Highly Uniform Deposition of LP-CVD 3i3N4 Films on Tungsten for Advanced Low Resistivity “Poly-Metal” Gate Interconnects

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1. Introduction
In advanced ULSI’s, low resistivity gate interconnects are strongly required to suppress gate RC delays. Currently, SALICIDE (self-aligned silicide) and polycide gate structures are widely used to achieve a sheet resistivity of 5-10 Ω/□. To realize lower sheet resistivity of 1-2 Ω/□ or comparable sheet resistivity with lower gate height, a new gate structure is necessary.

We propose a poly-Si/WSiN barrier layer/ W multilayered gate structure (poly-metal ).[1] [2] We can achieve a low resistivity of 1.4 Ω/□ with a poly-metal structure (poly-Si(700nm)/WSiN(50nm)/W(100nm)) and comparable resistivity of 5 Ω/□ with an extremely thin poly-metal structure (poly-Si(700nm)/WSiN(50nm)/W(450nm)).

Moreover, to obtain reduced chip size, SAC (self aligned contact) structure is applicable to poly-metal gate as depositing SiN cap and spacers. Thus a poly-metal structure with SiN cap and spacers is extremely suitable for IG-DRAM or later generation L.Sls. (Fig. 1)

For the purpose of forming the cap and spacers, an LP-CVD SiN film has several merits, e. g. good coverage, low impurities and high thermal stability. However, an abnormal growth of SiN film on W easily occurs. (Fig. 2) We found out the abnormal growth is caused by the oxidation of W surface.

In this paper, we will show the process of the abnormal growth and propose methods for highly uniform deposition of SiN films.

2. Abnormal growth of an SiN film on W
SiN deposition is carried out with vertical-type LP-CVD furnace. The sequence of deposition is shown in Fig. 3. Si wafers should be loaded below 550°C. At temperatures higher than 550°C, W is easily oxidized and the expansion when W oxide is formed causes film peeling.

The process of abnormal growth is investigated. Fig. 4(a) and (b) show W surface before and after SiN deposition.

During heating up in N2 ambient up to the deposition temperature (780°C), whiskers are formed on W surface and SiN is conformally deposited on whiskers. Thus granular surface of SiN film is formed. As described below, this effect is strongly dependent of the amount of oxygen at the interface of W and SiN. Hence these whiskers are considered to be W oxide.

3. Suppression of abnormal growth
There should be two ways to suppress abnormal growth of SiN films; 1) suppression of W surface oxidation before deposition 2) in-situ reduction of W oxide before deposition.

Oxidation suppression method (Low temperature load-in)
In order to prevent oxidation of W surface, low temperature load-in is tried out. The morphology of SiN surface is much improved by lowering load-in temperature down to 350°C. (Fig. 5(a)-(c))

In-situ reduction of W oxide
In-situ reduction method in NH3 ambient is examined. In order to clarify its effect, load-in temperature is raised to 400°C. NH3 flow is provided at a temperature that the morphological change of W surface would not be so severe (600°C). Fig. 6(a)-(c) shows surface of SiN on some NH3 reduction conditions. It is clearly shown that NH3 reduction improves SiN4 morphology. Fig 7(a)-(c) show SIMS profiles of SiN4/W interface. By 30Torr, 30 min. NH3 flow, the amount of oxygen at the SiN/W interface could be decreased to about the same amount of 350°C loaded wafer which has smooth SiN4 surface as shown in Fig. 5(c).

4. Discussion
It is shown that the two methods mentioned above are both useful to suppress abnormal deposition of SiN film on W. It is considered to be essential that the amount of oxygen at the SiN/W interface be decreased. Load lock chamber and inert gas purge chamber are also thought to be effective to prevent oxidation of W surface. However, we think the method of in-situ reduction is superior to the methods of preventing oxidation of W surface. Because it is thought to be difficult to control the surface condition of W with oxidation suppression methods just before deposition starts. If an oxidation suppression method can be used, it is desirable to use in-situ reduction method together with it.

5. Conclusion
For the formation of poly-metal gates with SiN cap/spacers, a uniform deposition technique of LP-CVD SiN on W is necessary. An abnormal growth of SiN occurs when W surface is oxidized. Two methods are demonstrated for suppressing abnormal growth. Both oxidation suppression method and in-situ reduction method are effective. However, in-situ reduction method is considered to be suitable to control surface oxidation of W just before SiN deposition.

By using the in-situ reduction method, poly-metal structure with SiN cap/spacers can be successfully formed. And this structure should be extremely useful for the ULSIs of IGDRAM and later generation.

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Reference
Fig. 1 Concept of self-aligned contact technique of poly-metal with Si3N4 cap/spacers.

- Wafer load in (< 550°C)
- Evaculation (< 1m Torr)
- Heat up (780°C)
- Heat recovery (~30 min.)
- Deposition (780°C, NH3/SiH2Cl2 = 10/1, 0.5 Torr)
- Evaculation (< 1m Torr)
- Cool down

Fig. 2 Abnormal growth of LP-CVD SiN4 on W.

Fig. 3 A typical sequence of LP-CVD SiN4 deposition on W.

(a) (b) (c)

Fig. 4 W surface before (a) and after (b) SiN4 deposition. Whiskers are observed on W surface before deposition.

(a) (b) (c)

Fig. 5 Surface morphology of low-temperature load-in SiN4 films on W. (a) 450°C (b) 400°C (c) 350°C

(a) (b) (c)

Fig. 6 Surface morphology of SiN4 surface on W with NH3 in-situ reduction method. (a) no reduction (b) 0.4 Torr 30 min. reduction (c) 30Torr 30min. reduction.

Fig. 7 SIMS profiles of SiN4 on W with NH3 in-situ reduction method (a) 0.4Torr 30 min. reduction (b) 30Torr 30 min. reduction (c) ref. 350C load-in, no NH3 reduction.