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Blanket CVD-W Formed by SiH_4 Reduction of WF_6 on TiN for Planar Interconnection

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A deposition mechanism of CVD-W on TiN by SiH_4 reduction of WF_6 was studied, especially for initial nucleation, and key points for uniform nucleation were clarified, i.e. first, the chemical activation of TiN surface by WF_6 exposure, second, promotion of SiH_4 decomposition on the activated TiN, resulting in a enhancement of W nucleation by trace amounts of Si on TiN surface. In application to the planar interconnection, low junction leakage current and low contact resistance were realized by the deposition sequence developed.

1. Introduction

One of the key issues to realize the blanket CVD-W interconnection which has a excellent step coverage is to develop the glue or adhesion layer on inter-insulating layer such as SiO_2 because blanket CVD-W shows extremely poor adhesion on the insulating films. It is also required that the glue layer has good contact to both type of diffusion layer. Titanium nitride (TiN), which has been developed as the effective barrier layer in aluminum wiring, [1] was shown to satisfy the above-mentioned requirements. [2]~[4] In view of the film formation aspect, however, TiN has a serious problem in initiating the deposition of W on it.

In order to overcome the difficulty, the blanket CVD-W process that is applicable to the formation of W onto TiN glue layer has been developed using a novel SiH_4 reduction of WF_6. In this paper, deposition characteristics of the newly developed SiH_4 reduction process will be shown in conjunction with the initial nucleation features. Also will be given some of the electrical performance of the blanket CVD-W film in CVD-W/TiN/$TiSi_2$/Si contact structure.

2. Experimental

Depositions were done in a cold-wall batch type LPCVD reactor. WF_6, SiH_4 and H_2 gas were used as the reactant gases and Ar gas as the carrier gas.

In the case of W deposition onto TiN, the gas sequence or the order of the introduction of reactant gases into the reaction chamber plays an essential role for improving the deposition characteristics. We investigated the effect of " WF_6-pretreatment " of TiN surface on the deposition characteristics of SiH_4 reduction of WF_6.

TiN was deposited onto thermally grown silicon dioxide or Si substrate by reactive sputtering followed by rapid thermal annealing in a nitrogen ambient.

3. Results and Discussions

-Deposition Characteristics-

Figure 1 shows the thickness of W films formed by SiH_4 reduction or H_2 reduction onto TiN with and without the WF_6 pretreatment as a function of the deposition time. The thickness of W films was measured by cross-sectional SEM observation at the center of 6-inch diam. substrate. Figure 2 shows the sheet resistance maps. As clearly seen in Fig.1, an incubation period of about 90 sec is observed in the case of the SiH_4 reduction process without the WF_6-pretreatment, resulting in poor thickness uniformity as shown in Fig.2. However, newly developed process, in which the WF_6-pretreatment followed by SiH_4 reduction of WF_6 shows linear relation between film thickness and the deposition time without incubation period, resulting in good thickness uniformity. On the other hand, H_2 reduction process with and without the WF_6-pretreatment has an incubation period, resulting in poor uniformity of the film thickness. The WF_6-pretreatment of TiN has no effects on W nucleation in H_2 reduction process.

In order to investigate the effect of the WF_6-pretreatment on TiN, TiN surface after pretreatment was analyzed by the fluorescent X-ray analysis and ESCA.

Figure 3 shows the fluorescent X-ray signal intensities of Ti and W from TiN with the WF_6-pretreatment as a function of the pretreatment temperature. Decrease of Ti

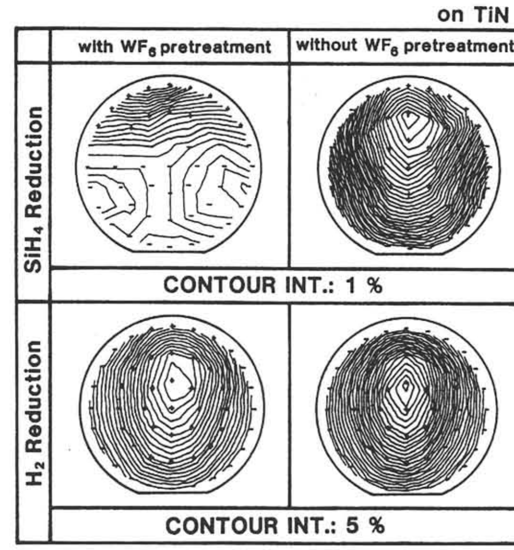

Fig.2 Sheet resistance maps of W films deposited by SiH_4 or H_2 reduction onto TiN with and without WF_6 pretreatment.

signal and increase of W signal are observed at high temperature region typically used for the blanket CVD-W process (higher than 400 °C), implying WF_6 reacts with TiN and modification of TiN surface occurs during the WF_6 pretreatment.

Figure 4 is the ESCA spectrum from the TiN surface to show the effect of the WF_6 pretreatment for SiH_4 and H_2 reduction process. In Fig.4, (a) is the spectrum only with the WF_6-pretreatment, (b) is that exposed

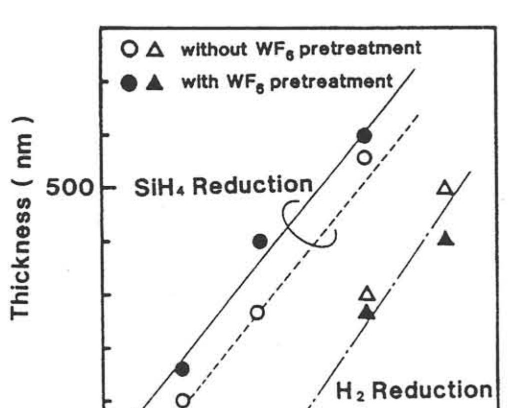

Fig.1 Thickness of W films deposited by SiH_4 or H_2 reduction onto TiN with and without WF_6 pretreatment as a function of deposition time.

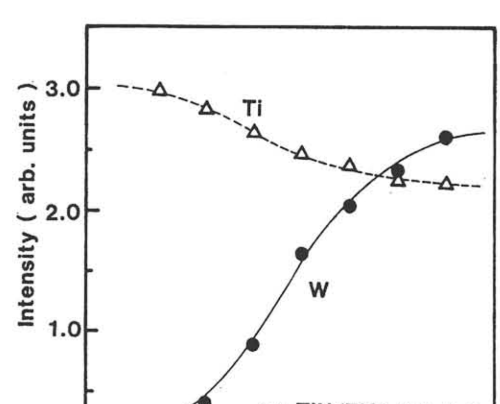

Fig.3 Fluorescent X-ray signal intensities of Ti and W from TiN with WF_6 pretreatment as a function of pretreatment temperature.

with H_2 for 60 sec after the WF_6-pretreatment and (c) is that exposed with SiH_4 for 60 sec after the WF_6-pretreatment, respectively. In the sample (c), Si signals clearly appear in addition to W signal on the TiN surface by the exposure of SiH_4 after the WF_6-pretreatment. This result shows that decomposition of SiH_4 is promoted only on the TiN surface pretreated with WF_6. It was confirmed that the trace amounts of Si on the WF_6- and SiH_4-exposed TiN surface enhanced the initial nucleation of W deposition.

Figure 5 shows the SEM observations at the initial stage of W deposition with and without the WF_6-pretreatment. With the WF_6-pretreatment dense nucleation of W was observed on TiN. While without the WF_6-pretreatment, it was sparse.

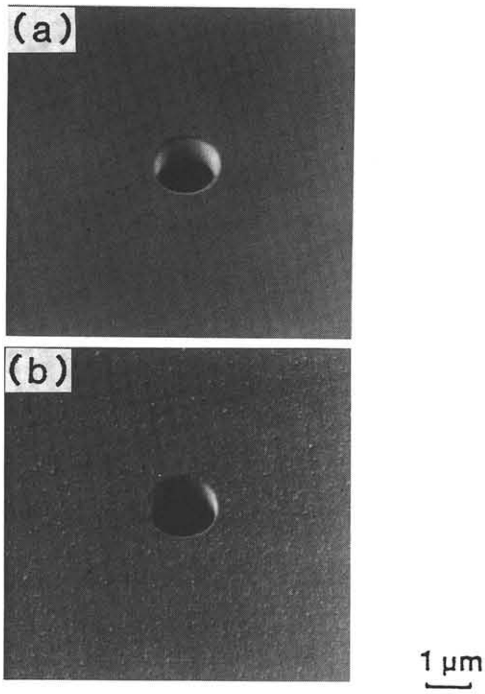

Fig.5 SEM observations at the initial stage of W deposition. (a) is with WF_6 pretreatment and (b) is without WF_6 pretreatment.

-Electrical Characterizations-

In order to investigate electrical characteristics of the newly developed SiH_4 reduction process for W deposition on TiN, a junction leakage current and a contact resistance for an N^+ diffusion layer were measured. As shown in Fig.6, for a junction leakage current measurement two types of test pattern were used to clarify the effect of W film stress on a junction leakage current. One is a wide pattern (1125 μm x 1875 μm) covering 130200 contacts of 1.0 μm□, the other is a stripe wiring pattern (2.2 μm x 800 μm x 600 wires) contained 120000 contacts of 1.0 μm□ which is very similar to actual devices. For a contact resistance measurement the 4-terminal Kelvin pattern was used. The results of junction leakage current and contact resistance were compared with those of $AlSi/TiN/TiSi_2/N^+Si$.

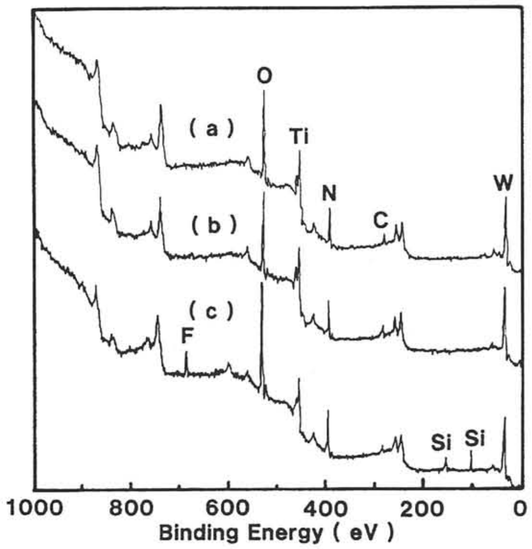

Fig.4 Results of ESCA analysis. (a) is the spectrum only with WF_6 pretreatment, (b) is that exposed with H_2 for 60 sec after WF_6 pretreatment and (c) is that exposed with SiH_4 for 60 sec after WF_6 pretreatment, respectively.

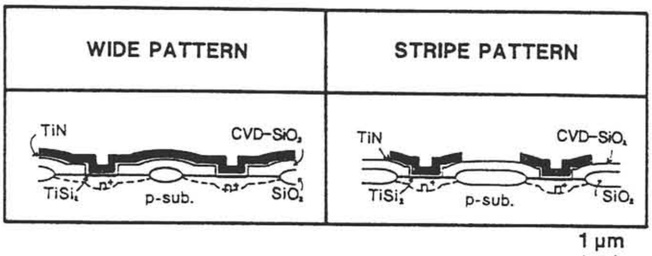

Fig.6 Test device for junction leakage current measurement.

Figure 7 shows the histograms of junction leakage current at V_R=5V for both patterns. In the wide pattern, the leakage current of W films is about six times larger than that of AlSi films. While in the stripe pattern, the leakage current of W films are almost the same as that of AlSi. The higher leakage current in the wide pattern is due to its high tensile stress, while in the stripe pattern the W film stress is reduced by chopping the film and has no visible effects on a junction leakage.

Figure 8 shows the histograms of contact resistance. The contact resistance is almost the same as that of AlSi, and sufficiently low due to the $TiN/TiSi_2$ structure.

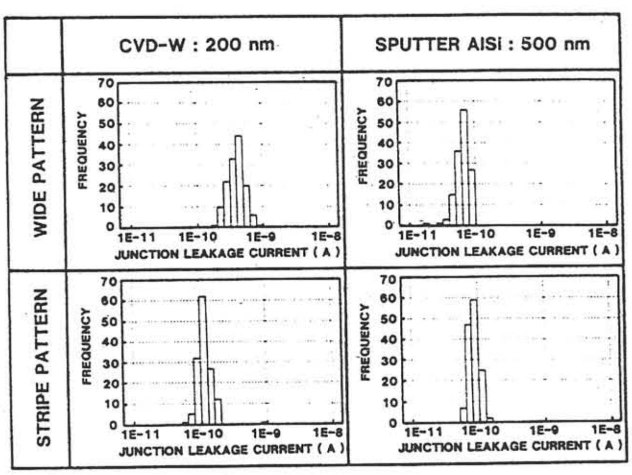

Fig.7 Histograms of junction leakage current at V_R=5V of W films compared with that of AlSi films.($TiN/TiSi_2/N^+$/p-sub.)

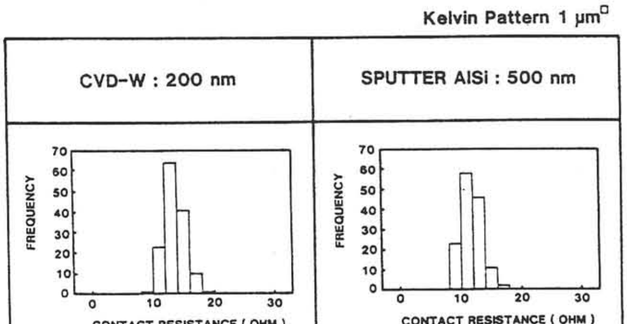

Fig.8 Histograms of contact resistance of W films compared with that of AlSi films.

4. Conclusions

The blanket CVD-W deposition process has been developed successfully using SiH_4 reduction on TiN which acts as glue and barrier layer. The key point of this novel process is, first, the chemical activation of TiN surface by WF_6 exposure, second, promotion of SiH_4 decomposition on the activated TiN, resulting in a enhancement of W nucleation by trace amounts of Si on TiN surface. The CVD-W films were deposited on TiN with good thickness uniformity and without incubation period.

The blanket CVD-W films were applied to the wiring material, and a low junction leakage current and a low contact resistance were realized for $CVD\text{-}W/TiN/TiSi_2/Si$ structure.

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