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Analyze of Syncrotronic Radiation Spectrum due to Arrangement of Si (111) and Si (100) Substrates

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Abstract: In this research we have studied synchrotronical radiation spectrum of both Si (111) and Si (100) substrates by using 130 – 131 eV incoming photon energy. Difference in atomic arrangement of these two substrates orientations is obviously. Atomic arrangement in Si (111) is 7×7 but in Si (100) is 2×1. Consequently, Si (111) may be used as well Si (100) in nano transistors as a semi conductor device.

Key words: Atomic arrangement, nano transistor, semi conductor, substrate, synchrotron radiation technique, thin film

INTRODUCTION

Many efforts have made to study the oxide films on germanium and silicon sub-layers. The structural type of these substrates, plausibly are not identical (Momose *et al.*, 2002; Ren *et al.*, 2004). An interesting subject that brings in many considerations is the difference in atomic arrangement of surfaces of these samples. The change in atomic arrangement of surfaces depends on temperature (Morgen *et al.*, 2005). The presence in the Si 2p spectra of the chemically inequivalent atoms due to $2p_{3/2}$ and $2p_{1/2}$ peaks has typically been used to discuss the structure of Si (111) and Si (100). The chemically shifted Si 2p lines are variably broadened that is due to the different atomic configurations in bulk silicon (Morgen *et al.*, 2005).

If for example, silicon substrate has heated to 700ºC and then leave for cooling to ambient temperature, the atomic arrangement will be 7×7 circles (Bahari *et al.*, 2005; Feltz *et al.*, 1994; Shklyaev and Suzuki, 1996). While this method for Si (100) substrate at 300 - 400ºC leads to different arrangement which will be 2×1, i.e. an atomic structure as rectangle (Kuhn *et al.*, 1978; Bahari *et al.*, 2006a).

Apart from this, cutting the samples in directions with different Miller indexes, gives the different atomic arrangements (Bahari *et al.*, 2006b). This difference can be observed on synchrotronical radiation spectrum. Using synchrotronical radiation spectra is identical to x-ray Photon Spectroscopy (XPS) spectrum technique, but the only difference is that in synchrotronical radiation spectra, the energy of either descent radiation or descent photon over sub-layers is changeable. In other terms, in XPS method the energy has a constant value and cannot be applied for different orientations of silicon. But the synchrotronical radiation spectrum is preferential for this study because the energy of incoming photons can be controlled as we need. In this work the synchrotronic radiation spectra of Si (111) and Si (100) have compared and the difference in atomic arrangement has been shown by Dumas and Chabal (1991).

MATERIALS AND METHODS

X-ray photoelectron spectroscopy (XPS) is carried out at the synchronize radiation facilities at Aarhus University, Denmark. This method of study is a quantitative spectroscopic technique that measures the elemental composition, empirical formula, chemical state and electronic state of the elements that exist within a material. XPS requires ultra high vacuum (UHV) conditions. We have used the program FitXPS, to decompose the spectra at all steps in spin-orbit, split Gaussian-Lorentzian shaped components (Adams and Andersen, 2009).

Two samples of Si (111) and Si (100) has been provided. One side of these samples is polished. Any of these samples cut off two pieces of 2×2 cm length. These pieces have the specific resistance of 2 Ω cm. As the surface of these samples is in contact with atmospheric environment then they can make unwanted bonds with carbon and hydrogen atoms. So they must be cleaned before any experimental works.

After the cleaning procedure, the samples of Si (111) and Si (100) should be washed by ethanol for about 2 hours. Then the sample have brought out of becker and

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washed with acetone. For advanced cleaning, the samples have put in an ultra sonic bath at 45ºC for about 50 min in Payame Noor University. Thus the surfaces of Si (111) and Si (100) samples have much more cleanness.

Having very pure surface with high degree of cleanness, sputtering method has performed. The samples have put in the furnace at 700ºC and very pure Ar gas injected into it about 10 minutes. The formed Ar^+ ions are the best substance for sputtering because of their heavy atomic masses and they can remove undesirable particles from surface in best manner. In fact, when a clean surface of silicon put under air effect, a thick film of silicon dioxide may be form on it. By sputtering method this silicon dioxide film will remove layer by layer.

RESULTS AND DISCUSSION

After this step, the furnace has cut off and allows the temperature goes down slowly from 700 to 400ºC and thus expected Si (111) with 7×7 circle arrangement will be formed. As mentioned before, the arrangement of Si (100) in ambient temperature is 2×1. For studying the different particularity of surfaces of these samples, their synchrotronic radiation spectrum was required. The spectrums of Si (111) and Si (100) surfaces have prepared in two different ranges of energy, 130 and 131 eV (Fig. 1 and 2).

Figure 1 shows the existence of peaks of rest atom in E_K = 27.7 eV and ad atom in E_K = 26.8 eV which may be attribute to 7×7 atomic structure which is form in surface of Si (111). In fact at higher kinetic energy of Si (111) spectrum there is a peak that may be due to rest atoms, while, the part between higher peak of $Si2p_{3/2}$ and lower peak of $Si2p_{1/2}$ may be due to ad atoms. This is in comparison with the pair of up - dimer atoms and the pair of down – dimer atoms in Si (100) spectrum (Fig. 2).

Figure 3 shows both spectra on one plot. What is concerning Si (111) with more obviousness, are the existence of ad – atoms, rest – atoms and dimers which occur in 7×7 structure. Only two types of up – dimers and down – dimers occur in Si (100) with 2×1 structure and these dimers put in both sides of higher peak of $Si2p_{3/2}$.

One of interesting consequents obtained from the spectra is appearance of $2p_{3/2}$ and $2p_{1/2}$ peaks in Si (111) and Si (100). In fact, the surface under each peak is the number of received electrons to analyzer, which are defined by intensity. Moreover, the number of quantum states is $2(2j+1)$. Total angular momentum j is the sum of l (orbital angular momentum) and s (electron spin), i.e. $J = l + s$. For 2p state, $n = 2$ then $l = 1$. Therefore, for spin up state s is equal to 1/2 and for spin down state s is equal to-1/2. Thus the surface area under higher peak, considering $j = l + s = 1 + 1/2 = 3/2$, compared with the

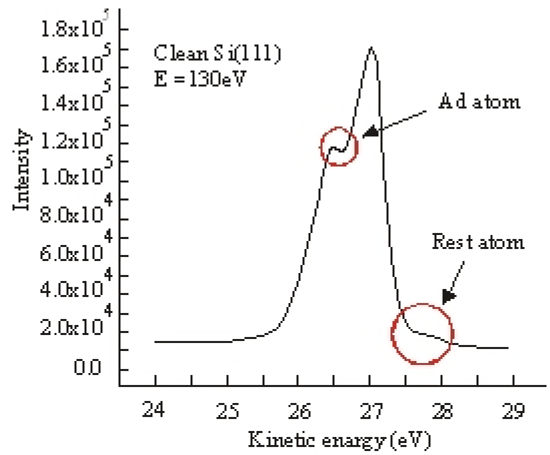

Fig. 1: The synchrotronic radiation spectrum of Si (111) surface

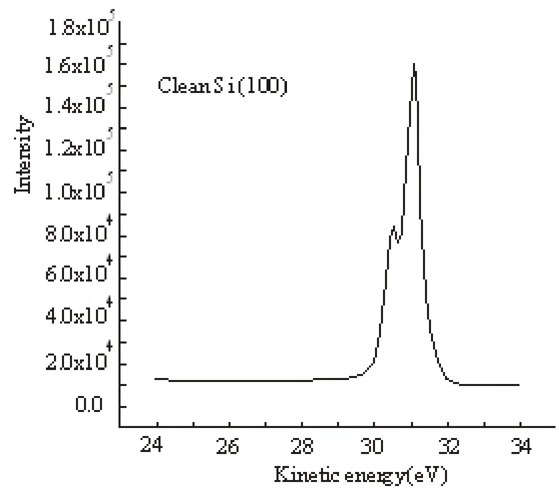

Fig 2: The synchrotronic radiation spectrum of Si (100) surface

surface area under lower peak, considering $j = l - s = 1 - 1/2 = 1/2$, is equal to $2(2\ (3/2) + 1) / 2(2\ (1/2) + 1) = 2$. This means that the surface the surface area under of higher peak compared with the surface area under of lower peak is twice greater. In other terms, intensity of $Si2p_{3/2}$ peak compared with $Si2p_{1/2}$ peak for both substrates Si (111) and Si (100) is equal 2. But in Si (100) the peaks are closer. The interval between these two peaks in Si (111) is equal 0.61 eV, while this interval in Si (100) is equal 0.59 eV. These results have been affirmed by standard program FitXPS.

CONCLUSION

Comparing the spectra obtained from Si (111) and Si (100) shows the good agreement of operational electronical properties. Consequently, Si (111) may be

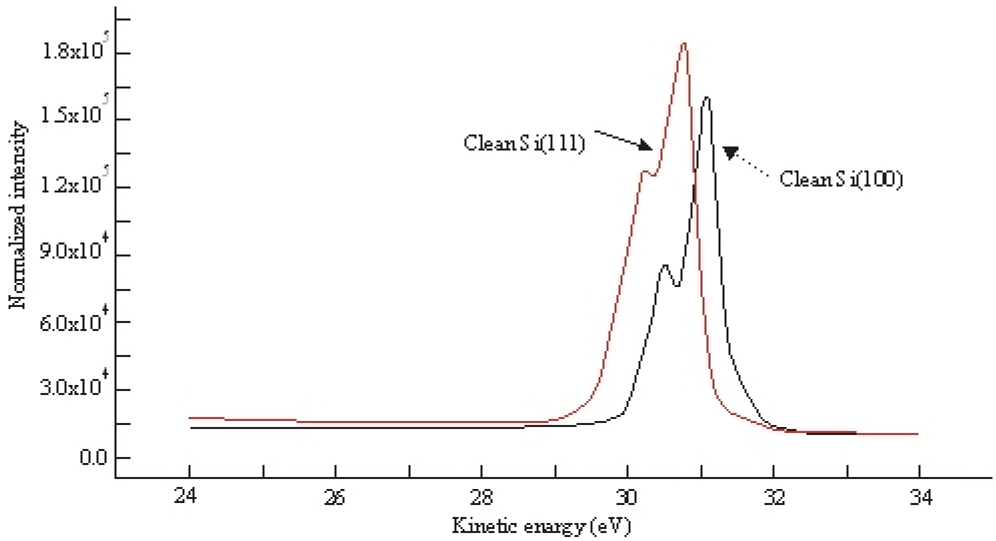

Fig. 3: Comparing two spectra obtained from Si (111) and Si (100)

used as well Si (100) in electronic circuits and nano transistors as a semi conductor device. Considering that, atomic arrangements of two substrates are different and this is due to effect of temperature and does not correspond to Miller indexes.

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