Nickel Silicide Formation Using a Stacked Hotplate-Based Low Temperature Annealing System

Tomomi Murakami[1], Benoit Froment[2], Michel Ouaknine[3] and Woo Sik Yoo[3]

[1] WaferMasters Service Factory
2020-3 Oaza Tabaru, Mashiki, Kamimashiki, Kumamoto,
[2] STMicroelectronics Srl
850, Rue Jean Monnet 38926 Crolles Cedex, France
[3] WaferMasters, Inc.,
246 EastGish San Jose, CA 95112 USA

As CMOS device dimensions get smaller and smaller, precise control of silicide thickness, sheet resistance and thermal exposure during formation and anneal is required. Among silicides, nickel silicide is considered to be one of the most suitable materials for aggressively scaled structures. Indeed, NiSi has lower reaction temperature for silicide formation, reduced line width sensitivity, lower Si consumption and lower sheet resistance [1-2].

Sputtered Ni films (9 nm thick) on 200 mm diameter Si wafers were annealed to form nickel silicide using a stacked hotplate-based low temperature annealing system in the temperature range of 200~550^{o}C. Details of the annealing system and its thermal characteristics are published elsewhere [3]. Sheet resistance, reflectance and surface roughness (investigated with Scanning Probe Microscopy) of nickel silicide were measured before and after annealing. Wafer curvature height was measured to estimate film stress change after annealing. We also investigated the impact of the nickel capping layer and multi-step annealing process on the roughness and on thermal stability of films.

The sheet resistance change of annealed films was investigated as a function of annealing temperature (Fig. 1). Ni_2Si formation was observed beginning at 200^{o}C. Sheet resistance was increased from 25.8 ohm/sq. (as-deposited nickel) to 36.0 ohm/sq. after annealing at 200^{o}C for 5 minutes due to Ni_2Si formation. As annealing temperature increased, the sheet resistance sharply decreased to ~10 ohm/sq. above 300^{o}C by forming a lower resistivity NiSi phase. The lower resistivity NiSi phase was stable up to 550^{o}C. At 700^{o}C, higher resistivity NiSi islands were formed and resulted in a very high sheet resistance value of 230 ohm/sq.

The effect of TiN capping over Ni film on surface roughness of the resulting silicide and resistance of silicide to thermal stress were investigated in detail. A sputtered TiN layer (10nm thick) was used as a capping layer. Wafers annealed at 550^{o}C showed slightly increased roughness compared to those annealed at lower temperatures. Uncapped wafers had increased surface roughness after annealing compared to those with a TiN-capping layer (Fig. 2). TiN-capping layer has effect to suppress roughness increase at given temperature, though there was no significant difference in sheet resistance between wafers with and without the TiN-capping layer.

A low temperature (200~250^{o}C) pre-annealing had no influence on the sheet resistance, its uniformity, film roughness and wafer curvature. Pre-annealing did not give any better thermal stability to the NiSi film (Fig. 3). Unlike the previous report by D.X. Xu [4], the multi-step anneal did not cause significant change in sheet resistance and uniformity of resulting NiSi films. Various thermal stress measurement results will be discussed at the conference.

REFERENCES

1. Q.Xiang, *Abst. of 201th Electrochem. Soc. Meeting,* 2002-1, 583 (2002)
2. Y. Hu and S.P.Tay, *J.Vacuum Sci. Technol.* (B), **19**(2), 376 (2001)
3. W.S.Yoo, T. Fukada and J.Yamamoto*; European Semiconductor,* April 2001, 129.
4. DX. Xu, *Thin solid film*, **326**, Feb 143 (1998)

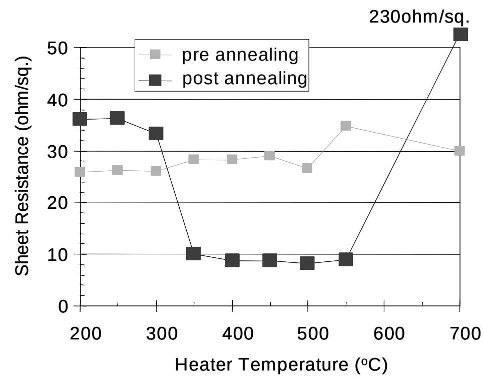

Fig. 1 Sheet resistance of pre and post annealing of TiN capped Ni on Si wafers after annealing.

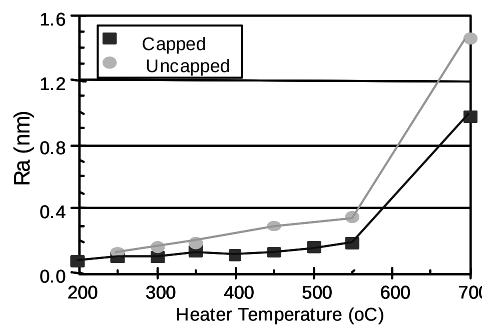

Fig. 2 Surface roughness after annealing for 5 minutes.

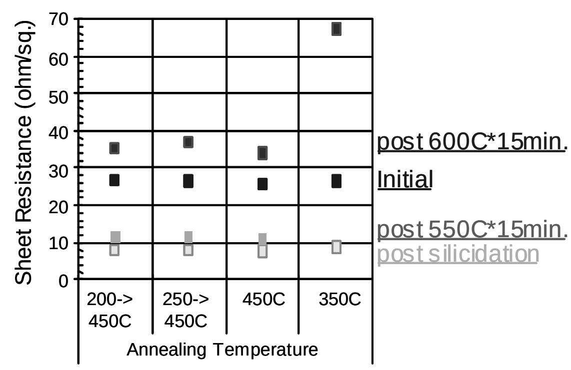

Fig. 3 Changes in sheet resistance of TiN capped wafers after successive anneals.