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The role of nano particles (Si) in gate dielectric

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Abstract

The progressively decreasing feature size of the circuit components, particles and electronic devices has tremendously increased the need for studying and investigating the nano structural properties of materials. We have grown titanium oxide on the Si (100) substrate at 500°C and one atmosphere pressure. Some researchers have believed that an intermediate silicon oxide film can be made between titanium oxide film and substrate but which turned to be of less use. We added silicon nano particles (100 nm) into titanium oxide film that could modify the titanium oxide morphology as revealed in x-ray diffraction patterns and scanning electron microscopy images. The obtained results show that the existence of silicon nano particles in titanium oxide film resulted in better stability. The improved film can thus be used as a good gate dielectric film for the future CMOS (Complementary metal oxide semiconductor) devices.

Keywords: Nanotechnology, nano transistor, nano particle, gate dielectric.

Introduction

In the last decades, the nanotechnology which deals with features as small as a one billionth of a meter, has begun to enter in to many scientific and practical area from main stream physical sciences include the use of nano scale materials, such as nano particles (silicon, silver & gold nano particles) in nano opto electronic device and nano electronic researches (Ha *et al.,*1996; Wang & Zhang, 2001; Kim *et al.,* 2006; Zainal & Lee, 2006; Gozzelino *et al.,* 2007; Rogachev, 2008).

The semiconducting industry has witnessed an exponential growth in accordance with Moore's law. In this new era, the circuit and the system engineer has been faced with the challenges of scaling. To overcome these problems like channel length, width, contacts and gate dielectric, we start in the earnest to gauge the possibility of newer device structures gate dielectric to mitigate theses problems.

MOSFET (Metal oxide semiconductor field effect transistor) is one of these key elements of integrated circuits (ICs). Their channel lengths continue to shrink rapidly to the sub-10 nm dimensions called for by the international technology roadmap for semiconductors coupled with a high work function material (HWFM), nano scale channel lengths open up the possibility of near-ballistic MOSFET operation (Zainal & Lee, 2006; Gozzelino *et al.,* 2007).

We think the titanium oxide can fill this gap due to higher dielectric constant and band gap energy. The problem is the formation of an intermediated layer (silicon oxide) which can affect on capacitance. We have demonstrated the series of experiments to solve this problem. For this purpose we added silicon nano particles into the titanium oxide film and the obtained results indicate the modified titanium oxide film structure.

Experimental procedures and discussion

The silicon sample (n-type, 5Ω-cm, 1 cm x 1cm) were cut out of wafers and introduced to the furnace after a rinse with ethanol and stone in an ultrasonic bath. A furnace connected to a gas flow system has been used for the growth of titanium oxide layers on Si (100) substrates. Meanwhile, the silicon samples are preheated to 10000°C for 20 min in argon gas at a pressure of one atmosphere to remove the native oxide layer (Bahari *et al.,* 2009). Following the oxidation, argon was let in to the system at the temperature of 500°C and the sample were cooled to ambient temperature in this gas at one atmosphere pressure.

On the other hand, we evaporated Ti – wire with passing current through the wire and the titanium atoms are then deposited on the silicon oxide sample, in which the titanium oxide could be formed. After that we added silicon nano particles on the titanium oxide film. The effects of nano particles are revealed in Fig. 3 & 4 in comparison to titanium oxide film without silicon nano particles (Fig. 5).

We expect that the incorporation of silicon atoms into the TiO_2 film reduces tunneling current and defects generally and allows the use of physically thicker films without reduced capacitance compared to single-layer oxides. To maintain current levels required for circuit operation, the gate oxide-equivalent thickness, t ox-eq, is

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Fig.1. XRD pattern of silicon oxide film without adding nano silicon particles.

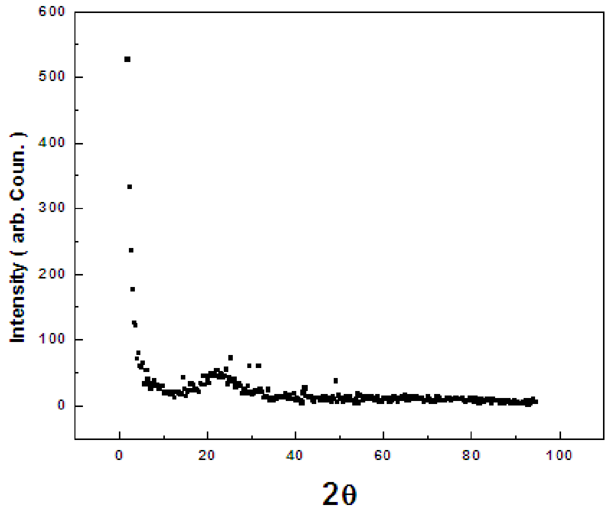
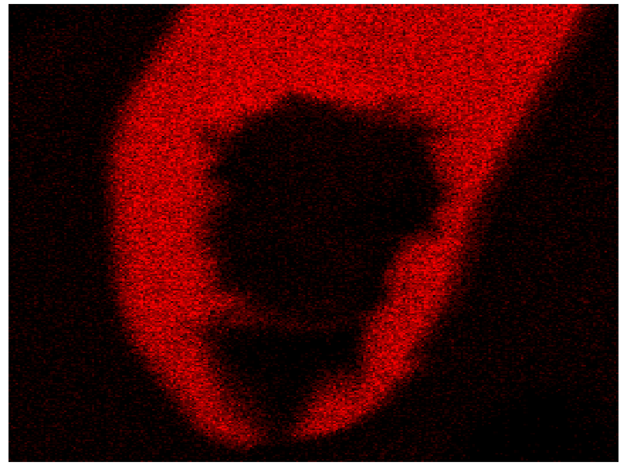


Fig.3. EDX (Energy dispersive X ray) image of the titanium oxide film with 100 nm silicon nano particles



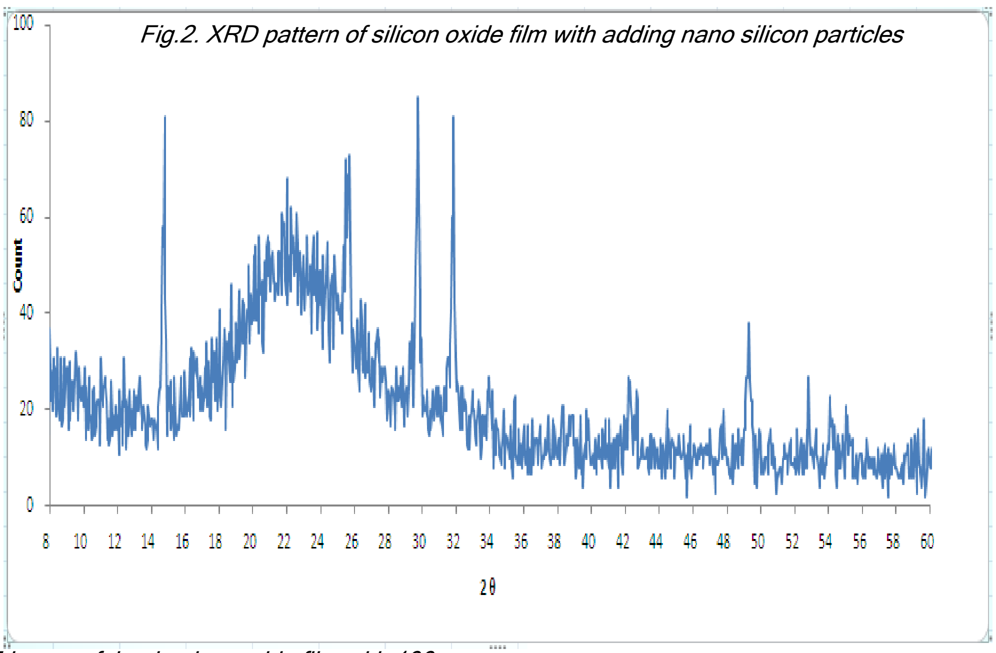


Fig.2. XRD pattern of silicon oxide film with adding nano silicon particles

Fig.4. SEM image of the titanium oxide film with 100 nm silicon nano particles

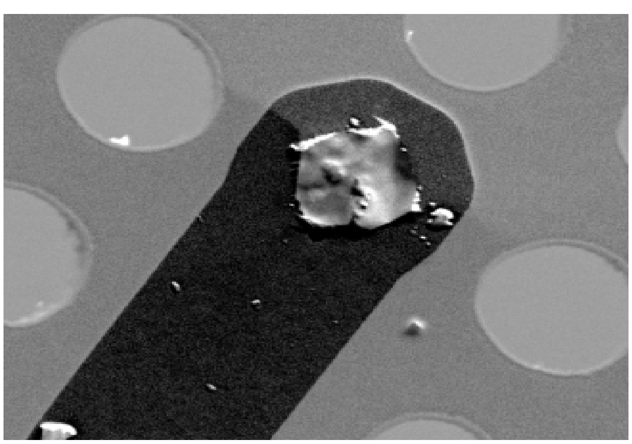
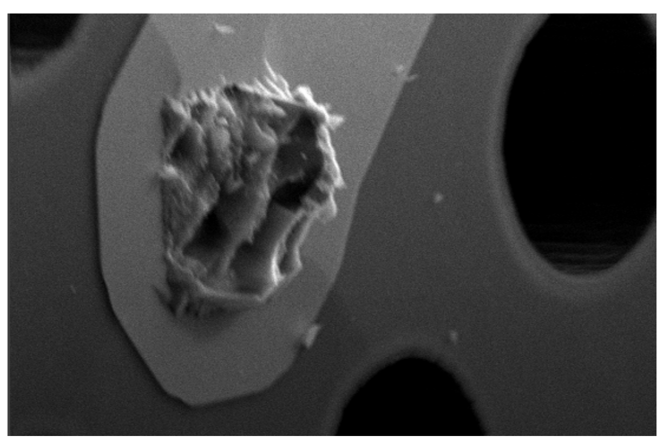


Fig.5. SEM image of the titanium oxide film without silicon nano particles



$$K_O \varepsilon_o \frac{A}{t_{ox}} = K_x \varepsilon_o \frac{A}{t_{ox-eq}}$$

$$\Rightarrow \frac{t_{ox-eq}}{t_{ox}} = \frac{k_m}{k_o}$$

$$\Rightarrow C = K_o \varepsilon_o \frac{A}{t_{ox}}$$

$$\Rightarrow t_{ox} = K_o \varepsilon_o \frac{A}{C}$$

$$\Rightarrow t_{ox-eq} = t_{ox} \frac{k_x}{k_o}$$

Where ε_o is the permittivity of free space and A is the area of the capacitor.

Fig. 1 and 2 show the X-ray diffraction (XRD) patterns of silicon, Sio_2 nano particle with and without silicon nano particle, respectively. It is clear those diffraction peaks corresponding to the Sio_2 have strongest peaks which are visible in the range of 5-25°C. It means that the shell region of the composite particles affects on silicon oxide film and can therefore reduce the leakage current due to a better morphology surface structure as revealed in Fig. 4 and 5. These points imply that the incorporation of nano silicon particles can modify and stable the film structure (Bahari *et al.,* 2005; Morgen *et al.,* 2005; Bahari *et al.,* 2006; Zainal *et al.,* 2006; Gozzelino *et al.,* 2007; Park *et al*., 2008).

It is clear that the reactions between oxygen, titanium and silicon atoms occur throughout the near- interfacial transition region and film surface as well as film bulk structure resulting in the Ti-O, O-Ti-O and O-Ti-Si or Ti-O-Si bonds near the interface. Both the surface exchange reaction and the (near) interface reactions depend on the film growth ambient conditions. Although details of this dependence on pressure, temperature, time and processing conditions, the effect of surface and gaseous impurities should be taken into account (Morgen *et al.,* 2007; Bahari, 2008; Bahari *et al.,* 2008; Bahari *et al.,* 2009).

It also indicates that any mode of silicon nano particle (100 nm) incorporations can change the film structure as shown in Fig.1 and 2. It reveals that a reaction occurring at a well-defined geometrical plate (the TiO_2/Si interface) does not apply to indicate that titanium oxide films as good gate dielectrics of CMIS transistors.

Conclusion

The relative concentrations of silicon and oxygen were determined using the intensities of the Si_2p, C^{15} and O^{15} photoelectron lines in our recent works (Morgen *et al.,* 2007; Bahari, 2008; Bahari *et al.,* 2008; Bahari *et al.,* 2009). It demonstrated the smaller particles and higher surface to volume ratio of these particles. In addition, the stability of SS is attributed to the Si-O stretch bond and thus characteristic of silicon nano particles, where it has been interpreted as an indication of SS-oxidized coated and surface oxidation.

References

1. Bahari A (2008) The Effect of the fractal clusters on the Si (111) - 7×7 surface. *World Appl. Sci. J.* 4, 261.
2. Park B, Im KJ, Cho K and Kim S (2008) Electrical characteristics of gold nanoparticle-embedded MIS capacitors with parylene gate dielectric. Org. Electron. 9,878-882.
3. Bahari A, Morgen P and Li ZS (2006) Valence bend studies of the formation ultra thin pure silicon nitride films on Si(100). *Surface Sci.* 600, 2966-71.
4. Bahari A, Morgen P and Li ZS (2008) Ultra thin silicon nitride films on Si(100) studied with core level photoemission. *Surface Sci*. 602- 2315-24
5. Bahari A, Morgen P, Li ZS and Pederson K (2006) Growth of a stacked silicon nitride/silicon oxide dielectric on Si (100). *J. Vacuum Sci. Technol. B.* 24, 2119-23.
6. Bahari A, Robenhagen U and Morgen P (2005) Grown of ultra thin silicon nitride on Si (111) at low temperatures. *Phy. Rev. B*. 72, 205323-9.
7. Bahari A, Suzban M, Rezaea L and Roodbari M (2009) Chemical bonding configurations at the interface of SiO_2/Si (111) - 7x7. *Asian J. chem.* 21, 1609-1615.
8. Rogachev AS (2008) Exothermic reaction waves in multilayer nanofilms. *Russ. Chem. Rev.* 77, 21-38.
9. Gozzelino L, Minetti B, Gerbaldo R, Ghigo G, Laviano FL, Giunchi G, Perini G, Cavallin E, Agostino T, Panetta A, Mezzetti M and Politecnico di Torino E (2007) Effects of nanoparticle doping on electrical properties of MgB_2 bulks and wires obtained by reactive Mg liquid infiltration technique. *Appl. Super conductivity IEEE.*17, 2726-2729.
10. Ha HY, Nam SW, Lim TH, Oh IH and Hong SA (1996) Properties of the TiO_2 membranes prepared by CVD of titanium tetraisopropoxide. *J. Membrane Sci.*111, 81-92.
11. Kim BH, Ahn JH and Jeong JH (2006) Preparation of TiO_2 thin film on SiO_2 glass by a spin coating-pyrolysis process. *Int. J. Appl. Ceramic Technol.* 32, 223-225.
12. Morgen P, Bahari A, Pedersen K and Li Z (2007) Plasma assisted growth of ultrathin nitrides on Si surfaces under ultrahigh vacuum conditions. *J. Phy.* 86, 12019-38.
13. Morgen P, Bahari A, Rao MG and Li ZS (2005) Roads to ultra thin silicon oxide. *J. Vacuum Technol. A.* 23, 201-207.
14. Wang YL and Zhang KY (2001) Study of the growth morphology of TiO_2 thin films by AFM and TEM. *Surface Coatings Technol.* 140,155-160.
15. Zainal Z and Lee CY (2006) Properties and photoelectron-catalytic behaviour of sol-gel derived TiO_2 thin films. *J. Sol-Gel Sci.Technol.* 37, 19-25.