Detailed AFM Study of the Effect of Variation in Deposition Rate and with Progressive Annealing on Silicon Nanostructures Deposited using HWCVD

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Abstract: - As there is hardly any work carried out on effect of growth variations on Silicon Nanocrystals / nanostructures, we experimented and found that as the deposition rate is increased the structures the height of the nanostructures also increased. Further the appearance of the nanostructures and their evolution with annealing is being reported for the first time.

Key-Words: - HWCVD; Silicon Nanostructures; AFM; Annealing; Deposition Rate; Growth; Silicon Nanocrystals;

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1 Introduction

Recently silicon nanocrystals (Si -nc) fabricated using different process such as PECVD [1, 2], LPCVD [3], RTCVD [4], pulsed-gas VHF plasma cell methods [1], electrochemical etching [5] received considerable attention, mainly because of its application potentials in silicon-based photonics viz., LEDs, LASERs, photodetectors, etc. But not much work was done for growing Silicon Nanostructures by depositing the films at low temperature using HWCVD process [6, 7, 8]. The primary advantage of this HWCVD technique is that it allows deposition at low temperatures ensuring a controlled growth; the deposition rate can be easily controlled by changing the gas flow rates.

2 Experimentation

Experiments were started with deposition of heterostructures of Si_xN_y/a-Si-nc/Si_xN_y/a-Si-nc having thicknesses as 4nm/3nm/4nm/3nm on RCA cleaned n – type <100> Si substrates. The substrate and the filament temperatures were maintained at 250ºC and 1900ºC respectively. The substrate and filament temperatures are 250ºC and 1900ºC respectively. The samples A, B, C, D, E and F were grown with deposition rates for amorphous Silicon namely 0.4 Å/s, 0.86 Å/s, 1.15 Å/s, 1.23 Å/s, 1.44 Å/s and 1.50 Å/s, respectively. The multilayer structures were post-annealed in a quartz reactor tube in Ar atmosphere for 30 minutes at 800˚C and 900˚C. The nomenclature for unannealed sample say A,B,.. are A01, B01,.. etc. while those sample A, B,.. annealed at 800˚C and 900˚C were named A02, B02,.. and A03, B03,.. respectively. The same rule have been followed in naming the other samples as well.

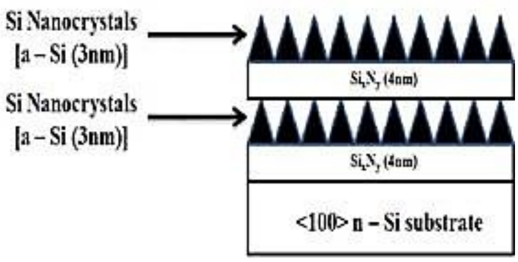
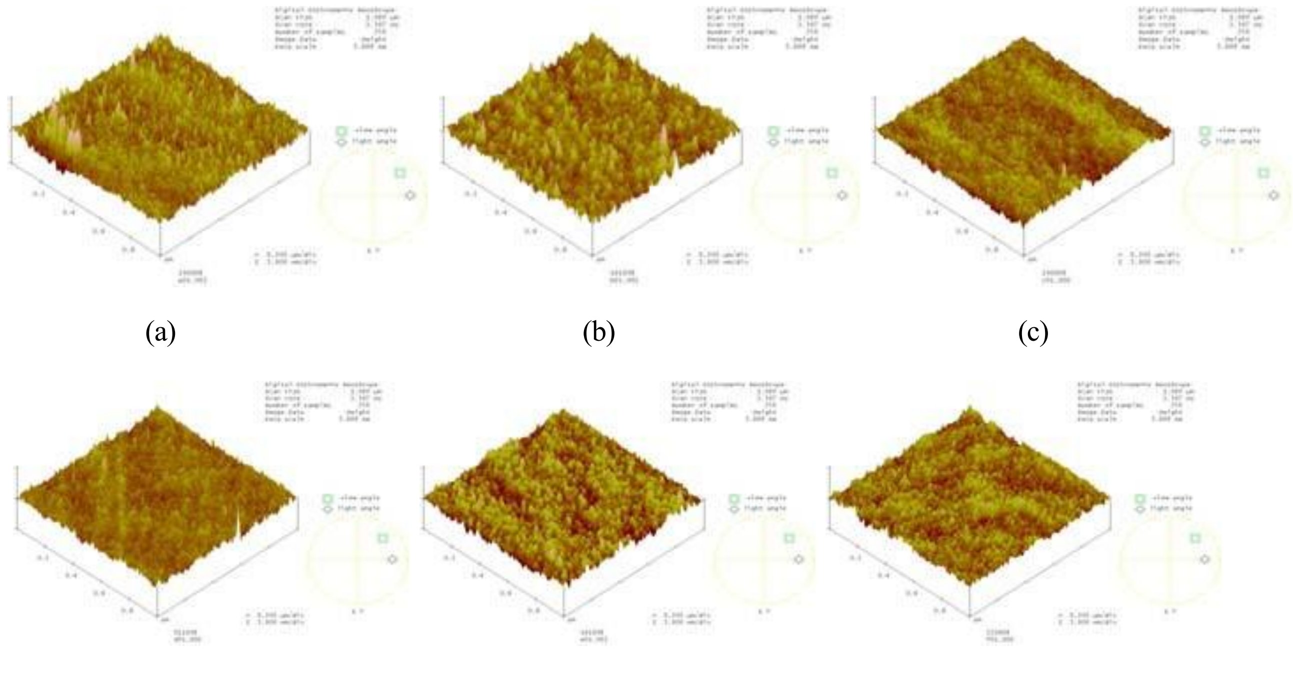


Fig.1: Schematic of the Si_xN_y/Si-nc /Si_xN_y/ Si-nc Heterostructure deposited on n – type <100> Si.

3 Results and Discussions

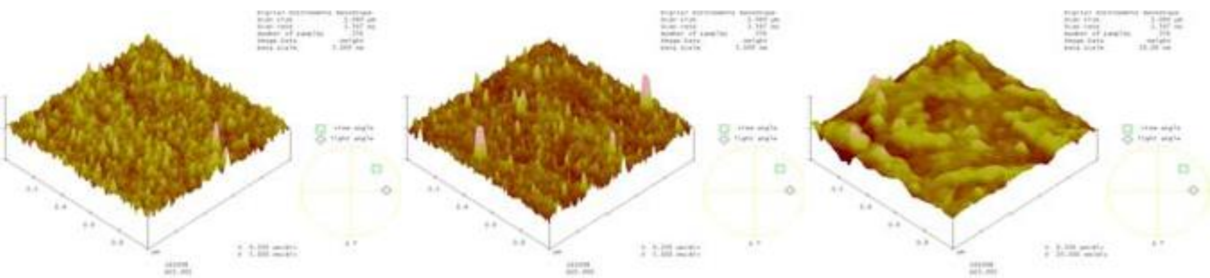
To get a better understanding of the crystal structure, we used atomic force microscopy (AFM) [9] to characterize the size distribution of the Si nanocrystals. Digital Instruments NanoscopeIV



(a) (b) (c)

(d) (e) (f)

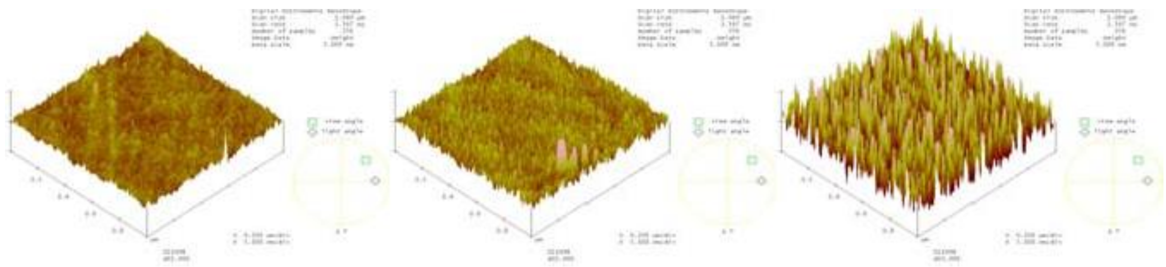
Fig.2: AFM results of (a) A01, (b) B01, (c) C01, (d) D01, (e) E01 and (f) F01.



(a) (b) (c)

Fig.3: Images of (a) B01 showing formation of small nanocrystals, (b) B02 {annealed at 800ºC} shows that the nanocrystals increase in size and (c) B03 {annealed at 900ºC} depicts that the nanocrystals coalesced to form large sized nanocrystals.

(multimode) Scanning Probe Microscopy was used to do AFM analysis. It is known that the real sizes of nanoclusters are truly represented by the height values from AFM measurements, while their lateral dimensions are usually enlarged due to the tip-particle convolution effect. Thus, the height values were taken to be the crystal sizes. RMS surface roughness was also found to increase with increasing annealing temperature. Nanostructures can be viewed in as deposited samples (B01 and D01) also. With progressive annealing the nature of the nanostructures coalesced to form larger sized nanostructures like clustered dots, which were more spherical in shape (Samples B02 and B03) or the nanocrystals transformed to form nanopillars (Sample D03) and *The appearance of the nanostructures and their evolution with annealing is being reported for the first time.* As the rate of deposition is increased, the diameter of the nanostructures decreases and they tend to increase in height. The grain height of ~4.2 nm is observed in D03.



(a) (b) (c)

Fig.4: Images of (a) D01 showing formation of very small nanocrystals, (b) D02 {annealed at 800^{o}C} shows that the nanocrystals increase in size and (c) D03 {annealed at 900^{o}C} depicts that the nanocrystals form nanopillars.

4 Conclusion

With progressive annealing the nature of the nanostructures coalesced to form larger sized nanostructures like clustered dots, which were more spherical in shape. As the rate of deposition is increased, the diameter of the nanostructures decreases and they tend to increase in height. This kind of nanostructures can act as templates for various optoelectronic applications and also improve the overall performance of the optoelectronic device.

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The author contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

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Conflict of Interest

The author has no conflict of interest to declare that is relevant to the content of this article.