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Selective Tungsten CVD with High Deposition Rate for ULSI Application

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For the application of selective tungsten CVD on ULSI device fabrication, two serious problems yet remain such as loss of selectivity and damage on devices. The selective tungsten deposition with the high rate of 1μm/min has been achieved by new CVD system having a cold susceptor, where the high selectivity has been well maintained continuously. We have also found that the tungsten-Si contacts with good performance of low contact resistance and no device damage can be formed by controlling the initial growth of tungsten.

1.INTRODUCTION

Selective Tungsten CVD has played a very important role as a technique to improve the planarization in the fabrication of ULSI devices. It has been intensively investigated because of its excellent performance of submicron hole filling. But two serious problems yet remain, which are the loss of selectivity and the damage on devices. The performance of selective tungsten CVD depends on the chamber function. In the conventional CVD system with a hot wall chamber, it is difficult to maintain the selectivity for a long time. The leakage current of the junction in devices may increase, because WF_6 can strongly react with the Si substrate to cause tungsten encroachment on Si.

The purpose of this paper is to develop highly-reliable metallization process by selective tungsten CVD for ULSI device fabrication. The selective formation of tungsten plugs with the high deposition rate of 1μm/min can be achieved at 210°C with new CVD system. We have also found that tungsten/Si contacts with low contact resistance and without no device damage can be formed by controlling the initial growth of tungsten.

2.EXPERIMENTAL

Selective tungsten depositions were carried out with a new CVD system having three features such as Xe lamp heating, a cold susceptor, and separate gas nozzles[1]. The tungsten deposition rate was determined from SEM cross sectional observation of the plugs formed on 1μm contact hole. Contact resistances were measured by the Kelvin method. Leakage current was measured with n^+/p junction having 40μm□ contact window. The n^+ diffused layer was formed by thermal diffusion of phosphorus from Phosphosilicate glass. All the samples were treated with 1% DHF dipping, and rinsing with ultrapure water for 1min before the deposition. Thermal annealing was not carried out after tungsten deposition. To clarify the effect of wafer pre-treatment on the contact performance, N_2 gas sealed process where dissolved oxygen concentration in ultrapure water was suppressed below 20 ppb was applied as a final cleaning procedure to obtain a native-oxide-free Si surface.

3.RESULTS AND DISCUSSION

Figure 1 shows the cross sectional photographs of tungsten filled in contact hole by this process and Arrhenius plots of the deposition rate. The tungsten film is deposited without the degradation of selectivity in the temperature region of 210°C or lower as seen from the photograph(B) in Fig.1. Further rise of temperature leads to an anomalous growth as seen from the photograph(A). The selective formation of tungsten plugs with the high deposition rate of 1μm/min can be achieved at 210°C. It means that this selective process is capable of single wafer processing. Any maintenances for chamber cleaning were not required in this system because no by-products can be observed on the cold chamber wall and the cold susceptor. The deposition of tungsten with high selectivity can be available with good stability.

The XPS depth profiles of W, F, O, and Si in the tungsten film deposited at 210°C are shown in Fig.2. Segregation of fluorine or oxygen is not observed at tungsten-Si interface. Detection of some percents of

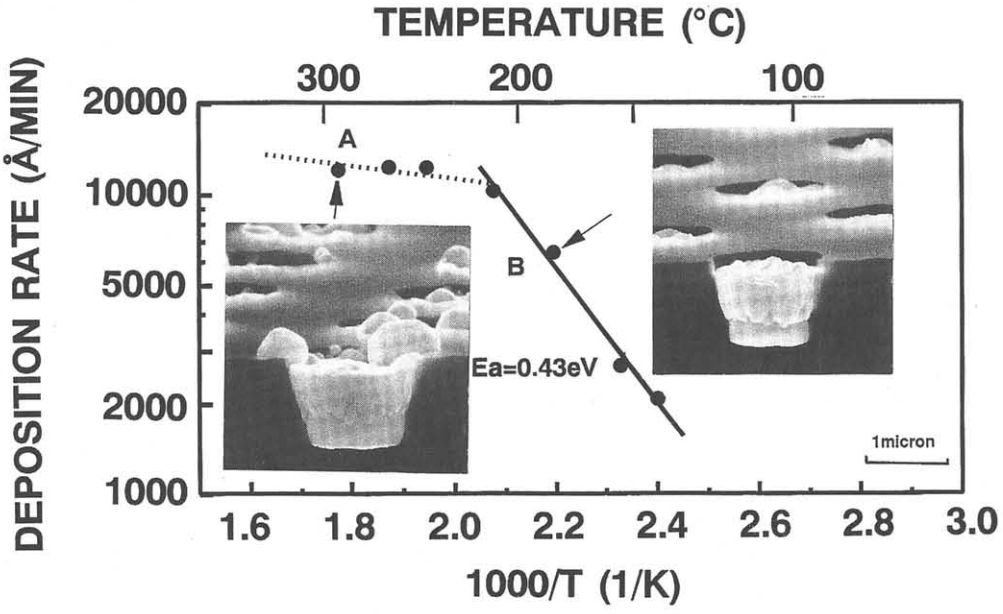

Fig.1 Arrhenius plot of tungsten deposition rate, where $WF_6/SiH_4/H_2/Ar$=10/4/100/100 SCCM and P_T=138mTorr

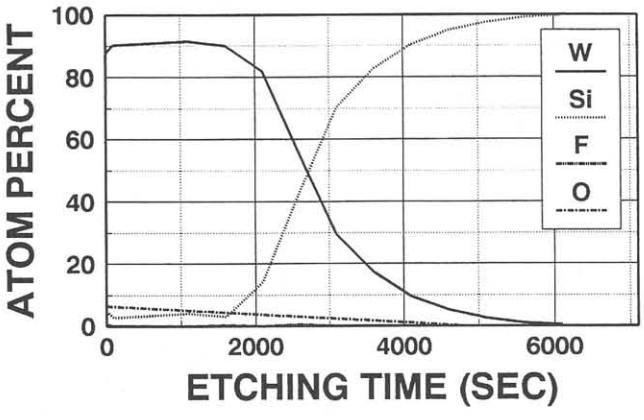

Fig.2 XPS depth profiles of W, F, O, and Si in a tungsten film.

oxygen atoms is assumed to be caused by residual gases in XPS equipment. The film contains a few percent of Si atoms as reported in Ref.2. No fluorine atoms is observed in the deposited film. The formation of clean tungsten–Si interface is confirmed by XPS analysis.

Figure 3 shows the reverse leakage current of $W/n^+/p$ junction metallized by this selective deposition process. The evaluation was carried out for the samples metallized by various conditions of initial growth of tungsten. The junction with low leakage current density can be obtained by using an additional step of initial tungsten growth for 30sec with WF_6 gas only(sample A). However, the others (sample B,C) exhibit large leakage current. It seems to be caused by the co–existence of WF_6 and SiH_4 during the initial

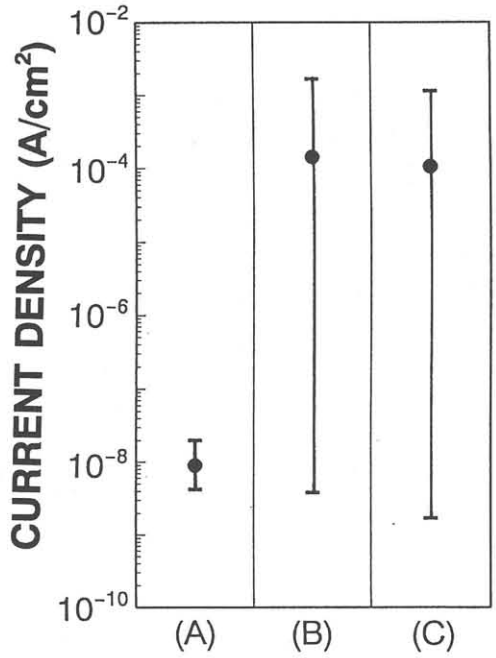

Fig.3 Dependence of reverse leakage current of $W/n^+/p$ junction on conditions of initial tungsten growth, (A)WF_6/SiH_4=10/0SCCM, (B)WF_6/SiH_4=10/0.5SCCM, and (C)no additional step.

formation of tungsten films degrades the characteristics of the interface.

Figure 4 shows the dependence of tungsten/n^+–Si contact resistance on the time of an initial film formation step. The condition of the initial film formation is the same as that of sample A in Fig.3. Contact resistance can be reduced by adjusting the time of initial film formation, where WF_6 gas is only introduced right before the

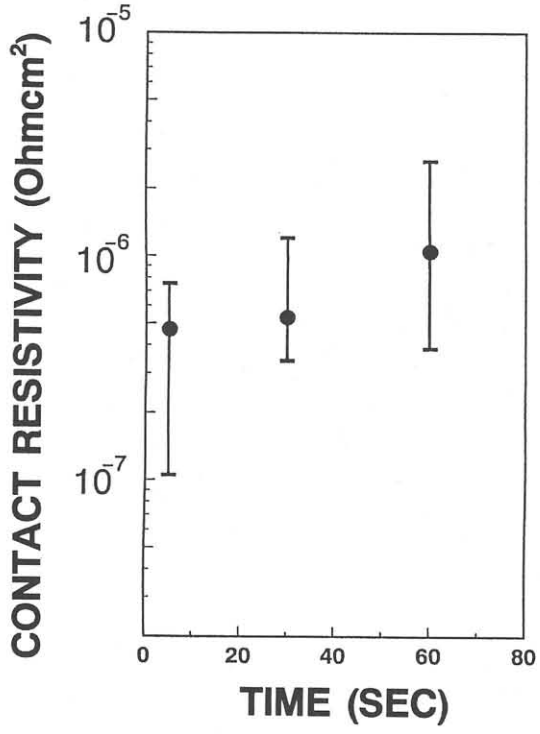

Fig.4 Dependence of W/n⁺–Si contact resistance on initial film formation time.

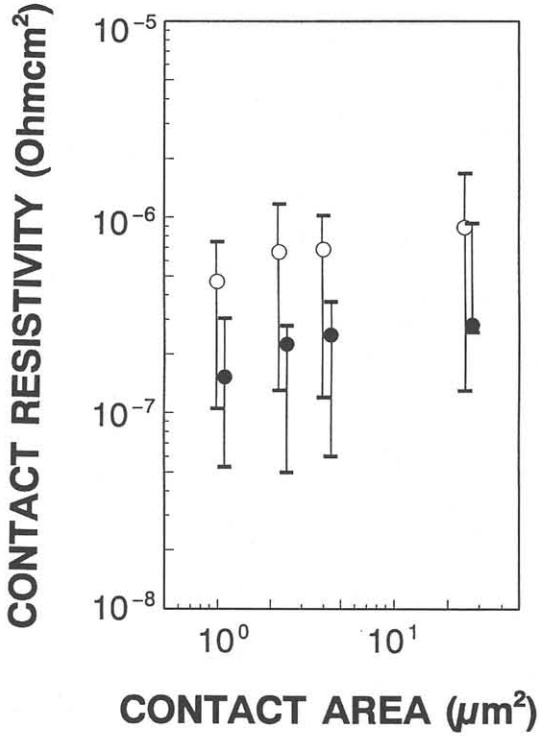

Fig.5 Dependence of W/n⁺–Si contact resistance on the pre–treatment process. The symbols ○ and ● represent conventional and N_2 sealed processes, respectively.

deposition. It is found that the tungsten/Si contact with good performances of low contact resistance and no device damage can be formed by controlling the initial growth of tungsten.

The enhancement of the tungsten/Si contact performance can be also obtained by the control of Si surface. It is already reported that native–oxide–free process(N_2 gas sealed process) is very useful for the formation of the aluminum/Si contact with low contact resistance[2]. It can be expected that this process is also effective on the tungsten/Si contact formation. Contact resistance of tungsten/n⁺–Si contact is reduced by this process as shown in Fig.5. Utilizing N_2 gas sealed process as a pre–treatment of selective tungsten CVD process, the contact resistance can be reduced.

4.CONCLUSIONS

By the development of a new CVD system, selective tungsten deposition with the high deposition rate of 1μm/min has been achieved. It can also provide the cleaning–free process, and enables us to keep the high selectivity continuously for a long time. We have also found that tungsten–Si contacts with good performances of low contact resistance and no device damage can be formed by controlling the initial growth of tungsten. It is important to control the surface reaction by optimizing initial film formation condition as well as preparating the clean Si surface in order to obtain high performance tungsten/Si contact. This technology enables us to apply the selective tungsten CVD on the direct metallization on submicron devices to reduce the number of process steps in ULSI metallization.

Selective tungsten CVD with high deposition rate, in which the initial tungsten growth and silicon surface are controlled, will provide highly reliable and simple metallization process in ULSI production.

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