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Critical Conditions for Reliable Self-Aligned Titanium Silicide Contact Formation

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INTRODUCTION

Titanium silicide is a leading candidate among low resistive contact materials for scaled-down VLSI's. A silicide formation method based on the reaction between Si and Ti has generally been employed because of self-alignability and $TiSi_2$/Si-interface cleanness. However, this conventional method causes considerable silicide film roughness which is a severe problem in reliable contact formation on shallow junctions. In this paper, the intrinsic conditions necessary for smooth silicide formation are clarified. In addition, contact formation utilizing Ge ion beam mixing is demonstrated as a practically effective method to meet the conditions.

CONDITIONS FOR SMOOTH SILICIDE FORMATION

A conventional self-aligned silicide formation process consists of metal deposition, selective silicidation followed by selective wet etching to leave silicide only on the contact area, and silicide stabilization annealing. The roughness of silicide films thus formed (Fig. 1(a)) has thus far been believed to be due to nonuniform silicidation caused by an interfacial native oxide layer between metal and Si[1]. This estimate, however, was revealed to be insufficient as will be explained.

Silicide formation of a sample prepared by Ti/Si sequential deposition in UHV with an oxide-free interface was examined. In this sample, the deposited Si layer was single-crystalline due to epitaxial growth. Surface morphology of the resultant silicide film is shown in Fig. 1(b), where considerable roughness still remains although the roughness is slightly less than that resulting from the conventional process. However, it was recently found by the present authors that when amorphous Si was deposited instead of single crystal Si, silicide film morphology was drastically improved as shown in Fig. 1(c).

The above results clearly indicate that the necessary conditions for a roughness-free silicide film formation are primarily (i) amorphization of the Si substrate surface and additionally (ii) removal of the interfacial oxide barrier. The effect of amorphization can be understood as destabilizing Ti/Si interface at relatively lower temperatures and thereby realizing uniform silicide nucleation all over the interface. Oxide barrier removal is also required to minimize spatial fluctuation in the silicidation reaction due to extrinsic oxide disturbance. Generally, in the case of silicidation of refractory metals having the oxide reduction effect such as Ti, Zr, Hf, etc., this condition(i) may be essential.

PRACTICAL SILICIDE FORMATION METHOD

Next, a practical silicide contact formation method to meet the conditions will be discussed. The ion beam mixing technique is known to be an effective method for smooth silicide film formation[2]. The reason for this is clear from the previously mentioned fact, i.e., the amorphization effect. This convenient technique has been refined in the present study for practical VLSI fabrication. Ge ion beam was newly employed as the mixing ion beam from the perspectives of no harm caused in silicidation, doping flexibility and high efficiency for amorphisation of the Si substrate surface. SEM micrograghs of titanium silicide surfaces examined for various Ge ion doses are shown in Fig. 2. The dose required for minimizing silicide roughness corresponds to that for amorphizing Si at the Ti/Si interface, that is around $5\times10^{14}cm^{-2}$. In addition, it was confirmed from SIMS profiles shown in Fig. 3 that silicidation consumed most of the substrate surface damaged region induced by Ge ion irradiation. Moreover, the silicide resistivity of about $15\mu\Omega$ cm was not affected by the Ge ion beam mixing. These features are favourable for contact formation on shallow junctions.

The silicided junction characteristics are shown in Fig. 4. The junctions of which depth was~0.2μm, were formed by ion implantations with Arsenic(80keV, $5\times10^{15}cm^{-2}$) or Boron(25keV, $1\times10^{15}cm^{-2}$) and rapid thermal annealing(RTA) at 950 °C for 20s. The leakage current level was not inferior to conventional unsilicided junctions. These results indicate that Ge ion beam mixing is useful on a practical basis for improved VLSI contact formation.

CONCLUSION

A new finding on the necesary conditions for a roughness-free silicide formation has been reported. Light has been shed on the further development of practically refined contact formation methods in addition to the Ge ion beam mixing technique demonstrated here.

References

1) A. H. van Ommen, et al., J. Appl., Phys, 58, 4043(1985).
2) E. Nagasawa, et al., Jpn. J. Appl. Phys., 22, L57(1983).

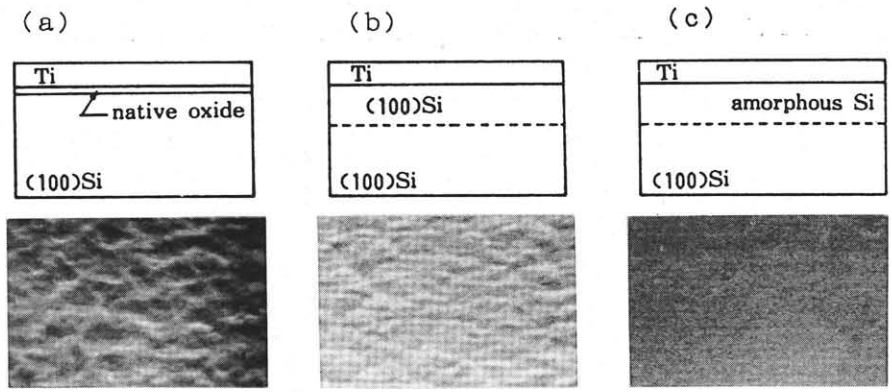

Fig. 1

SEM micrograghs of titanium silicide surface for three conditions. Drawings above micrographs show sample structures before silicidation at 800℃ for 30s in Ar.

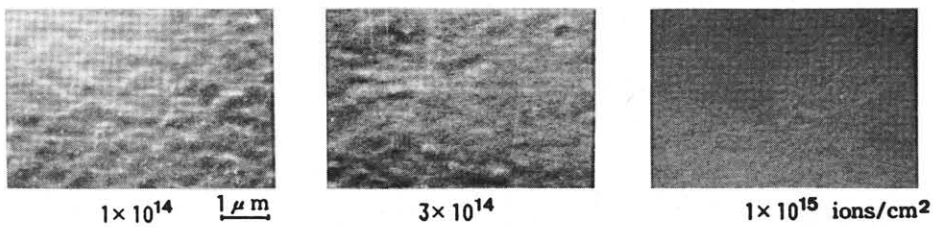

Fig. 2 SEM micrograghs of titanium silicide surface for various Ge ion doses. 110keV-Ge ions were implanted through 40nm Ti. Silicidation condition is the same as Fig. 1.

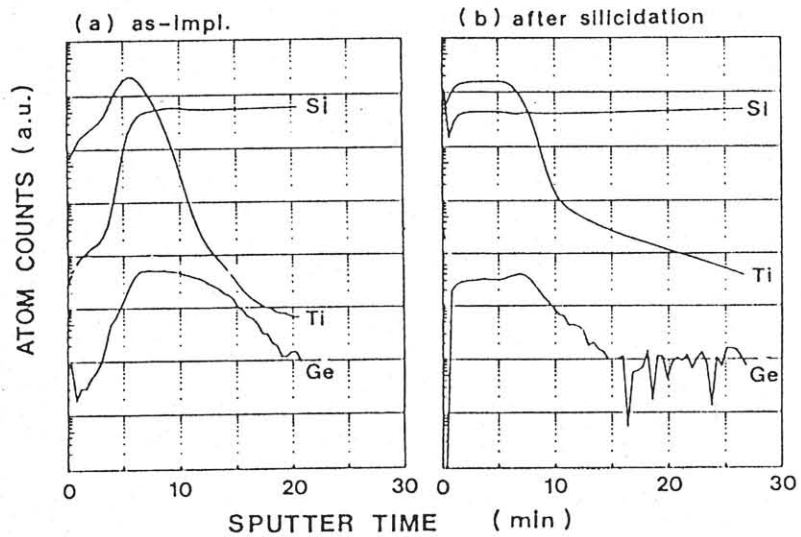

Fig. 3. SIMS profiles of Ge implanted samples before and after silicidation.

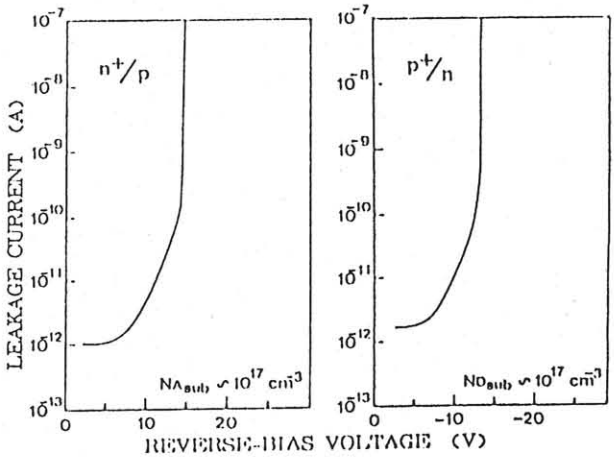

Fig. 4 Reverse-biased junction characteristics for titanium silicided junction.