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Formation of Ni Silicide Using Flash Lamp Technology

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1. Introduction

Continuous shrinkage of minimum feature size requires the minimization of thermal budget in order to suppress diffusion and deactivation of dopants. In silicidation process, especially, lowering temperature has been studied extensively using Ni instead of Co which has been used currently [1,2]. The other approach_in order to reduce thermal budget is to shorten the heating time instead of lowering temperature. High temperature, in general, gives high quality in the film formation such as Si oxidation, CVD and sputter so on. The migration of atoms enhanced at high temperature leads to the stable structure with high density. Therefore, we have tried the novel silicidation with high temperature and very short time (msec) using flash lamp [3]. This paper reports the structure and electrical properties of Ni silicide formed by msec order pulse heating.

2. Experimental

P type (100) Si wafer was cleaned by Ar sputtering and followed by sequential deposition of Ni and TiN with the thickness of 25 and 10nm, respectively. This sample was loaded into the flash lamp equipment which has the similar structure reported previously [3], and then exposed to irradiation with about 1msec width after preheating to 200°C. The irradiation energy is proportional to the voltage charging capacitors in the circuit. 1910V and 2460V were used in this experiment. The highest temperature reached is over 1000°C according to estimation of the sheet resistance of implanted layer.

3. Results and Discussion

Fig.1 shows XRD spectra of the samples irradiated at the charging voltage of 1910V. 1~4 shots irradiation induces only decrease in Ni metal peak, suggesting consumption of Ni to the reaction with Si. Any new peak dose not appear less than 4shots and 10shots irradiation produces polycrystalline Ni2Si. Cross-sectional TEM photographs are also shown in fig.2. The reaction layer formed by 1~4 shots is evidently classified into 3 layers. These layers consist of a Ni rich layer, Si rich layer and intermediately layer, as the composition are summarized in Table 1. No signal except to Ni and TiN in Fig.1 demonstrates that these layers are not crystal, but amorphous. Fig.3 indicates how each layers changes with a number of irradiation. The first one shot produces 3 layers. Further irradiation decreases the upper Ni rich layer and increases the lower Si rich layer.

On the basis of these results, the following process can be considered. Flash lamp irradiation induces diffusion of Ni and Si each other to produce amorphous mixed layer. Further irradiation enhances diffusion of Ni into the lower Si rich layer and then crystal Ni2Si educes from amorphous mixed layer. Finally all mixed layers convert to Ni2Si.

Fig.4 shows XRD spectra of the samples irradiated at the charging voltage of 2460V. Only one shot in this case produces polycrystalline Ni2Si and NiSi. Additional one shot increases NiSi because of conversion from Ni2Si to NiSi.

Fig.5 indicates variation in sheet resistance as a function of the shot number with a parameter of charging voltage. The sheet resistance of 4Ω/□(specific resistance of about 15 $\mu\Omega\cdot$cm) has accomplished at 2 shots of 2460V. Fig.6 shows cross-sectional TEM photograph of the sample with the sheet resistance of 4Ω/□. It should be noted that the interface between NiSi and Si substrate is extremely smooth. Its roughness is only 4nm (from peak to valley).

4. Summary

A very short time silicidation at high temperature has been studied using flash lamp for the first time. Optimization of the energy and the number of irradiation leads to production of the silicide with the sheet resistance low enough to apply to devices. In addition, it can be excepted that the smooth interface between silicide and Si substrate will lead to formation very low leakage junction.

Reference

[1] Q.Xiang et al., Symp.on VLSI Tech., p.23,2001
[2] S.Song et al., IEDM, p235.2000
[3] T. Ito, et al., SSDM, p182, 2001

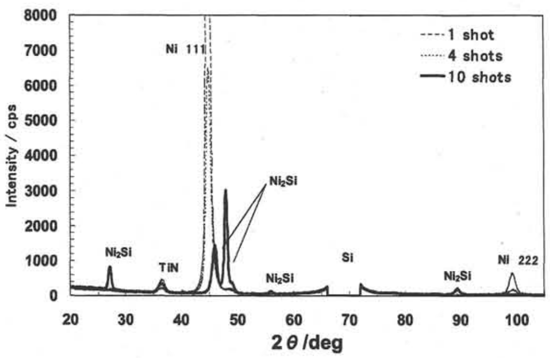

Fig.1 XRD spectra of the samples at the charging voltage of 1910V. The incidence angle of X-ray is 0.5° off from 2θ/2 to avoid diffraction from Si substrate.

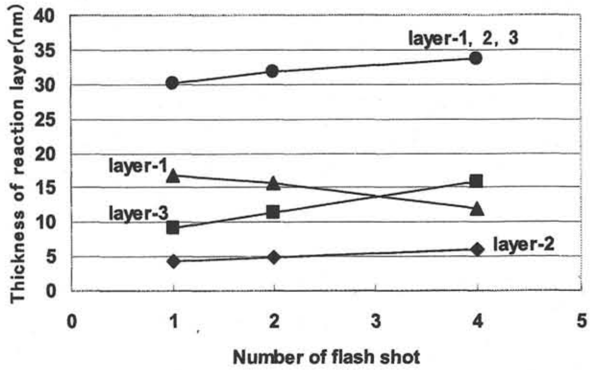

Fig.3 Thickness of reaction layer as a function of the shot number.

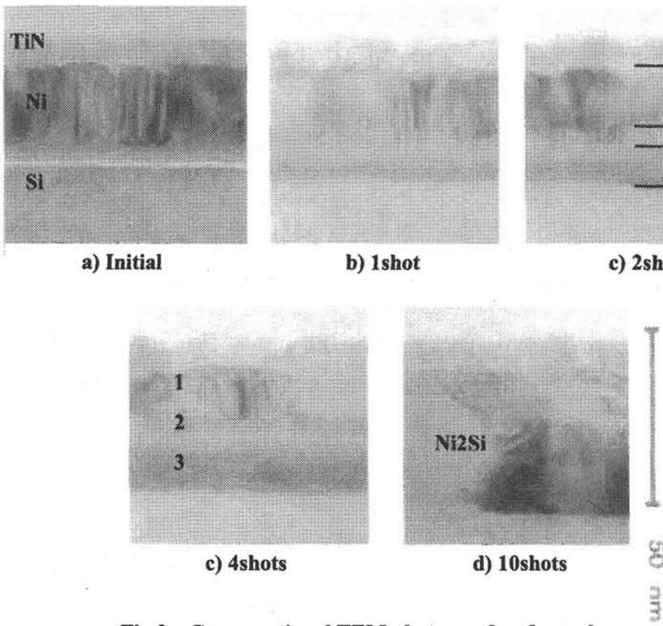

Fig.2 Cross-sectional TEM photographs of samples.

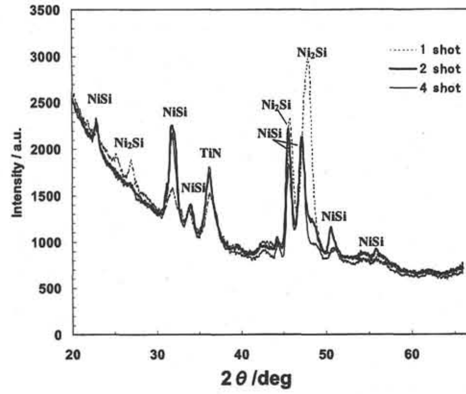

Fig.4 XRD spectra of the samples at the charging voltage of 2460V. This XRD is three-axis X-ray diffraction.

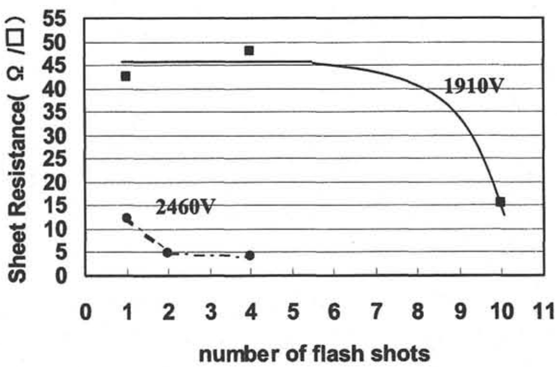

Fig.5 Sheet resistance of sample as a function of the shot number.

Table 1 Composition of each layer formed by the irradiation of 4shots

mesurement point	Si [at %]	Ni [at %]
1	40.0	60.0
2	56.2	43.8
3	63.1	36.9

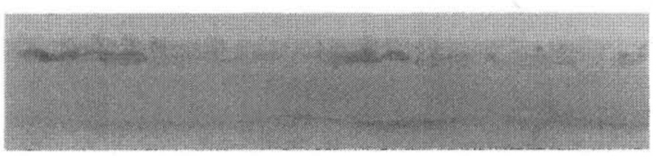

Fig.6 Cross-sectional TEM photograph of sample with the sheet resistance of 4Ω/□.