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Thermal Oxynitridation and nitridation on silicon substrate

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Abstract

There are some principle bottles which neck to the scaling of silicon devices. The main point is that integration density has a hained in credible heights and on-chip functionality. It has advanced from simple adders to systems-on-chip in the same time frame. It now appears that thin silicon oxinitride and silicon nitride can remain the principle gate dielectric materials for the future of logic, CMIS (Complementary-Metal-Insulator-Semiconductor), and memory devices. This paper discusses the advantages of these films as gate dielectric of CMIS generations.

Keywords: Nano transistor, Scaling of Silicon, Leakage Current and Gate dielectric.

INTRODUCTION

High-K dielectric materials, have gained in recent years, increasing importance in many applications, in particularly, in the MISFET (Metal-Insulator-Semiconductor-Field-Effect-Transistor), because they posses certain unique properties and capabilities which ultra thin silicon dioxide does not have. Physical and chemical of materials, especially, SiO_xN_y / Si and SiO_3N_y / Si interfaces are important technological fields, but difficult scientific challenges. The analysis is difficult scientifically because an interface may consist of as little as two monolayers, corresponding to 3×10^{15} atom/cm ^{2} or a mere 5×10^{-9} moles/cm^2 [1-2]. In addition to the practical difficulty of detecting such a small amount of material, one would like to be able to understand the properties of these oxynitride and nitride films to compare the ultra thin SiO_2 and SiO_xN_y / Si (or Si_3N_4) films as suitable materials for the future of nano transistor devices [3 – 10].

MATERIALS AND METHODS

Experimental Procedures and Discussion

Experimental procedure and discussion the silicon sample (n-type, 5Ω-cm, 1cm × 1cm) were cut out of wafers and introduced to the furnace after a rinse with ethanol and stone in an ultrasonic bath (Fig.1). A furnace connected to a gas flow system has been used for the growth of nitride and oxynitride layers on Si(100) substrates. Meanwhile, the silicon samples are preheated to

1000 ° C for 20 minutes in argon gas at a pressure of one atmosphere to remove the native oxide layer. Following the nitridation and/ or oxynitridation, 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. The SiO_x and or Si_3N_4 films as found in our recent works[4] are shown in Figs. 1 and 2.

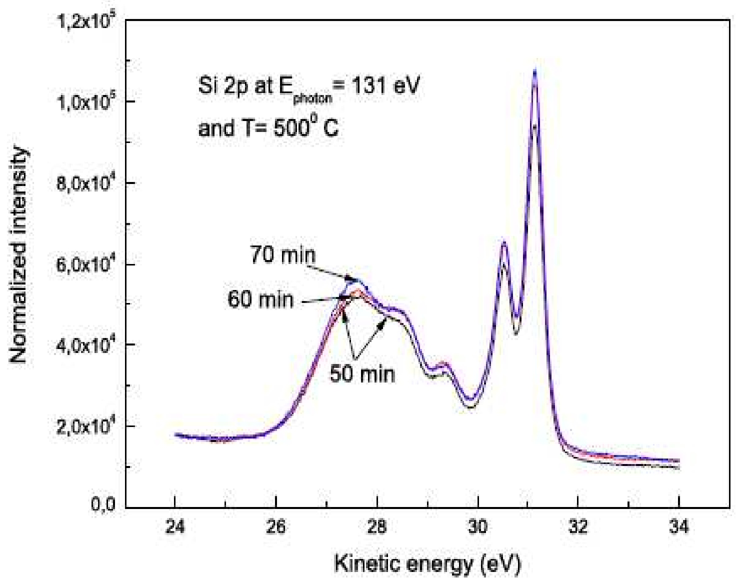

Fig.1 Oxidation of the silicon sample at 60 and 70 minutes

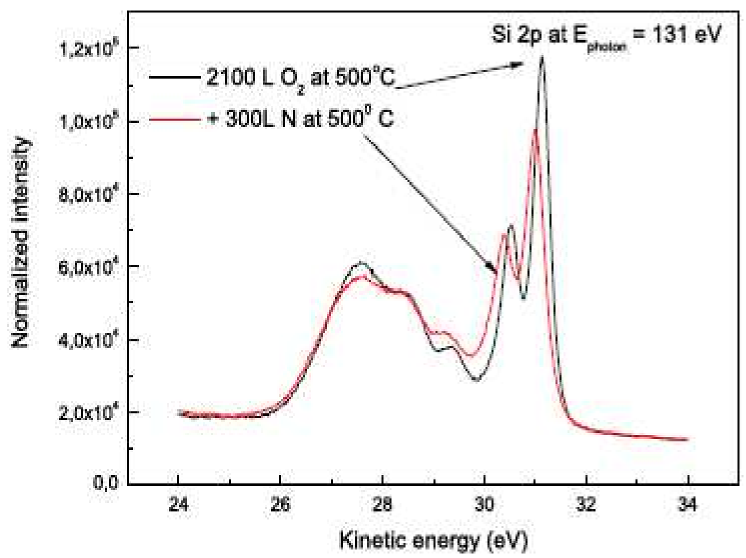

Fig. 2 Nitridation of the silicon sample at different oxide thickness on the silicon substrate

Here, we consider two kinds of photoemission spectra from our recent works and discuss the nano structure of these films. The obtained results:

The incorporation of nitrogen atoms into the SiO_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

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

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

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

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

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

Where ε_o is the permittivity of free space and A is the area of the capacitor. The process of nitridation and oxynitridation is similar, but we could dissociate N_2 into N atoms- by using power supply and a new cone crucible.

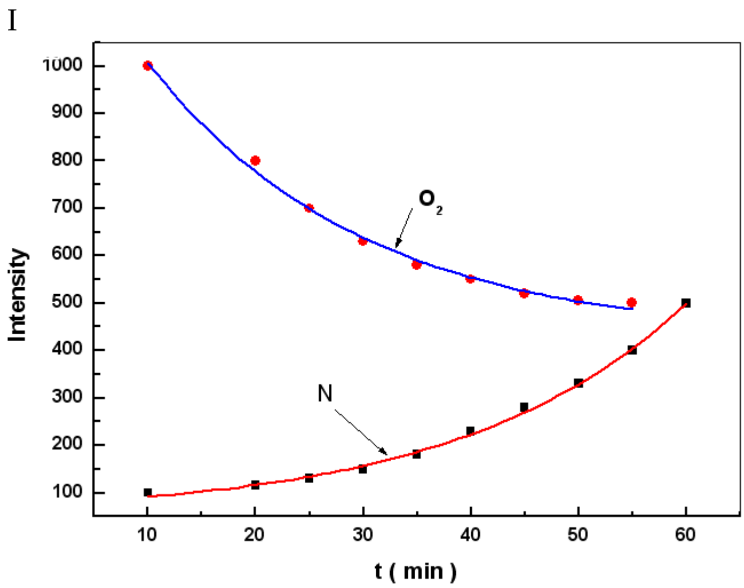

Fig. 3 The oxynitride growth behavior with atomic nitrogen and molecular oxygen

Fig.3 shows that the reactions between oxygen and nitrogen occur throughout the near-interfacial transition region resulting in the N-O, O-N-O and O-N-Si or N-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. It indicates that any mode of silicon oxynitridation (and nitridation) as a reaction occurring at a well-defined geometrical plate (the SiO_xN_y / Si and SiO_3N_y / Si interface) does not apply to indicate that both silicon oxynitride and silicon nitride films can be introduced as good gate dielectrics of CMIS transistors.

CONCLUSION

We believe that the near- interfacial reaction is a result of continued oxynitridation and or nitridation of incompletely oxidized core nitridizealy silicon, i.e., Si^{+1},Si^{+2} and Si^{+3} components at the interface, interstitials and silicon clusters. Our results show that for thin films, the surface exchange reaction occurs independent of the growth reaction near the interface. However, the surface reaction is very important in sub- 2nm films, in this regime the surface and the near-interface reactions overlap in space and as a result, should affect each other.

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