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Amorphous Silicon (a-Si:H)/Silicon Nitride (a-SiN_x:H) Superlattice by D.C Plasma Enhanced Chemical Vapour Deposition: Preparation and Characterisation

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Using a home-built direct current plasma enhanced chemical vapour deposition (PECVD) system, twenty alternate layers of hydrogenated amorphous silicon nitride (a-SiN_x:H)/hydrogenated amorphous silicon (a-Si:H) superlattice had been successfully deposited onto crystal silicon and quartz substrates. The most suitable deposition conditions for the a-Si:H well layer, and the a-SiN_x:H barrier layer had been determined independently as a function of silane (SiH_4) flow-rate and ammonia (NH_3) to silane (SiH_4) flow-rate ratio respectively. The position on the cathode which produced the best quality a-Si:H and a-SiN_x:H films and the most suitable deposition rate in terms of controllability for ultra thin layer deposition were also determined. The structural, optical and electrical properties of the a-SiN_x:H/a-Si:H superlattice structures produced were then studied as a function of the a-Si:H well layer thickness.

From the detailed analysis, it was found that the most suitable deposition rate for the well layer (a-Si:H) was identified to be deposited at a silane (SiH_4) flow-rate of 20sccm. The films produced at this SiH_4 flow-rate have low hydrogen content coupled with high refractive index value and low optical energy gap of 1.82 eV. The NH_3) to SiH_4 flow-rate ratio of 16 was identified to be to be the most suitable gas ratio for the a-SiN_x:H barrier layer. It was observed that the films produced at this flow-rate ratio had a refractive index value of 1.9 which was closest to the value of stoichiometric a-SiN_x:H and the optical energy gap of 5.2 eV made it most suitable barrier layer for the fabrication of a-SiN_x:H/a-Si:H superlattice structure.

A significant blue shift in the optical energy gap along with a significant increase in the slope of the Tauc's plot was observed as the well layer thickness decreased to 10Å. The integrated intensities and peak positions of the Si-H(wagging and stretching), Si-N and N-H absorption bands showed that the Si-H bonds were partially substituted by Si-N-H bonds as the well layer thickness was decreased. The structure of the well layer then became a more ordered consisting mainly of Si-Si bonds which further decreased the energy gap. This increased the contrast between the energy gaps of the well and barrier layer further. The dark conductivity decreased and the activation energy increased as the a-Si:H well layer thickness decreased. These results provided strong evidence of the presence of quantum confinement effects in these a-SiN_x:H/a-Si:H superlattice structures.