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ChemTech

International Journal of ChemTech Research
CODEN(USA): IJCRGG ISSN : 0974-4290
Vol.2, No.4, pp 2104-2108, Oct-Dec 2010

Characteristic of TiN-SiO_2 Nano Structures as a Chemical field-effect-transistor's element

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Abstract: Titanium nitride is a so suitable photo catalyst material for water and air purification. The photo catalytic performance of these compounds depends on characteristic of TiN-SiO_2 nano structures such as the size and surface area as produced with sol-gel method. For this purpose, we have tried to synthesis Titania nano particles in SiO_2 matrix and studied their spectra with using XRD technique. Furthermore, some corrections for determining nano particle size have been done with x-powder method.
Key words: Nano structures, TiN, SiO_2, sol-gel and XRD technique.

Introduction

Titanium nitride has attracted much attention with respect to the continued scaling in complementary-metal-oxide-semiconductor (CMOS) technology [1-5]. In fact, future high performance devices for higher speed and lower power consumption would require high-k dielectric material to replace conventional gate SiO_2 material. This good dielectric can help engineers for developing of nano fabrication techniques in that people may enable to fabricate the MOSFETS with gate lengths in the sub-100 nm range [6-10].

As the size of the material reach the nanometer regime, approaching the size of nano particles, they directly interact with silicon substrate atoms, in contrast to conventional macro-and micro-devices, which deal with assembly of relatively large amount of samples. Nano particles, TiN powders, exhibit novel electronic, optical, and mechanical properties inherent with the nano scale dimension. Such properties are more sensitive to the environment and target atoms in the samples.

We have thus demonstrated a series of experiments to synthesis thin titanium nitride powder on the silicon dioxide. Matrix with using sol-gel method and studied its structure with x-ray diffraction (XRD) technique. Chemical sensors based on such a mechanism are referred to as chemical field-effect-transistors (chem. FET), which have been widely used in many applications [1].

Experimental Proceeding and Details

Titania is known to have three natural polymorphs, i.e. rutile, anatase, and brookite. Only anatase is generally accepted to have significant photo catalytic activity. Titania can be synthesized by various techniques, such as precipitation [15], chemical vapor deposition [16], hydrothermal method [17] and glycothermal method [18]. Another common technique that can result Titania with extremely high surface area is sol-gel method.

The sol-gel process is commonly applied to synthesis such TiN materials owing to its several advantages such as low temperature processing and the ability to prepare materials in various shapes, compared with the conventional preparation procedures of glass and ceramics [19,20]. In this work we prepare TiN by using hydrolysis procedure of $TiCl_4$ which is transformed to anatase by heating it at 300, 500 and 700 ^oC. It obviously depends on the preparation procedures and TiN content in combination. Anatase is

generally transformed to rutile if calcinations temperature and TiN content increase. By adding more SiO_2 to TiN, the obtained powder trend to crystalline structure.

The preparation of TiN-SiO_2 gel is below, such that Tetraethyl-Orthosilicate (TEOS) (Merk, ≥99) was hydrolyzed with di-ionized water in that NH_4F. NH_4F acts as a mutual solvent. TEOS, in NH_4F was hydrolyzed with water containing acetic acid at room temperature. The solution was then mixed with titanium chloride $TiCl_4$ (Merk, ≥99) at 0 ^oC in specific molar ratio to obtain various content of TiN. After 30 min stirring at room temperature, the sol was vibrated for 20 min in ultrasonic bath to deconglomerate particles and then relaxed at room temperature for 30 min. The sol was stirred at 60 ^oC until it becomes gel and removes NH_4F (about 24 hours). After gelation, samples were dried at 60 ^oC to remove water and acetic acid and leave a white to light yellow lump depend on TiN content. After that the lump samples were milled with mortar and calcinated in 300, 700 and 900 ^oC. The thermal gradient during experiments procedure was 5 deg/min and the samples were put in oven during 2 hours at calcinations temperature stated above.

The composition, structure and surface morphology of the TiN-SiO_2 powder were investigated by XRF, XRD, FT.IR (Fourier Transform Infrared absorption) and FE-SEM (Field Emission Scanning Electron Microscopy) (S-4160, Hitachi 1993).

Table 1. The result of XRF analysis.

Sample	Weight Percent
100	70.75%TiN-29.25%SiO_2
200	59.43%TiN-40.57%SiO_2
300	54.94% TiN-45.06% SiO_2
400	44.1% TiN-55.90% SiO_2
500	33.88% TiN-66.12% SiO_2
600	31.76% TiN-68.24% SiO_2

Discussion

Figure 1 shows that TiN-SiO_2 synthesis procedure is a function of TiN content and temperature. The TiN / SiO_2 content (say, SiO_2 matrix), x, changes from 20 to 80, as revealed in Fig.1. Of course, we plotted just 4 XRD-patterns, x = 20, x = 80, amorphous and amorphous structure at room temperature with origin to distinguish them easily. However, there is just a one broad peak in two spectra in Fig.2. Which indicate the TiN-SiO_2 is amorphous. It can be considered as good gate dielectric for the future of chem FET devices. Due to reducing tunneling, leakage current and preventing the boron diffusion through the ultra thin gate silicon dioxide film. The other points in Fig.1 (or Fig.3) are phase variations in the XRD patterns.

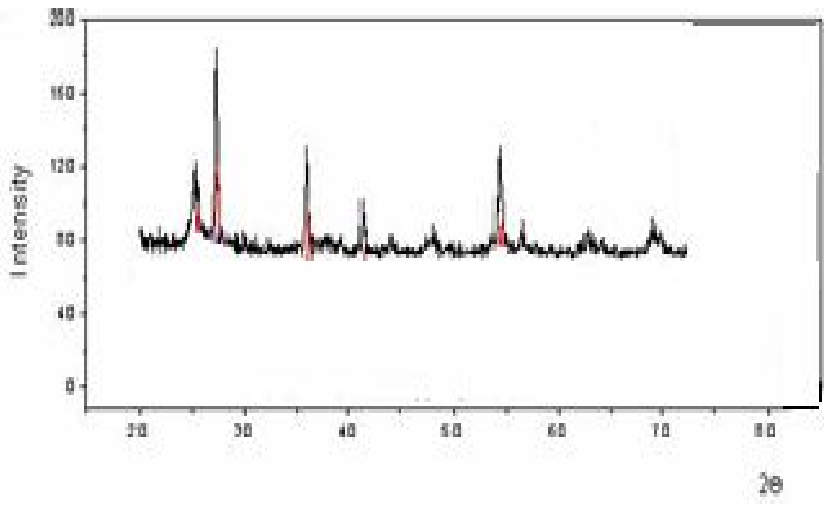

Fig.1. XRD pattern of TiN-SiO_2 powder.

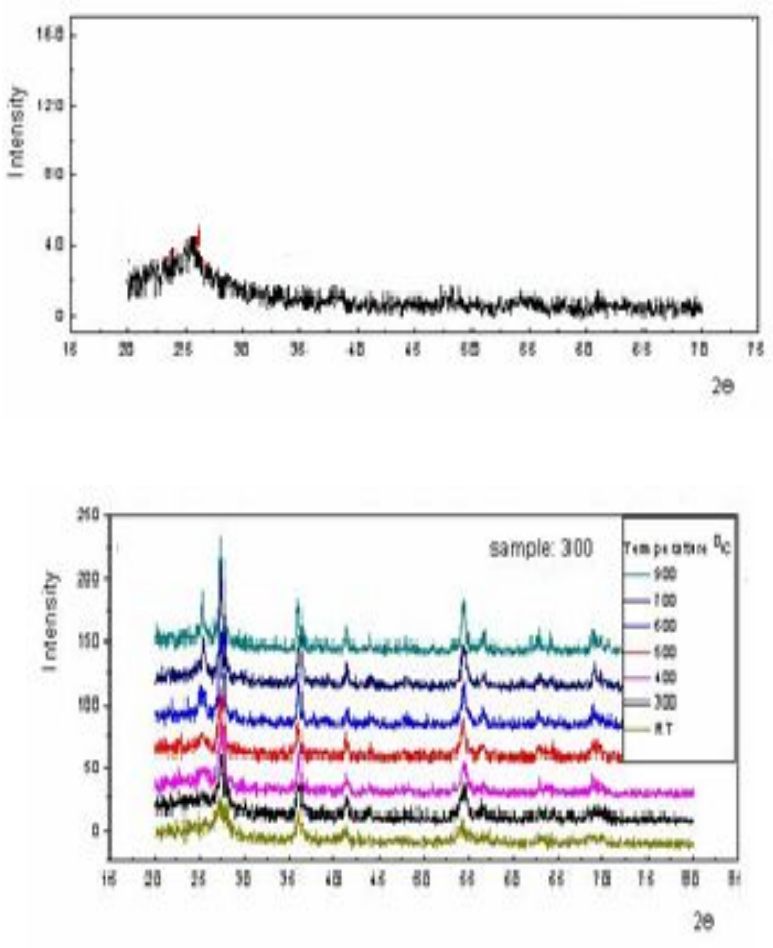

Fig.2. Amorphous TiN could be formed at room temperature (up) and at 300^{o}C (down) and at one atmosphere pressure.

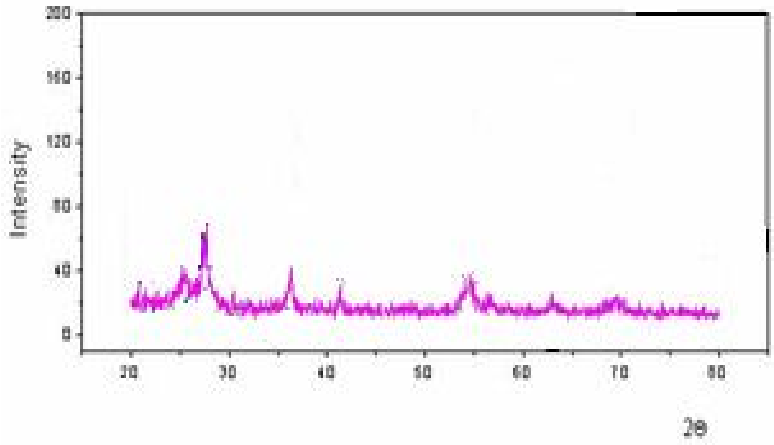

Fig.3. The Anatas phase has being clear with increasing TiN content.

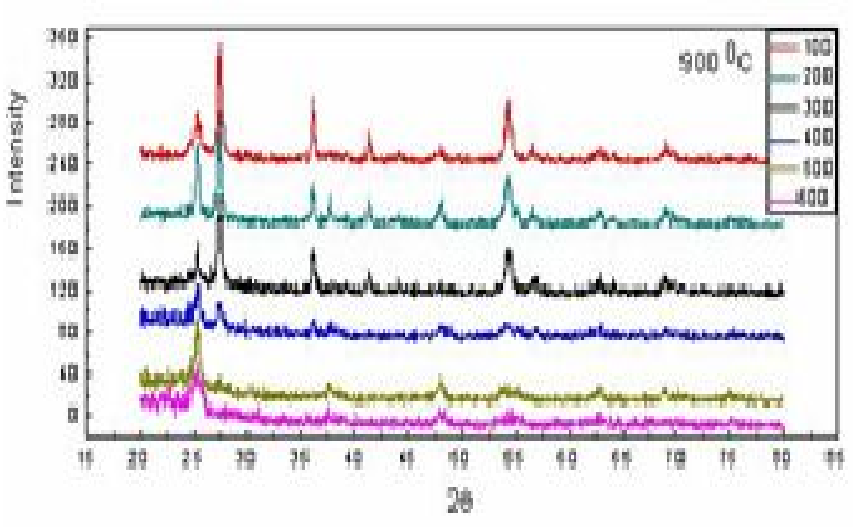

Fig.4. The exponentially behavior of Ti-Si with different Ti content in TiN/SiO_2.

It is clear that the Rotail phase has been changed to Anatas phase with increasing TiN content in SiO_2 matrix.

Some workers [11-14] have studied Ti-Si combinations and found that the temperature is a key point for this phase variation. But, as stated above, we found that TiN content in to SiO_2 matrix is a dominate reason for phase variation, as shown in Fig.4.

The different Ti content in Ti-Si is plotted in Fig.4. As shown in Fig.4. The initial part of the graph indicates that there are no more Si atoms for Si-Ti bonds and or Si-Ti-N Si-N-Ti. Bonds, while the Ti nano particles as well as TiN nano particles with 6-10 nm (Fig.5 is shown as an example) could diffuse though the SiO_2 film and make back bonds with Si and N atoms (and or N_2 molecules).

Furthermore, the Sherly method cannot be used for determine of nano particles size. We have therefore applied the other method, called x-powder, for finding the nearly exact size of particle by fitting the huge peak of XRD-pattern (dash-line in Fig.5). The difference between Sherly and x-powder method is revealed in back ground line (dots in Fig.5).

Conclusions

The effect of Ti content in SiO_2 matrix has been well understood in high pressure and /or ambient environment. This is desired for electronics applications but is the nature of nano scale chemical sensors relying on the interaction between TiN and SiO_2 in the environment.

The hysteresis was attributed to charge traps either in SiO_2 film or TiN film. However, we found that the major cause can be attributed to synthesis procedure, especially the strong SiO_2 surface-bound species.

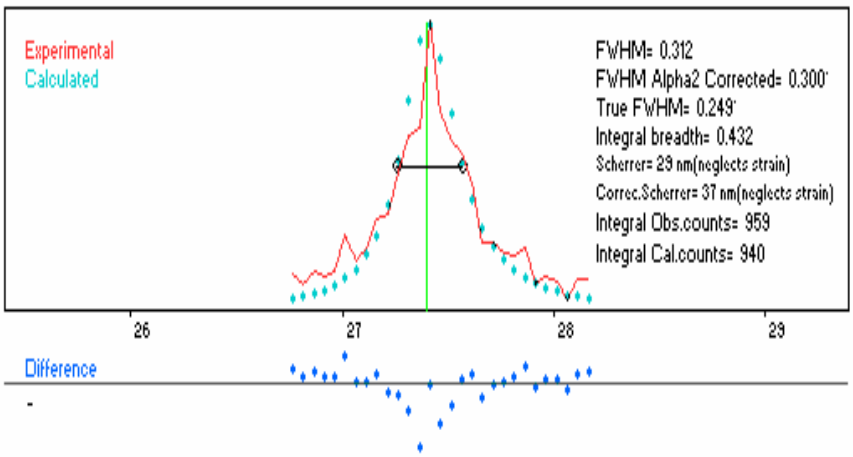

Fig.5.The correction nano particle size with using X-powder method.

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