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Low-temperature synthesis of nc-Si/a-SiNx: H quantum dot thin films using RF/UHF high density PECVD plasmas

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The discovery of light emission in nanostructured silicon has opened up new avenues of research in nano-silicon based devices. One such pathway is the application of silicon quantum dots in advanced photovoltaic and light emitting devices. Recently, there is increasing interest on the silicon quantum dots (c-Si QDs) films embedded in amorphous hydrogenated silicon-nitride dielectric matrix (a-SiNx: H), which are familiar as c-Si/a-SiNx:H QDs thin films. However, due to the limitation of the requirement of a very high deposition temperature along with post annealing and a low growth rate, extensive research are being undertaken to elevate these issues, for the point of view of applications, using plasma assisted deposition methods by using different plasma concepts. This work addresses about rapid growth and single step development of c-Si/a-SiNx:H QDs thin films deposited by RF (13.56 MHz) and ultra-high frequency (UHF ~ 320 MHz) low-pressure plasma processing of a mixture of silane (SiH4) and ammonia (NH3) gases diluted in hydrogen (H2) at a low growth temperature (230°C). In the films the c-Si QDs of varying size, with an overall crystallinity of 60-80 %, are embedded in an a-SiNx: H matrix. The important result includes the formation of the tunable QD size of ~ 5-20 nm, having a thermodynamically favorable <220> crystallographic orientation, along with distinct signatures of the growth of α-Si3N4 and β-Si3N4 components. Also, the roles of different plasma characteristics on the film properties are investigated using various plasma diagnostics and film analysis tools.

Keywords: Energy materials, PECVD, quantum dot film, Si quantum dot, plasma application