposition, was still 35% lower than that of W. These results indicate that Al contact using Al reflow with Co wetting film is one of the promising candidates for advanced-node low resistive contact.

4. Conclusions

With the Co wetting film, 35nmϕ contact hole is filled with Al using reflow method. The blanket film evaluations reveal resistivity of Al with Co wetting film is 35% lower than that of W even after the reflow-anneal. These results show that Al contact plug can lower the resistivity of contact plug and is one of the promising candidates for advanced-node low resistive contact.

References

[1] V. Kamineni *et al.*, *Interconnect Technology Conference / Advanced Metallization Conference (IITC/AMC)* (2016) 105.
[2] U. Kwon et al., *2012 Symposium on VLSI Technology* 29.

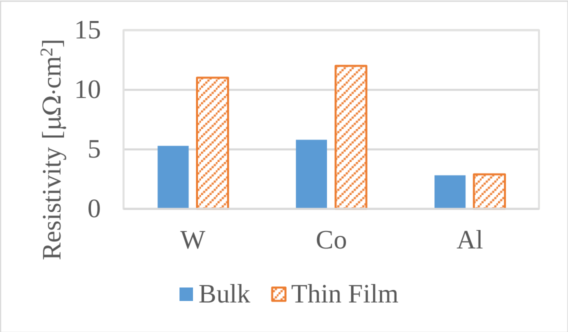

Fig.1 Comparison of resistivity of W, Co and Al bulk films and thin films.

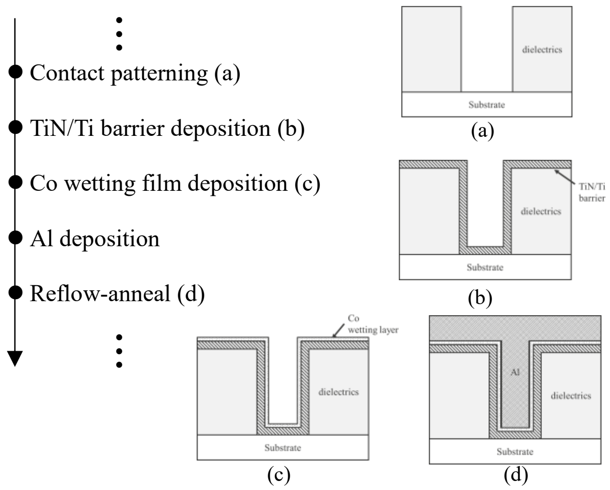

Fig.2 Process flow for studying filling performance of Al contact with Co wetting film.

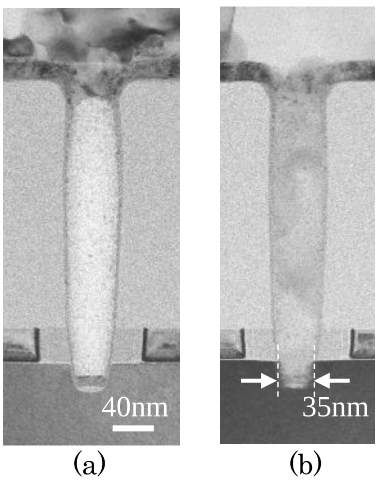

Fig.3 X-TEM images of trench pattern after reflow-anneal (a) with Ti wetting film, and (b) with Co wetting film.

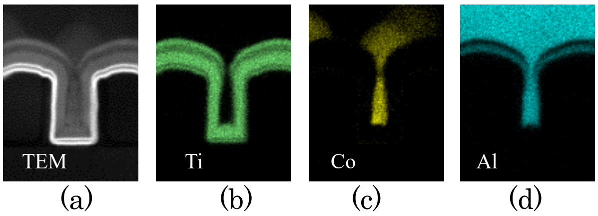

Fig.4 EDX images of trench pattern with Co wetting film after reflow-anneal. (a) X-TEM, and mapping images of (b) Ti , (c) Co, and (d) Al.

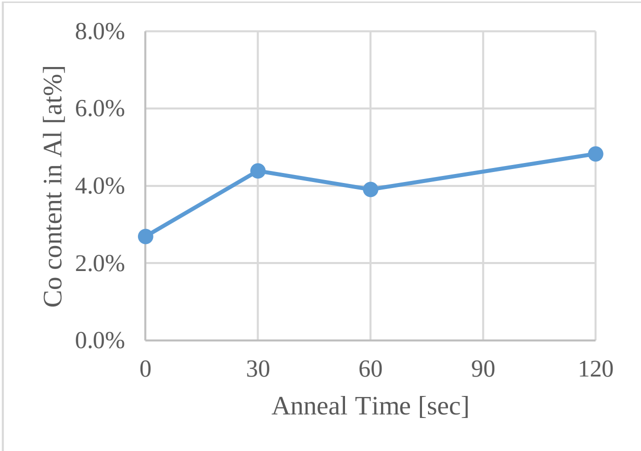

Fig.5 Co content vs. anneal time for thin Al blanket wafers with Co wetting films evaluated by XPS analysis.

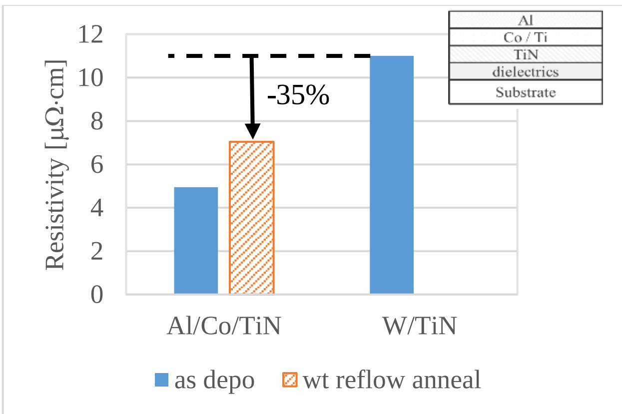

Fig.6 Resistivity of Al/Co/TiN stacked films with and without reflow anneal (400°C, 120sec) and W/TiN film.