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JOURNAL DE PHYSIQUE
Colloque C4, supplément au n°9, Tome 49, septembre 1988

INFLUENCE OF THE FABRICATION CONDITIONS ON THE p^+-$TaSi_2$/POLY-Si GATE QUALITY

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Résumé - L'effet des différentes étapes de fabrication du poly-siliciure sur la qualité resultante du dopage p^+ de la grille est examiné. En particulier on étudie la diffusion de bore en correlation avec la contamination en oxigène. Le rôle de l'interface $TaSi_2$/poly-Si et de l'atmosphere de recuit sur la redistribution du bore est montré.

Abstract - The effect of different polycide fabrication steps on the resulting p^+ gate quality is investigated. In particular the boron diffusion is studied in correlation with the oxygen contamination. The role of the quality of the $TaSi_2$/poly-Si interface and of the annealing atmosphere on the boron redistribution are pointed out

1 - INTRODUCTION

The $TaSi_2$/poly-Si bilayers constitute a well suited system for the fabrication of p^+-gates /1/. Nevertheless controversial results concerning the boron redistribution after implantation into the $TaSi_2$ layer have been reported /1,2/, questioning the p^+ $TaSi_2$ polycide quality, i.e. the p^+ work function ϕ_M reproducibility. Earlier experiments suggested a correlation of the boron profiles with the oxygen distribution in $TaSi_2$ /3/. Recently, evidence for TaB_2 formation after high dose implantation ($2x10^{16}cm^{-2}$) has been reported /4/. However, the effect of oxygen contamination in $TaSi_2$ or Ta-B compound formation on the B outdiffusion from $TaSi_2$ into the poly-Si is yet unclear.

In this paper we first discuss the effects of an interfacial oxide on the B transport across the $TaSi_2$/poly-Si interface and point out the importance of poly-Si surface cleaning prior to $TaSi_2$ deposition for good p^+ polycide behavior. Next, the role of oxygen on the B diffusion within the silicide is discussed. Finally the effects of annealing ambient on the B redistribution in the p^+ $TaSi_2$ polycide are investigated.

2 - EXPERIMENTAL

MOS-capacitors (0.01 to 8 mm^2) with $TaSi_2$/poly-Si gates were fabricated on n- or p-type (100) Si. The gate oxide thickness was 25 nm. The poly-Si cleaning prior to $TaSi_2$ sputtering consisted of a buffered HF dip and an in-situ sputter cleaning with Ar ions. The silicide films were prepared by Ta and Si cosputtering to a thickness of 200 nm. The Ta-Si sandwich thickness was ≈ 1.3nm. After $TaSi_2$ deposition on poly-Si (100 nm) the wafers were covered with a CVD-oxide (100 nm). B was implanted either into $TaSi_2$ or into poly-Si prior to Ta-Si sputtering. The B doses used were $5x10^{15}cm^{-2}$ and $2x10^{16}cm^{-2}$. Finally the samples were annealed at 900°C in a N_2 or Ar/H_2 atmosphere.

SIMS profiles of B and oxygen were recorded using oxygen (O_2^+) and cesium (Cs^+) primary ions, respectively. For Capacitance-Voltage C(V) measurements the oxide cap was removed. SIMS measurements were done before and after the oxide cap etching; the SIMS results for samples with and without oxide cap did not differ. B implantation standards for poly-Si and $TaSi_2$ were used to calibrate the B SIMS signal. Unimplanted polycide samples were used to determine the background SIMS signal. For B (O^+ primary ions) the background was $3-5x10^{17}cm^{-3}$ in $TaSi_2$ and $2-4x10^{16}cm^{-3}$ in poly-si. The oxygen profiles (Cs^+ primary ions) were limited by a background of about 10^3 counts.

3 - RESULT AND DISCUSSION

3.1 - TaSi2/POLY-Si INTERFACE

Earlier experiments with $TaSi_2$ on mono-Si have shown, that interfacial oxides impede B transport from $TaSi_2$ into mono-Si /5/ for T≤900°C. At the barrier brakes down /2,5/, but this temperature is not capatible with modern CMOS processes. In order to elucidate the role of interfacial oxide on poly-Si on the B transport across the $TaSi_2$/poly-Si interface at 900°C, samples with and without the poly-Si surface cleaning were investigated.

The B profiles for the samples with appropiate poly-Si surface cleaning and with interfacial oxide are shown in Fig. 1. The B profiles can be roughly divided into a region af low B diffusivity (the implanted region), and a tail region of fast diffusing B (grain boundary enhanced diffusion) /1,6/. There is no significant difference between the low diffusivity regions of both type of samples. In contrast the tail regions differ significantly (Fig. 1). For the clean interface sample the flat tail saturates at $1\text{-}2\times10^{19}cm^{-3}$ /1,6/. For the sample with interfacial oxide the B concentration in the tail region continuously decreases. Additionally a pronounced peak is observed at the $TaSi_2$/poly-Si interface. In the poly-Si the B doping is very low. At the poly-Si/gate-oxide interface the B concentration is as low as or lower than $1\times10^{17}cm^{-3}$.

A B pile-up is a characteristic of interfaces between thick oxides and silicide /7,8/. Fig. 2 shows an example of B accumulation at the oxide-cap/$TaSi_2$ interface. By increasing the implantation energy the B profile peak is moved deeper into $TaSi_2$, and the B accumulation near the oxide cap (100nm) is separated from the implanted region. In the case of interfacial oxide the resulting B profile exhibits a similar B pile-up at the $TaSi_2$/poly-Si interface (Fig. 1, curve b), although in this case the oxide thickness is only 3-5nm. Furthermore, the charactersitc B distribution in the tail region for the $TaSi_2$/poly-Si bilayers (Fig. 1, curve a) is altered. In the sample with interfacial oxide the B profile within the $TaSi_2$ layer strongly resembles those obtained for $TaSi_2$ between two thick oxide layers /7/. The fast diffusing B accumulates in $TaSi_2$ near and at the $TaSi_2$/poly-Si interface inducing a B concentration decrease in the tail region deeper in the $TaSi_2$ layer.

C(V) measurements confirmed the SIMS results. For the sample with interfacial

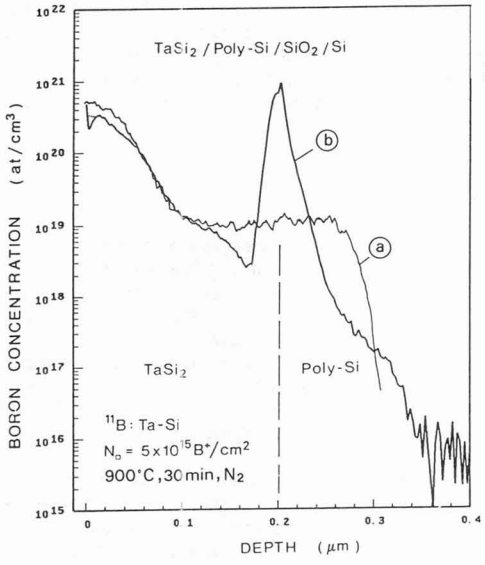

Fig. 1

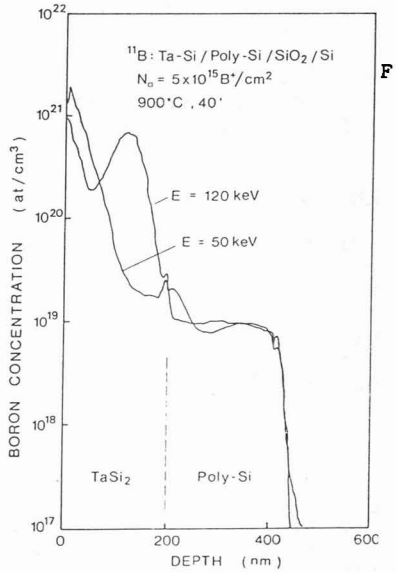

Fig. 2

Fig. 1 Boron profiles after annealing at 900°C in N_2 for samples a) with poly-Si surface cleaning and b) with interfacial oxide.
Fig. 2 Boron profiles after annealing in N_2 for two implantation energies. Boron was implanted into the as-deposited silicide.

oxide the C(V) characterstic are shifted to more negative gate voltage values indicating a lower p^+-ϕ_M. This consistent with the insufficient doping of the underlying poly-Si from SIMS measurements.

3.2 - OXYGEN CONTAMINATION

Fig. 3 shows the oxygen profiles for the samples with poly-Si cleaning and with interfacial oxide. The corresponding B profiles are shown in Fig. 1. The oxygen concentration in the as-deposited $TaSi_2$ layer has a constant value throughout the layer and the poly-Si is largely oxygen free. For annealed samples with poly-Si surface cleaning a decrease of the oxygen concentration towards the oxide/$TaSi_2$ and $TaSi_2$/poly-Si interfaces is observed. Additionally, oxygen diffuses into the poly-Si increasing its oxygen content by several orders of magnitude. For the sample with interfacial oxide the oxygen concentration remains quite constant in $TaSi_2$ and increases near the oxide/$TaSi_2$ interface. The poly-Si remains practically oxygen free. The interfacial oxide appears as a small oxygen peak at the $TaSi_2$ interface. Apparently an interfacial oxide also hinders the oxygen diffusion across the interface.

The oxygen profiles for samples with poly-Si cleaning with and without B implantation were alike. Moreover for a B dose increase from $5x10^{15}cm^{-2}$ to $2x10^{16}cm^{-2}$ no dose effect related to the oxygen distribution is found. It follows that neither the presence of B nor the implantation affects the oxygen distribution in the polycide. A similar oxygen distribution is also expected in the case of B implantation into the poly-Si prior to $TaSi_2$ deposition. In this way implantation effects within $TaSi_2$ are avoided. As shown in Fig. 4, a widely uniform B concentration is obtained and again a B pile-up near the oxide/$TaSi_2$ interface is observed. The oxygen concentration near the oxide/$TaSi_2$ interfaces can decrease, increase or remain at a constant value

Fig. 3

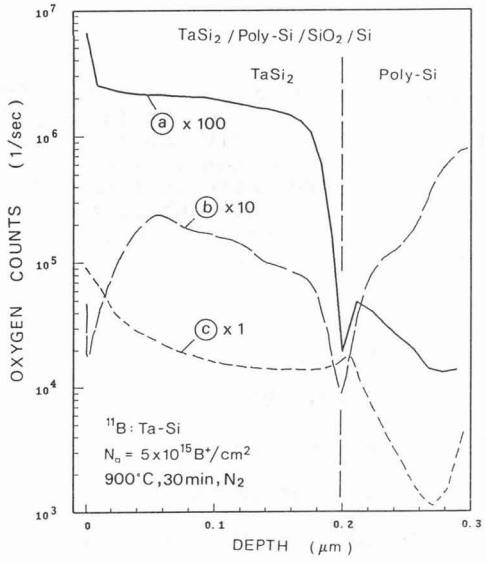

Fig. 4

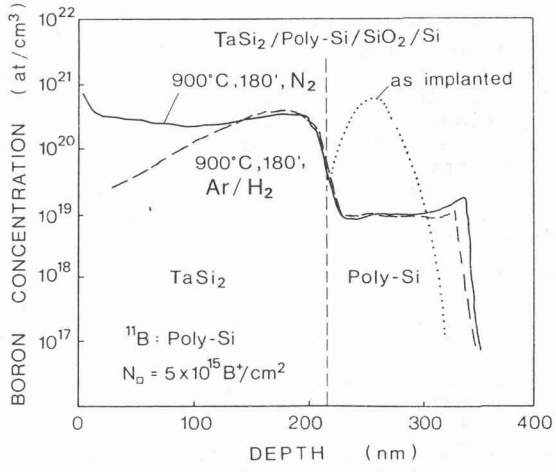

Fig. 3 Oxygen profiles for a) as-deposited $TaSi_2$, and after annealing at 900°C in N_2 for samples b) with poly-Si surface cleaning and c) with interfacial oxide.
Fig. 4 Boron profiles in case of boron implantation into poly-Si prior to $TaSi_2$ deposition: a) as-implanted and after annealing in b) N_2 and c) Ar/H_2.

though in either case B accumulates near the oxide/$TaSi_2$ interfaces. This suggests that oxygen does not significantly affect the B redistribution.

3.3 - ANNEALING AMBIENT

For samples annealed in Ar/H_2 dopant loss has been detected in spite of a 100nm oxide cap /3/. In order to investigate the dependence of the B redistribution on the annealing ambient (Ar/H_2 or N_2) independently of implantation effects in $TaSi_2$, B was implanted into undoped poly-Si prior to $TaSi_2$ deposition. The same poly-Si surface cleaning was used as described before.

Typically for CMOS processes, after the gate fabrication step the remaining 900°C processing time is 180-250 min. Fig. 4 shows the resulting B profiles after annealing in Ar/H_2 or in N_2 at 900°C for 180 min. After annealing most of the implanted B diffuses into the $TaSi_2$ layer. If annealed in N_2 a high and uniform B concentratin ($\approx 2x10^{20}cm^{-3}$) is achieved. For Ar/H_2 anneals a considerable dopant loss occurs in spite of the 100nm oxide cap. This is due to the increase of the B diffusivity in oxide by several orders of magnitude in case of H_2 containing annealing ambients /9/. Such a B loss to the oxide cap is only possible if a sufficient B supply is assured by the $TaSi_2$ layer. This suggests that the grain boundary diffusionis the dominant mechanism for the B redistribution even for long annealing times. Other mechanisms such as Ta-B compound formation do not seem to significantly affect the B redistribution. Nevertheless this does not rule out that B in $TaSi_2$ partly exists as TaB_2.

A rough estimate gives that approximately half of the implanted dose is lost if annealed in Ar/H_2. Although for B dose $\geq 5*10^{15}cm^{-2}$ the polycide p^+-ϕ_M remains unchanged (B concentration in poly-Si $\approx 1x10^{19}cm^{-3}$). But, on the other hand, the B contamination of the furnace might be of concern. The poly-Si doping does not depend on the B dose for doses $\geq 5x10^{14}cm^{-2}$ and for low B doses the resulting B redistributin is quite independent of the implantation scheme /6/. If low doses are used, however, subsequent processing must avoid H_2 containing anneals in order to assure p^+-ϕ_M reproducibility.

4 - CONCLUSION

In summary we haver shown that a native oxide constitutes an effective diffusion barrier for B. Therefore the cleanliness of the $TaSi_2$/poly-Si interface is a crucial factor for reproducible p^+-$TaSi_2$ polycide gates. The content and distribution of oxygen in the polycide does not affect the B diffusion. Annealing at 900°C in H_2 containing ambients leads to dopant loss in spite of a thick oxide cap. In case of long annealing times and/or of low B doses the dopant loss would reduce the p^+doping of the p^+ polycide, i.e. of the underlying poly-Si layer, deteriorating the MOS properties.

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