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Key Factors for the Development of Silicon Quantum Dot Solar Cell

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Si quantum dot (QD) imbedded in a SiO_2 matrix is a promising material for the next generation optoelectronic devices, such as solar cells and light emission diodes (LEDs). However, low conductivity of the Si quantum dot layer is a great hindrance for the performance of the Si QD-based optoelectronic devices. The effective doping of the Si QDs by semiconducting elements is one of the most important factors for the improvement of conductivity. High dielectric constant of the matrix material SiO_2 is an additional source of the low conductivity. Active doping of B was observed in nanometer silicon layers confined in SiO_2 layers by secondary ion mass spectrometry (SIMS) depth profiling analysis and confirmed by Hall effect measurements. The uniformly distributed boron atoms in the B-doped silicon layers of $[SiO_2(8\ nm)/B\text{-}doped\ Si(10\ nm)]_5$ films turned out to be segregated into the Si/SiO_2 interfaces and the Si bulk, forming a distinct bimodal distribution by annealing at high temperature. B atoms in the Si layers were found to preferentially substitute inactive three-fold Si atoms in the grain boundaries and then substitute the four-fold Si atoms to achieve electrically active doping. As a result, active doping of B is initiated at high doping concentrations above 1.1×10^{20} atoms/cm^3 and high active doping of 3×10^{20} atoms/cm^3 could be achieved. The active doping in ultra-thin Si layers were implemented to silicon quantum dots (QDs) to realize a Si QD solar cell. A high energy conversion efficiency of 13.4% was realized from a p-type Si QD solar cell with B concentration of 4×1^{20} atoms/cm^3. We will present the diffusion behaviors of the various dopants in silicon nanostructures and the performance of the Si quantum dot solar cell with the optimized structures.

Keywords: Silicon, Quantum dot, Solar cell, Doping, Activation