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Deposition of Polycrystalline Silicon by Rapid Thermal CVD and Its Application to Direct Contact to $TiSi_2$

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We studied the deposition of polycrystalline silicon (polysilicon) and in-situ cleaning by RTCVD. This technique was applied to form direct contacts with $TiSi_2$. High deposition rates of polysilicon, such as 100~200 nm/min, could be obtained by using RTCVD. The native oxides on $TiSi_2$ were removed by baking in H_2/Ar at 900 °C. In-situ cleaning was followed by deposition of polysilicon, and test structures for contact resistance measurements were formed. The distribution of the contact resistance and the mean value were both improved in comparison with those of LPCVD. These results show the reduction of residual oxygen and good control of interface quality between polysilicon and $TiSi_2$ were obtained by using RTCVD.

1) Introduction

Polycrystalline silicon (Polysilicon) formed by LPCVD is one of the most important and widely used materials for LSI. For the future ULSI, however, there are increasingly more requirements such as grain size control, interface control, contamination control, in-situ doping with excellent uniformity and coverage, ultra thin film for novel device application, etc. Recently, rapid thermal CVD (RTCVD) was introduced as a new film formation technique.[1) 2)] It has an ability to reduce residual oxygen, and to control film quality and grain size by rapid thermal processing. Multi step processing is easily implemented including in-situ cleaning. In this study, we investigated the deposition of polysilicon by RTCVD and we used this process to form direct contacts with $TiSi_2$ which were very difficult to process using conventional LPCVD techniques.

2) Experimental

The configuration of the equipment is shown in Fig. 1. It consists of the reactor, the gas supply system, and the pumping system. A wafer was heated up by an arc lamp through the upper quarts window. The temperature of the wafer was measured by a pyrometer by monitoring the infrared radiation from the back side of the wafer. The pumping system has a turbo pump and a dry pump, and the base pressure was 3.1E-7 torr. 4% H_2/Ar and 100% SiH_4 were used for the in-situ cleaning and the deposition of polysilicon, respectively. Table 1 and Fig. 2 show the process conditions and the process sequence, respectively. After bringing the wafer into the chamber and purging with N_2, the chamber was evacuated to the base pressure. Next,an in-situ cleaning was carried out by baking in H_2/Ar at 800 to 1000 °C for 30 sec. After the in-situ cleaning, the wafer was cooled down to 500 °C and the ambient was changed from H_2/Ar to SiH_4 for the deposition of polysilicon. The pressure and the flow rate were set to 0.5~1.0 torr and 50~200 sccm. The deposition temperature was varied from 680 to 900 °C. After deposition, the lamp power was switched off and the gas supply was stopped at the same time. The deposition of the polysilicon by RTCVD was used to form direct contacts with $TiSi_2$. 200 nm polysilicon was deposited on 70 nm $TiSi_2$ and the resistance of 3000 direct contacts with 1.0 um diameter was measured.

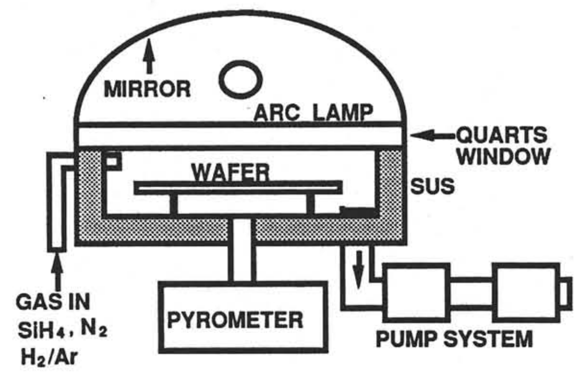

Figure 1 Schematic diagram of RTCVD system.

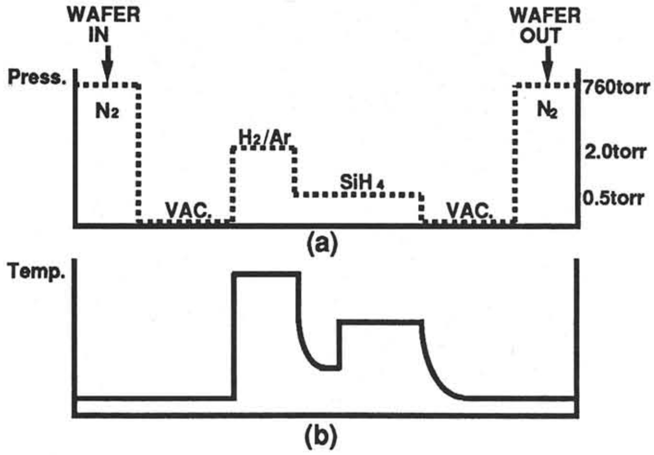

Figure 2 Process sequence of in-situ cleaning (H2 bake) followed by deposition of polysilicon, for (a) pressure and gas flow, and (b) temperature.

Table 1 Process parameter of RTCVD for (a) in-situ cleaning, and (b) polysilicon deposition

(a) In-situ cleaning

CLEANING GAS	H_2/Ar (4 / 96%)
TEMPERATURE	800~1000 °C
RAMPING RATE	100 °C / sec
PRESSURE	2.0 torr
FLOW RATE	500 sccm
TIME	30~60 sec

(b) Polysilicon deposition

REACTANT GAS	SiH_4(100%)
TEMPERATURE	680~900 °C
RAMPING RATE	100 °C / sec
PRESSURE	0.5~1.0 torr
FLOW RATE	50~200 sccm
TIME	60~120 sec

3) Results and discussion

Figure 3 shows the dependence of the deposition rate of polysilicon on the substrate temperature with the pressure and the flow rate as a parameter. The Si substrate was covered with 100 nm thermal oxide and the deposition time was fixed at 60 sec. RTCVD of polysilicon showed a very high deposition rate, such as 10~20 nm/min at 700~750 °C. The surface-reaction-limited and the mass-transport-limited reaction regime were clearly seen, and the transition temperature between the two regions was 760 °C. The activation energy of the surface reaction was 1.5 eV at a pressure of 0.5 torr and a flow rate of 50 sccm, and increased to 1.8 eV with increasing pressure and flow rate. Under higher pressure and larger flow conditions in the mass-transport-limited regime, a direct precipitation in the vapor phase was observed and the deposition rate was reduced.

The Surface of $TiSi_2$ is usually covered with a mixture of TiO_2 and SiO_2. These oxidized substances have to be removed before the polysilicon deposition to form direct contacts with $TiSi_2$. An in-situ cleaning of $TiSi_2$ surface was carried out by baking in H_2/Ar at 800~1000 °C. The $TiSi_2$ surface was analyzed by ESCA.

Figure 4 shows the dependence of the relative photoelectron intensity of Ti2p (I_{TiO2}/I_{TiSi2}) and Si2p (I_{SiO2}/I_{TiSi2}) on the baking temperature. The relative intensity of the sample baked at 800 °C was almost the same as that without baking. But, after baking steps at 900~1000 °C, TiO_2 and SiO_2 on $TiSi_2$ are removed.

This in-situ cleaning and the deposition by RTCVD were applied to form direct contacts with $TiSi_2$. In-situ cleaning by baking in H_2/Ar was carried out at 900 °C for 30 sec. 200 nm polysilicon was deposited at 720 °C for 120 sec with a pressure of 0.5 torr and a flow rate of 50 sccm. Polysilicon deposited by the conventional LPCVD at 620 °C was prepared as a reference sample.

Figure 5 shows a cross-sectional SEM photograph of the RTCVD sample. No degradation of $TiSi_2$ was observed. Difference in surface morphology between the polysilicon on $TiSi_2$ and that on SiO_2 was not observed.

Figure 6 shows the histograms of the resistance measurements of 3000 contacts with 1.0um diameter by LPCVD (a) and RTCVD (b), (c). In the case of LPCVD,

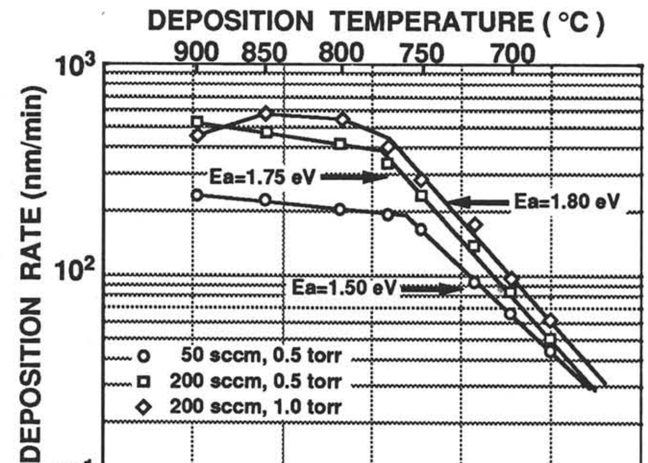

Figure 3 Dependence of deposition rate on the substrate temperature with the pressure and the flow rate as a parameter.

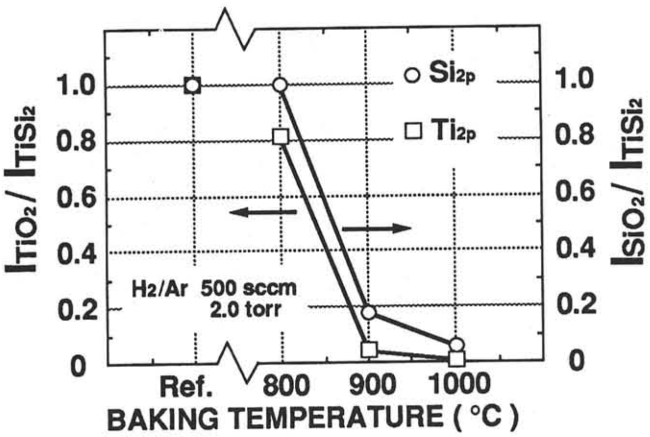

Figure 4 Relative photoelectron intensity of Ti2p (I_{TiO2}/I_{TiSi2}), Si2p (I_{SiO2}/I_{TiSi2}) from $TiSi_2$ surface as a function of temperature for H_2 bake measured by ESCA.

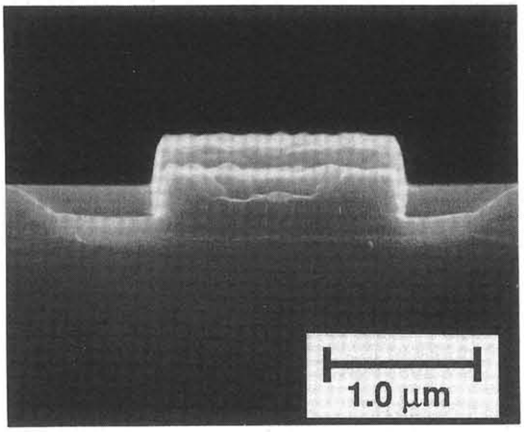

Figure 5 Cross-sectional SEM photograph of polysilicon deposited by RTCVD. Contact structure is Polysilicon (200nm) / $TiSi_2$ (70nm) / Si substrate.

the contact resistance showed a broad distribution and there were many contacts with high resistance. However, the contact resistance of polysilicon by using RTCVD without in-situ cleaning showed a sharp distribution. By using RTCVD with in-situ cleaning, the distribution of the contact resistance was more improved in comparison with that without in-situ cleaning and the mean value of the contact resistance decreased. These results show the reduction of residual oxygen and an excellent control of interface quality between polysilicon and $TiSi_2$ were obtained by using RTCVD.

4) Conclusion

The deposition of polysilicon and in-situ cleaning on $TiSi_2$ by baking in H_2/Ar by RTCVD were investigated. RTCVD showed high deposition rate of polysilicon such as a 100~200 nm/min at 720 °C. The oxidized substances on $TiSi_2$ were removed by baking in H_2/Ar at 900 °C. This process was used to form direct contacts with $TiSi_2$, and the distribution and the mean value of the contact resistance was improved compared with those of LPCVD. The RTCVD process showed an excellent control of interface quality and will be a versatile process for future ULSI applications.

Acknowledgement

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Reference

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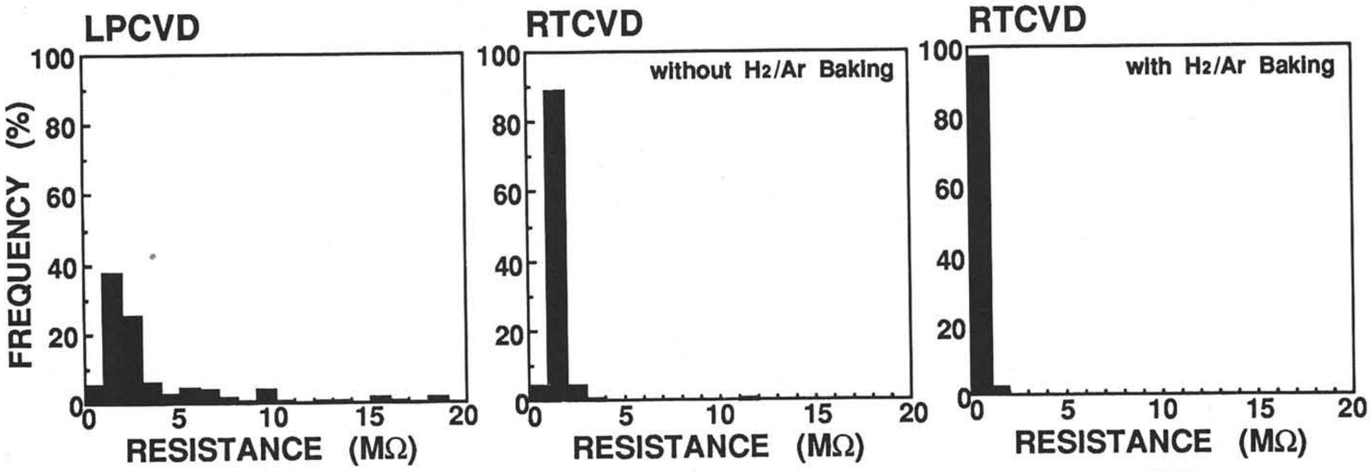

Figure 6 Histograms of the resistance of 3000 contact holes with 1.0um diameter. Polysilicon was deposited onto $TiSi_2$ by (a) LPCVD, (b) RTCVD without in-situ cleaning, and (C) RTCVD with in-situ cleaning.