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Low Resistivity Tungsten/Titanium-Silicide/Silicon Contact for Submicron VLSI

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A size dependence and a thermal stability of W/$TiSi_2$/Si and W/WSi_2/Si contact structure have been investigated in comparing with conventional Al-Si/Si contacts. Contact resistances of W/$TiSi_2$/Si and W/WSi_2/Si contacts increase as the scaling law. In the submicron contacts, the contact resistivity of W/$TiSi_2$/Si less than 1×10^{-7}ohm-cm^2 for n^+Si, and 1×10^{-6}ohm-cm^2 for p^+Si were obtained even after 700°C, 30min annealing.

1. Introduction

In submicron multilevel interconnect technology, low resistance and thermally stable contact formation is one of the key technologies. In a scaled down design, contact resistance increases in proportion to square of a scaling factor. In conventional Al-Si contacts, there are additional degradation factor due to a precipitation of excess Si at Al-Si/Si interface after a sintering process. To supress the Si precipitation, contact structures having a barrier layer, such as TiN, WSi_2, TiW inbetween Al-Si and Si, have been proposed.

To realize a submicron multilevel interconnect, high thermal stability of the contact is required for a processing of planalized interlayer dielectrics. In a Al-Si/Si contact system, however, a maximum allowable temperature is restricted below about 500°C because of a hillock formation or a stress migration.

To overcome these problems, refractory metal interconnect and several kinds of contact structure such as W/WSi_2/Si(1)(3), W/TiN/$TiSi_2$/Si(2), W/WSi_2/Ti/Si(3) were proposed.

The purpose of this work is to realize the thermally stable multilevel interconnect with simple and low resistance contact structure. This paper describes the thermal stability of W/$TiSi_2$/Si, W/WSi_2/Si and Al-Si/Si, and the dependence of these contact resistivity on their contact size.

2. Size dependence

The size dependence of contact resistance (Rc) for W/$TiSi_2$/Si and W/WSi_2/Si contacts has been investigated in comparing with conventional Al-Si/Si contact system. $TiSi_2$ and WSi_2 films were used as a diffusion barrier layer between a W interconect and a Si substrate. The $TiSi_2$ barrier layer was employed because of its lower electrical barrier height to n^+Si than WSi_2.

The cross section of W/$TiSi_2$/Si contact is shown in Fig.1. The $TiSi_2$ film was deposited by co-sputtering method in which the composition of $TiSi_x$ were precisely controled. W was deposited by usual sputtering method. $W/WSi_2/Si$ contacts were formed by almost the same process as $W/TiSi_2/Si$.

The thickness of $TiSi_2$ and W were 0.1μm and 0.3μm, respectively. n^+ and p^+ diffusion layers were formed by As^+ and BF_2^+ implantation. Their junction depth were 0.2μm and 0.3μm, and their surface concentration were $4\times10^{20}/cm^3$, and $2\times10^{20}/cm^3$, respectively. The contact sizes were from 0.8μm to 2.3μm. The shape of a contact below 1.5μm was rather circular than square, so the contact size was defined by its diameter.

Fig.2 shows the Rc of each structure as a function of the contact size. Fig.2 (a) shows Rc for n^+Si contact, and Fig.2 (b) shows Rc for p^+Si contact.

For the n^+Si contact, the Rc of the 0.8μm Al-Si/Si contact reaches 300ohms, while the $W/TiSi_2/Si$ and $W/WSi_2/Si$ contacts show 15ohms and 40ohms, respectively. The Rc of $W/TiSi_2/Si$ and $W/WSi_2/Si$ increase almost as the scaling law. The Rc of $W/TiSi_2/Si$ shows one tenth of the Al-Si/Si contact at every size.

For p^+Si contact, the Rc of the contact, except the Al-Si/Si, also increases almost as the scaling law below the contact size of 1.5μm. The discrepancy of increasing rate of the Rc above 1.5μm has not been clarified yet. The Rc of 0.8μm Al-Si/Si contact is 70ohms while $W/TiSi_2/Si$ and $W/WSi_2/Si$ contacts show 150ohms and 450ohms, respectively. The Rc of $W/TiSi_2/Si$ contact is about two times of Al-Si/Si contact. In these results, $W/TiSi_2/Si$ shows well balanced contact characteristics for both n^+Si and p^+Si

Fig.3 shows contact resistivity for n^+Si. The accurate area of each contact was measured by the SEM micrograph of processed device. From Fig.3, the contact resistivity of 0.5μm $W/TiSi_2/Si$ structure is expected

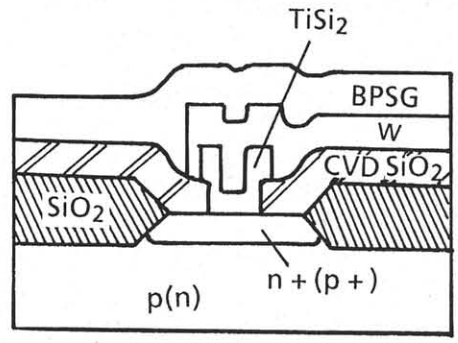

Fig.1 Cross section of $W/TiSi_2/Si$ contact structure.

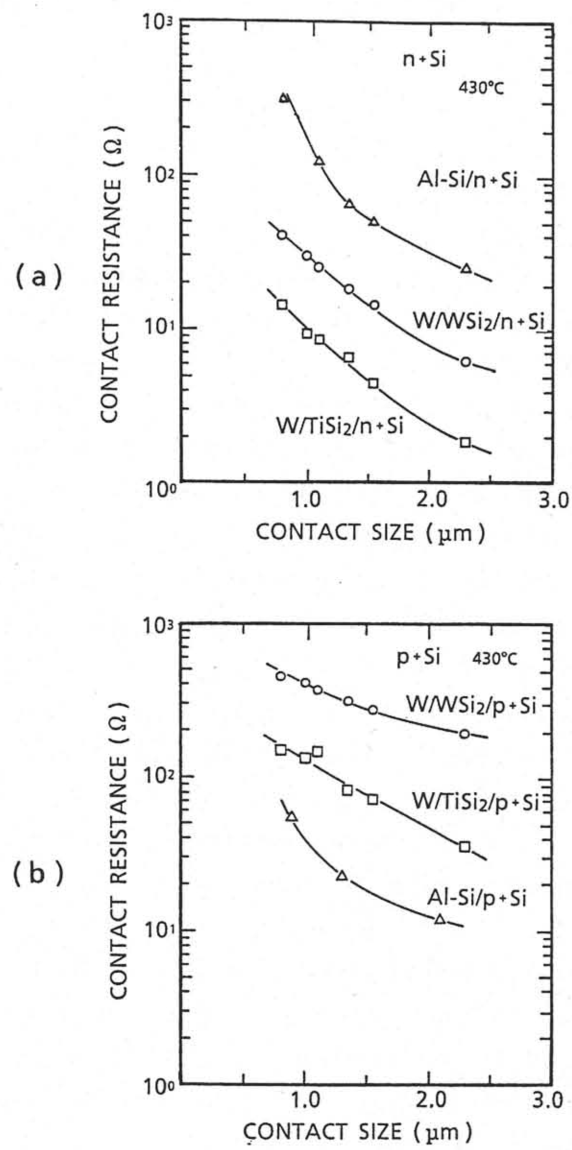

Fig.2 Contact resistance after 430°C annealing, as a function of contact size, (a) n^+Si, (b) p^+Si.

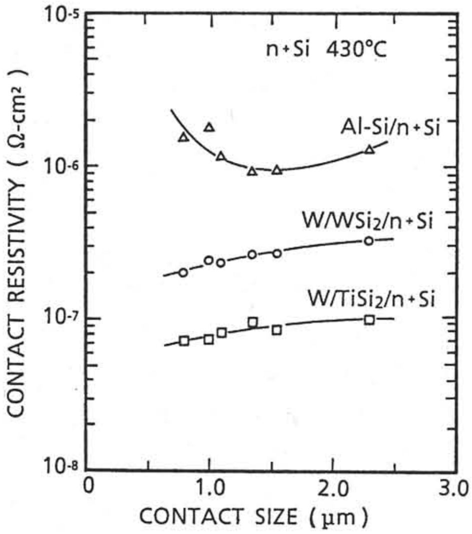

Fig.3 Contact resistivity after 430°C annealing, as a function of contact size.

7×10^{-8}ohm-cm^2 for n$^+$Si and 6×10^{-7}ohm-cm^2 for p$^+$Si.

3. Thermal stability of contact structure

In multilevel interconnect system thermal stability of under layer interconnect is especially important subject. Samples with W/$TiSi_2$/Si or W/WSi_2/Si contacts were covered with BPSG film and annealed at temperature up to 700°C, 30min.

Fig.4 shows the dependence of Rc of 0.8μm contacts on the annealing temperature. Although the Rc of the Al-Si/Si contact increases rapidly above 450°C, W/$TiSi_2$/Si and W/WSi_2/Si contacts were almost stable up to 700°C. The Rc of W/$TiSi_2$/Si contact seems to increase slightly at 700°C, but it indicates 15ohms after 700°C, 30min annealing. The Rc of W/WSi_2/Si contact shows 45ohms after 700°C annealing.

Fig.5 shows the experimental results of the thermal stability for the other sized contacts. From the result, it is confirmed that the Rc of contacts from 0.8μm to 2.3μm are quite stable up to 700°C for W/$TiSi_2$/Si and W/WSi_2/Si structures and there is no

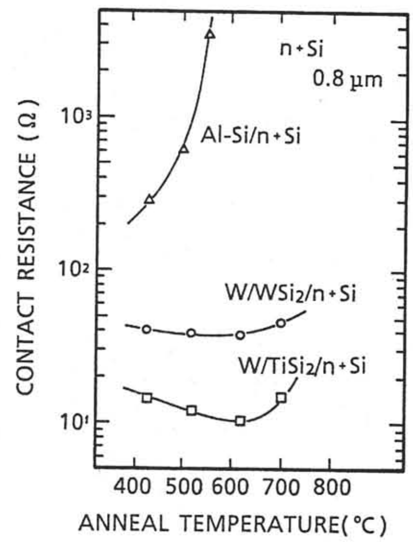

Fig.4 Contact resistance as a function of anneal temperature.

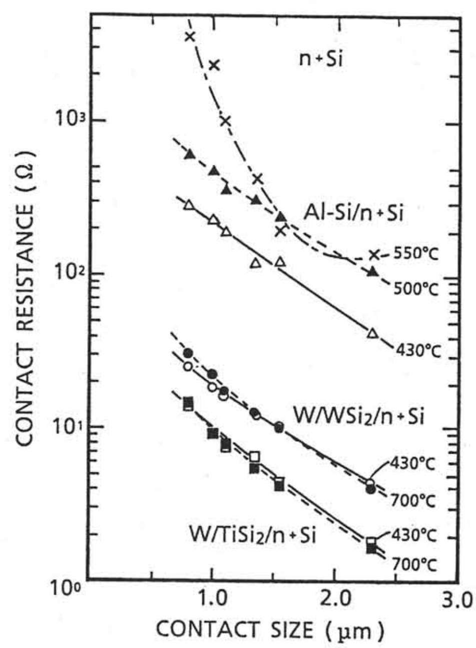

Fig.5 Contact resistance as a function of contact size, comparing after 430°C and higher temperature annealing.

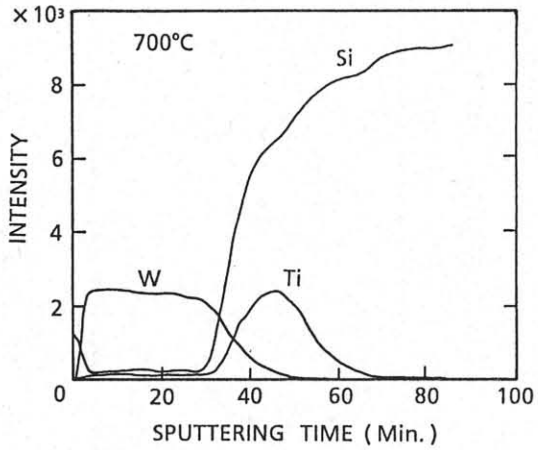

Fig.6 AES depth profile of W, Ti and Si in the W/$TiSi_2$/Si structure after 700°C annealing.

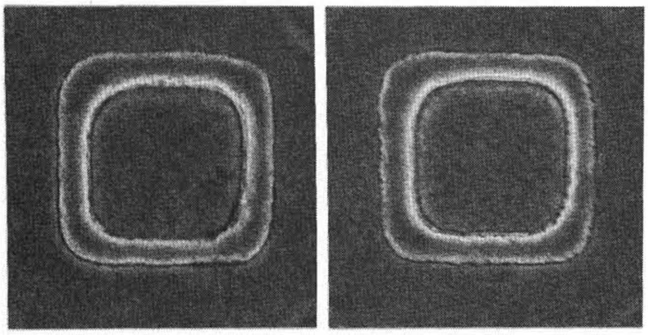
430°C 700°C

Fig.7 SEM micrographs of W/$TiSi_2$/Si contact surface, after 430°C and 700°C annealing.

size dependence in the thermal stability of Rc.

Fig.6 shows the depth profile of W, Ti, and Si in the W/$TiSi_2$/Si structure by AES analysis. The results shows that the depth profiles are not largely changed by 700°C, 30min annealing.

Fig.7 shows SEM micrographs of W/$TiSi_2$/Si contact surface after 430°C and 700°C annealing. No difference of the surface morphology between these two samples is obserbed.

These annealing experiments indicate that the Rc of W/$TiSi_2$/Si structure is thermally stable up to 700°C, and no evident reaction occured below 700°C. The same thermal stability was obserbed in W/WSi_2/Si structure.

4. Conclusion

From our investgation about W/$TiSi_2$/Si and W/WSi_2/Si contacts, it is confirmed that the contact resistance of these structurers in a scaled-down design, around 0.5μm, increases almost as the scaling law, without any additional factor.

For n^+Si contact, the contact resistivity of the W/$TiSi_2$/Si structure is lower than one tenth of the Al-Si/Si contact. Even in the submicron contacts, the contact resistivity of less than 1×10^{-7} ohm-cm^2 for n^+Si, and 1×10^{-6}ohm-cm^2 for p^+Si were obtained after 700°C 30min annealing.

By using the W/$TiSi_2$/Si contact structure, simple submicron multilevel interconnect system can be expected. In this system, W is used as the under layer metalization and Al-Si is used as the second metalization with high temperature planalized dielectric interlayer processing.

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