Chapter 5
Atomic Force Microscopy (AFM) Study on Argon Dilution a-Si:H Film

5.1 Introduction

In this work, the Atomic Force Microscope (AFM) is using to study the surface morphology of argon dilution a-Si:H films. In most thin film research, the Scanning Electron Microscope (SEM) is used to give a clear 2 dimensional image of the surface. Contamination and defects can be detected from SEM images but detailed information of microstructures on the a-Si:H surface cannot be detected. AFM provides a clear 3 dimensional image, which is effective in studying the microstructure formation and surface morphology of the film. In this work, the AFM provides important information on the surface roughness, grain sizes and homogeneity of the a-Si:H films surface.

The formation of microstructure in hydrogenated amorphous silicon (a-Si:H) thin film produced by plasma enhance techniques has been known since early works [1,2]. It has been tacitly assumed that the a-Si:H materials is homogeneous with hydrogen-decorated and structurally the material is uniformly disodered with continuous random network [3]. The microstructure formation greatly influence the properties and function of a-Si:H application such as solar cell and TFT transistors [4]. Especially in the solar cell technology, the microstructure formation has often been considered as a drawback for a-Si:H film because of the deterioration of the film quality, the enhancement of the film roughness and porosity, and the production of pinholes in solar cells [5].

The microstructure formation of a-Si:H film is referred to as a major effect of inert gasses dilution of silane during deposition [6]. Argon as a metastable heavy atom is passive in chemical reaction, but plays an important in role the growth mechanism of a-

Si:H. It is important to note that argon dilution will result in argon ion bombardment on the surface of a-Si:H during deposition which can have both beneficial and detrimental effects on the a-Si:H film [7]. Argon dilution of silane(SiH_4) in plasma glow discharge deposition of a-Si:H is known to produce films with improved microstructures and structural properties [8]. However, the optimal condition of argon dilution is important to produce high quality homogenous microstructure a-Si:H film for future applications. In this chapter, the results and analysis of the AFM images of the argon diluted a-Si:H films are presented and detailed.

The AFM images of argon diluted a-Si:H films in this work will be shown in section 5.2. The observation of the a-Si:H films and the effect of argon dilution on the microstructure formation of a-Si:H films are briefly presented and the discussion bases on the glass and crystal silicon (c-Si) substrates.

In section 5.3, the results of AFM presented before will bring to discuss the effect of the glass and c-Si substrates on the surface morphology of a-Si:H. The comparison of the a-Si:H surface base on the glass and c-Si substrates will be presented. The important of different substrate to the microstructure formation of a-Si:H is also introduced.

The results of the surface roughness grain size obtained from the AFM study will be presented in section 5.4 and 5.5. The variation of surface roughness and grain size with argon to SiH_4 ratio shown and briefly discuss. Finally, this chapter will be ended with conclusion in section 5.6.

5.2 AFM Images of a-Si:H : Effect of Argon Dilution.

The AFM images of a-Si:H samples investigated in this work are displayed in 3-Dimension with scan area $4\mu m^2$($2\mu m$x$2\mu m$) and 200nm vertically. In this section, the AFM images of a-Si:H films prepared using 5sccm and 20sccm silane flow-rate, undiluted and diluted in argon at 5sccm, 10sccm and 15sccm are studied and analyzed. The 5sccm and 20sccm silane flow-rate a-Si:H films are categorized as in the previous chapter as high and low argon dilution films respectively. The effects of the different argon flow-rate mixed with silane at flow-rate of 5sccm and 20sccm on the surface morphology of the films are studied. Since the films are deposited on the glass and c-Si substrates, the effects of argon flow-rates on a-Si:H films deposited on these substrates are analyzed separately in section 5.2.1 and 5.2.2 respectively.

5.2.1 Effects of Argon flow-rate on Surface Morphology of a-Si:H Films on Crystal Silicon(c-Si) Substrate.

Figures 5.1(a) to 5.1(d) and figures 5.2(a) to 5.2(d) show the AFM image of high and low argon dilution a-Si:H films deposited on c-Si substrate respectively. Figures 5.1(a) and 5.2(a) are AFM images of a-Si:H films prepared from pure silane at 5sccm (5S) and 20sccm (20S) respectively. The lower silane flow-rate sample, sample 5S exhibits a smooth morphology with isolated columnar structure while the higher silane flow-rate sample, sample 20S exhibits a uniformly distributed granular clusters with two isolated large clusters.

In early SEM study, this columnar morphology has been observed by *J.C.Knigths* [3] on the a-Si:H films. The granular structure and isolated island clusters are also observed by many a-Si:H researchers utilizing the STM [9,10] and AFM [11].

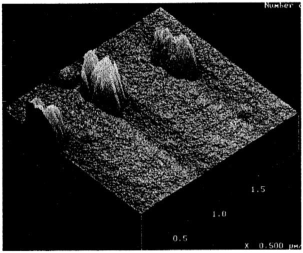

Figure 5.1(a): AFM image of a-Si:H deposited on the c-Si prepared from pure silane at flow-rates of 5sccm (sample 5S).

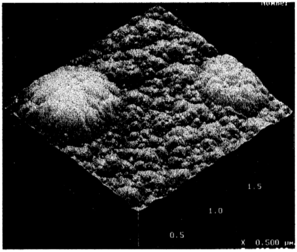

Figure 5.2(a): AFM image of a-Si:H deposited on c-Si, prepared from pure silane at flow-rate of 20sccm (sample 20S).

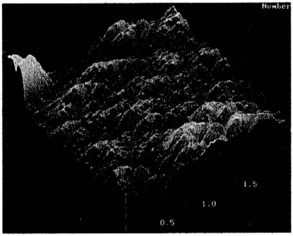

Figure 5.1(b): AFM image of a-Si:H deposited on the c-Si prepared from 5sccm silane mixed with argon at flow-rates of 5sccm (sample 5A/5S).

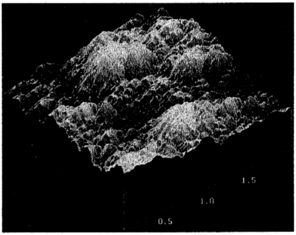

Figure 5.2(b): AFM image of a-Si:H deposited on c-Si, prepared from 20sccm silane mixed with argon at flow-rate of 5sccm (sample 5A/20S).

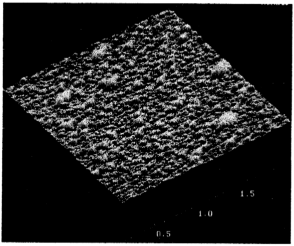

Figure 5.1(c): AFM image of a-Si:H deposited on the c-Si prepared from 5sccm silane mixed with argon at flow-rates of 10sccm (sample 10A/5S).

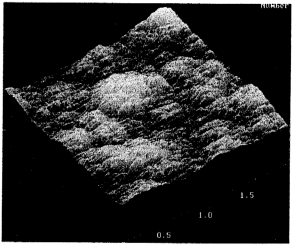

Figure 5.2(c): AFM image of a-Si:H deposited on c-Si, prepared from 20sccm silane mixed with argon at flow-rate of 10sccm (sample 10A/20S).

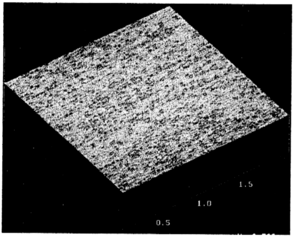

Figure 5.1(d): AFM image of a-Si:H deposited on the c-Si prepared from 5sccm silane mixed with argon at flow-rates of 15sccm (sample 15A/5S).

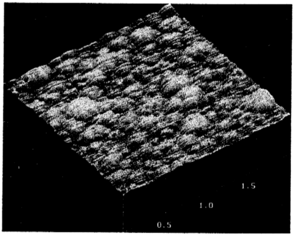

Figure 5.2(d): AFM image of a-Si:H deposited on c-Si, prepared from 20sccm silane mixed with argon at flow-rate of 15sccm (sample 15A/20S).

The growth of granular structure and columnar structures is believed to be related to the Si-H bonding configuration and hydrogen clustering, especially in the Si-H_2 bond formation [12,13]. Based on the study of argon diluted a-Si:H films, *H. Meiling* [14] proposed that the gas phase polymerization results in the formation of $(Si\text{-}H_2)_n$ cluster. Thus, this effect is most obvious in the higher silane flow-rate films when argon is absent in the gas discharge during deposition.

Figures 5.1(b) and 5.2(b) show the AFM images of 5A/5S and 5A/20S, which are prepared from 5sccm and 20sccm flow-rates of SiH_4 respectively with 5sccm argon dilution. The surface morphology of 5A/5S and 5A/20S show a distinct cluster morphology which is different from the surface morphology of the other samples. This type of surface can be described as wavy columnar structures formed due to the presence of clusters of $(Si\text{-}H_2)_n$ bonds [14].

Figures 5.1(c) and 5.1(d) shows the images of a-Si:H films prepared from 5sccm flow-rates of silane diluted with argon at flow-rates of 10sccm and 15sccm. It is clear that these samples have more homogeneous morphology. Sample 10A/5S exhibit morphology of small granular cluster uniformly distributed within the scanning area without any isolated features, while sample 15A/5S do not show any significant clustering of structures thus the structure can be deduced as amorphous.

Figures 5.1(d) and 5.2(d) show the AFM images of a-Si:H films prepared from 20sccm silane flow-rates diluted in argon at flow-rates of 10sccm and 15sccm respectively. These samples also exhibit uniformly distributed granular clusters without any isolated features. However, the granular structures are significantly larger than the structures observed in the 10A/5S film. Sample 15A/20S has smaller clusters compared to sample 10A/20S demonstrating that the increase in argon flow-rate reduces the grain structures in these films.

From the AFM images of the a-Si:H film on silicon substrates, the surface morphology of the films generally exhibit a uniform distributed granular cluster. Isolated structures which are observed in the pure silane a-Si:H samples disappear with the argon dilution. Significant decrease in granular cluster sizes is observed in figures 5.1(c), 5.1(d), 5.2(c) and 5.2(d), where the Ar: SiH_4 ratio was increased from 0.5 to 3. The highest argon to silane flow-rate ratio films has no grains or granular structure demonstrating an amorphous morphology. Thus, argon have the effect of reducing the granular cluster size in a-Si:H films and improving the homogeneity of the microstructures in a-Si:H films. According to *H. Meiling*, argon dilution in plasma deposited a-Si:H have the effect of argon ion bombardment [14]. Sufficient ion bombardment on the a-Si:H film will dissipate energy that enhances the surface diffusivity of precursors and eliminate clustered H from the film, resulting in the observed improvement of microstructure properties.

5.2.2 Effects of Argon flow-rate on Surface Morphology of a-Si:H Films on Glass Substrate.

Figures 5.3(a) to 5.3(d) and 5.4(a) to 5.4(d) show the AFM images of high and low argon dilution a-Si:H films respectively prepared on glass substrate. Figure 5.3(a) and 5.4(a) are the AFM images of a-Si:H films prepared from pure silane at flow-rates of 5sccm and 20sccm respectively. These a-Si:H films prepared from pure SiH_4 exhibit similar morphology of uniformly distributed small granular cluster. However, the sample prepared using higher SiH_4 flow-rates (sample 20S) have three isolated island clusters and also the granular clusters is larger in size than the lower silane flow-rates sample (sample 5S). This indicates that higher SiH_4 flow-rates result in larger clusters and uneven surface morphology due to the presence of isolated island.

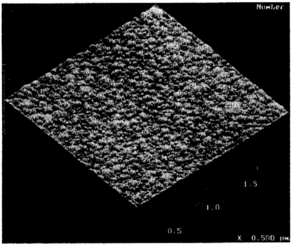

Figure 5.3(a): AFM image of a-Si:H deposited on the glass substrate prepared from pure silane at flow-rates of 5sccm (sample 5S).

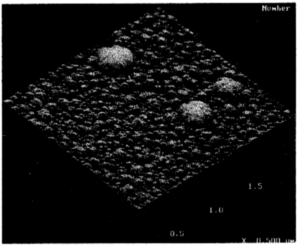

Figure 5.4(a): AFM image of a-Si:H deposited on the glass substrate prepared from pure silane at flow-rates of 20sccm (sample 20S).

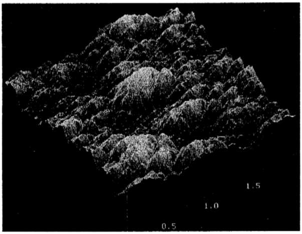

Figure 5.3(b): AFM image of a-Si:H deposited on the glass substrate prepared from 5sccm silane mixed with argon at flow-rates of 5sccm (sample 5A/5S).

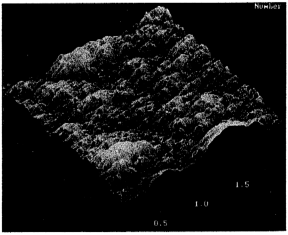

Figure 5.4(b): AFM image of a-Si:H deposited on the glass substrate prepared from 20sccm silane mixed with argon at flow-rates of 5sccm (sample 5A/20S).

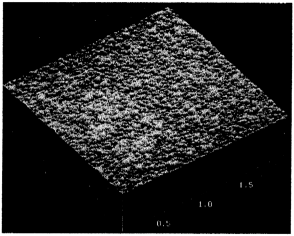

Figure 5.3(c): AFM image of a-Si:H deposited on the glass substrate prepared from 5sccm silane mixed with argon at flow-rates of 10sccm (sample 10A/5S).

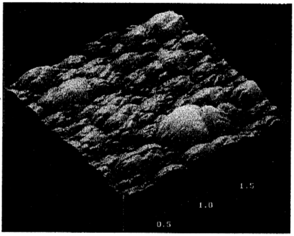

Figure 5.4(c): AFM image of a-Si:H deposited on the glass substrate prepared from 20sccm silane mixed with argon at flow-rates of 10sccm (sample 10A/20S).

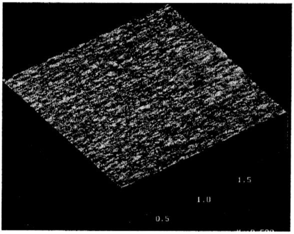

Figure 5.3(d): AFM image of a-Si:H deposited on the glass substrate prepared from 5sccm silane mixed with argon at flow-rates of 15sccm (sample 15A/5S).

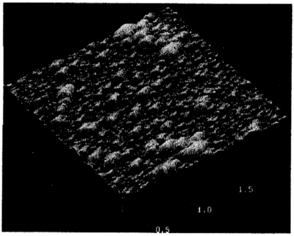

Figure 5.4(d): AFM image of a-Si:H deposited on the glass substrate prepared from 20sccm silane mixed with argon at flow-rates of 15sccm (sample 15A/20S).

Figures 5.3(b) and 5.4(b) are the AFM images of a-Si:H films prepared from 5sccm and 20sccm SiH_4 flow-rates diluted with argon at 5sccm flow-rate. As in the a-Si:H films deposited on the c-Si substrate, the surface morphology in distinctly different from the other samples. The surfaces are uneven and randomly distributed with sharp clusters (wavier) and usually are associated to the presence of columnar structures within the film structure [14].

Figures 5.3(c) and 5.3(d) are images of a-Si:H films prepared from silane at 5sccm flow-rates in argon at flow-rates of 10sccm and 15sccm respectively. Sample 10A/5S show uniformly distributed small granular clusters and a more even surface compared to the earlier samples. Sample 15A/5S shows a smooth and homogeneous surface with some very fine granular clusters, which are so fine that the surface morphology can be deduced as amorphous.

Figures 5.4(c) and 5.4(d) are AFM images of a-Si:H films prepared from 20sccm silane flow-rate with argon dilution at flow-rates of 10sccm and 15sccm respectively. These two samples exhibit uniformly distributed granular clusters without any isolated features. The size of the clusters for the sample prepared using higher argon flow-rate is larger compared to the sample prepared using the lower argon flow-rate. This indicates that the increase in argon dilution reduces the granular cluster size in a-Si:H films prepared on glass substrate as in the a-Si:H film prepared on c-Si substrate.

From the AFM images of all the a-Si:H on the glass substrate, it is observed that higher flow-rates of silane films have more uneven surface morphology with large clusters as compared to the lower silane flow-rates films. The argon as a diluent gas in the preparation of a-Si:H film have the effect of reducing the size of the granular clusters and improving homogeneity of the microstructures in a-Si:H films. Based on the argon to silane flow-rates (Ar:SiH_4) ratio, the morphology of the samples become more homogeneous (smooth) and the cluster sizes are reduced as the argon to silane flow-rate ratio is increased. This can be observed in figures 5.3(c) to 5.4(d) where the argon to silane flow-rate ratio approaches 3, the surface morphology of the sample 15A/5S becomes smoother with very fine granular clusters.

5.3 AFM Images of a-Si:H : Effect of Substrate

The effect of a-Si:H deposited on the different substrates is studied in this work. The surface of the substrate provide the interface for the growth of a-Si:H and the bonding between the a-Si:H with the substrate material is an important factor which influences the formation of microstructure in the deposited a-Si:H films [4]. The surface of c-Si is important in providing a support base for silicon to bond. In a-Si:H technology, the substrate material is specific contact to a particular application. The a-Si:H thin film used in solar cell and some semiconductor transistors are usually deposited on c-Si substrate while in thin film transistors(TFT) for LCD display, the substrate required is definitely glass or quartz.

The effects of glass and c-Si substrates on the deposited a-Si:H which will be studied in this section categorized into high and low argon dilution a-Si:H films as described previously in section 5.2. The surface morphology of high and low argon dilution a-Si:H films on both glass and c-Si substrate are discussed and analyzed in section 5.3.1 and 5.3.2 respectively.

5.3.1 Effect of Substrate on High Argon Dilution a-Si:H Films.

Figures 5.5(a) and 5.5(b) show the AFM images of the a-Si:H films prepared from pure silane at flow-rate of 5sccm(5S) on c-Si and glass substrates respectively. The films on c-Si substrate exhibit a smooth surface with three isolated columnar structure within the scanning area. The smooth surface of the a-Si:H demonstrates an amorphous morphology while the isolated columnar structures indicate the presence of isolated Si-H_2 clustering probably at surface defects of the substrates. The film on glass substrate exhibit uniformly distributed small granular clusters. Thus, at low silane flow-rate, significant surface morphology differences are observed in a-Si:H deposited on glass and c-Si substrates, showing substrate dependence. C-Si substrate results in an amorphous film structure while glass substrate produces grainy a-Si:H film structure.

Figures 5.5(c) and 5.5(d) is the AFM images of a-Si:H films prepared from the discharge of 5sccm silane diluted with 5sccm argon (5A/5S) on c-Si and glass dilution respectively. The introduction of argon into the 5sccm silane discharge (high argon dilution) results in films with similar surface morphology on both c-Si and glass substrates. Films on both substrates demonstrate wavy columnar structures, which are significantly different from the surface morphologies of films deposited using other argon flow-rates.

Figures 5.5(e) and 5.5(f) is the AFM images of a-Si:H films prepared from 5sccm silane diluted with 10sccm argon (10A/5S) on c-Si and glass substrates respectively. Consistent with the analysis made on the 5A/5S films, the film morphologies are independent of substrate with argon dilution of 5sccm silane (high argon dilution). Both films demonstrate morphology of fine granular structures.

Figures 5.5(g) and 5.5(h) display the AFM images of a-Si:H films prepared from 5sccm silane diluted with 15sccm argon (15A/5S), i.e. the highest argon dilution films studied in this work deposited on c-Si and glass substrates respectively. The surface morphologies of both these films demonstrates an amorphous films structure which further confirm that high argon dilution results in the a-Si:H thin film structure being argon flow-rate dependent and independent of substrates.

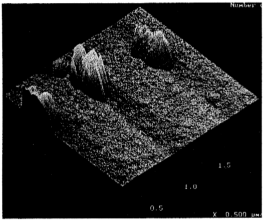

Figure 5.5(a): AFM image of pure 5sccm silane prepared a-Si:H film (sample 5S) on c-Si substrate.

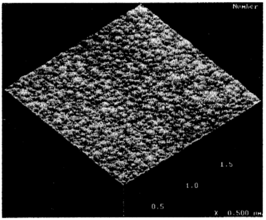

Figure 5.5(b): AFM image of pure 5sccm silane prepared a-Si:H (sample 5S) on glass substrate

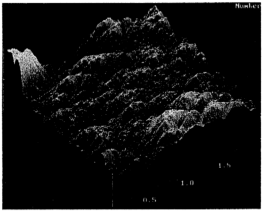

Figure 5.5(c): AFM image of high argon dilution a-Si:H sample 5A/5S on c-Si substrate.

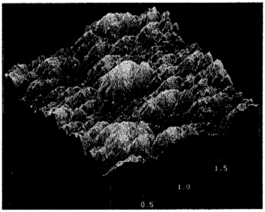

Figure 5.5(d): AFM image of high argon dilution a-Si:H sample 5A/5S on glass substrate.

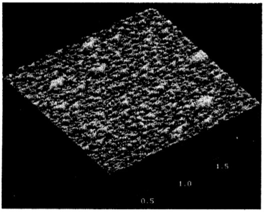

Figure 5.5(e): AFM image of high argon dilution a-Si:H sample 10A/5S on c-Si substrate.

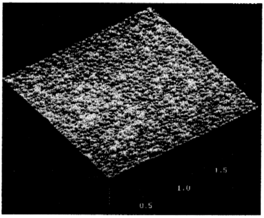

Figure 5.5(f): AFM image of high argon dilution a-Si:H sample 10A/5S on glass substrate.

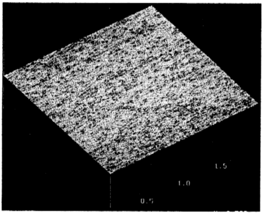

Figure 5.5(g): AFM image of high argon dilution sample 15A/5S on c-Si substrate.

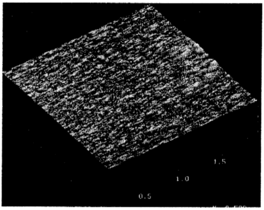

Figure 5.5(h): AFM image of high argon dilution sample 15A/5S on glass substrate.

From the AFM images of the a-Si:H films deposited at low silane flow-rate of 5sccm undiluted and diluted in argon, the film morphology of the films are independent of substrates with argon dilution. The film morphologies are strongly dependent on the argon flow-rate, which shows a decrease in grain structure sizes with increase in argon flow-rate. At the highest argon dilution with 15sccm argon, the film structure becomes amorphous.

5.3.2 Effect of Substrate on Low Argon Dilution a-Si:H Films.

Figures 5.6(a) and 5.6(b) show the AFM images of a-Si:H films prepared from pure silane at flow-rate of 20sccm (20S) on c-Si and glass respectively. Both the a-Si:H on glass and c-Si exhibit a morphology of granular clusters with isolated island clusters which is significantly larger than the other granular structures. The smaller granular structures appear to be slightly larger and less uniformly distributed on c-Si substrates. The isolated island clusters are very large in the a-Si:H film on c-Si as compared to the isolated clusters of the a-Si:H on glass.

Figures 5.6(c) and 5.6(d) show the AFM images of a-Si:H films prepared from the discharge of 20sccm silane diluted with 5sccm argon (5A/20S) on the c-Si and glass substrates respectively. As observed in the a-Si:H prepared from the discharge of 5sccm silane diluted with 5sccm argon , the surface morphologies show similar wavy columnar structures which confirms that this surface morphology is characteristic of a-Si:H films prepared from silane diluted with 5sccm of argon.

Figures 5.6(e) and 5.6(f) show the AFM images of a-Si:H prepared from silane at flow-rates of 20sccm diluted with argon at 10sccm flow-rates (10A/20S) on the c-Si and glass substrates respectively. The film on c-Si exhibit large island clusters with irregular sizes separated by valleys filled with small grainy structures. The film on glass shows morphology of irregular shapes and sizes of granular structures. The sizes of the microstructures are comparable to the microstructures in the 5A/20S films although the structure is changed to grainy structures from the wavy columnar structures in the 5A/20S films. This effect could be contributed to the different a-Si:H bonds clustered together in these films.

Figures 5.6(g) and 5.6(f) display the AFM images of a-Si:H prepared from the discharge of 20sccm silane mixed in 15sccm argon (15A/20S) on c-Si and glass substrates respectively. The film on c-Si has smooth amorphous morphology. The film on glass shows small grainy structures with intermittent large grainy structures. The surface morphology is significantly different for films deposited on glass and c-Si substrates.

From the observation of all the AFM images in figures 5.6(a) to 5.6(h), the surface morphology of high argon silane flow-rate a-Si:H films prepared using 20sccm silane, undiluted and diluted in argon show strong dependence on substrates. The features are significantly different in films on c-Si and glass substrates. These films are produced using low argon to silane flow-rate ratio which is less than one. Thus, low argon to silane flow-rate ratio (<1) produces inhomogeneous microstructural a-Si:H films on both c-Si and glass substrates. Argon bombardment during the discharge of these reactive and diluent gasses at this ratio is insufficient in improving the homogeneity of the microstructure.

5.4 Variation of Surface Roughness with Ar:SiH_4 Flow-rates Ratio

The surface roughness of the a-Si:H films are determined directly from the measurement made using a computer software linked to the AFM. The data on the surface roughness for all samples are tabulated in table 5.1. The variation of the surface roughness with argon to silane flow-rate ratio (Ar:SiH_4) are illustrated in figure 5.7 for both samples deposited on glass and c-Si substrates. Both plots show similar trends with peaks at argon

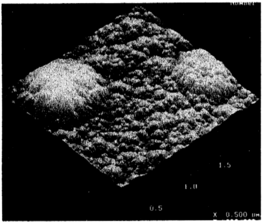

Figure 5.6(a): AFM image of pure 20sccm silane prepared a-Si:H sample 20S on c-Si substrate.

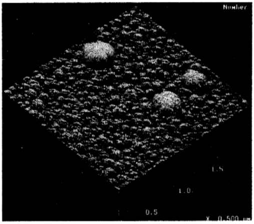

Figure 5.6(b): AFM image of pure 20sccm silane prepared a-Si:H sample 20S on glass substrate.

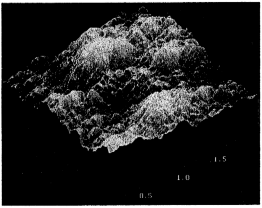

Figure 5.6(c): AFM image of low argon dilution sample 5A/20S on c-Si substrate.

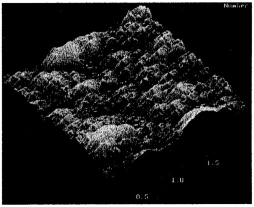

Figure 5.6(d): AFM image of low argon dilution sample 5A/20S on glass substrate.

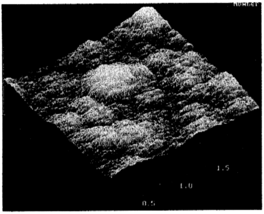

Figure 5.6(e): AFM image of low argon dilution sample 10A/20S on c-Si substrate.

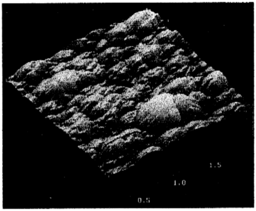

Figure 5.6(f): AFM image of low argon dilution sample 10A/20S on glass substrate.

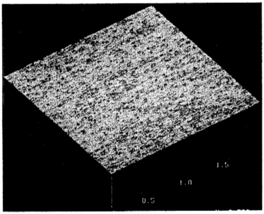

Figure 5.6(g): AFM image of low argon dilution sample 15A/20S on c-Si substrate.

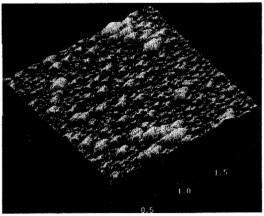

Figure 5.6(h): AFM image of low argon dilution sample 15A/20S on glass substrate.

to silane flow-rates ratio of 0.25 and 1. However, the surface roughness are significantly higher for films on c-Si substrates when the films are prepared from pure silane ($Ar:SiH_4=0$) and silane diluted with argon at 5sccm ($Ar:SiH_4=0.25$ and 1) flow-rate. The absence of argon dilution and low argon flow-rate irrespective of the argon to silane flow-rate ratio result in higher surface roughness in a-Si:H films deposited on c-Si as compared to films deposited on glass substrates. The surface roughness are highest in both c-Si and glass substrates when the argon flow-rate is 5sccm during deposition irrespective of argon to silane flow-rate ratio. The films as observed in figures 5.5(c), 5.5(d), 5.6(c) and 5.6(d) have wavy columnar structures. At high argon to silane flow-rate ratios the surface roughness decreases and saturate at a minimum value for both films on c-Si and glass substrates. Thus, high argon dilution produces sufficient ion bombardment on the a-Si:H films which eliminates clustered H from the resulting in a more homogeneous microstructural films.

Samples		Roughness (±0.3nm)		mean grain diameters (nm)	
	$Ar:SH_4$	c-Si	glass	c-Si	glass
5S	0	16.5	2.0	0	88 ± 3
20S	0	15.1	3.7	155 ± 7	132 ± 4
5A20S	0.25	33.9	18.4	494 ± 43	339 ± 36
10A20S	0.5	11.6	12.1	429 ± 25	306 ± 19
15A20S	0.75	4.4	5.2	209 ± 12	140 ± 8
5A5S	1	32.0	25.2	406 ± 22	402 ± 36
10A5S	2	2.8	2.4	117 ± 5	76 ± 3
15A5S	3	0.9	1.6	0	45 ± 3

Table 5.1: Data of surface roughness and mean grain diameter of a-Si:H on the c-Si and glass substrates.

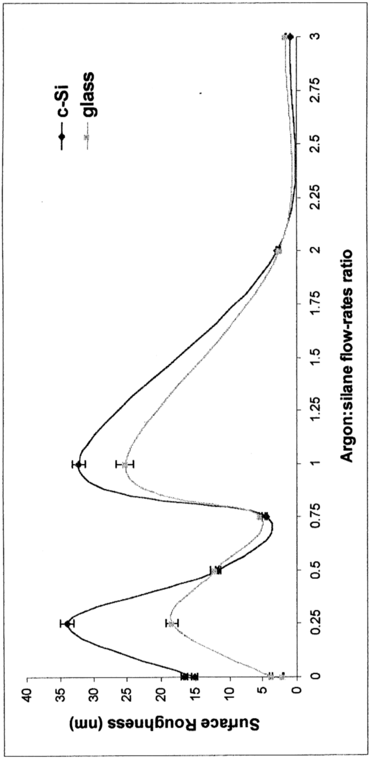

Figure 5.7: Graph of surface roughness versus Ar:SiH_4 flow-rates ratio for all the samples.

5.5 Variation of Mean Grain Diameter with Ar: SiH_4 Flow-rates Ratio.

The mean grain diameter is measured by averaging the diameters of 20 granular clusters on a magnified two dimensional AFM images of the a-Si:H film surface. The mean grain diameter of the a-Si:H samples studied in this work is tabulated in table 5.1. The variation of the mean grain diameter with argon to silane flow-rates ratio for samples on c-Si and glass substrates are shown in figure 5.8. The trends appears to be similar to the variation of surface roughness with argon to silane flow-rate ratio. Similarly, peaks are observed at argon to silane flow-rate ratio of 0.25 and one. The samples represent a-Si:H films deposited with argon flow-rate of 5sccm mixed with silane of flow-rates of 5sccm and 20sccm. These films show a surface morphology of wavy columnar structures which is related to clusters of $(Si\text{-}H_2)_n$ bonds [14]. The mean grain diameter however is large (~500nm) for a-Si:H films prepared using argon to silane flow-rate ratio of 0.25 than one. Thus, even for the columnar structures, the grain size is reduced with high argon dilution. For the low argon dilution films ($Ar:SiH_4<1$), the mean grain diameters are significantly larger for a-Si:H films or c-Si substrates. However, with high argon dilution ($Ar:SiH_4\geq1$), the mean grain diameters of clusters in a-Si:H films show insignificant difference. This further confirm that high argon dilution produces a-Si:H films with surface morphologies which are not substrate dependent. The mean grain diameter also decreases and saturates at the lowest magnitude in both samples on glass and c-Si substrates. High argon dilution produces fine granular structures in a-Si:H films with grain diameters less than 50nm. Nanostructures are thus present in high argon dilution a-Si:H films ($Ar:SiH_4\geq2$) and quantum confinement effect could be present in these films.

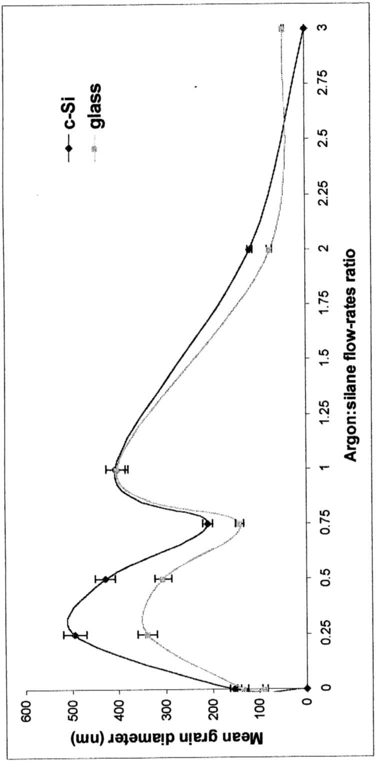

Figure 5.8: Graph of mean grain diameter versus argon:silane flow-rates ratio for all the samples.

5.6 Conclusion.

Argon is a heavy and matestable atom which is passive in the chemical reaction of a-Si:H deposition. However, argon ion bombardment has the effect of improving microstructural properties of the a-Si:H film formed. In this work, high argon dilution significantly improves the homogeneity of the film structure resulting in a homogeneous microstructure a-Si:H films. At the highest argon dilution of silane ($Ar:SiH_4$=3), homogeneous nanostructure a-Si:H films are produced on both c-Si and glass substrates. The high argon dilution of silane provides sufficient ion bombardment, which removes clustered H thus reducing the grain size and improves the homogeneity of the film structure. The destructive effect of argon ion bombardment on the a-Si:H surface becomes almost insignificant due to the screening effect of the high concentration of argon ions in the plasma close to the film surface.

Surface dependent of the microstructural properties of a-Si:H films is eliminated with high argon dilution of silane during deposition. Low argon dilution produces destructive bombardment effects on the c-Si substrate surface which has a direct effect on the properties of the a-Si:H film deposited. Glass substrates have less destructive bombardment effect on the substrate surface. The different destructive argon ion bombardment effect on glass and c-Si substrates produces different surface morphologies of the a-Si:H films deposited. With high argon dilution properties of a-Si:H films deposited are not dependent on the substrate used. This is important since the properties of a-Si:H films studied on glass substrates can be applied to films deposited on c-Si. Thus, high argon dilution produces homogeneous nanostructural a-Si:H films irrespectively of the substrates used.

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