Surface engineered doped silicon nanocrystals applied for fabrication of transparent solar cells

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The photovoltaic market based on silicon has shown an exponential growth rate in the last twenty years. Further improvements in solar cell efficiency exists through the control of Si size and surface properties at quantum confinement sizes which shifts the energy bandgap of the Si to the optimum (i.e. 1.6 eV) giving a maximum efficiency for single junction solar cells. Indeed, the phenomenon that can significantly enhance efficiency (>50%) is the generation of multiple excitons (MEG) in silicon nanocrystals (Si NCs). Taking advantage of quantum confinement effects in silicon, the band gap engineering can be achieved by optimizing the Si NC size. In principle, Si NCs can be synthesized simply from cheap materials at low cost. For Si NCs that can be dispersed in a colloidal solution, thin films can also be fabricated by various deposition procedures, including simple one-step solution coating. The impact of the Si quantum dots (QDS) size distribution on film formation, and thus on the device performance, is still under scrutiny. For instance, it is challenging to form a smooth Si QD film by one-step solution coating. A non-continuous and rough film is usually obtained, where pinholes introduce shunting pathways limiting the solar cell performance.

In this contribution, we present pulsed Femto second (fs) laser induced surface engineering of colloidal Si NCs and their integration into ultra-thin films (<30 nm) by low angle spray deposition in vacuum. A room temperature electrochemical etching pre-synthesis of boron and phosphorous doped Si NCs with quantum confinement size (~3 nm) is used to avoid any modification of the dopant position inside the Si NCs. Surface engineering of Si NCs induced by fs laser allows smooth thin film (surface roughness < 2 nm) deposition at different temperatures. We demonstrate that the tuning of the substrate temperature results in changing the photoluminescence (PL) and transport properties of the films. PL decay studies confirm the good quality of smooth Si NCs ultra-thin films. We also demonstrate the impact of the solar cell performance for devices produced with an ultra-thin Si NC film, deposited at room temperature and with high optical transparency.