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Nano Structural Properties of TiN in Integrated Chemical Systems

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Abstract: In the last decade due to tunneling and leakage current as well as boron diffusion through the ultra thin gate SiO_2, some high-k dielectrics have been introduced for replacing conventional SiO_2 as the gate dielectric in sub-0.1 μm complementary metal-oxide-semiconductor-Field-Effect-Transistors. TiN film is one of these materials which can fill this gap due to the reasonably high dielectric constant, large band gap, high heat of formation and superior thermodynamic stability.

In this work we have thus demonstrated the series of CVD experiments to growth nano-scale TiN film in an Ar/N_2 media to see the effect of Ar/N_2 flow rate on the nano structural properties of TiN film with analyzing ZAF and photoemission spectra.

Keyword: Nano structures, Nano Scale, TiN, ZAF method and Gate dielectric.

Introduction

With the continued downscaling and shrinking the nano electronic devices scales, in particularly, MOSFET (Metal-Oxide-Semiconductor-Field-Effect-Transistor). Gate dielectric, high-dielectric constant (high-k) gate materials, as alternatives to SiO_2, have been extensively investigated. In addition, we are walking to a new area in where the rapid growth of the semiconductor industry demands technical capabilities [1-7]. In fact, when SiO_2 film thickness is thinned to 1 nm, which corresponds to only 4-5 atoms layer, the new technology problems arose.

Shrinking this thickness can result in changes in the device operation condition, making it extremely difficult to maintain device tolerances.

On the other hands, some issues such as exponentially increase in the gate-dielectric leakage current has caused significant concern regarding the operation of CMOS devices, in particularly with regard to standby powder dissipation, reliability and lifetime [9-15]. These issues induced to search the other good gate dielectric. From the view point of gate fabrication, TiN can be introduced as a good gate dielectric for the future of CMIS generations. However, TiN should be grown on the silicon substrate without any impurity and dirty. Researchers believe that Ar and N_2 gasses do not affect on the thin film growth procedure. The present work shows that the Ar/N_2 flow rate could significantly influence the nano structural properties of TiN.

Experimental procedure and details

The n-type silicon samples with resistivity of 5 Ω-cm and size of 3 cm×1 cm were cut out of the wafer then rinsed with ethanol in an ultrasonic bath and then introduced in the UHV chamber. The chamber was then baked before the measurements. The background pressure was 2×10^{-10} Torr after baking. All further cleaning was done inside the UHV chamber by heating with a direct current through the sample, initially up to 1200 °C and later at higher temperatures to restore a clean Si surface. Earlier measurements with a residual gas mass spectrometer in the line of the beam have shown that a very high proportion (about 50 percent) of oxygen is produced with this setup. Typical total pressure in the chamber during exposure was around 5×10^{-7} Torr.

Discussion

It is clear from the ZAF spectrum that the flow rate can influence the film growth due to the small peaks around the huge peaks. These peaks are due to the other transitions like k_β, $k\gamma$ and etc. The huge peak indicates the k_α transition. However, the background shows that Ar/N_2 flow rate is included, meaning this ratio influences the nano structural properties of TiN film. For this purpose, the Si, Ti and N peaks in photoemission spectra, have been plotted with Fit XPS [2] method [shown in Figs.1 through 3.

Both Ti and N make bonds with silicon atoms as shown in Fig.2, 3 and 4. Si diagram shows an exponentially decay behavior, whereas Ti and N are self-limiting growth. The Boltazmann behavior of Ti and N are not exactly similar.

The broader peak-width in Fig.1 suggests that TiN film has been affected with Ar/N_2 flow rate. This might result in a positive effect on its mechanical properties. Relatively, the multilayered coatings prepared at lower Ar/N_2 flow rate exhibit lower residual stress, which is beneficial to inhibiting coating elimination. The larger curve slope in Fig.2respect to that in Fig.3 shows the higher hardness based on the Oliver Formula [16].

Whilst the same we larger curve slopes.

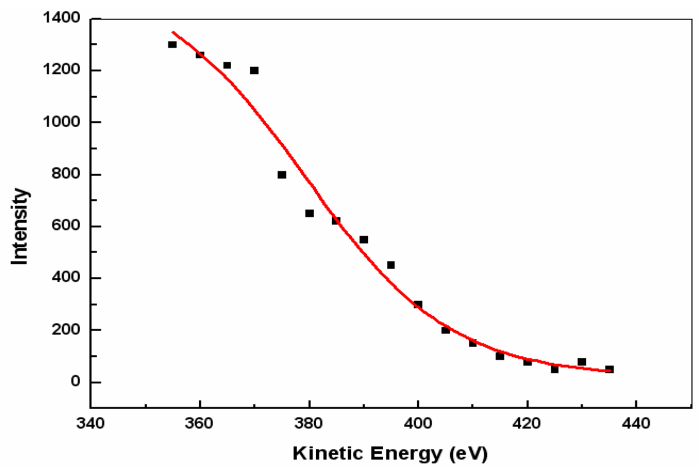

Fig.1. Si behavior in TiN/Si structure

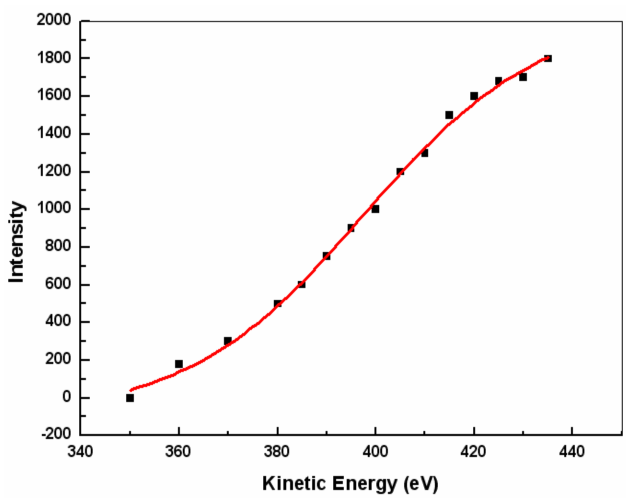

Fig.2. Ti behavior in TiN/Si structure

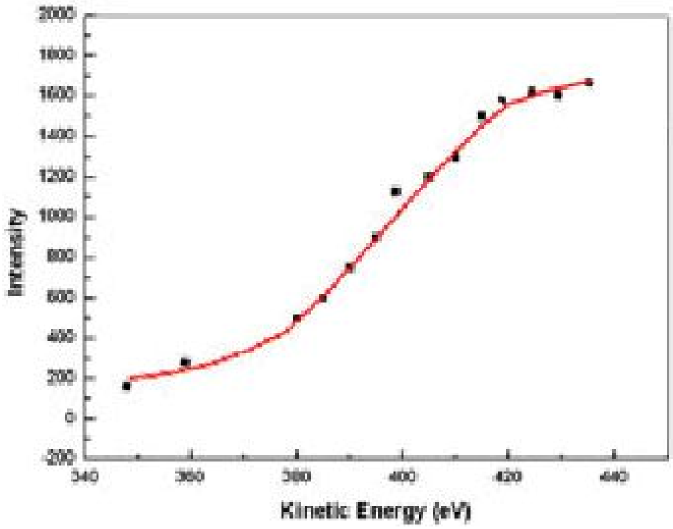

Fig.3. N behavior in TiN/Si structure

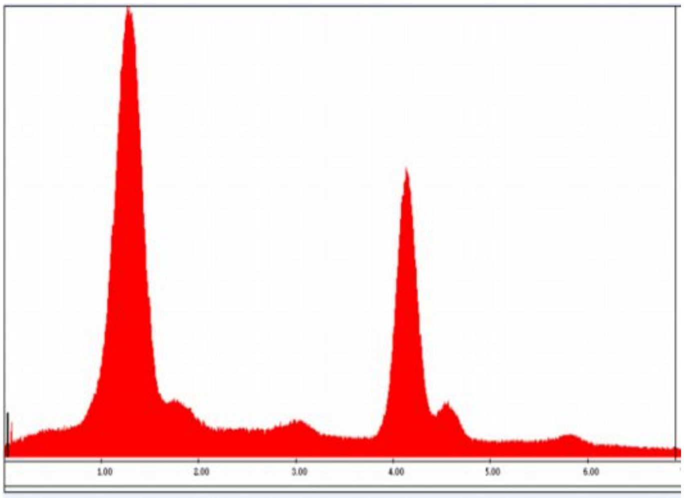

Fig. 4. ZAF spectrum indicate the effect of Ar/N $_2$ flow rate on the film growth

Conclusion

As stated above, the Ar/N_2 flow rate changes the nano structural properties of TiN film. The N_2 molecules are dissociated into atomic nitrogen in that Ti-N-Si bonds could be formed. This film can be used as a good gate dielectric for the next nano transistor devices due to high-k dielectric and thicker equivalent oxide thickness.

References

[1] P. Morgen, A. Bahari,U. Robenhagen, M. Rao and K. Pederson, Roads to ultrathin silicon oxide, *J. Vac. Sci . Technol*. A,**23** (2005) 201.

[2] A. Bahari, U. Robenhagen, P. Morgen, Z.Li, Growth of ultrathin silicon nitride on Si(111) at low temperature, Phy . Rev,B,**72** (2005) 205323.

[3] P. Morgen, A. Bahari and K. Pederson, Ultrathin dielectric films on Si Growth and properties, *ISA, Newsletter*, **9** (2005) 2.

[4] A. Bahari, Z.S.Li and P. Morgen, Valence band studies of the formation of ultrathin pure silicon nitride film on Si(100), *Surf . Sci*. **600** (2006) 2966.

[5] A. Bahari, P. Morgen, K. Pederson and Z.Li , Growth of a stacked silicon nitride / silicon oxide dielectric on Si(100), *J. Vac. Sci. and Technol* B, **24**(2006)2119.

[6] A. Bahari and M. Bagheri, Formation of nanothickness silicon oxide on Si (111) with the assistance of Cs,IJ N N, **2** (2006) 27.

[7] A. Bahari, The effect of Cs on SiO_2 growth, *Ir. Surf.*, **4** (2007) 13.

[8] A. Bahari, M. Suzban, L. Rezai, M. Rezai, M. Roodbari, P. Morgen, Chemical Bonding Configuration at the Interface of SiO_2 /Si, *Asian J. Chem*., **21**(2009) 1609.

[9] A. Bahari, The effect of the fractural clusters on the Si(111)-7×7 surface, WASJ., **4** (2008) 5.

[10] X. Zhaug, Y. Kang, S. Liu, Y. Yang. and D. Li, *J.Mater.sci.Technol*. **23** (2007) 461.

[11] K. Nozari, A. Pahlavan, A. Bahari and M. Roodbari, The effects of the geometry of confinement potential on many body properties of quantum wires, Far. East. *J. Dyn. Systems*, **10** (2008) 221.

[12] A. Bahari and M. Zokai, Nanostructural properties of Bismuth, *WASJ*,**7** (2009) 1.

[13] G.Heand L. Zhauy, *J.Mater.sci.Technol*, **23** (2007) 433.

[14] P. Morgen, A. Bahari, K. Pederson, Z. Li, Plasma assisted growth of ultrathin nitrides on Si surfaces under ultrahigh vacuum condition, *J. Physic. Conf.,* **86** (2009) 01200.

[15] A. Bahari and F. Vahimian, Surface nanocrystallization of stainless with ZAF method and SEM technique, *WASJ*, **11** (2009) 24.

[16] W.C. Oliver and G. M. Pharr., An Extension of the Oliver and Pharr Method to Ultra-Thin Structures, Coatings, Functionally Graded Coatings and Multilayer Systems, *J. Mater. Res*., **7**(1992)1564.

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