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Non-equilibrium plasmas for engineering composition bandgap, and surface properties of silicon tin nanocrystals.

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In order to harvest the excess absorbed photon energy normally lost to heat as additional charge carriers via carrier multiplication (CM) is one of the challenge to significantly enhance the conversion efficiency of solar cells. This is a process that can occur as well as in silicon nanocrystals (Si-ncs) with quantum confinement effects, whereby absorption of a photon bearing at least twice the bandgap energy produces more than two electron-hole pairs. Silicon alloying with other materials offers the opportunity for composition bandgap tuning in silicon-compatible devices taking the advantage of the mature silicon technology and an established industrial infrastructure. The silicon-tin ($Si_{1-x}Sn_x$) system is an interesting candidate as an optically active material where the concentration of Sn can be effectively used to change indirect band gap to direct and at the same time extend the range of achievable bandgaps bellow energy gap of silicon (1.15 eV). However, due to the large difference in size between Si and Sn atoms and the corresponding thermodynamic instability, $Si_{1-x}Sn_x$ alloys are inherently metastable. Therefore up to date, the synthesis methods used to fabricate even bulk SiSn tin films are very limited and reported Sn-rich nanocrystals with metallic behavior, which have not relevant optoelectronic characteristics. It is believed that semiconducting silicon-tin nanocrystals (SiSn-ncs) with quantum confinement can benefit from precise bandgap tuning bellow and over band gap of elemental silicon. Due to the incorporation of Sn, the absorption edge could be lowered compared with Si-ncs extending the absorption range to an important part of the solar spectrum and unique physical phenomenon as CM could become observable at smaller photon energies. In this contribution the synthesis of SiSn-ncs by ns and fs pulsed laser ablation in liquid medium from material stand point of view is demonstrated. The plasma generated by the laser short pulses is spatially confined in the liquid medium and is characterized by high pressure (GPa) with unique kinetic pathways for nucleation and growth of SiSn-ncs. Given the crucial role played by surface characteristics we show that the 3-dimenstional surface engineering of SiSn-ncs utilizing a atmospheric-pressure microplasma treatment provides a uniform passivation layer without using any lengthy surfactants resulting in room temperature PL of SiSn nanocrystals

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