Extended Abstracts of the 1993 International Conference on Solid State Devices and Materials, Makuhari, 1993, pp. 458-460 **PB-3-5**

Anomalous Resistance in 0.1μm-Region Ti-Silicided Poly Si Gate

Minoru Takahashi, Iwao Kunishima, Masao Iwase, Hiromi Niiyama
Tomohisa Mizuno, Naoki Yasuda and Makoto Yoshimi

ULSI Research Labs, R&D Center, Toshiba Corporation
1, Komukai Toshiba-cho, Saiwai-ku, Kawasaki 210, Japan

It has been found that the resistance of Ti-silicided poly Si gate exhibits anomalous increase as the gate width decreases to 0.1 μm region. Temperature dependence of the sheet resistance showed that the high resistance exhibited semiconductor-like behavior. This anomaly can be quantitatively modeled by statistical generation of high resistance regions.

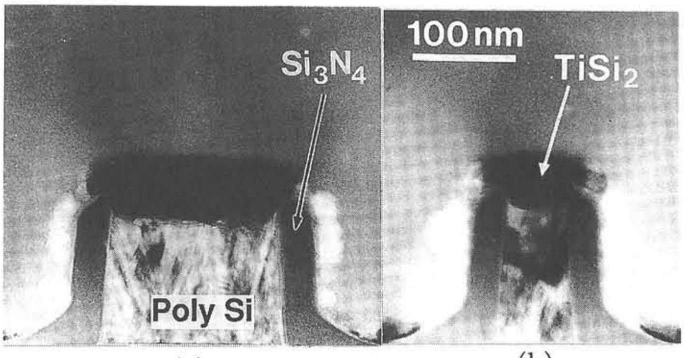
1 Introduction

Reduction of parasitic resistance is essential in realizing high-performance MOS LSIs. Salicide (self-aligned silicide) process using $TiSi_2$ is widely used for this purpose. J.P.Gambino et al. [1] reported that a highly-doped Ti-silicided poly Si gate exhibited resistance increase as the poly Si width decreases to less than 1 μm, which they ascribed to the lowering of the phase transition rate from C49 to C54. However, no detailed report is known on experimental data of $TiSi_2$ salicide in the 0.1 μm region.

In this paper, we report that the resistance of Ti-silicided poly Si gate exhibits an anomalous increase as the poly Si width decreases to 0.1 μm, which cannot be explained by Gambino's model.

2 Experimental

A 0.1 μm-width poly Si whose thickness was 200nm was formed using E-beam lithography and high-selectivity RIE. After sidewall formation using Si_3N_4 and impurity doping (BF_2, 20 keV, 2×10^{15} cm^{-2} and As, 30 keV, 2×10^{15} cm^{-2}, for P^+ and N^+, respectively), thermal activation was carried out by 1000 °C RTA for 20 sec. Subsequently, $TiSi_2$ was formed selectively by deposition of Ti/TiN = 30 nm/70 nm, followed by 750 °C RTA for 30 sec and selective wet etching. Sheet resistance measurements as well as TEM observation were carried out. NiSi [2] was also studied by deposition of Ni (35 nm thick) and 500 - 600 °C RTA for 30 sec.



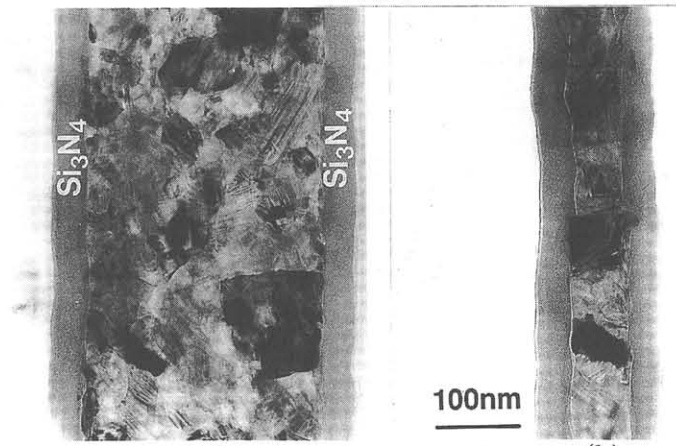
(a) (b)

Figure 1: Cross-sectional TEM view of $TiSi_2$ gate for (a) 0.17 μm width and (b) 0.06 μm width gate.

3 Results and Discussion

TEM observation shown in Figs 1 and 2 indicated that $TiSi_2$ films were formed with sufficient thickness continuously even on the 0.06 μm width gate. The grain size ranged from 20nm to 100nm. A bamboo structure was seen for the 0.06 μm width poly Si. The sheet resistance of Ti-silicided poly Si gate at room temperature exhibited an anomalous increase as the poly Si width (W) decreased below 0.2 μm as shown in Fig.3. Note that the increase in resistance amounted to as high as two orders of magnitude for P^+ and N^+ poly Si gate, whose resistance is approximately the same as non-silicided poly Si gates. This anomaly in the 0.1 μm region cannot be explained by the reported lowering of the phase transition rate.

It has been found that this anomaly depended on



(a) (b)

Figure 2: Planar TEM view of $TiSi_2$ gate for (a) 0.28 μm width and (b) 0.06 μm width gate.

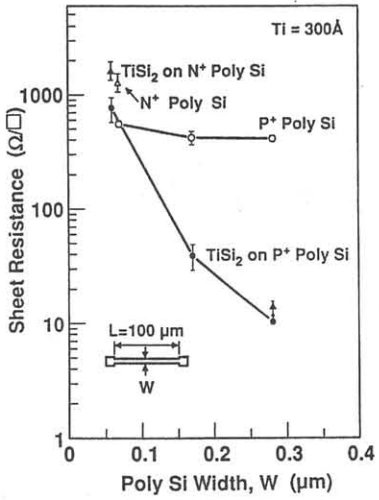


Figure 3: Poly Si width (W) dependence of sheet resistance for $TiSi_2$ silicided gate (•,▲) and non-silicided gate (○,△). A significant increase in sheet resistance is observed with a silicided 0.06 μm poly Si gate.

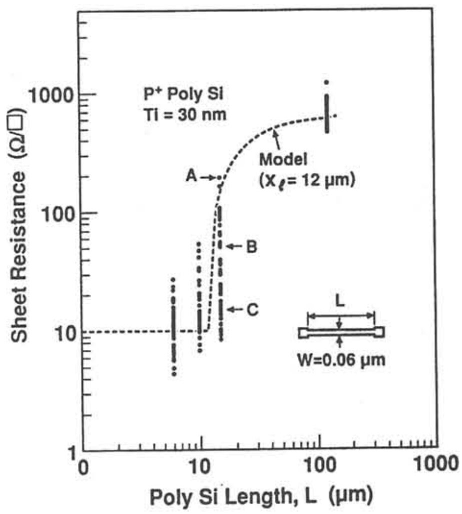
the poly Si length (L) of P^+ and N^+ poly Si as shown in Figs.4(a) and (b). The sheet resistance of the 0.06 μm width gate exhibited a significant increase and the scattering of the resistance became quite large, as the poly Si length(L) increased to over 12 μm and 5 μm for P^+ and N^+ poly Si, respectively. Whereas, at 122 μm length, the scattering became small and the resistance reached almost as high as 1000 $\Omega/\square$. These results suggest that the observed anomaly is caused by a statistical phenomenon which depends on the line length.

Temperature dependence of the sheet resistance is shown in Fig.5, where the high-resistance poly Si gates (shown as A and B in Fig.4(a)) are seen to exhibit a semiconductor-like behavior. Namely, the resistance decreased with increasing temperature, whereas, those showing normal resistance shown as C in Fig.4(a) exhibited a metallic behavior. The temperature dependence of A and B was quite similar to that of a nonsilicided P^+ poly Si gate which is shown by open circles in Fig.5. The results from Fig.3 to Fig.5 suggest that highly resistant regions are statistically generated associated with $TiSi_2$ formation.

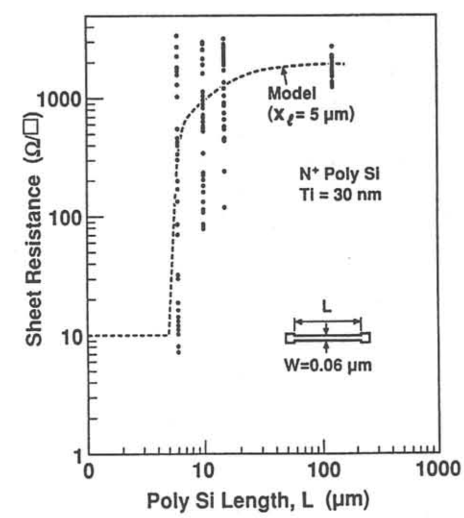
Fig.6 shows our model for the observed anomalous resistance. In this model, poly Si consists of silicided low resistance and semiconductor-like high resistance regions. Then, the observed sheet resistance is expressed by

$$\rho_s = (\rho_h x_h + \rho_l x_l)/(x_h + x_l)$$

where ρ_l and ρ_h are the resistivity of $TiSi_2$ and (P^+ or N^+) poly Si gate, and x_h and x_l are the length of high resistance and low resistance regions, respectively. The broken lines in Fig.4 show the calculated value which agrees quite well with the experimental data (a) and (b). Here, x_l of N^+ and P^+ poly Si



(a)



(b)

Figure 4: Poly Si line length (L) dependence of sheet resistance in 0.06 μm width $TiSi_2$ gate for (a) P^+ and (b) N^+ poly Si gates. The sheet resistance increased significantly with an increase in poly Si length, for both cases.

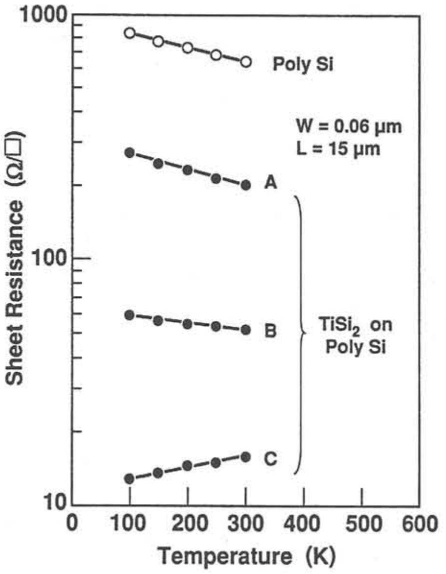


Figure 5: Temperature dependence of sheet resistance of 0.06 μm wide, 15 μm long $TiSi_2$ gates. A, B, C denote samples having various resistances shown in Fig.4. A and B exhibited semiconductor-like behavior, whereas, C exhibited metallic behavior.

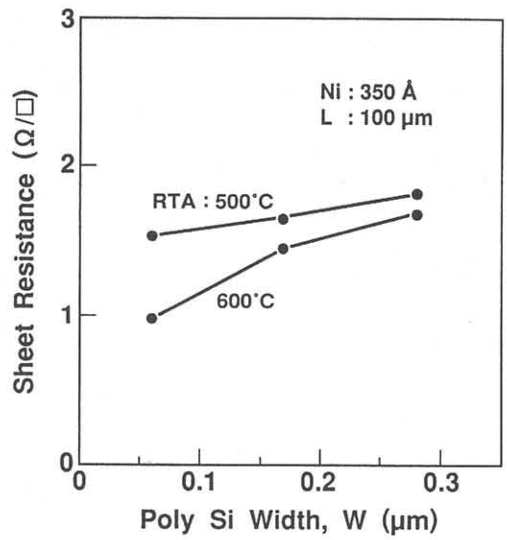


Figure 7: Poly Si width dependence of sheet resistance in NiSi gate for two silicidation temperatures. The sheet resistance is mostly independent of poly Si width or rather decreased as the line width decreased to less than 0.1 μm.

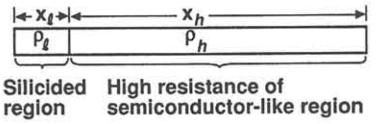


Figure 6: A model which explains the length dependence of Poly Si sheet resistance shown in Figs.4(a) and (b).

are 5μm and 12μm, respectively. Therefore, it is seen that the anomalous resistance shown in Figs.3 and 4 can be explained by this simple model, although the physical mechanism is not clear.

On the other hand, NiSi did not exhibit this anomaly down to 0.06 μm line width as shown in Fig.7. It should be noted here that the resistance of NiSi gate tended to decrease slightly as the gate width decreased, which was found to be due to a thickness increase in NiSi with a decrease in poly Si width (W).

4 Conclusion

It has been found that Ti-silicided poly gate exhibits anomalous resistance as the poly Si width decreases to 0.1 μm region. This phenomenon can be explained by the complex of high(Poly Si) and low($TiSi_2$) resistances. It has also been found that NiSi does not exhibit this anomally down to 0.1 μm region.

Acknowledgements

The authors would like to thank Dr.A.Toriumi for useful discussion, Mr.S.Nakamura for TEM observation,and Mr.T.Baba for his encouragement throughout this work. They are also grateful to Mr.F.Umibe for reviewing the original English manuscript.

References

[1] J.P.Gambino et al.; Extended Abstract of ECS Meeting, Phoenix, U.S.A., 1991, p.312.

[2] T.Morimoto et al.; IEDM, Tech. Dig., 1991, p.653.